Sources and Evolution of Nitrate-Nitrogen in Urban Stormwater Runoff

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OUTLINE

① Population Growth: *Urbanization, Algal Blooms*

② Policy driven: *Fertilizer Bans in Urban Areas*

③ Nitrogen Transport in Urban Neighborhoods

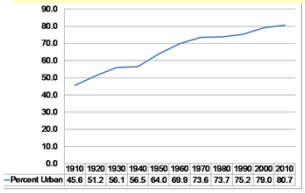
- ❑ High-frequency Stormwater Runoff Data

④ Conclusions

① Urban Population Explosion: *World*

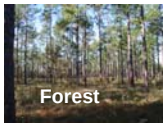
- **1850:** 2% people lived in cities
- **1900:** 6% people lived in cities
- **1950:** 29% people lived in urban areas (cities + suburbs
- **2010:** 50% people lived in urban areas (cities + suburbs)
- **2050:** 70% people will live in urban areas (cities + suburbs)

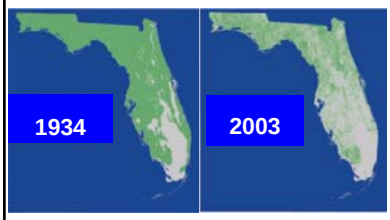
Urban Population (%): *US*



Land Use Changes in Florida:

Human modification of natural landscape

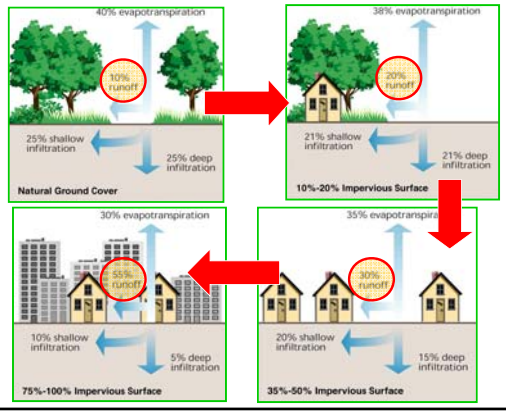




Population Growth

- 1900: 0.53 million
- 2015: ~20 million
- 2036: 36 million

Impacts of Urbanization: *Increase in Runoff*



Source: " In Stream Corridor Restoration: Principles, Processes, and Practices"

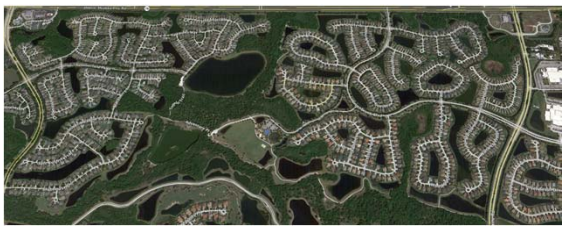
When it rains, a large amount of water……..

Runs off of impervious surfaces → Enters the stormdrains → Enters streams

Impact of Nutrients

- Excessive plant growth in streams/lakes
- Scum and algae near lake shores
- Unpleasant odors

② Fertilizer Bans in Urban Areas

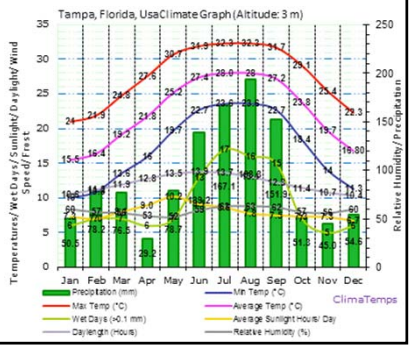


History of Regulations to Control Urban Nutrient Pollution in Florida

- 1999 – Watershed Restoration Act passed
- 2007 – Fertilizer ordinances begin to appear
- 2007 – Urban Turf Rule passed
- 2009 – Fertilizer ordinances mandated in some areas
- 2010 – State model ordinance developed

Rainfall Distribution in Florida

- Average annual rainfall: ~137 cm or 1370 mm
- 50-70% rainfall during wet season (June to September) in short-duration, high-intensity storms



