

# The importance of forest structure to rainfall partitioning and cloud interception: a comparison of native forest sites in Kona, Hawai'i

Kate A. Brauman, David L. Freyberg, Gretchen C. Daily

Stanford University

2nd International Conference on Forests and Water  
Raleigh, 15 September 2009



# Key Question



How does land cover in upland Kona affect coastal water resources?



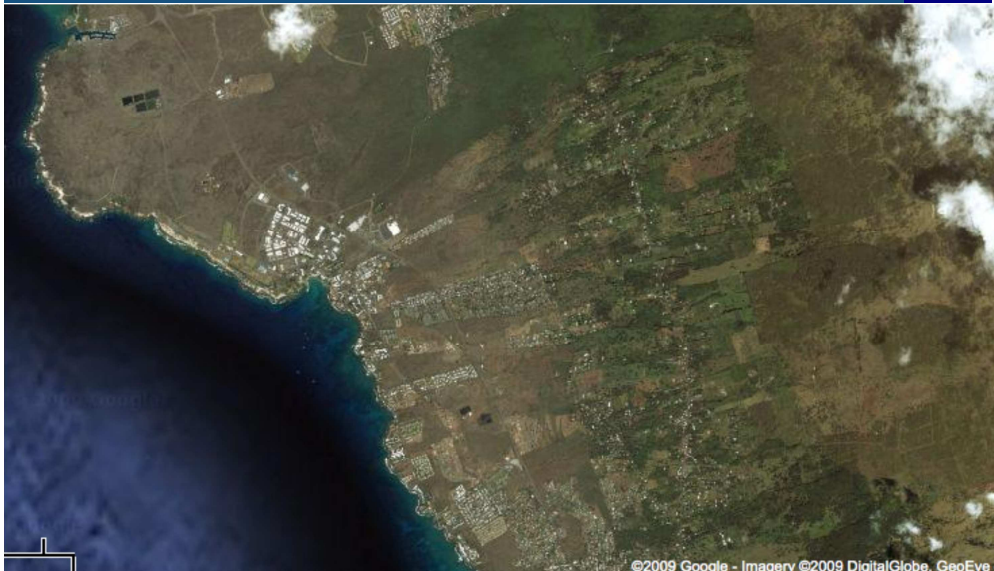
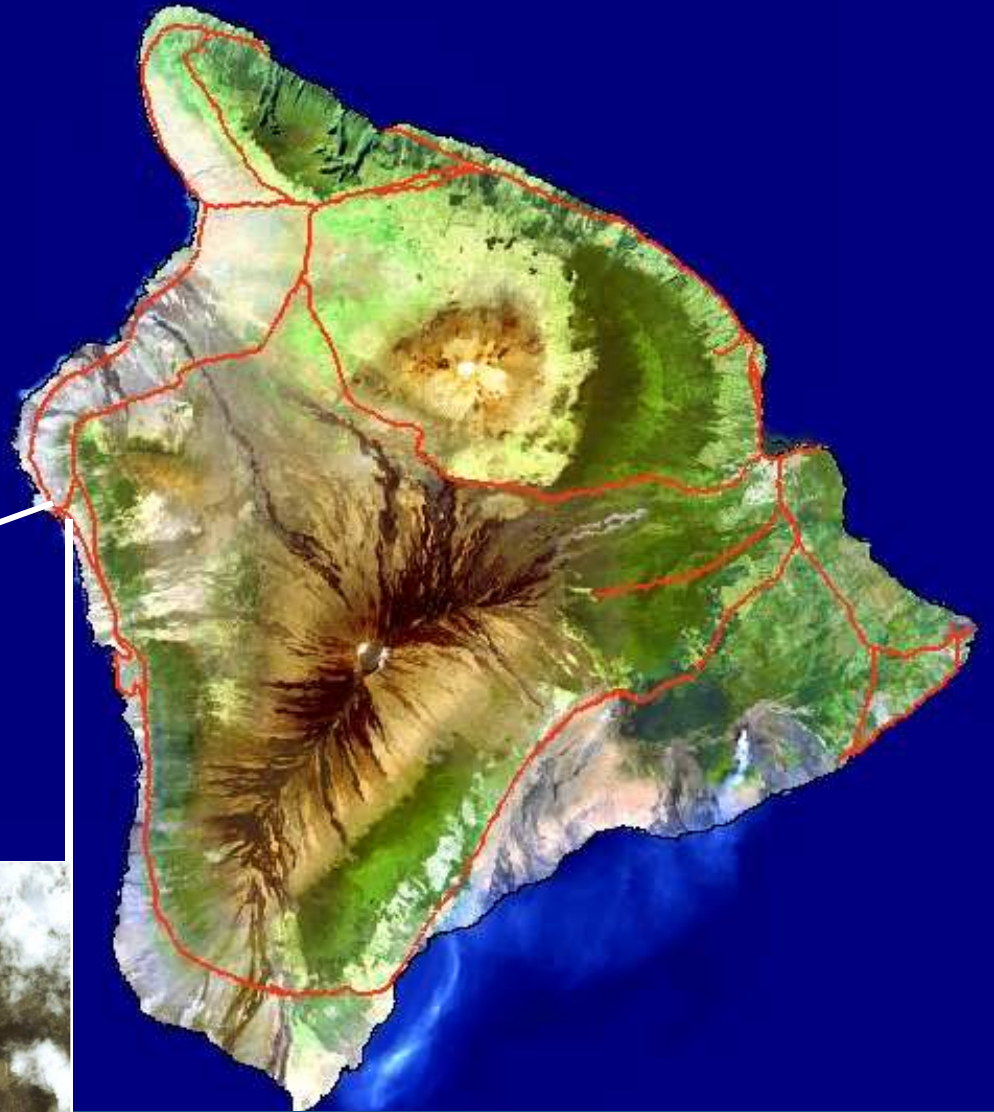
# Outline



- Hydrologic Ecosystem Services in Kona, Hawai'i
- Rainfall and Throughfall
- Forest Structure

