Reduction in Annual Runoff due to Tree Cover

This EnviroAtlas community map estimates the annual reduction in urban surface water runoff (in m^3/yr) from the interception by trees within each census block group. Runoff estimates were produced with the i-Tree Hydro analysis tool developed by the USDA Forest Service.


Photo: USGS, Missouri

Why is reduction in runoff important?

Urban and suburban development creates impervious surfaces (e.g., roads, parking lots, rooftops) that affect the quantity as well as the quality of local and regional water resources. As impervious surfaces increase to 10–20% of local watershed area, surface runoff doubles and continues to increase until, at 100% impervious surface coverage, runoff is five times that of a forested watershed.[1] Runoff speed and magnitude from impervious surfaces peaks following precipitation events.[2] With development, a stream that once may have had a consistent yearly base flow (sustained by water from groundwater, wetland, or forest storage) can become flashy, that is, alternating between flood stage and low flows.[3]

Normally, rainwater entering the soil recharges groundwater aquifers. Water percolates slowly through the soil to enter streams and rivers, contributing to consistent stream flows by regulating flow after precipitation events. Impervious surfaces greatly reduce rainwater percolation and groundwater recharge, lowering the groundwater table and thus contributing to potential shortages in water supply.[1,4] With a lower water table and loss of nearby natural water storage, an urbanized perennial stream may become intermittent or dry up in the summer months.

Flashy conditions negatively affect the channel structure and physical habitat of local streams. Flooding creates bank erosion, scours streambeds, widens and down-cuts stream channels, and releases sediment into streams.[2, 4] Surface runoff from impervious surfaces and decreased base flow also increase the temperature of receiving waters. As a result, wildlife that have adapted to local natural stream conditions may decrease in numbers and diversity. Sensitive native fish and aquatic invertebrate species may be replaced by more tolerant native and non-native species that can adapt to flood, drought, higher temperatures, and high sediment load.

The amount of watershed imperviousness is one of the best indicators of the effects of urbanization on fish communities. Recent studies have found that 8–12% imperviousness represented a transition zone where fish species number, measures of fish community quality, and stream base flow began to decline significantly.[4] The degradation in stream habitat and water quality that results from flashy stream conditions may also affect community aesthetics, recreational opportunities, and public health.[2]

The proportions of tree cover relative to impervious surfaces in community neighborhoods influence the quantity and speed of urban stormwater runoff entering waterways. Trees planted along roadways, in parking lots, retention basins, and riparian buffers can benefit communities by slowing and reducing surface water runoff and reducing the influx of pollutants into local waterbodies. Quantifying the effects of trees on surface runoff allows estimates of the quantity and distribution of trees needed to improve flashy stream conditions and stream base flow in urban areas. The i-Tree Hydro analysis tool used here is one approach to modeling the amount of runoff and pollutants intercepted by trees.

This EnviroAtlas map helps to visualize the relationships among tree cover, impervious surfaces, and surface runoff. Using surface water runoff information, planners and other interested users can identify the community neighborhoods and block groups where additional tree planting might improve the retention and filtration of runoff following heavy precipitation. This runoff data layer can serve as an important planning tool for mitigating flooding, drought, and pollutant load in receiving waterbodies.

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How can I use this information?

This map, Reduction in Annual Runoff, can be used by citizens, planners, and public health professionals to identify block groups that may have runoff-related problems associated with impervious surfaces. Users can compare the estimated annual reductions in surface runoff by trees among community census block groups. Other interventions besides tree planting might include the installation of retention basins and semi-permeable pavement.[2, 3]

This map layer can be overlaid with other community ecosystem service layers in EnviroAtlas (e.g., air pollution removal, carbon storage and sequestration, and air temperature effects) to illustrate the magnitude of multiple ecosystem services contributed by trees within a given area. Users might also overlay EnviroAtlas impervious surface maps and National Hydrography Dataset (NHD) flowline data (available in Vector Supplemental Data) to explore where tree planting would have the greatest return in terms of improving water quality in nearby waterbodies. Sets of community maps are also available illustrating land area, tree cover, and vegetated cover within 15 and 50 meter stream and lake buffers.

How were the data for this map created?

This data layer was derived from a high resolution tree and impervious cover map provided by the US EPA for selected communities. To estimate the effect of changes in tree and impervious cover on runoff, the i-Tree Hydro model was run to simulate cover change effects on a local or nearby watershed. The model was calibrated using hourly stream flow conditions and run numerous times to produce estimates in changes in runoff from changes in tree and impervious cover. To estimate the block group effect, the runoff outputs of the watershed were determined for each possible combination of tree cover (0-100%) and impervious cover (0-100), giving a total of 10,201 possible responses (101 x 101). For each block group, each percent tree cover and percent impervious cover combination was matched to the watershed hydrologic response output for that combination (actual streamflow data). The hydrologic response outputs were calculated as either absolute change or percent change in units of cubic meters of water per square meter of land area for water flow. The per square meter values were multiplied by the square meters of land area in the block group to estimate the effects within block groups.

What are the limitations of these data?

To generate the data for this map, modeled results for a local or nearby watershed were transformed into runoff results for all of the census block groups in the community. Trees within each block group were assumed to have a similar hydrologic effect as trees within the modeled watershed.

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded. Land cover maps and community boundaries are available under the Raster Supplemental Maps tab in the interactive map.

Where can I get more information?

A selection of resources on impervious surfaces and the ability of trees to reduce stormwater runoff is listed below. For additional information on how the data were created, access the metadata for the data layer from the drop down menu on the interactive map table of contents and click again on metadata at the bottom of the metadata summary page for more details. To ask specific questions about these data, please contact the EnviroAtlas Team.

Acknowledgments

The data for this map were generated by David Nowak, USDA Forest Service, and Tian Zhou, Bangshuai Han, and Ted Endreny, State University of New York. The fact sheet was created by David Nowak, USDA Forest Service, and Sandra Bryce, Innovate!, Inc.

Selected Publications

1. Paul, M.J., and J.L. Meyer. 2001. Streams in the urban landscape. *Annual Reviews of Ecological Systems* 32:333–365.

2. Nowak, D.J., J. Wang, and T. Endreny. 2007. Chapter 4: Environmental and economic benefits of preserving forests within urban areas: Air and water quality. Pages 28–47 *in* de Brun, C.T.F. (ed.), The economic benefits of land conservation. The Trust for Public Land, San Francisco, California.

3. Baker, D.B., R.P. Richards, T.T. Loftus, and J.W. Kramer. 2004. A new flashiness index: Characteristics and applications to midwestern rivers and streams. *Journal of the American Water Resources Association* 40(2):503–522.

4. Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management* 28(2):255–266.

Bentrup, G. 2008. Conservation buffers: Design guidelines for buffers, corridors, and greenways. General Technical Report SRS-109. U.S. Forest Service, Southern Research Station, Asheville, North Carolina. 110 p.