Florida Fertilizer Bans/Ordinances

- 08/2015 –Florida counties (28) and municipalities (76) now have some kind of fertilizer ordinance
  - ✓ Range from recommendations on application timing to complete rainy season "blackouts" (8 counties, 33 municipalities)

Most controversial

- **Blackout period (June-Sept)**
- **Ban on retail fertilizer sales during blackout (effective in Pinellas county, Tampa)**

RATIONALE

- **Higher rainfall causes more runoff, so the rationale is that by banning fertilizer applications, loss of nutrients in runoff from lawns will be reduced.**

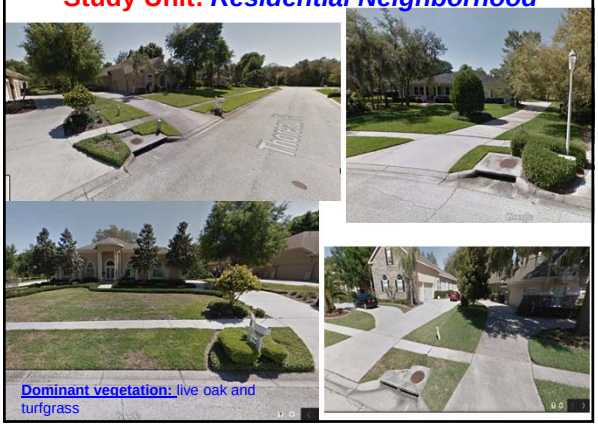
③ Nitrogen Transport from Residential Neighborhoods

- High-frequency Stormwater Runoff Data (5 minute intervals)

Study Unit: *Residential Neighborhood*

- Area: 13.4 ha (33 ac)
- 31 homes: average lot size is 0.24 ha (0.63 acres).
- Average home size: 4,400 ft^2 (408 m^2)
- 0.5 to 1 million USD

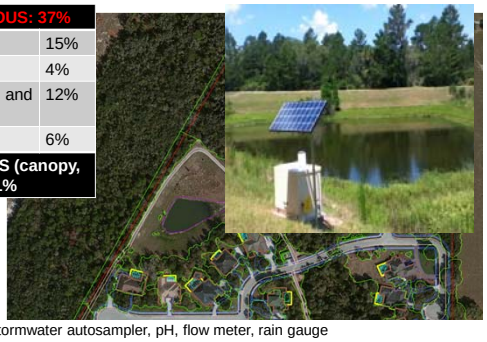
Study Unit: *Residential Neighborhood*



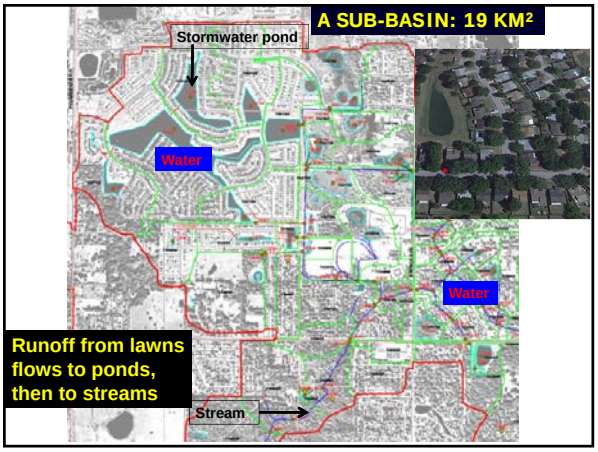
Dominant vegetation: live oak and turfgrass

Residential Neighborhood: *GIS Mapping*

IMPERVIOUS: 37%	
Rooftops	15%
Patios	4%
Driveways and sidewalks	12%
Roads	6%
PERVIOUS (canopy, grass): 61%	

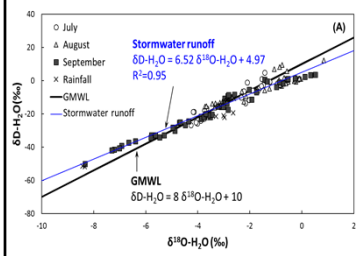


- Installed stormwater autosampler, pH, flow meter, rain gauge
- Collect runoff samples (every 5 minutes, upto 14 samples) from the outlet pipe draining the neighborhood
- Captured 25 stormwater events during 2014 wet season



What is the source of water in residential stormwater runoff?