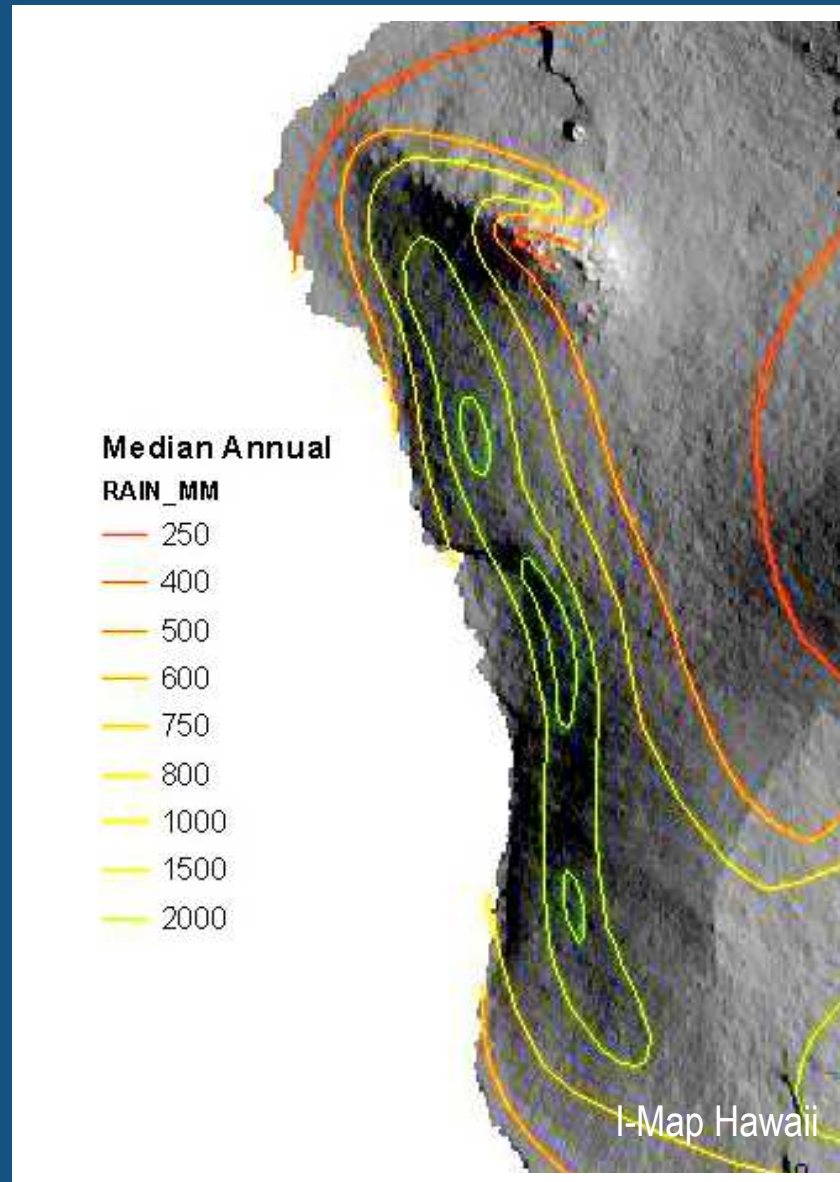


# Kailua-Kona, Hawai'i, USA

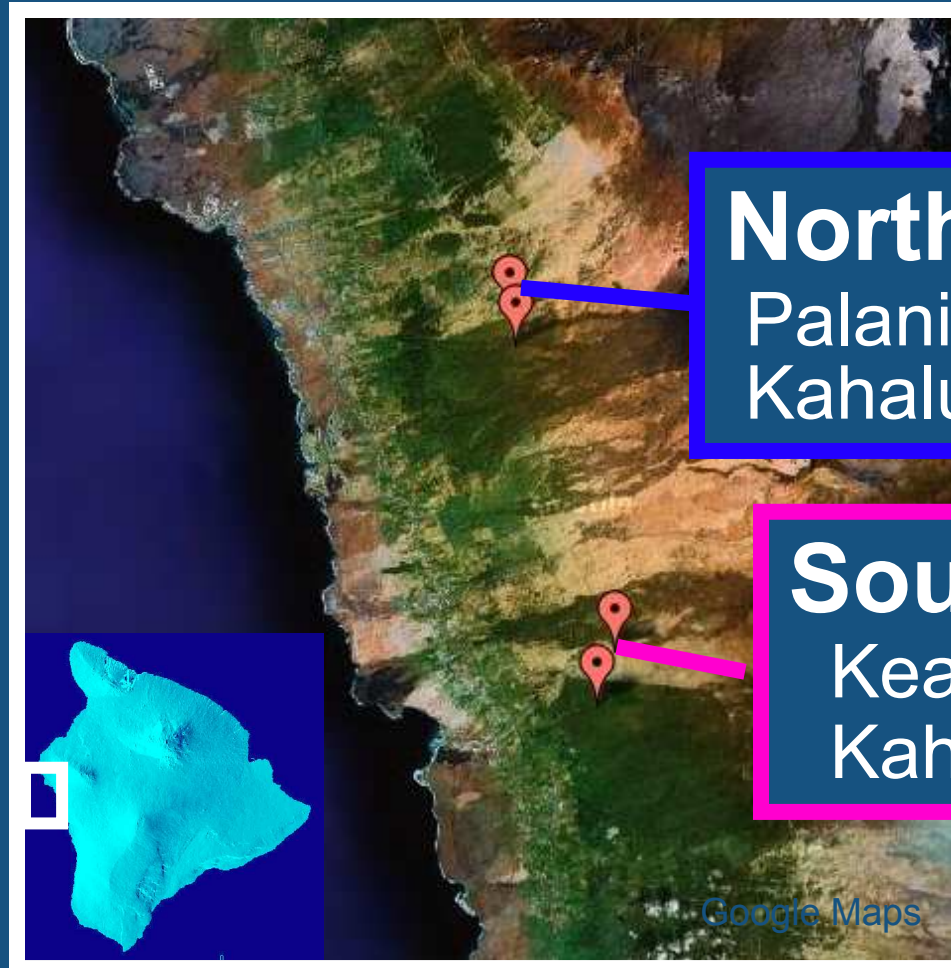




# Average Annual Rainfall



# Study Location: Kona, Hawai'i



**North Site**  
Palani Ranch  
Kahalu'u Forest

**South Site**  
Kealakekua Ranch  
Kahauloa Forest





South Site



Kealakekua Ranch



Kahauloa Forest







# Ecohydrologic Processes

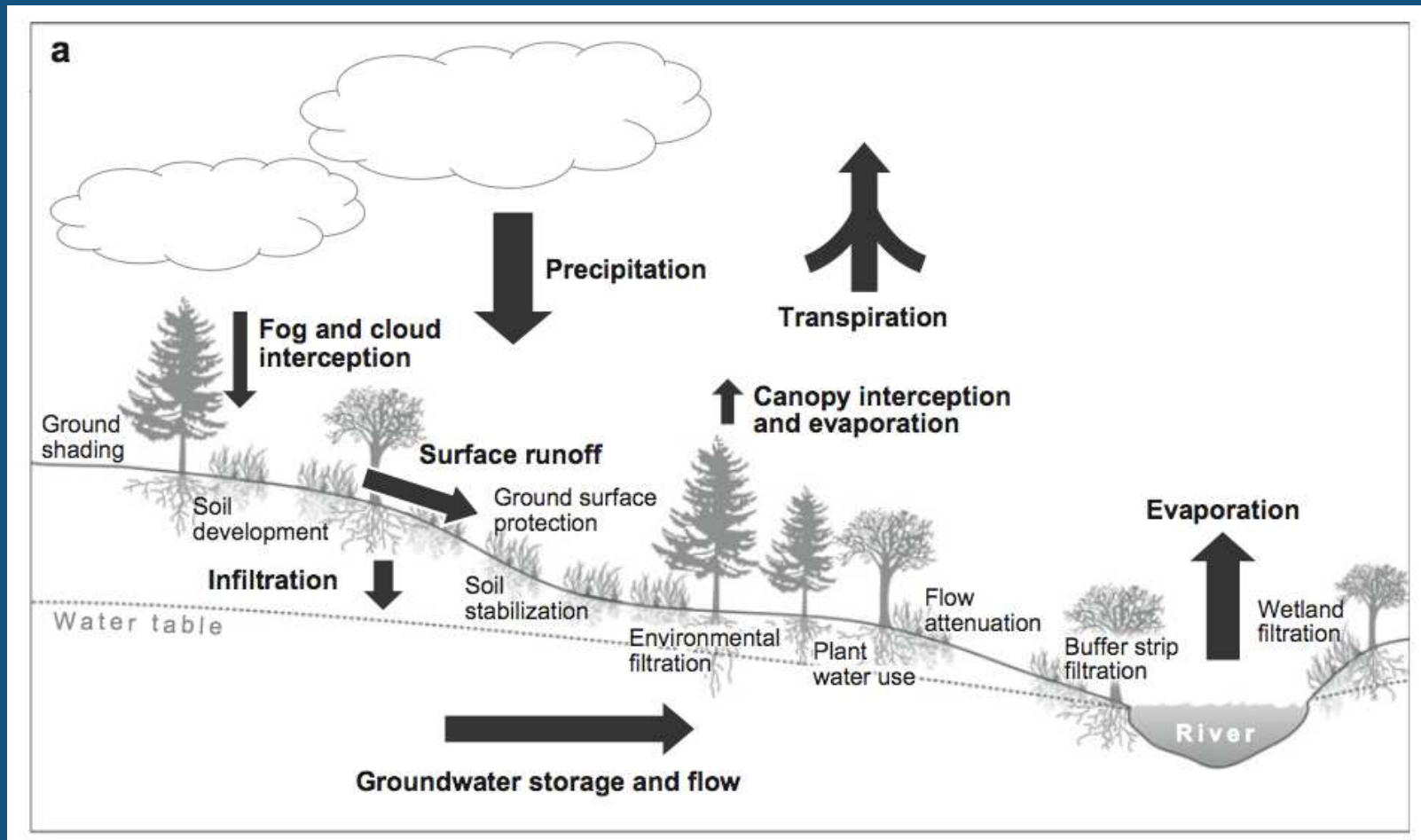


Figure from Brauman et. al. ARER 2007

# Hydrologic Service

*(what the beneficiary receives)*

Municipal Water  
Supply



## Hydrologic Attribute

*(direct effect of the ecosystem)*

## Hydrologic Service

*(what the beneficiary receives)*

Quantity

Municipal Water  
Supply

