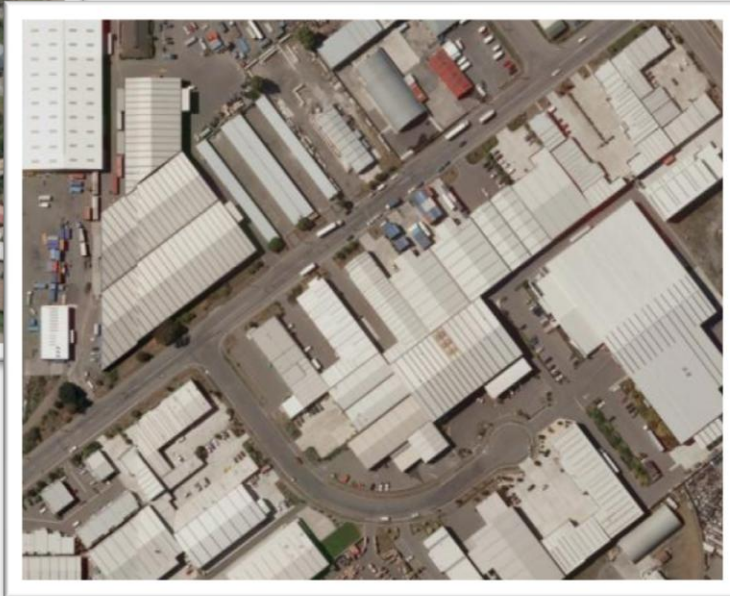
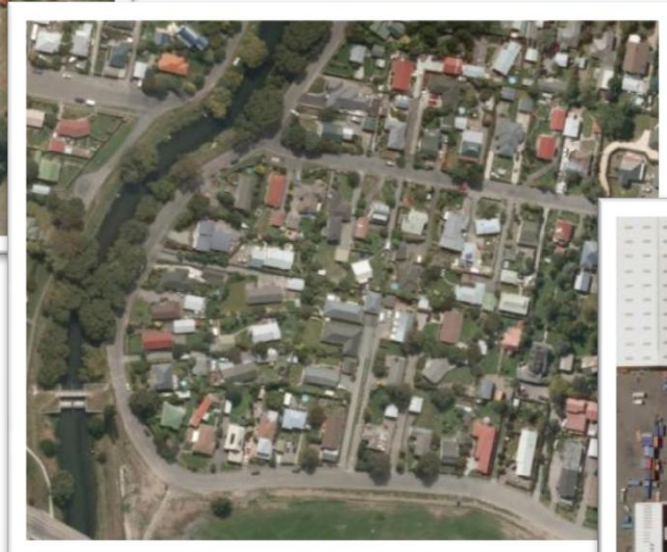


# Impacts of Porous Pavements on Soil Environment and Street Tree Growth

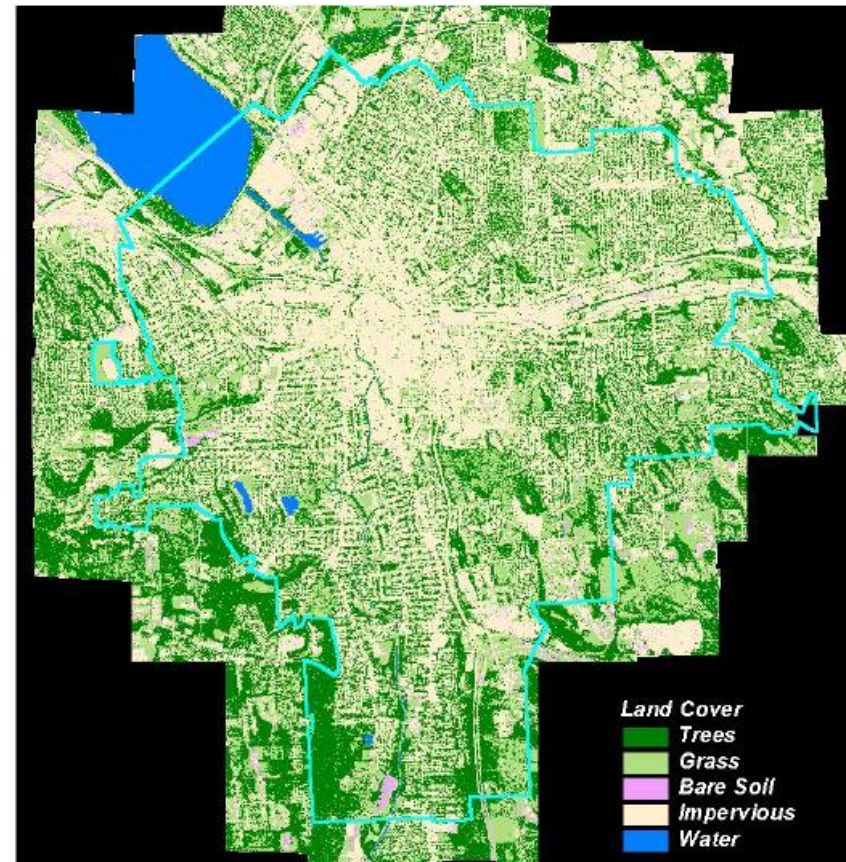
*Justin Morgenroth  
New Zealand School of Forestry  
University of Canterbury*

# Impervious Urban Surfaces



# Impervious Urban Surfaces

- Disrupt hydrological cycle
  - Local flooding, drought, limits evaporation, etc
- Associated with urban heat island effect
- Believed to hinder tree growth and physiology
- Reflected in canopy cover



# Pavement is Pervasive

- 93% of roads in America unpaved in 1904
- Change came with the ascendancy of the automobile
- Now, >50% of dense urban cores paved



Photo credit: Joel Tauber

# Porous Paving

- Monolithic construction:
  - Pervious paving
  - No-fines paving
  - Open-graded paving
  - Gap-graded paving
  - Percolating paving
  - Percrete
- NOT permeable paving
  - Blocks
  - Turfstone




# Porous Paving

- Main reasons for installation:
  - improved stormwater management
  - safety
- Alleged to provide great benefits to urban trees
- But do they?



# Here's What the Experts Think



- Prof. Bruce Ferguson, Landscape Architect, University of Georgia "***ideal for protecting trees in a paved environment***"
  - Paul D. Tennis, Civil Engineer, Portland Cement Association "***increase the longevity of trees by improving moisture and oxygen relations***"
  - Prof. Vern Schaefer, Civil Engineer, University of Iowa "***preserving native ecosystems***"
  - Where's the proof?
- 

# The Big Question

Across varying pavement profile designs, does porous paving affect tree growth relative to standard impervious paving

