Tree Rainfall Interception in Urban Areas

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1

There is much interest in the role of urban trees as a component of urban hydrology. Trees have been suggested to play a significant role in urban flood prevention and in stormwater management. However, limited data exist to quantify these benefits. We therefore conducted many measurements of urban tree interception for all seasons and for several tree types and sizes, as summarized in this presentation.

A Few Points from the Literature on Urban Tree Interception:

- Interacting mechanisms associated with urban trees and how they affect urban hydrology are poorly understood, especially at the spatial and temporal scales of urban area tree plantings (Berland, *et al*. 2017).
- "Inadequate research quantifying the urban tree contribution to rainfall/runoff processes limits their promotion by stormwater managers" (Kuehler, *et al*. 2017).
- "An important knowledge gap in current urban hydrological models are reliable, generic data about interception storage capacities of small urban plant species" (Smets, *et al*. 2019).

2

2

Objectives of Urban Tree Interception Measurements

- The experiments described in this presentation were conducted to examine canopy interception by direct measurements of throughfall under isolated or low density stands of mature urban deciduous and evergreen trees in the Southeast US.
- These measurements were conducted for about 400 rains over all seasons for different tree types at several locations in Alabama to determine statistically significant relationships for use in the WinSLAMM stormwater quality model. This large data set allows the identification of the significant factors (and their interactions) affecting runoff beneath trees in urban areas.

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New residential areas with few large trees

Older residential areas with many large trees

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4

- If a tree is located in a pervious area of the watershed (over lawns or other non-paved areas), interception may not affect outfall runoff quantities much; most of the un-intercepted rainfall is likely to be infiltrated with or without the trees.
- However, trees likely maintain good soil characteristics and minimize compaction, which would improve the infiltration of rainfall.
- The largest hydrological benefit of urban trees would be when directly connected impervious areas (roofs, walkways, parking areas, and streets) are heavily covered by an overstory of trees.
- If tree-covered impervious areas are directly connected to the drainage system, these benefits would be the greatest, but if the tree-covered impervious areas drain to pervious areas (such as disconnected roofs or walks surrounded by lawns), the benefits would be lower.

5

5

Mature Trees Over Paved Parking Areas for Significant Interception

Newly Planted Trees will Require Many Years before Significant Interception

Photos from misc. Internet sources

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6

Location of Large and Small Urban Tree Interception Measurements (Hoover. Alabama)

This lot was developed in 1957 with most of the large pines and oaks likely present before home construction. The site is well-wooded with mature trees in the front and sides of the lot, with open grass areas in the rear of the lot and along the streets.

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7

HOBO recording rain gage and Davis weather station in open area

The total annual rainfall for Birmingham, AL, in 2020 (one of the years of measurements) was 185 cm (73.05 inches), 49 cm (19.33 inches) above normal, which was the 5th wettest year on record. Central Alabama was directly impacted by two tropical systems, Hurricanes Sally and Zeta, and 35 tornadoes in 2020.

83 rains were monitored during 2020 at the single home site, 8 during winter (December only), 18 during spring (mostly April plus May), 39 during summer (June through August), and 18 during fall (September through November). The largest rain was 84 mm. The interevent periods ranged from about 7 h to 14 d. Rain durations ranged from about 0.1 h to 39 h.

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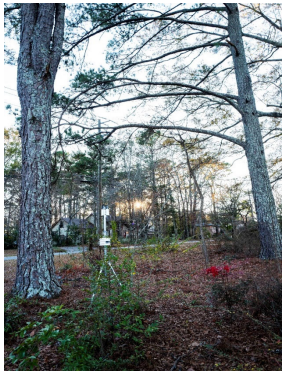
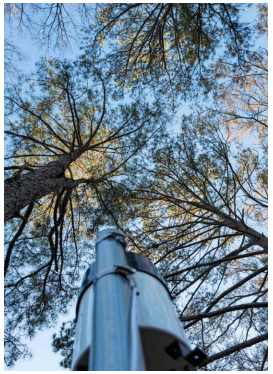
Rain gauge located under evergreen Loblolly pines:





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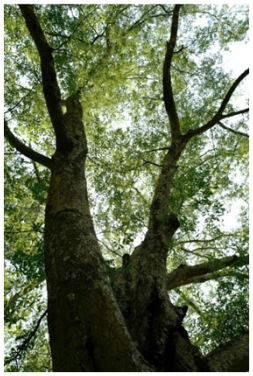
Rain gage under deciduous Water Oak:



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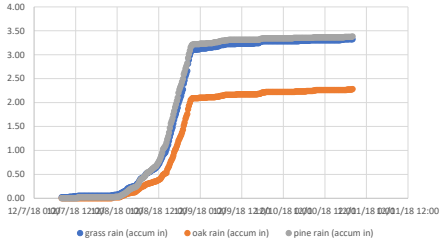
Cumulative rain plots (3.32 inches, December 7 to 11, 2018)

The following plot is the cumulative rainfall at the background location (surrounded by grass) vs. the cumulative throughfall measured under the pine and oak trees:

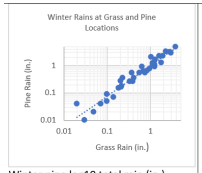


It is obvious that the throughfall under the pines were little different compared to the background rainfall, while the oak had substantial throughfall reductions.

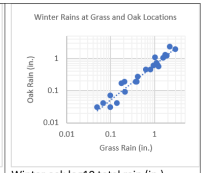
11

11

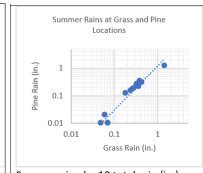
Winter, Spring, Summer, and Partial Fall Pine and Oak Tree Throughfall Equations



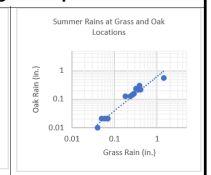
Winter pine log10 total rain (in.) = 1.07 Winter grass log10 total rain (in.)



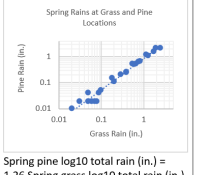
Winter oak log10 total rain (in.) = -0.203 + 1.17 Winter grass log10 total rain (in.)



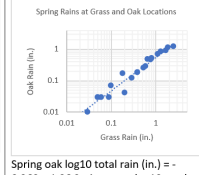
Summer pine log10 total rain (in.) = 1.51 Summer grass log10 total rain (in.)



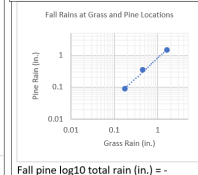
Summer oak log10 total rain (in.) = -0.215 + 1.17 Summer grass log10 total rain (in.)



Spring pine log10 total rain (in.) = 1.26 Spring grass log10 total rain (in.)



Spring oak log10 total rain (in.) = -0.260 + 1.06 Spring grass log10 total rain (in.)



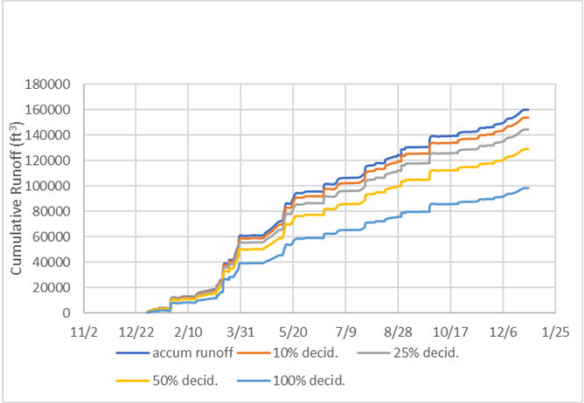
Fall pine log10 total rain (in.) = -0.0871 +1.255 fall grass log10 total rain (in.)

(fall oak tree data missing due to leaf interference of the rain gage and some fall pine tree data missing due to lightning static erasing data logger)

12

12

WinSLAMM calculated throughfall production functions for varying amounts of deciduous tree cover over directly connected paved parking area.



Maximum 100% deciduous tree cover resulted in about 40% runoff reduction from the paved area

13

13

Additional Tree Interception Monitoring Locations (201 additional events) by Ryan Bean (2022) during his PhD dissertation research at the University of Alabama :

- North Alabama (Pine/Oak/Grass)
  - 3/7/2016 started collecting data
  - Ended 1/13/2017
  - 312 days
  - 37 events
  - Hardiness Zone 7b
  - Elevation 1800 ASL
- Central Alabama (Pine/Oak/Grass)
  - Hardiness Zone 8a
  - 1100 ASL
  - 6/2/2016 started
  - 9/27/2019 (last collection)
  - 113 events
- South Alabama 1 (Pine/Oak/Grass)
  - Hardiness Zone 8a
  - Elevation 180 ASL
  - 3/7/2016 started collecting data
  - Ended 8/15/2017
  - 51 events
- South Alabama 2 (Bradford Pear/Easter Red Cedar/Grass)
  - 10/19/2019 started
  - Planning to add two more trees

He also conducted additional detailed measurements concerning the interception pattern beneath trees and interception measurements beneath different sized trees of the same type.