## Ecohydrologic Process

*(what the ecosystem does)*

## Hydrologic Attribute

*(direct effect of the ecosystem)*

## Hydrologic Service

*(what the beneficiary receives)*

Local climate interactions



Quantity



Water use by plants

Municipal Water Supply



# Ecohydrologic Process

*(what the ecosystem does)*

# Hydrologic Attribute

*(direct effect of the ecosystem)*

# Hydrologic Service

*(what the beneficiary receives)*

Local climate interactions



Quantity

Water use by plants



Municipal Water Supply

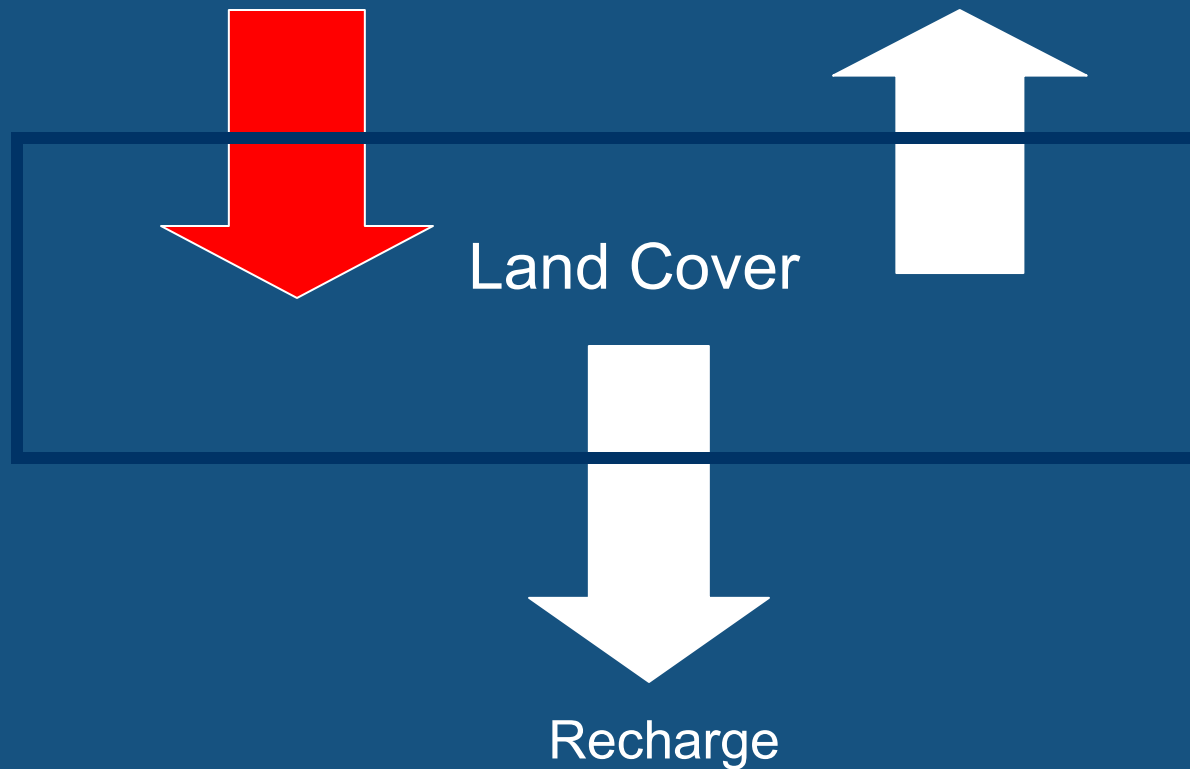


# Water Balance

$$R = P - ET$$

Precipitation

Evapotranspiration





# Outline



- Hydrologic Ecosystem Services in Kona, Hawai'i
- Rainfall and Throughfall
- Forest Structure