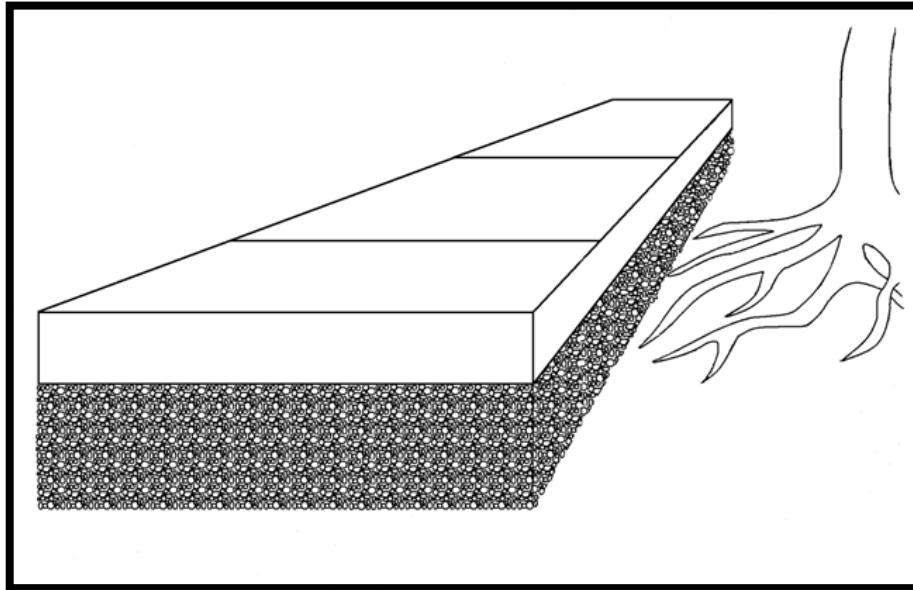




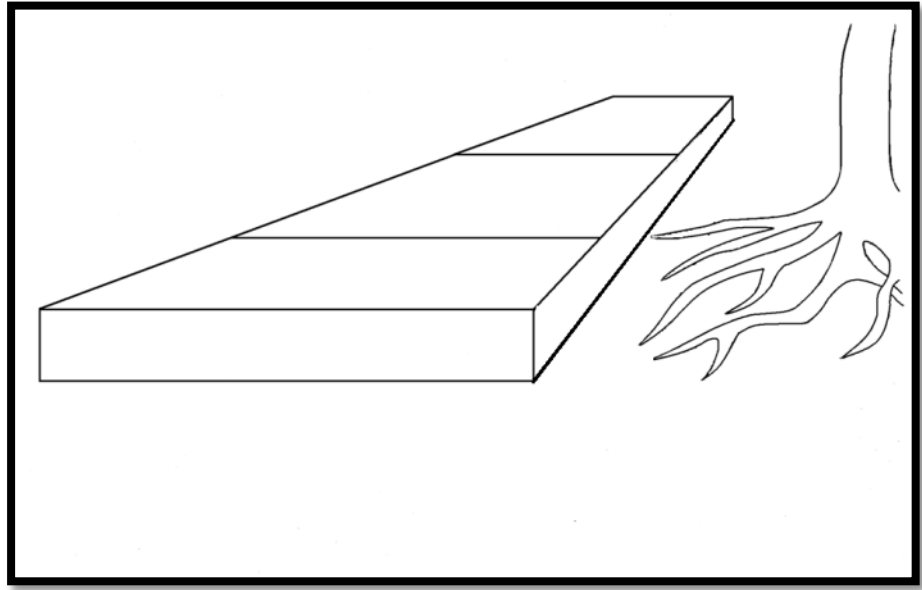
# Pavement Type



# Pavement Profile Design



Structural



Non-Structural

# Treatments



1. Control
2. Porous / Structural
3. Porous / Non-structural
4. Impervious / Structural
5. Impervious / Non-structural

# Data Collection

## Tree Growth:


- Stem Height
- Stem Diameter
- Shoot/Root Biomass
- Root Diameter and Distribution



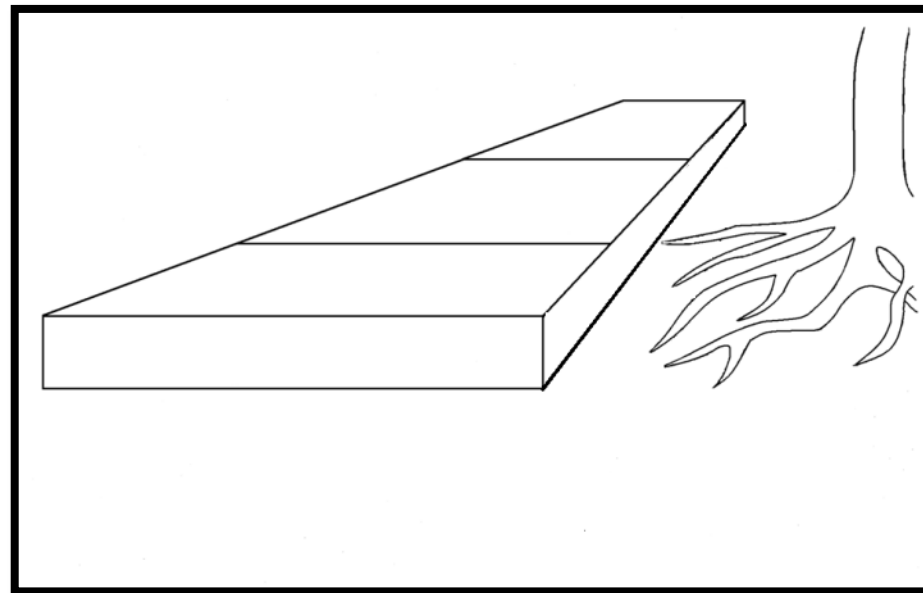
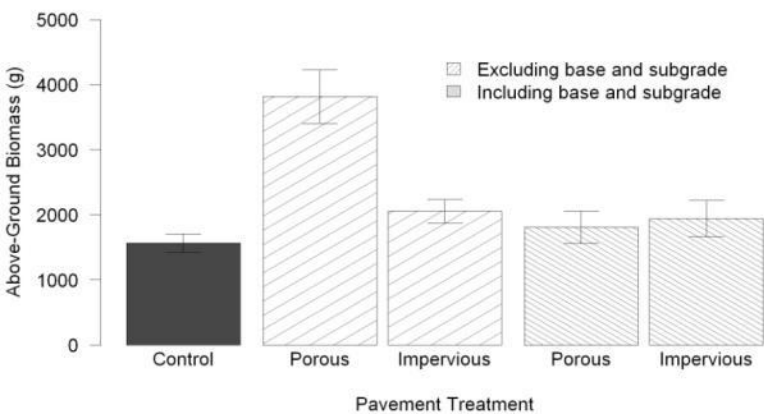
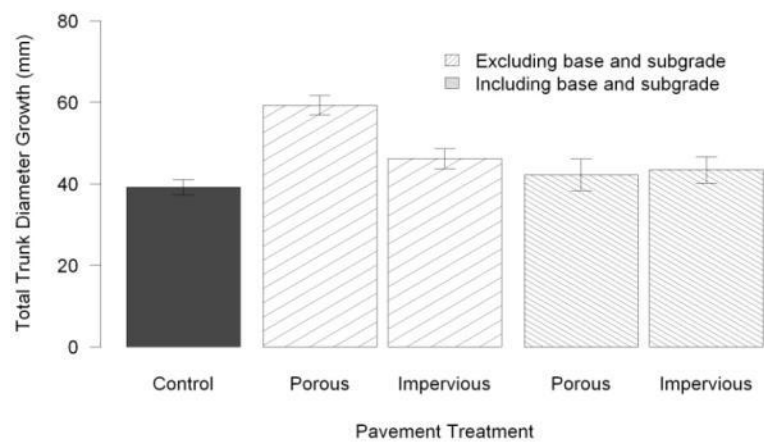
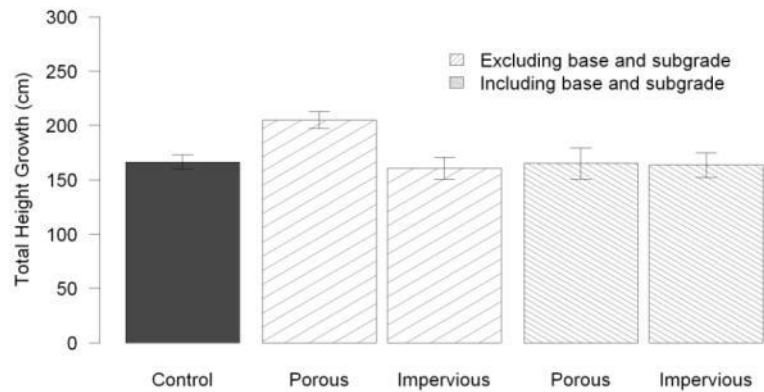
## Soil Factors:

