Hydrologic Processes of Forested Headwater Watersheds across A Physiographic Gradient in the Southeastern United States

Ge Sun, Johnny Boggs, Steven G. McNulty, Devendra M. Amatya, Carl C. Trettin, Zhaohua Dai, James M. Vose, Ileana B. La Torre-Torres, and Timothy Callahan

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Objectives

- Contrast hydrologic processes in three 1st-order forested watersheds (Hydrologic responses to rainfall events; high and low flows, saturated areas);

- Discuss implications to forest buffer designs across the SE region.
The Variable Source Area Concept (Hewlett and Hibbert, 1967)
Example 1: 25-foot wide Intermittent Stream SSC: A1
(low soil erodibility; 0-2% Slope)

From Florida Silviculture BMPs
Diverse Ecoregions
Runoff
Hypothesis

- Unique hydrologic processes across a topographic and climatic gradient: the Variable Source Area (VSA) and Runoff/Precip ratio

- Buffer designs for the uplands are not adequate for the coastal watersheds.
Three Research Sites
## Three Watersheds

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Coastal Plain, WS80</th>
<th>Piedmont, HFW1</th>
<th>Mountain, WS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>160</td>
<td>32</td>
<td>12</td>
</tr>
<tr>
<td>Eleve. (m)</td>
<td>3-10</td>
<td>166-200</td>
<td>710-1000</td>
</tr>
<tr>
<td>Climate: Precip</td>
<td>1350 mm/yr.</td>
<td>1120 mm/yr.</td>
<td>1880 mm/yr.</td>
</tr>
<tr>
<td>Air temp.</td>
<td>19.0 °C</td>
<td>15 °C</td>
<td>13.0 °C</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Mixed pine-hardwood</td>
<td>Deciduous hardwood</td>
<td>Deciduous hardwood</td>
</tr>
</tbody>
</table>
Research Sites (Santee)
NC Buffer BMPs Study
Results

• Streamflow Response to Storm Events
• Distribution of Daily PET, Rainfall, Flow
• Saturated areas in a watershed – where and when (Coweeta and Santee)
• Implications to buffer BMPs
Results

Strom Event Rainfall/Runoff Ratios: Piedmont vs Coastal Plain
Rainfall/Runoff Ratio

$y = 0.022 \ln(x) + 0.2214$

$R^2 = 0.341$

$p = 0.037$
Rainfall/Runoff Ratios for Two Contrasting Watersheds

(Data Source: La Torre-Torres, 2008  MS Thesis College of Charleston)
Coweeta Watershed (NC)

Coweeta W02 (1985-1990)

Area = 12 ha
Annual runoff = about 850 mm
Santee Watersheds (SC)

Area = 151 ha, 206 ha
Annual runoff = about 350 mm

Streamflow (mm/day)

Date


WS77 WS80
Water Table – Runoff Relations

Streamflow and Water Table Depth of Well #3 (2003-2005)
Nonlinear Hydrologic Response to Storms

from James and Roulet, 2007, Hydro Process, Vol 21
Results

Frequency Distribution of daily rainfall, potential ET, and flow rates
Rainfall

Comparison of Frequency Distribution of Daily Rainfall

Exceedance %

- Mountain (CW2)
- Pidemont (HFW1)
- Coastal plain (WS80)
Comparison of Frequency Distribution of PET

- Mountain (CW2)
- Pidemont (HFW1)
- Coastal plain (WS80)
Comparison of Frequency Distribution of Daily Flow

Flow

Exceedance %

Mountain
(Coweeta 2)

Pidemont (HFW1)

Coastal Plain
(WS80)

Flow (mm/day)
Results

Spatio-Temporal Distribution of Saturated Areas
Groundwater Table ( <15 cm) Frequency Distribution in 3 Years at Each Well
Watreshed 80
Frequency of Saturation at Coweeta
WS2 (2005-2007)

- Responded once (Max: -90 cm)
- No response, but not dry
- Very sensitive to rainfall, saturated all the events
- Stable at -60 cm
- Saturated once/4 responses

Dry

0 100 Meters
Conceptual Model of Forested Headwater Watersheds

Costal Watershed

Hilly Upland Watershed

ET  P

Dry

Wet

ET  P
1. Large saturated areas exist in coastal forested watersheds compared to the mountain watershed that has small, narrow saturation areas during storm events
2. Different hydrologic processes: Upland vs Wetland watersheds
3. Highest variability of flow in Coastal Watersheds due to topography and climate
4. Stormflow may generate mostly from zero-order sub-watersheds

Implications to Buffer Design
Implications to Buffer Design

5. Current design for buffer width for water quality protection may not be adequate for first-order wetland watersheds that have low water storage capacity and overland flow-prone with intermittent streams.