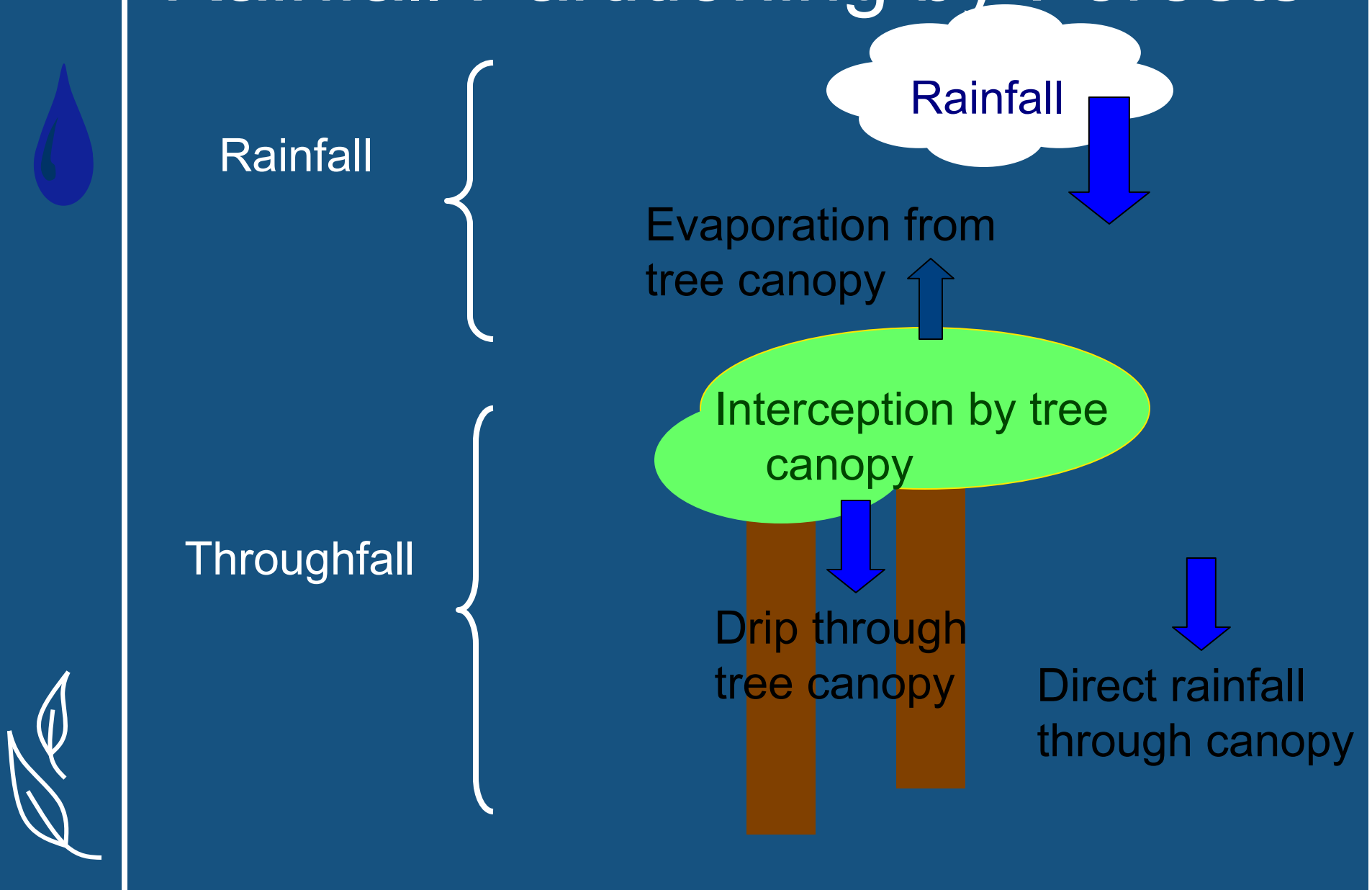
# Key Findings



- Fog provides at least 30% of throughfall
- Throughfall at the South site is nearly 50% greater than at the North site