2014 Wet Season



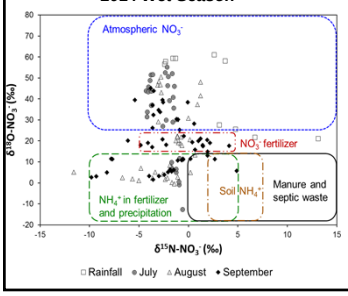
Yang and Toor. 2016. ES&T.

- Urban stormwater runoff = originated from rainfall. Slight evaporation during transport of water.
- No other source of water (e.g., irrigation water, sanitary sewer leaks, septic systems).
- Stormwater runoff transported N present in different sources.

What are the sources of nitrate-nitrogen in residential stormwater runoff?

Of total N, NO_3-N was 29% in July, 21% in August, and 47% in September

2014 Wet Season



Bayesian Mixing Model:

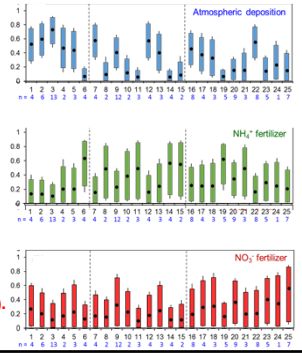
- Rainfall was the main source of NO_3-N in stormwater runoff in 56% of samples.
- Fertilizer containing NH_4-N: 34% of samples.
- Fertilizer containing NO_3-N: 8% of samples
- Mixed sources: 2% of samples.

Yang and Toor. 2016. ES&T.

Change in nitrate-N sources in stormwater runoff events

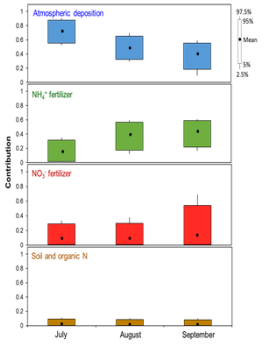
Of stormwater events:

- **15 events dominated by atmospheric deposition (mean credible interval: 33 to 72%)**
- **9 events were dominated by NH_4 fertilizer (mean: 38 to 63%)**
- **4 events were dominated by NO_3 fertilizer (mean: 35 to 56%).**



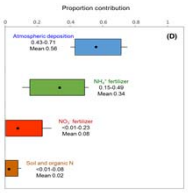
Source dominance during wet season

- Atmospheric deposition contributed more NO_3-N in the beginning of wet season:
  - ✧ July (55-88%)
  - ✧ August (32-65%)
  - ✧ September (18-55%)
- Chemical fertilizer (NH_4 fertilizer and NO_3 fertilizer) showed an increasing contribution from:
  - ✧ July (1-32%)
  - ✧ August (1-57%)
  - ✧ September (<1-49%)
- No change in soil and waste sources

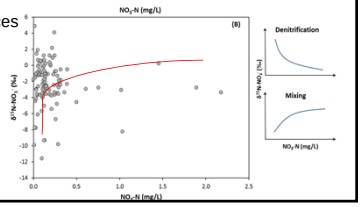


④ Conclusions

1. **Capturing storm-events led to identifying dominant NO_3-N sources in urban stormwater runoff:**
   - ➢ Atmospheric deposition (56%), Chemical fertilizers (42%), Soil/waste (2%)

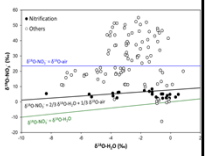


2. **No denitrification during transport of NO_3-N in stormwater runoff**
   - ➢ Mixing of different sources



④ Conclusions

3. **Nitrification contributed a part of NO_3-N (meaning fertilizer runoff from soils)**



4. **Most of the NO_3-N in runoff appears to originate from improperly applied fertilizer.**

Questions?

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δ^{15}N and δ^{18}O Reveal the Sources of Nitrate-Nitrogen in Urban Residential Stormwater Runoff

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