14

14

North Site

- In Pisgah, Al (34.73 N, 85.76 W),
- southern red oak
- loblolly pine
- Both trees are estimated to be greater than 50 years old
- The oak tree is about 40 feet tall and the pine is >50 feet tall

Bean 2022

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15

Central Site

- Forney, Al (34.10N, 85.48 W),
- white oak co-dominant
- loblolly pine co-dominant
- Both trees were estimated at less than 20 years old.
- Both tree are >35 feet tall and healthy.

Bean 2022

16

16

South Site 1

- Wetumpka, Al (32.57 N, 86.25 W),
- laurel oak and a loblolly pine.
- Both trees are estimated at less than 20 years old.
- Both tree are >25 feet tall and well developed

Bean 2022 17

17

South Site 2

- Wetumpka, Al (32.57 N, 86.25 W),
- Bradford pear
- Easter red cedar
- Both trees are less than 10 years old.
- Both tree are estimated to be 20 feet tall and well developed

Bean 2022 18

18

Effects of Tree Size on Interception

As the trees grow, it is expected that their storage capacity (minimum retention) increases. These tests examined:

- 4 willow oaks of different size (canopy and DBH) with rain gages
- 32 samples needed by design to detect a 20% difference in throughfall with 95% confidence
- All gauges were located North of tree at ½ radial distance of canopy (edge to trunk)
- Weather station data collected daily windspeed from nearby airbase

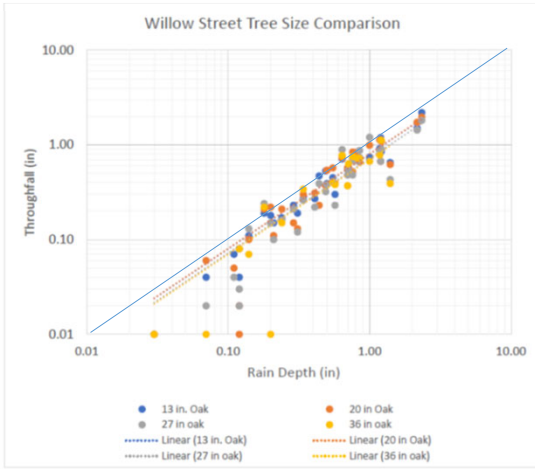
19

Bean 2022

19

Effects of Tree Size on Interception

- Lognormal regressions were used to plot the "combined" smaller and larger street expected throughfall
- Small storms (<0.25 inches) show significant differences in storage between the smaller vs. larger trees.
- Marginal differences were observed between smaller and larger trees for medium and large storms (>0.25 inches)



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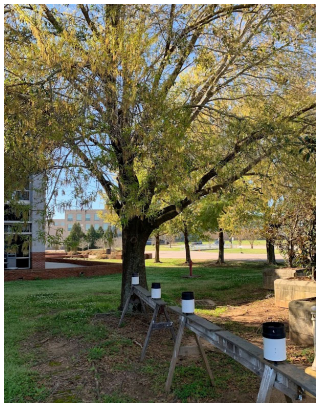
20

Interception Footprint under Trees

It is expected that throughfall will vary with less interception further distances from the base of a tree to the edge of the canopy. This study examined:

- Mature willow oak
- All oriented North and spaced 6 feet apart to the edge of the canopy
- 32 samples were needed by design to detect a 20% difference in throughfall with 95% confidence
- Weather station data collected for windspeed and direction from local airbase



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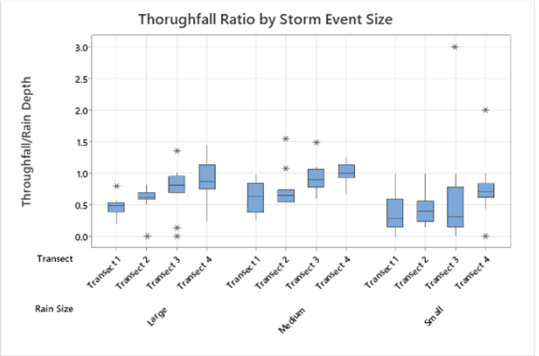
21

Interception Footprint under Trees

- Boxplots shown for small, medium and large rains (<0.25,0.25-0.75, >0.75 inch)
- Transect interception differences were most noticeable for the medium and large rains,
- The small rains all had consistent, and smaller, interception amounts at all locations, with the outermost canopy edge value larger.