# Rainfall Partitioning by Forests





# Rainfall Partitioning by Forests



*Pasture gage*

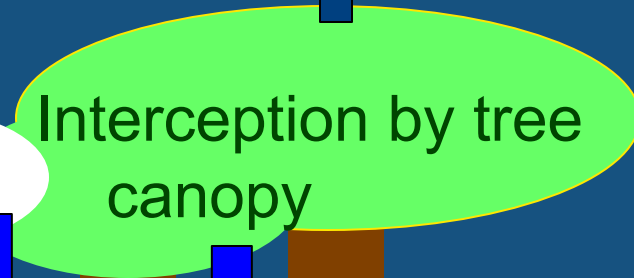


Evaporation from tree canopy



Fog incorporated directly onto water film on trees

Interception by tree canopy



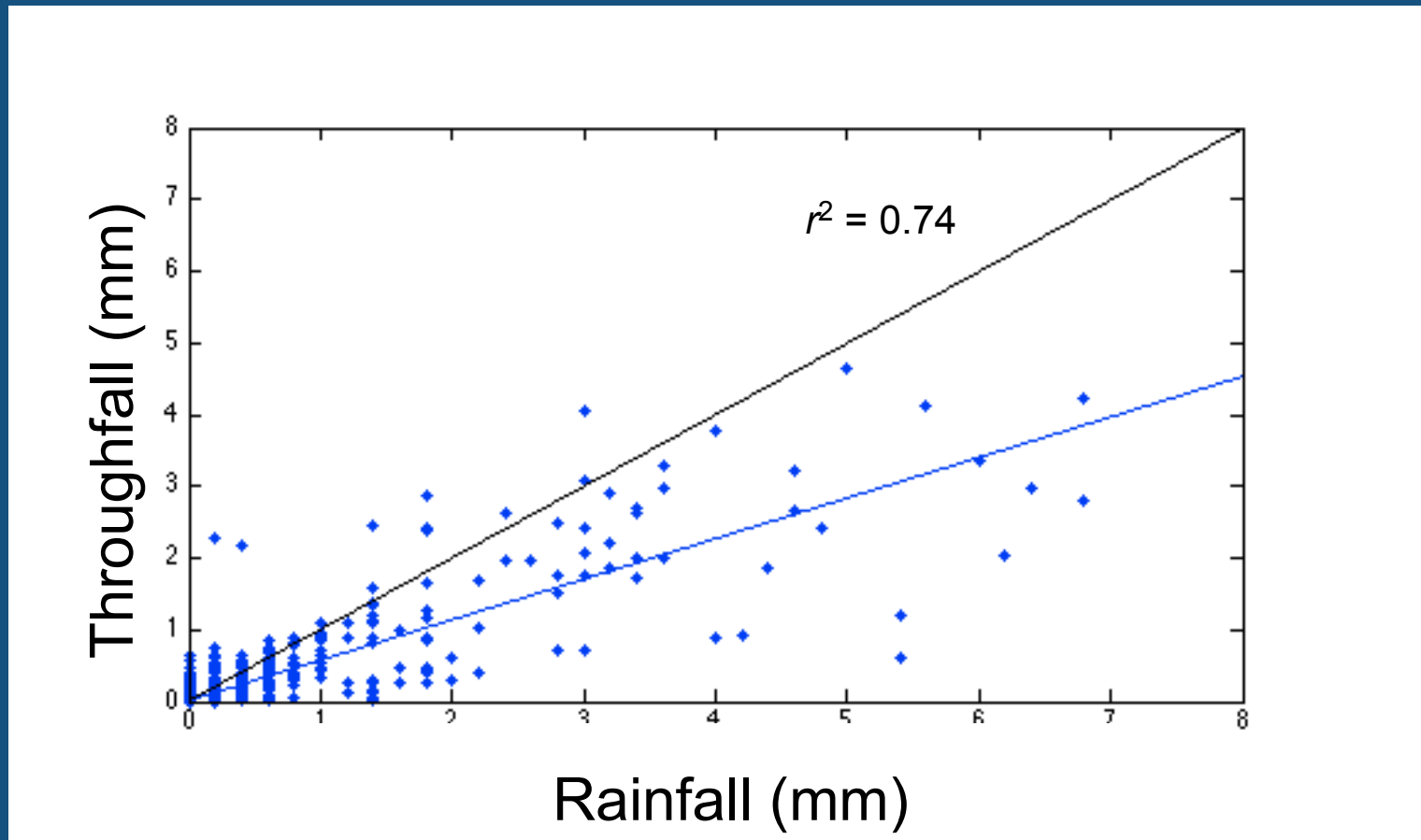
*Forest gages*



# Throughfall Collector



# Comparison of Hourly Precipitation Above and Below Canopy

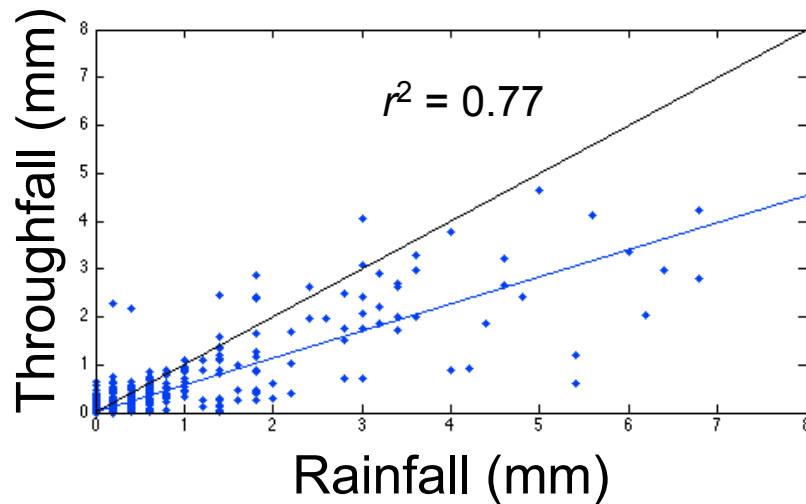


Throughfall = 59% of Rainfall

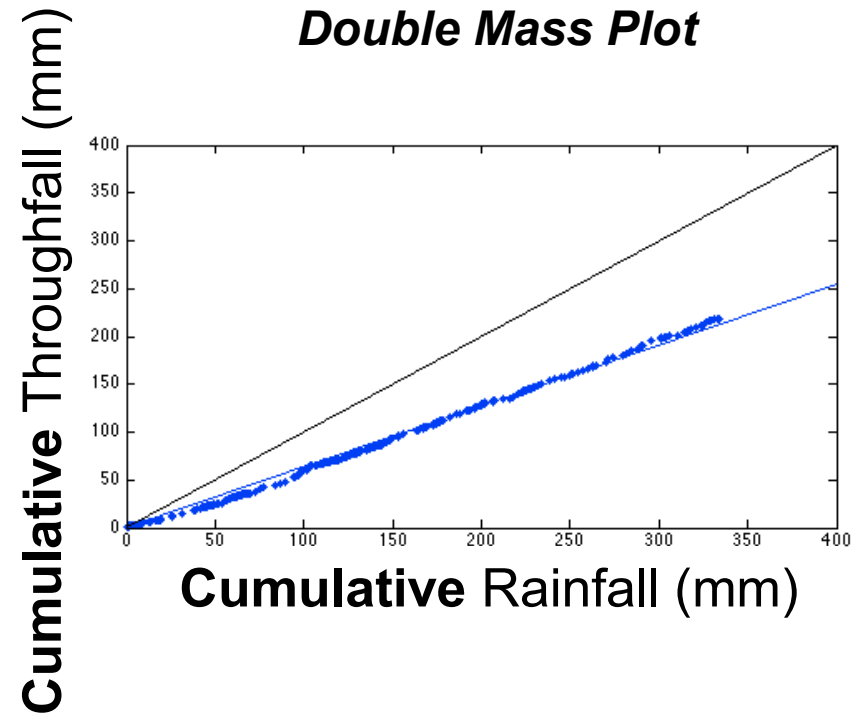


# Comparison of Hourly Precipitation Above and Below Canopy

**Scatter Plot**



**Double Mass Plot**



Throughfall = 59% of Rainfall

Throughfall = 64% of Rainfall

# Worldwide Throughfall Trends

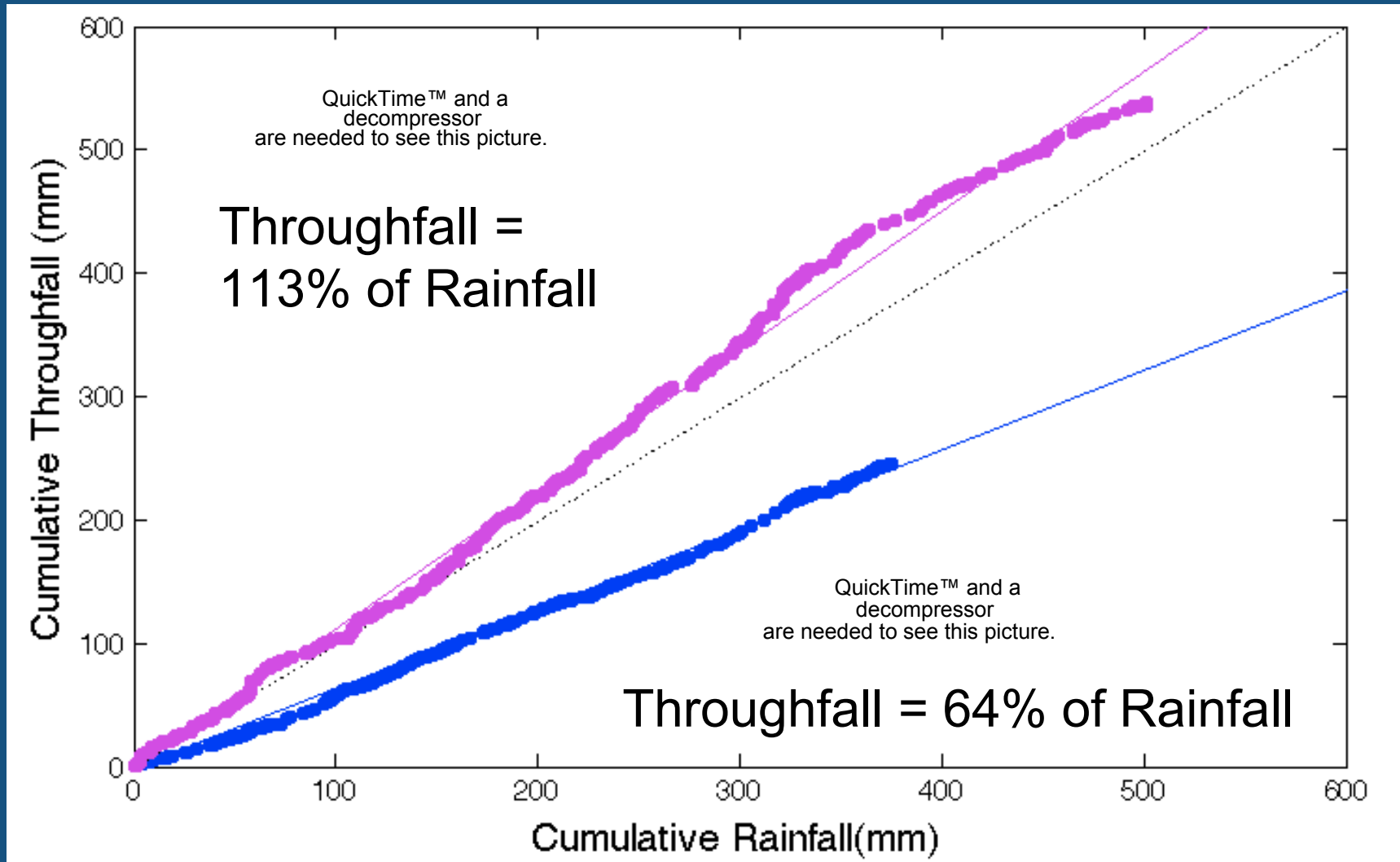


- Broadleaf and Coniferous Temperate Forests  
Throughfall = 69-89% of Rainfall
- Tropical Forests  
Throughfall = 61%-95% of Rainfall