- Water content
- Aeration
- pH

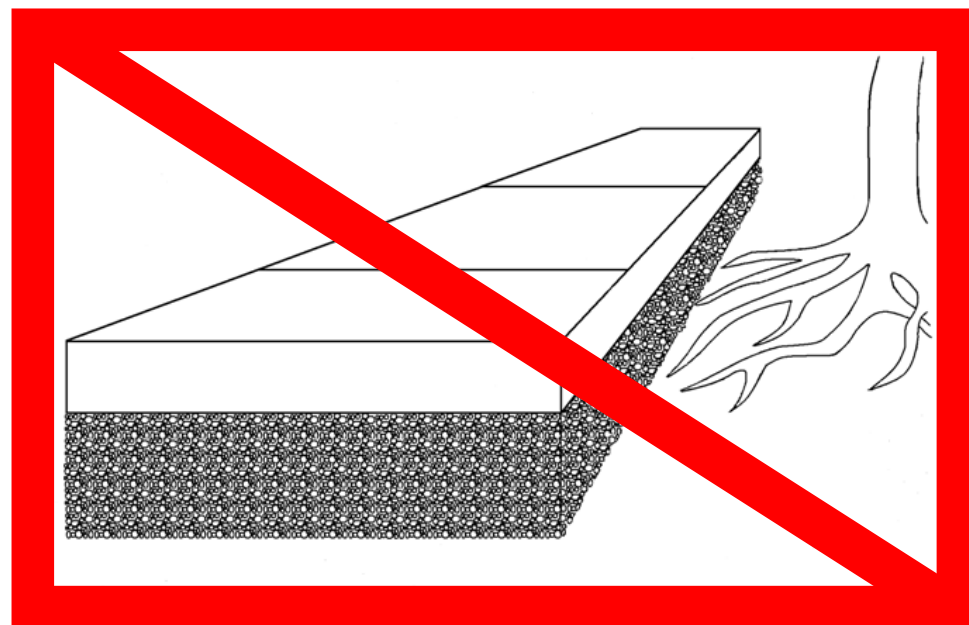





*Did the 4 different  
pavement treatments  
affect above and below-  
ground tree growth?*




