Ryan W. Bean

Doctoral Candidate, The University of Alabama, Department of Civil, Construction, and Environmental Engineering, Tuscaloosa, Alabama, U.S.A.

- Conducting research in rainfall interception on urban trees in the southeastern United States
- Masters of Science in Civil Engineering, 2014, The University of Alabama, Tuscaloosa, Alabama, U.S.A.
- Bachelor of Biosystems Engineering, 2009, Auburn University, Auburn, Alabama, U.S.A.

Division Chief for Design and Construction, The Alabama Army National Guard, Construction and Facilities Management Office, Montgomery, Alabama, U.S.A.

- Director for design and project management on all new military construction projects and major sustainment, restoration, and modernization projects

Email:
Ryan.w.bean2.mil@mail.mil

1

1

Urban Tree Rainfall Interception Measurements and Modeling in WinSLAMM, the Source Loading and Management Model

Proof of Concept and Preliminary Analyses

Ryan Bean, PhD student, University of Alabama
Bob Pitt, Emeritus Cudworth Professor of Urban Water Systems, University of Alabama
John Voorhees, Principal, PV & Associates
Mark Elliott, Associate Professor, University of Alabama

2

2

A Few Points from the Literature on Urban Tree Interception:

- Interacting mechanisms associated with urban trees and how they affect urban hydrology is 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).

3

3

Objectives of Urban Tree Interception Measurements Described in this Presentation

- The experiments described in this presentation and associated paper were conducted to comprehensively 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 85 rains over all seasons to determine statistically significant relationships for use in the WinSLAMM stormwater quality model. This large data set, plus data from the other locations and future measurements, allows the identification of the significant factors (and their interactions) affecting runoff beneath trees in urban areas.
- Additional measurements are currently being conducted for smaller trees and for rainfall variations under and surrounding urban trees.

4

4

Background & History of WinSLAMM

- **Development Began in mid-1970's**
  - Early EPA street cleaning and receiving water projects (San Jose and Coyote Creek, CA)
  - Castro Valley (CA), Bellevue (WA), Milwaukee (WI) and other NURP projects
- **Mid-1980's - Model used in Agency Programs:**
  - Ottawa bacteria stormwater management research
  - Toronto Area Watershed Management Strategy study
  - Wis. Dept. of Natural Resources: Priority Watershed Program
- **Intensive data collection started in WI in early 1990s.**
- **First Windows version developed in 1995.**
- **Current graphical interface released, after three years of work, in 2012.**
- **Continuously being updated based on user needs and new research results (such as described in the two WinSLAMM presentations at this conference).**

5

5

New residential areas with few large trees

Older residential areas with many large trees

6

6

- 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.

7

7

Mature Trees Over Paved Parking Areas for Significant Interception

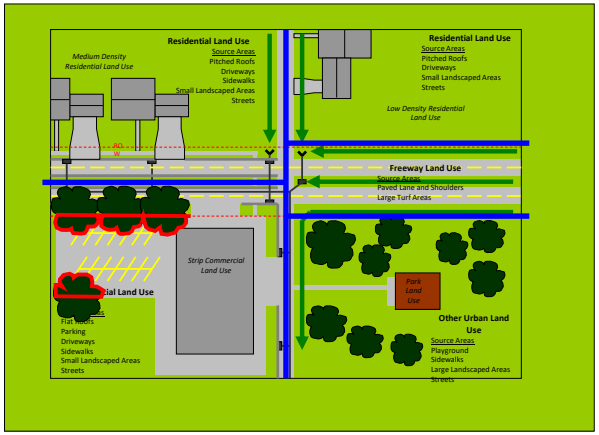
Newly Planted Trees will Require Many Years before Significant Interception

Photos from misc. Internet sources

8

8

Tree Interception Example for Directly Connected Paved Parking Area



9

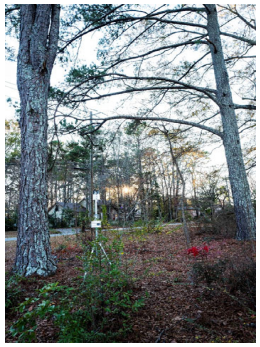
9

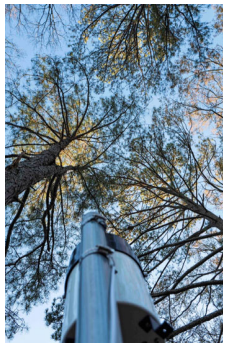
HOBO recording rain gage and Davis weather station surrounded by grass:

10

10

Rain gauge located under evergreen Loblolly pines:





11

11

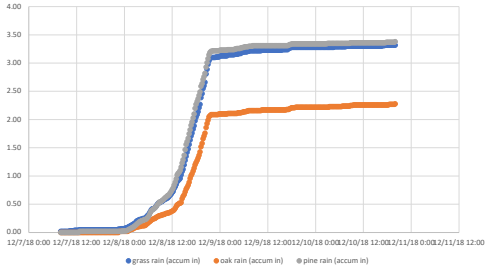
Rain gage under deciduous Water Oak:

12

12

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:

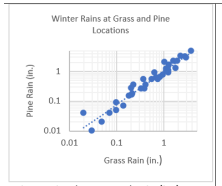


It is obvious that the throughfall under the pines were little different compared to the background rainfall, while the oak had substantial throughfall reductions.

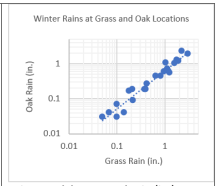
13

13

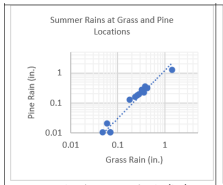
Winter, Spring, Summer, and Partial Fall Pine and Oak Tree Throughfall Equations



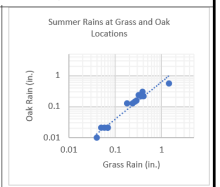
Winter pine log10 total rain (in.) = 1.07 Winter grass log10 total rain (in.)



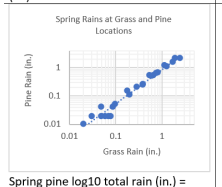
Winter oak log10 total rain (in.) = -0.203 + 1.17 Winter grass log10 total rain (in.)



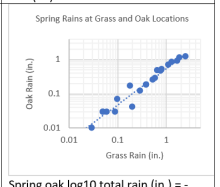
Summer pine log10 total rain (in.) = 1.51 Summer grass log10 total rain (in.)



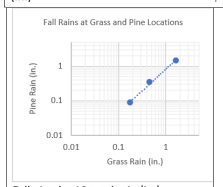
Summer oak log10 total rain (in.) = -0.215 + 1.17 Summer grass log10 total rain (in.)



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.)



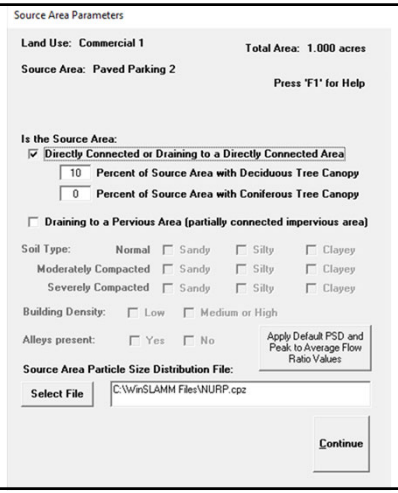
Fall pine log10 total rain (in.) = -0.0871 +1.255 fall grass log10 total rain (in.)

(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)

14

14

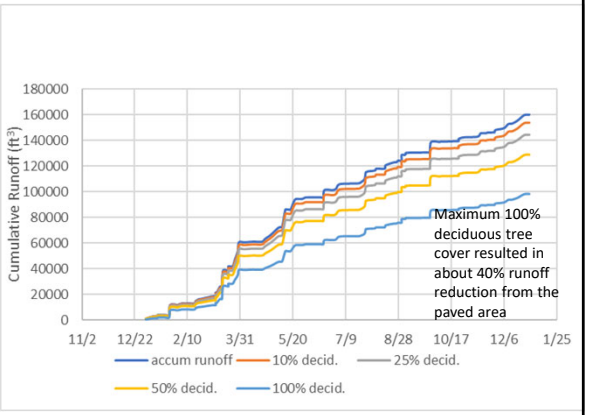
WinSLAMM pavement area data input screen showing tree cover information



15

15

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



16

16

Additional Tree Interception Monitoring Locations (201 additional events so far):

- 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

17

17

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

18

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.

19

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

20

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

21

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 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, likely due to the massive branch structure.
- Small and/or immature trees will have much smaller interception benefits.

22

22