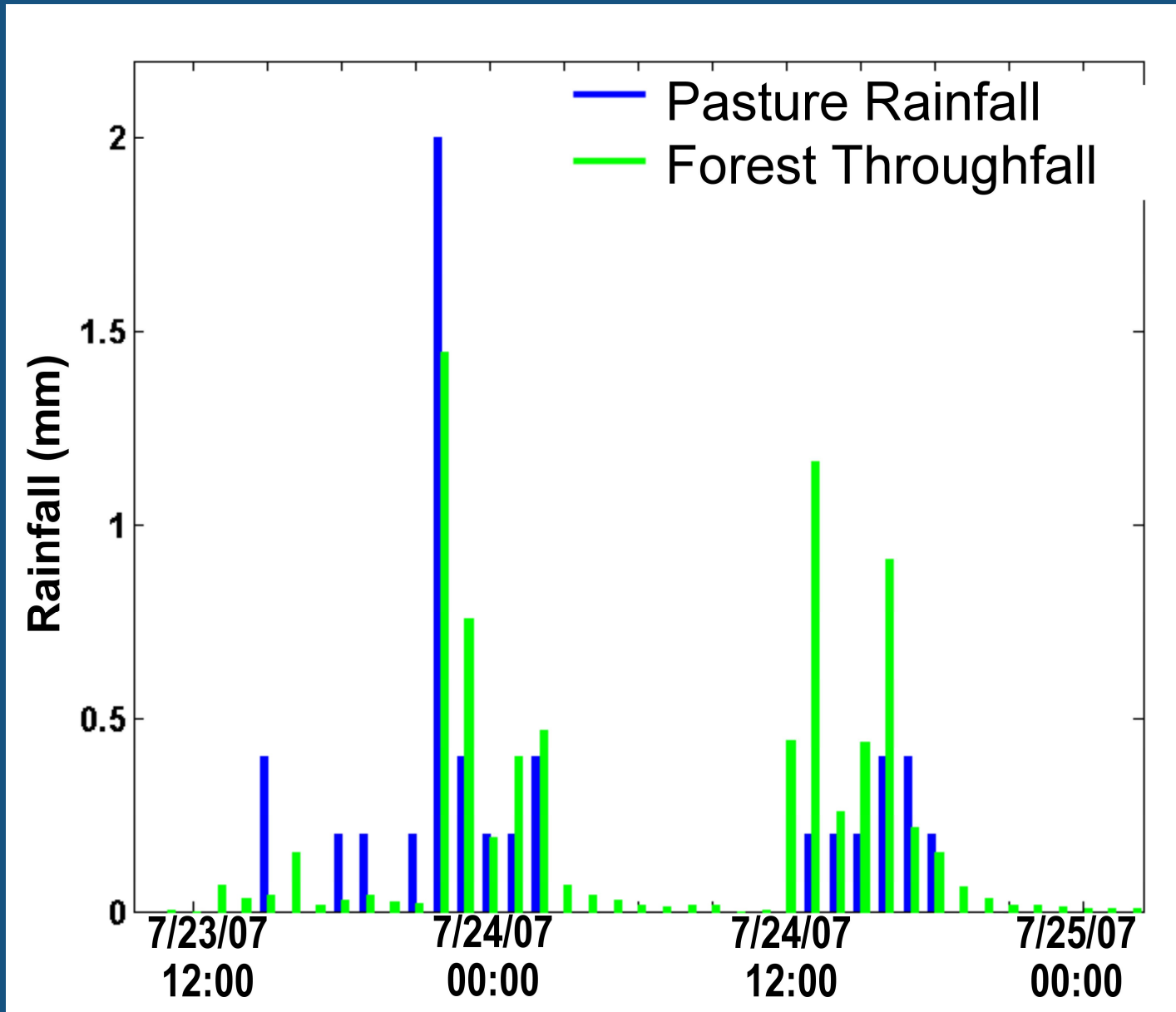


Cuartas, L.A., et al., *Agricultural And Forest Meteorology*, 2007.  
Germer, S., H. Elsenbeer, and J.M. Moraes, *Hydrology And Earth System Sciences*, 2006.  
Llorens, P. and F. Domingo, *Journal Of Hydrology*, 2007.  
Crockford, R.H. and D.P. Richardson, *Hydrological Processes*, 2000.  
Vernimmen, R.R.E., et al., *Journal Of Hydrology*, 2007.