# Diameter Growth

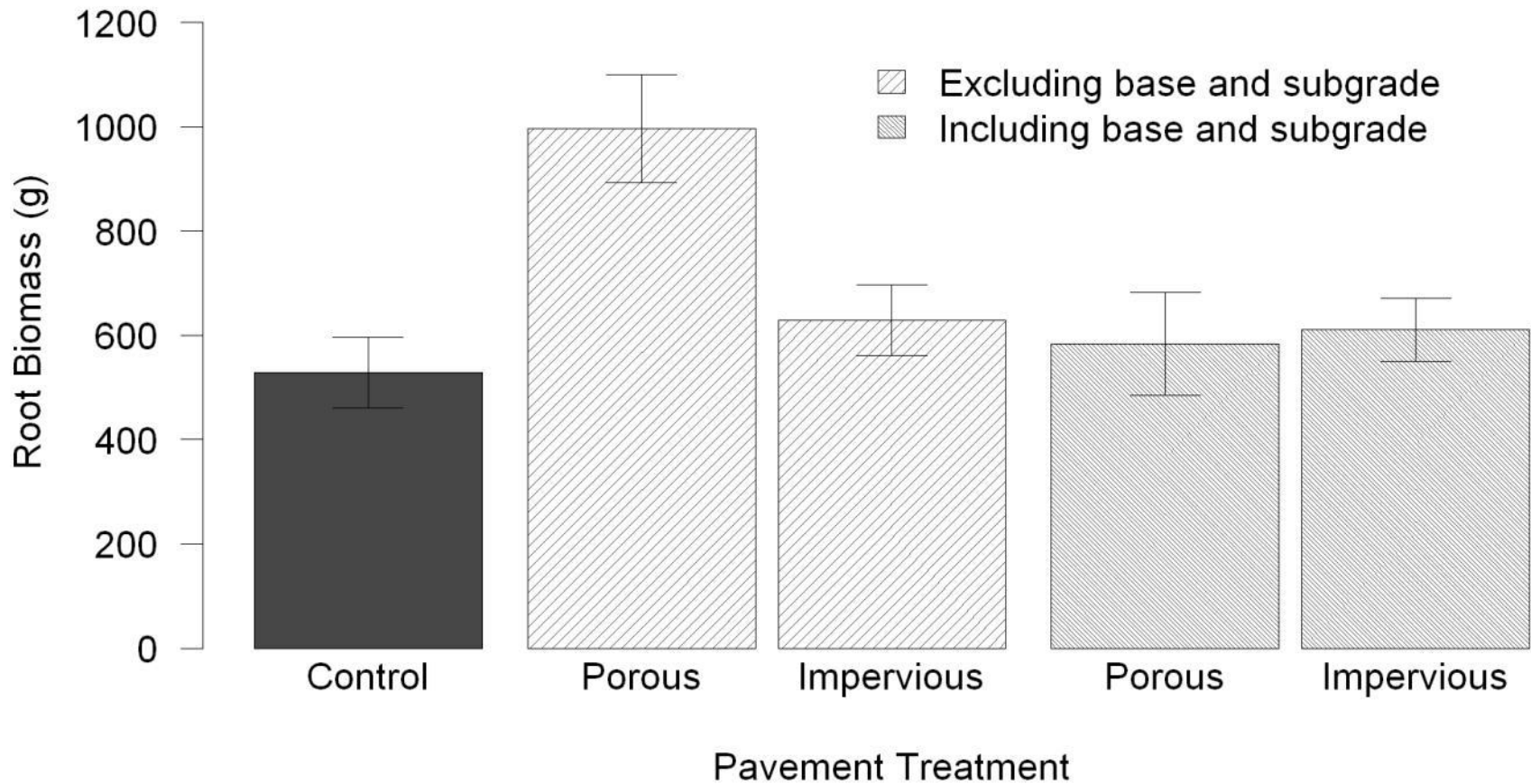




*Why is above-ground  
growth consistently  
greater with porous  
pavement?*



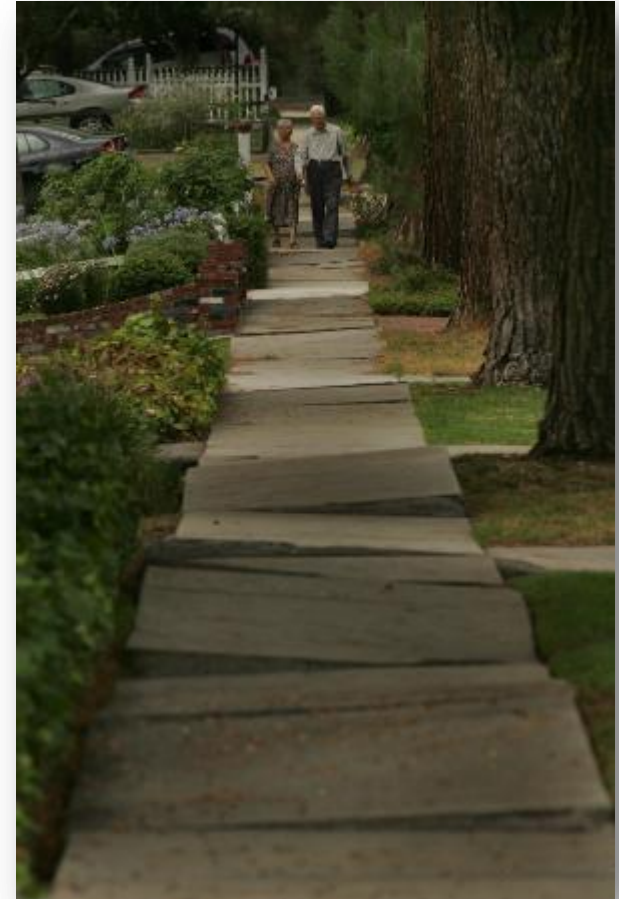
# Root Biomass





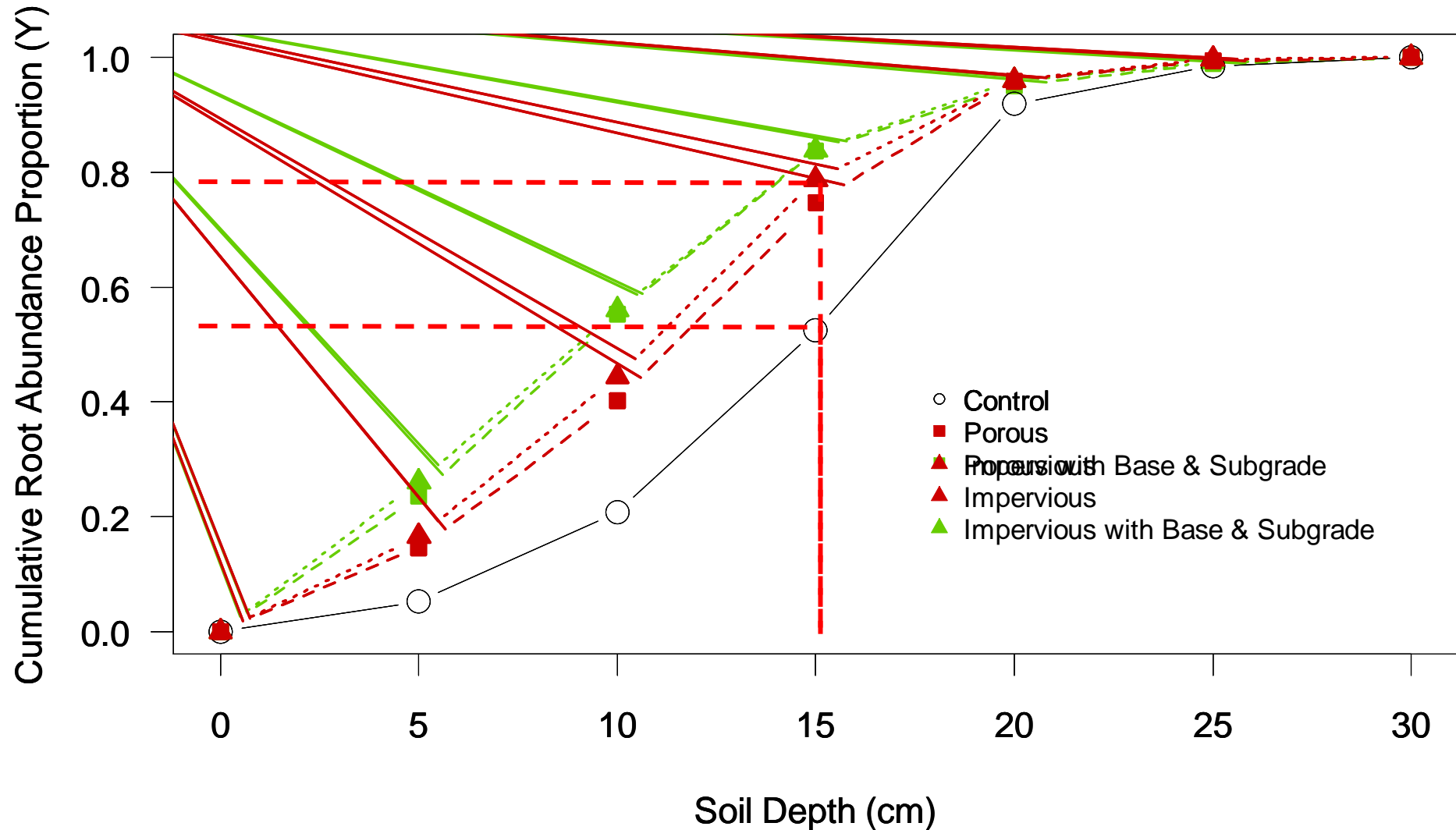
# Increased Root Growth

- Not always desirable
- Shallow root growth problematic
- Increased incidence of infrastructure conflict
  - Very Expensive Problem
- So how did pavement affect root distribution?




*Photo: Cracked, uneven sidewalk along Cabanas Avenue in Tujunga in 2006.  
Credit: Richard Hartog / Los Angeles Times*

# Root Distribution



# Tree Growth Summary



- Porous paving yielded greater:
    - Stem height and diameter growth
    - Shoot and root biomass
  - True only when pavement profile design excluded structural elements
  - All pavements resulted in shallow root growth
- 