Bean 2022 22

22

Additional measurements at Hoover, AL, for two Japanese Maple trees (*Acer palmatum*)

The two test trees were upright versions of Japanese maples (*Acer palmatum),* about 5 m tall, and were planted about 10 years ago. They are very popular urban trees and thrive in most of the U.S., except for the northern central plains/upper Midwest, New England, and extreme southern areas. They originated in Asia where they are also common.

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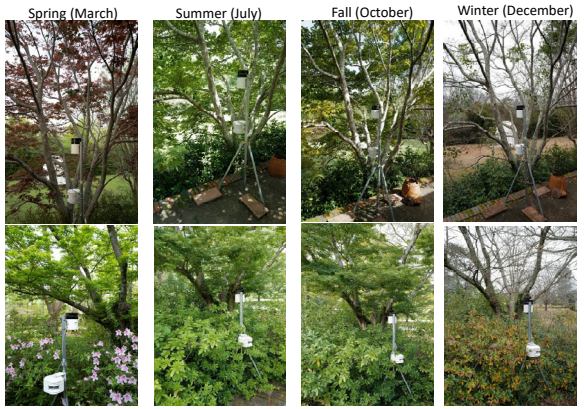
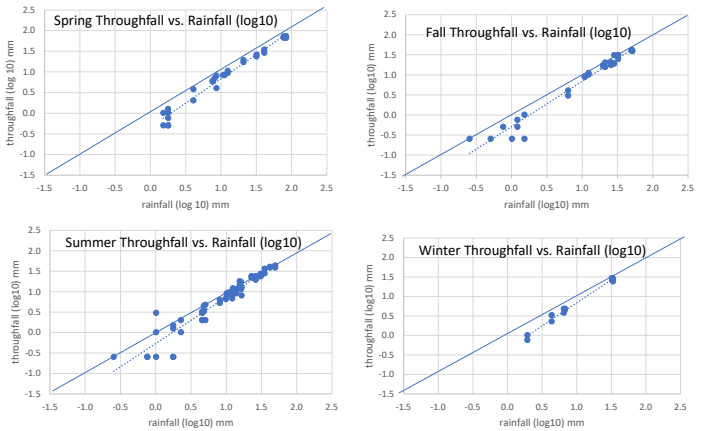


Monitored Japanese Maples during Different Seasons

24

24

Regressions of Rainfall (log10) vs. Throughfall (log10) by Season



Very similar rainfall vs. throughfall relationships for all seasons

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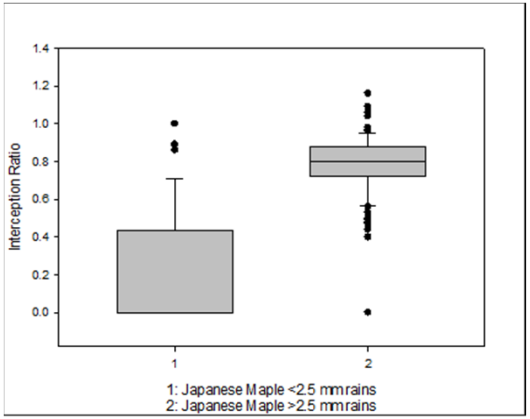
Interception Ratio (Throughfall/Rainfall) for Different Rain Depth Ranges



No significant interception differences by season, but significant differences by rain size. Larger interception ratios (less rainfall losses) for large rains, as expected.

26

26

Conclusions

- Urban trees add substantially to the standard of living of residents and are highly desirable.
- Urban trees have been recommended as a solution for urban drainage and flooding problems.
- Few data are available quantifying these benefits under actual field conditions, especially under a wide range of rain conditions for different tree species and seasons.
- Literature describing urban tree interception at many international locations indicate that canopy interception benefits are limited.
- During the measurements described in this presentation, tree specie type and rainfall amount had the greatest effect on throughfall; the large deciduous tree (even with few leaves during winter conditions) intercepted much more rainfall than the large conifer tree, or the small deciduous trees, likely due to the massive branch structure.

27

27

Conclusions (continued)

- Small and/or immature trees have much smaller interception benefits per canopy area compared to large trees due to the short distance rain falls through the canopy, decreasing the interception opportunities.
- For the small urban trees, no significant differences were noted for the different seasons, and only the smallest rains (<2.5 mm or 0.1 in) had interception values that were significantly different from the larger rains.
- No throughfall (100% interception) was generally recorded for rains <1 mm, the throughfall was about 25% of the rainfall (75% interception) for rains up to about 2.5 mm, and about 85% for larger rains (15% interception) for the small urban trees.
- Small urban trees have limited spread and reduced coverage (shadow) over adjacent impervious areas compared to large trees and therefore have limited runoff reducing benefits, especially considering their limited interception for most rains.

28

28