# Comparison of Hourly Precipitation Above and Below Canopy

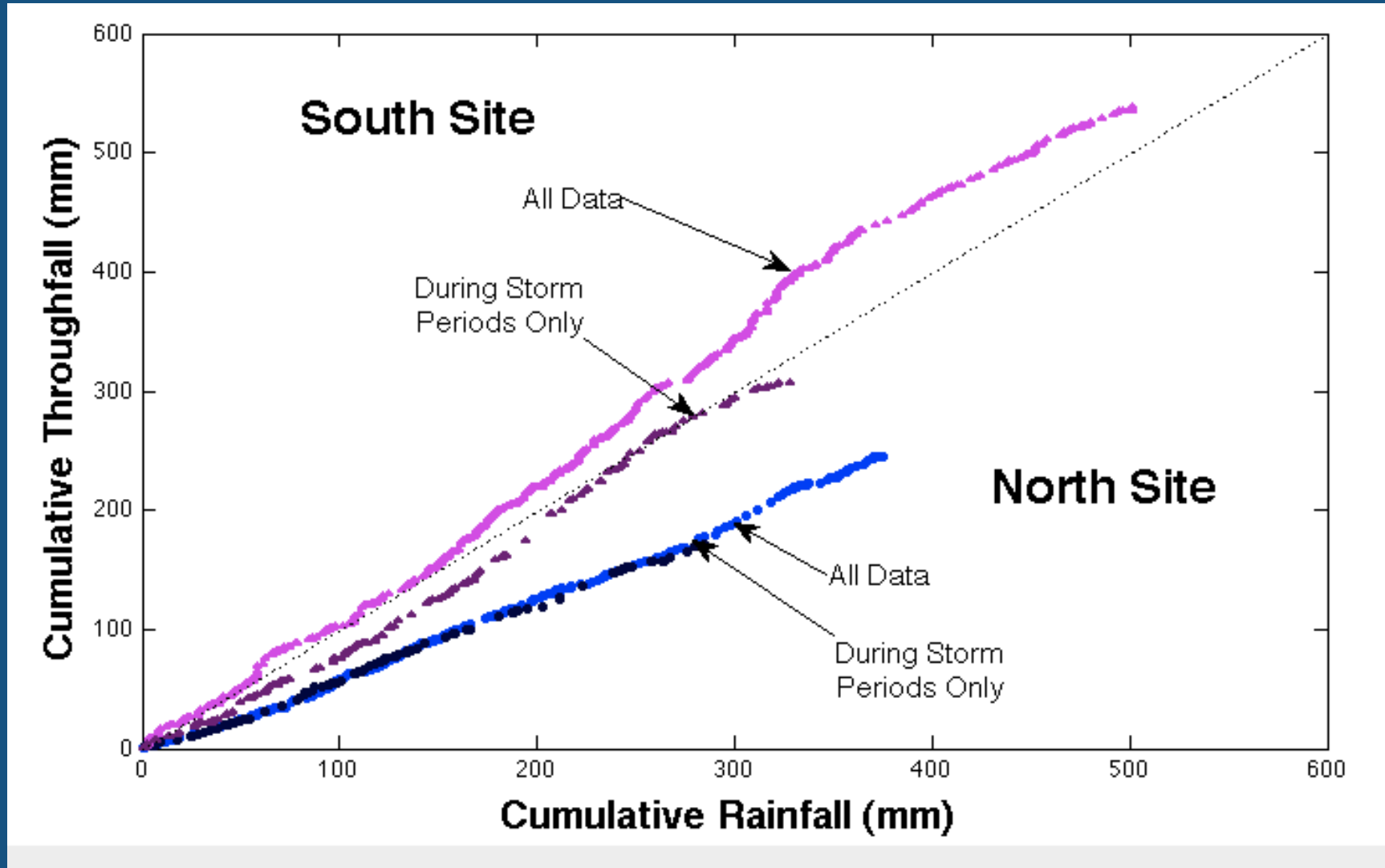


# Example Storm Events in Pasture and Forest



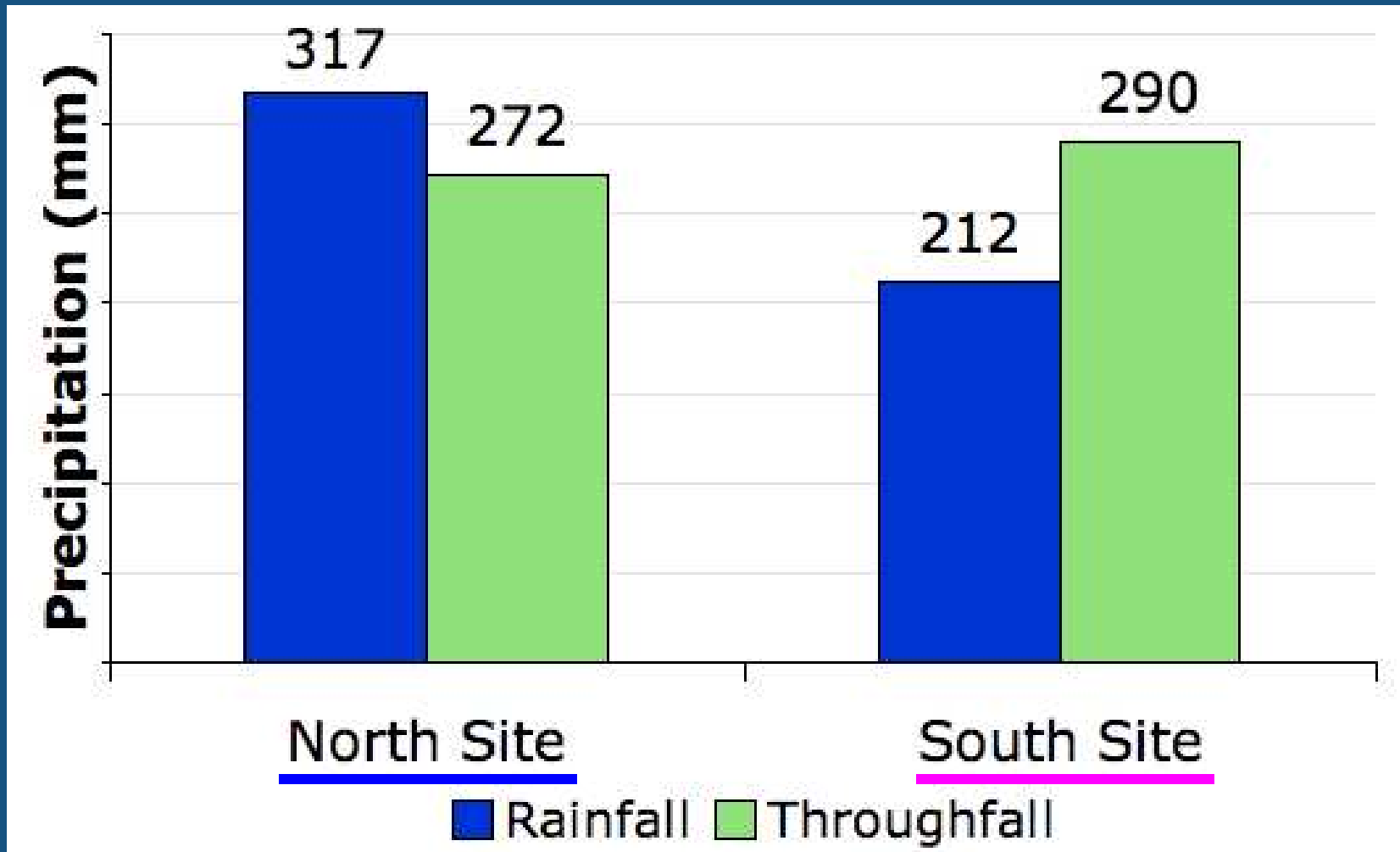


# Throughfall-Rainfall Relationships for All Overlapping Days and for Storm Periods Only



# Total Rain and Fog Input

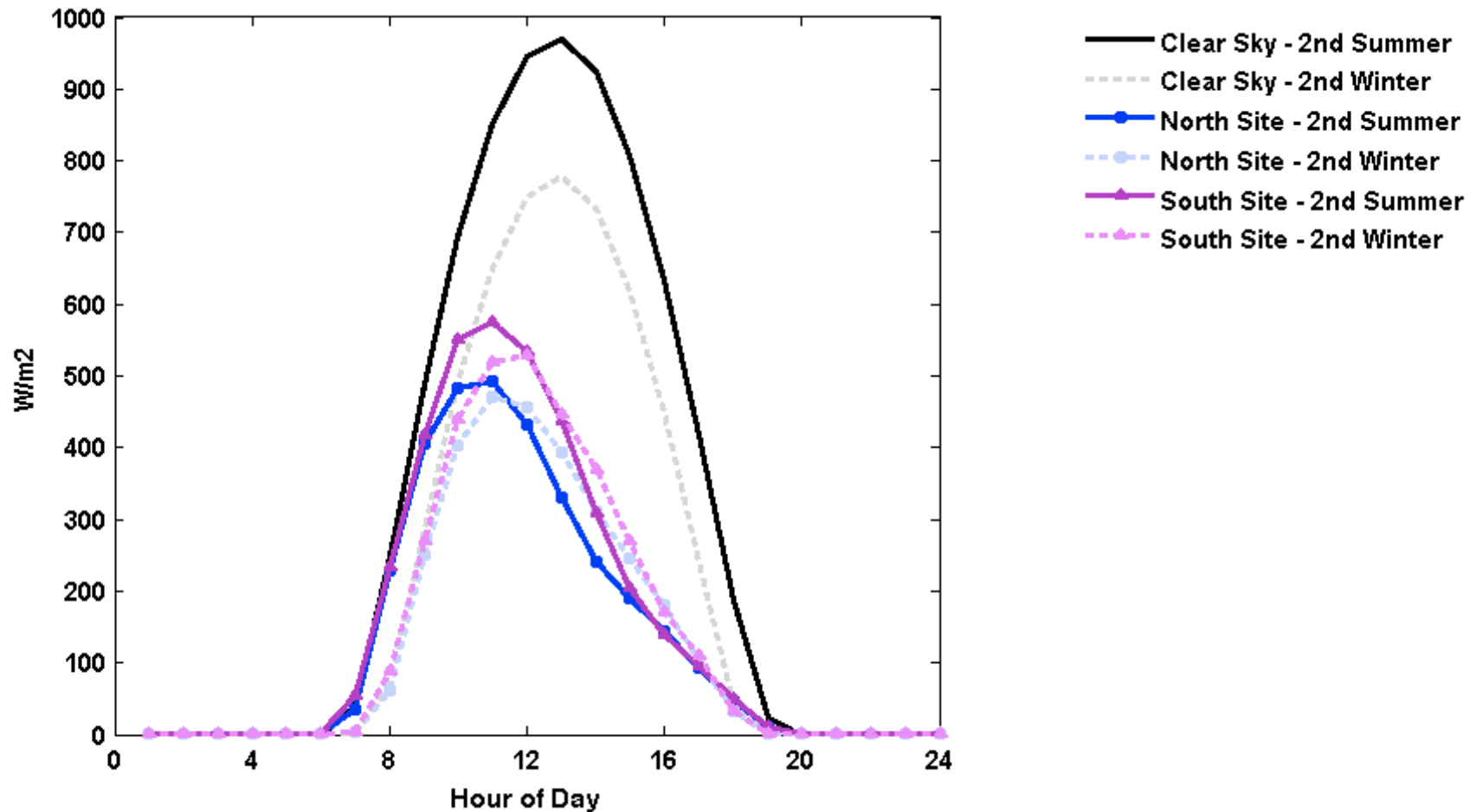
(over 7016 overlapping hours)