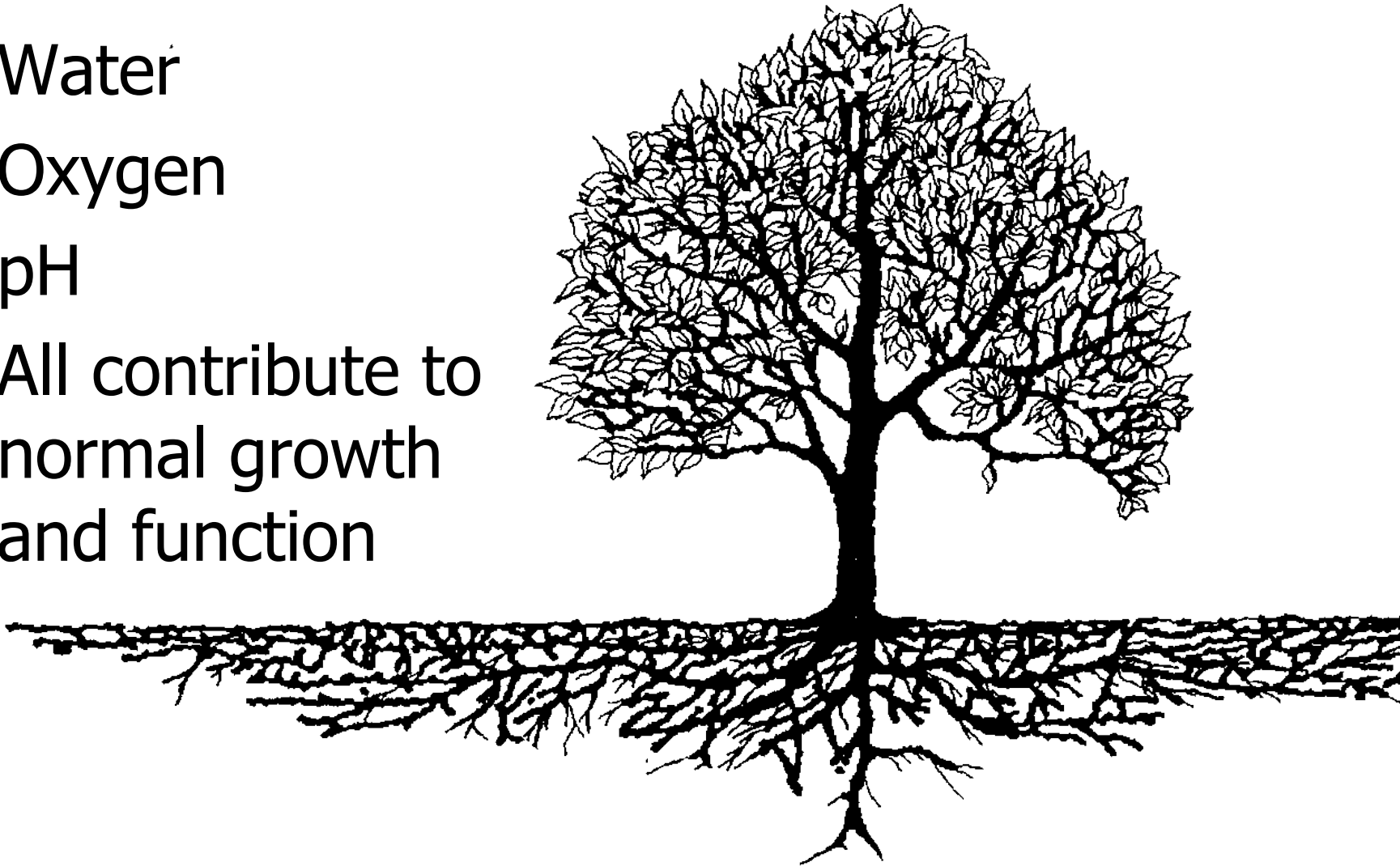


*What is it about porous pavements that allows trees to grow larger?*

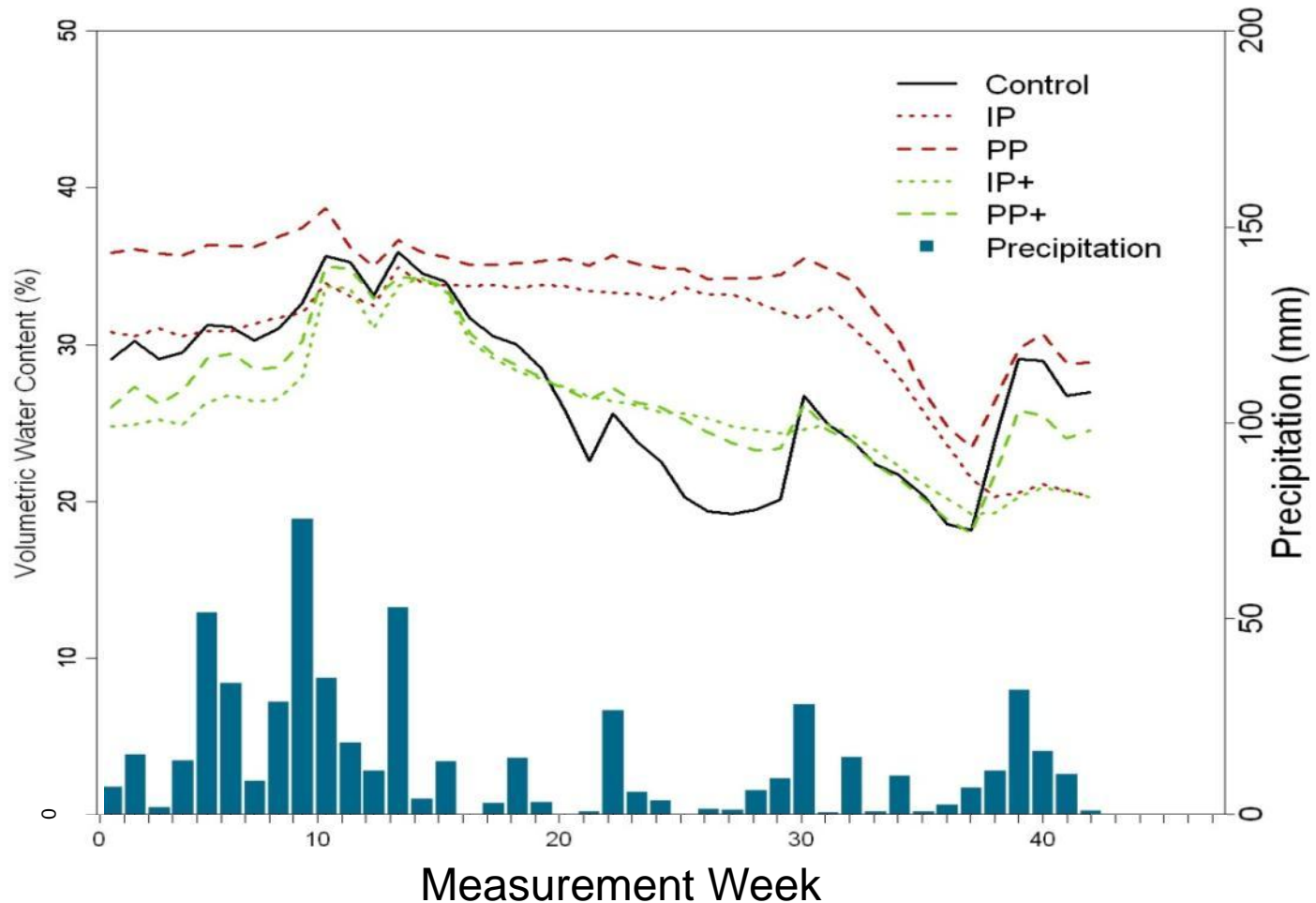


# Why are Trees Growing Larger?

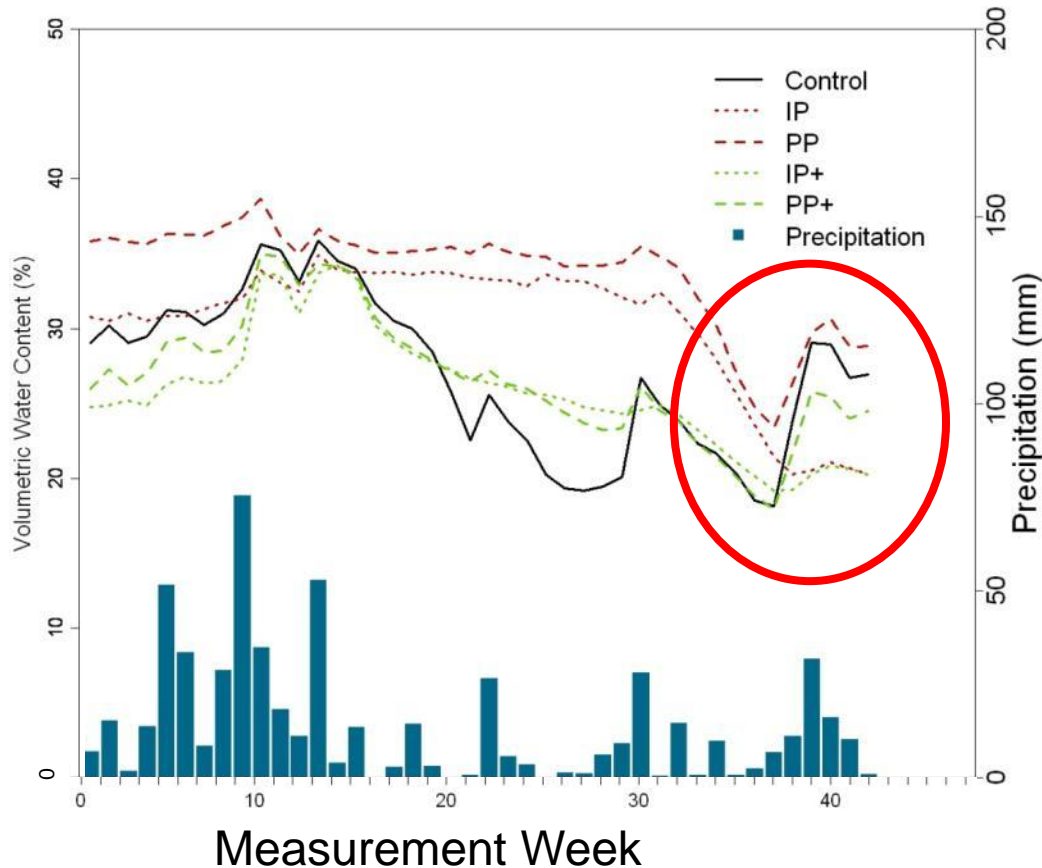
- Water
- Oxygen
- pH
- All contribute to normal growth and function



# Why are Trees Growing Larger?



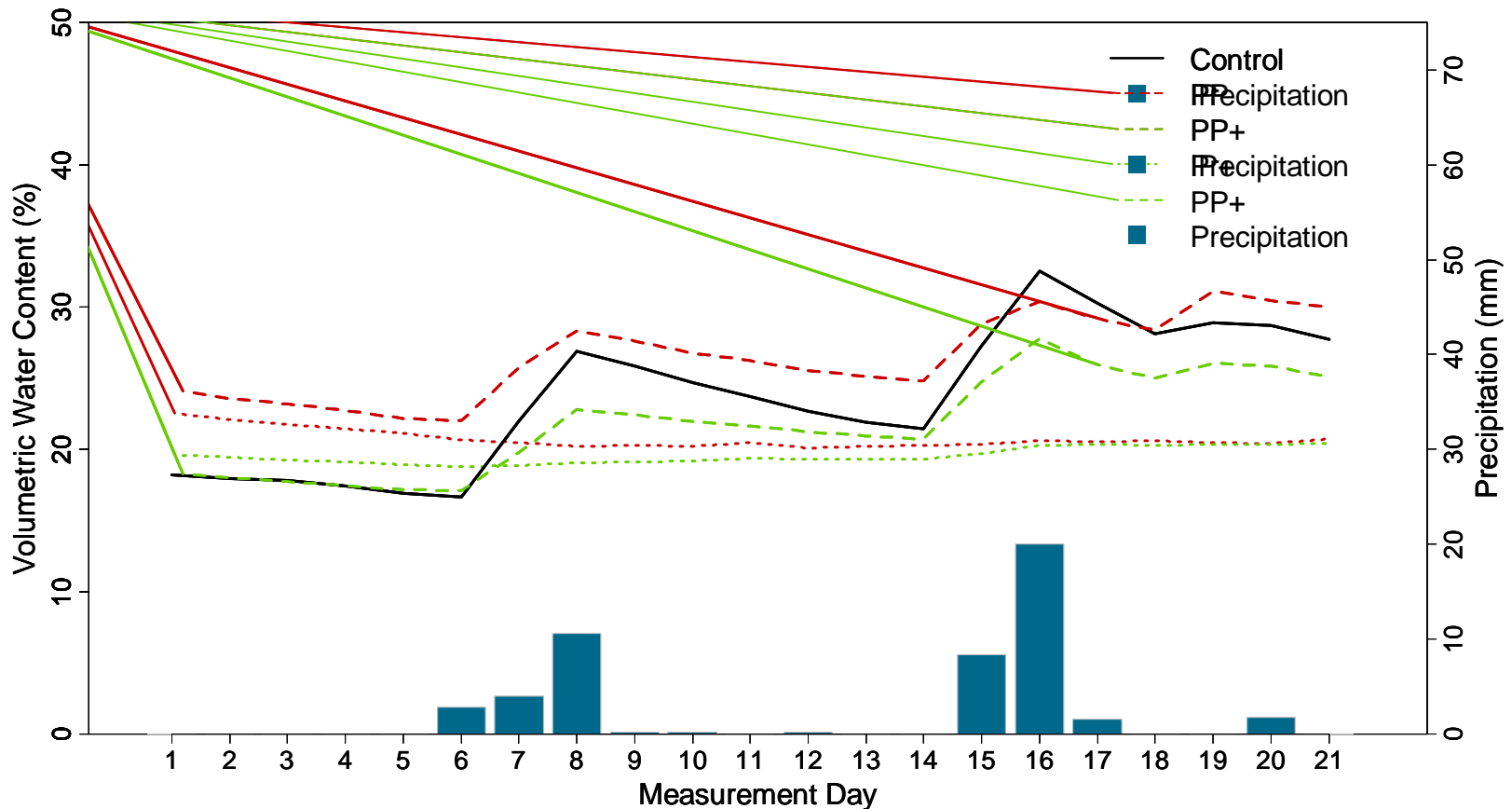
# 1 - Infiltration



- Porous pavement allows for rapid infiltration of rainfall
- Importance depends on current soil moisture

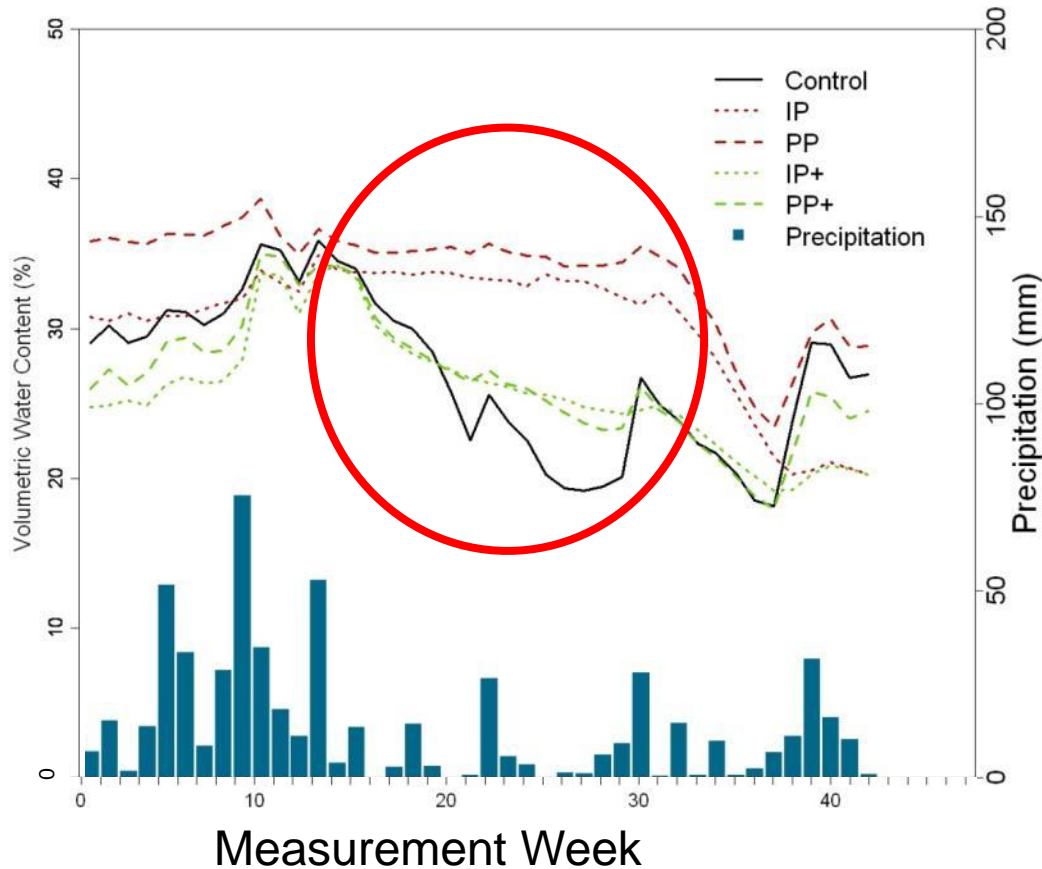
# 1. Infiltration

Increased infiltration at key times – late summer



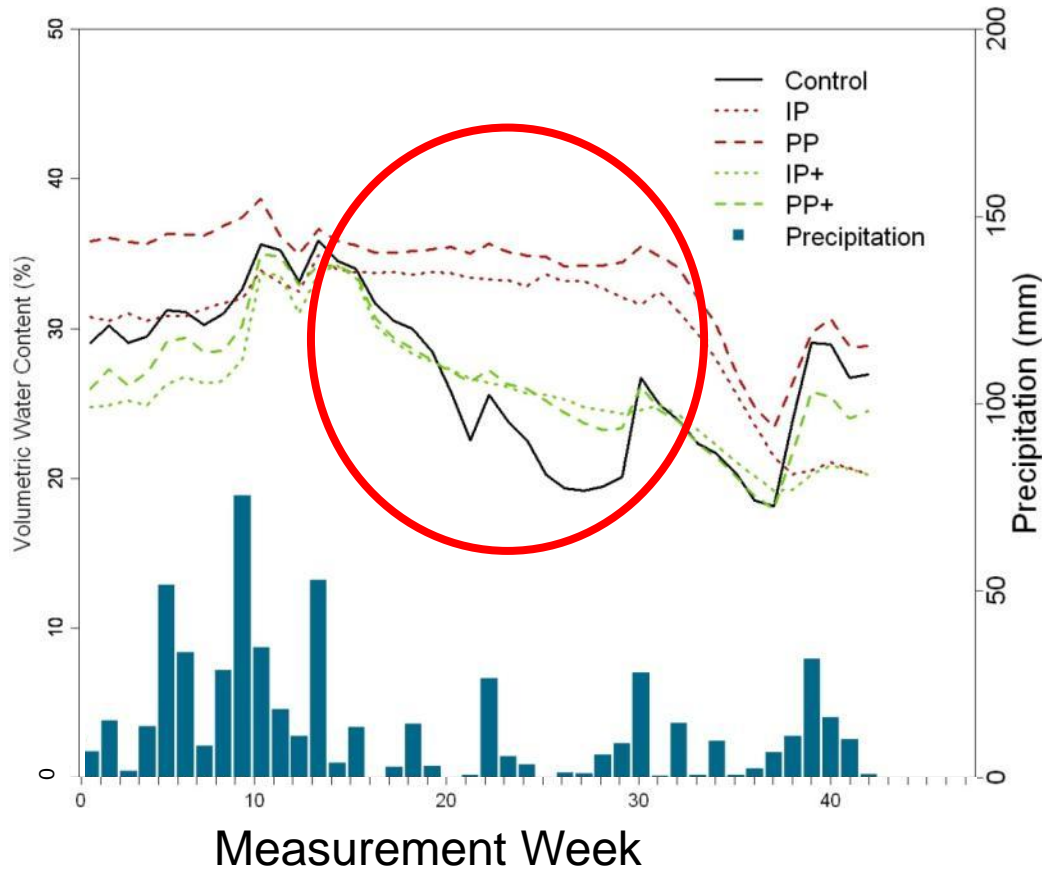


# 2 - Evaporation



- Pavement prevents evaporation of soil moisture
- Just like mulch
- Why didn't all pavements do the same thing?


# 3 - Distillation



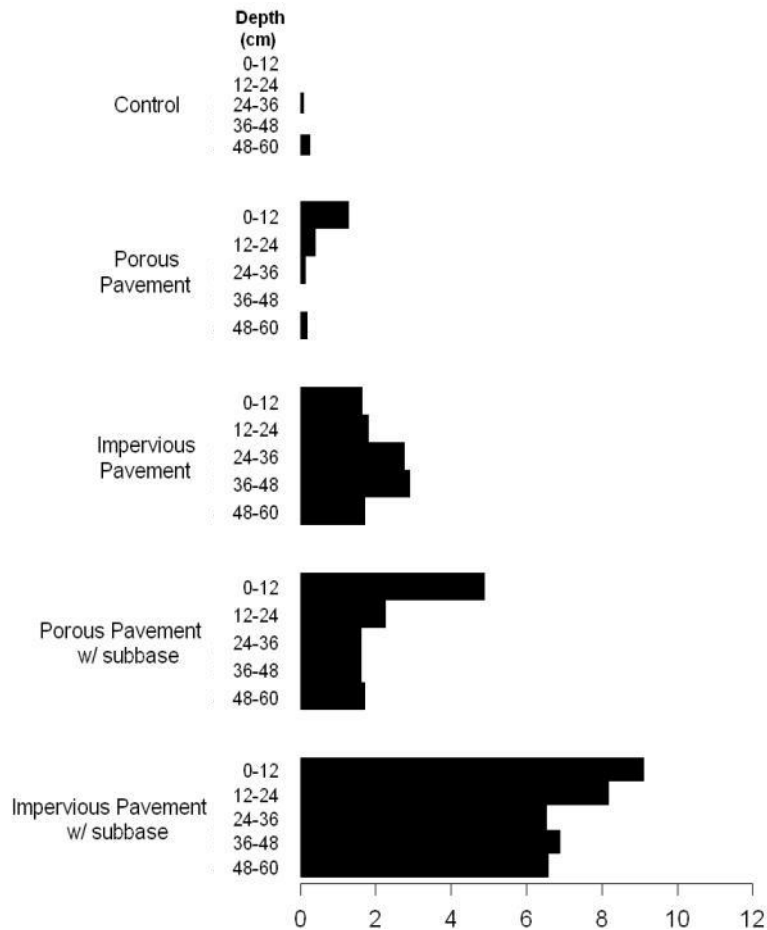
- Water follows temperature gradient
- Pavement cools faster than soil
- Gravel layer acts as capillary break

# Soil Moisture Summary



1. Soil moisture higher beneath paved surfaces due to buffering from evaporation
  2. Soil moisture higher without gravel subbase due to distillation effect
  3. Soil moisture higher beneath porous pavement due to infiltration
- 

# Why are Trees Growing Larger?



- During wet spring, no difference
- During dry summer, porous has greater aeration than impervious
- Likely related to diurnal soil moisture dynamics

# Why are Trees Growing Larger?

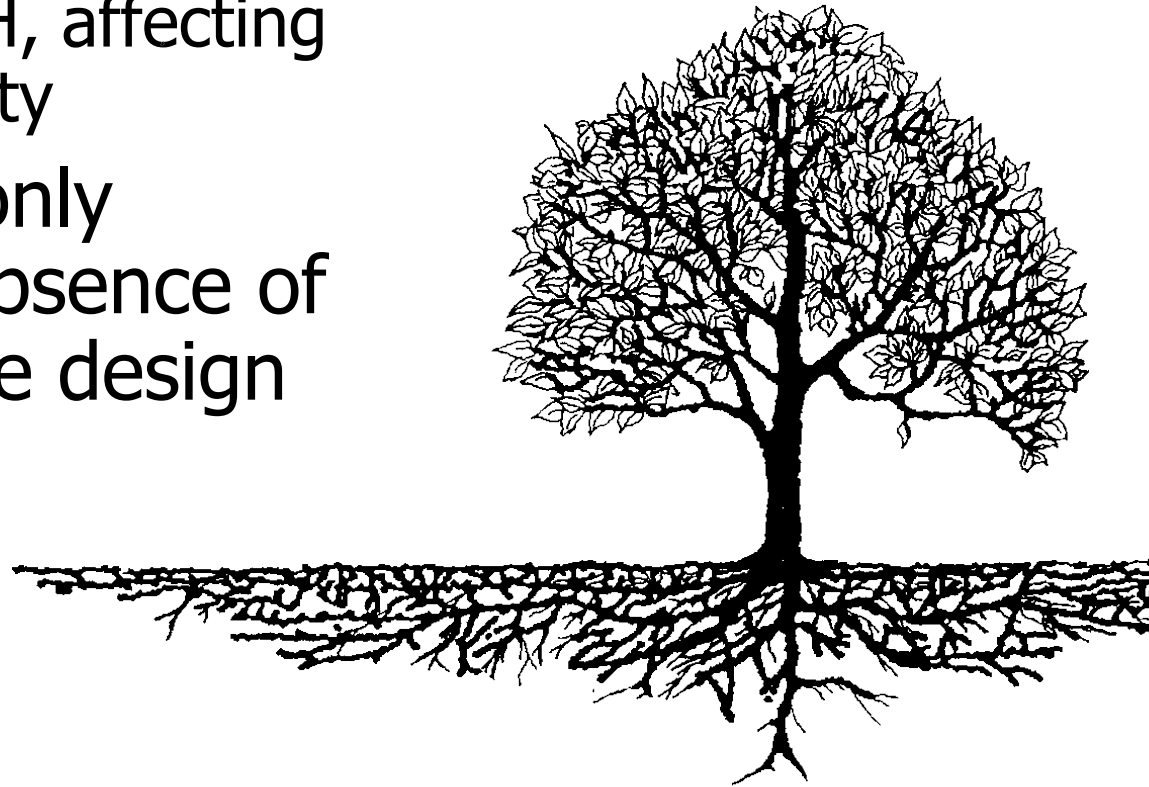


- Neutralisation of acidic soil via leaching of cations from pavements

<b>Treatment</b>	<b>pH</b>
Control	5.75
Impervious	6.00
Porous	6.35
Impervious + Structural	6.26
Porous + Structural	6.58

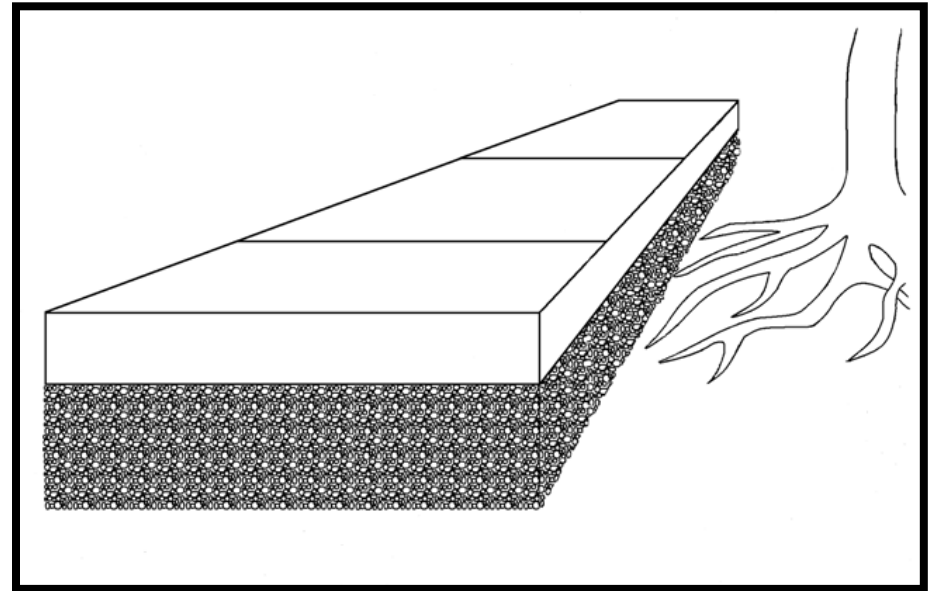
# Why are Trees Growing Larger?

- Porous pavement improved tree growth by:
  - Allowing for infiltration of rain at key times
  - Allowing for higher soil aeration
  - Increasing soil pH, affecting nutrient availability
- But tree growth only occurred in the absence of a structural profile design
- Why?



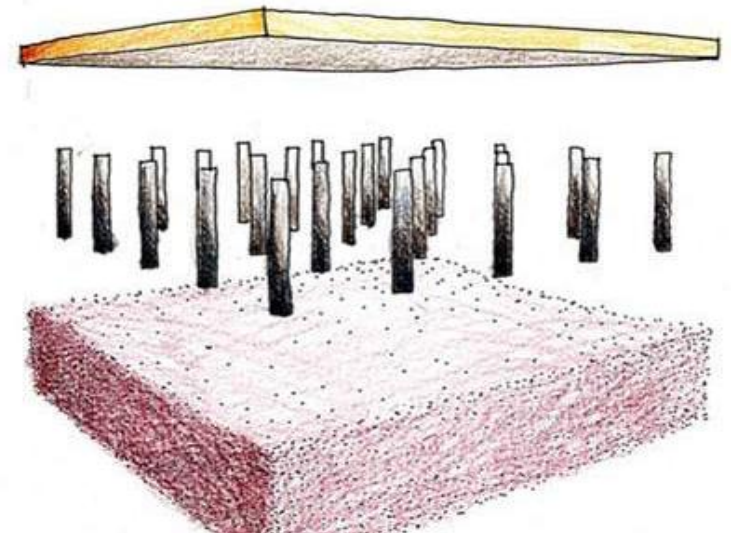
# Soil Compaction

- In structural plots, soil strength was 3x greater
- Compaction acted as a bottleneck
  - Prevented roots from taking advantage of better growing conditions



# Ideal Uses of Porous Pavement

- Porous pavement may be used effectively in conjunction with:
  - Suspended pavements
  - Engineered soils





# Take-Home Messages



- If porous pavement is installed to improve conditions for tree growth, important to remember:
  - Porous pavement is not a miracle cure
  - Care for soil necessary if porous pavement is intended to improve tree growth
  - Take care of the soil and the soil will care for the tree

# Acknowledgements



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