Fog adds ~ 0.1 mm/day

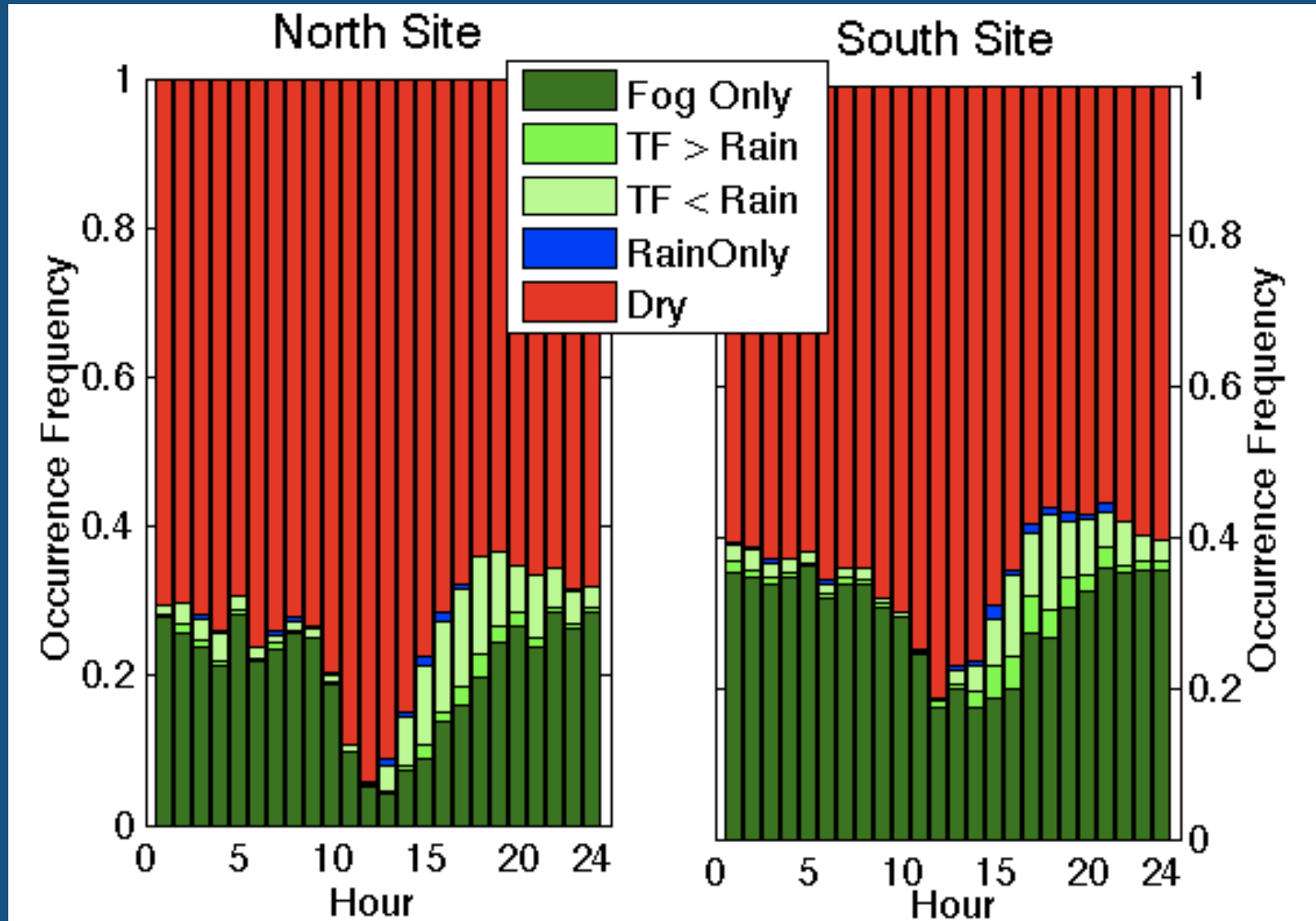
Fog adds ~ 0.3 mm/day

# Average Hourly Insolation



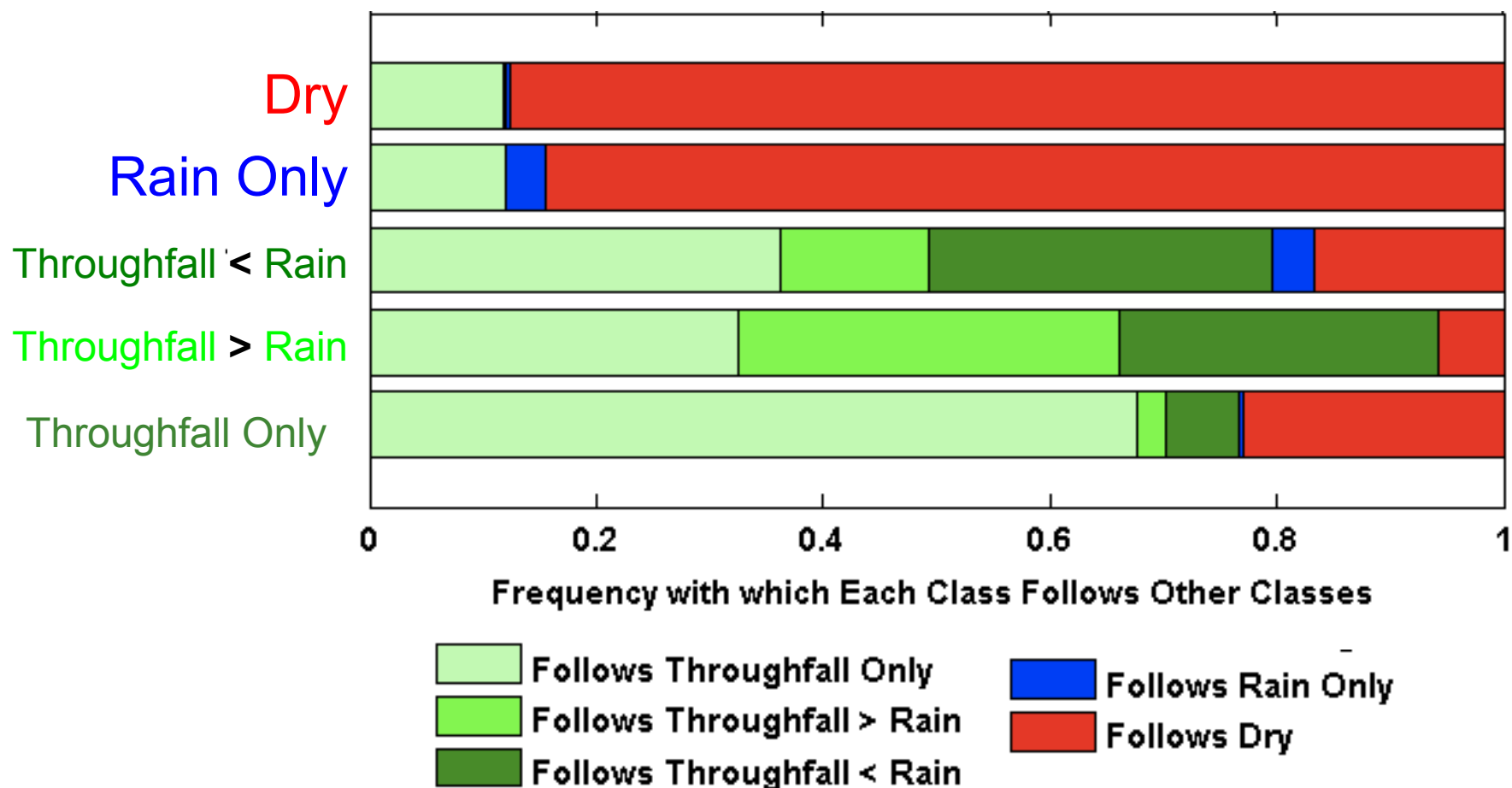
Adapted from Brauman, Freyberg, Daily. 2009 (in review)

# Frequency of Each Event Type

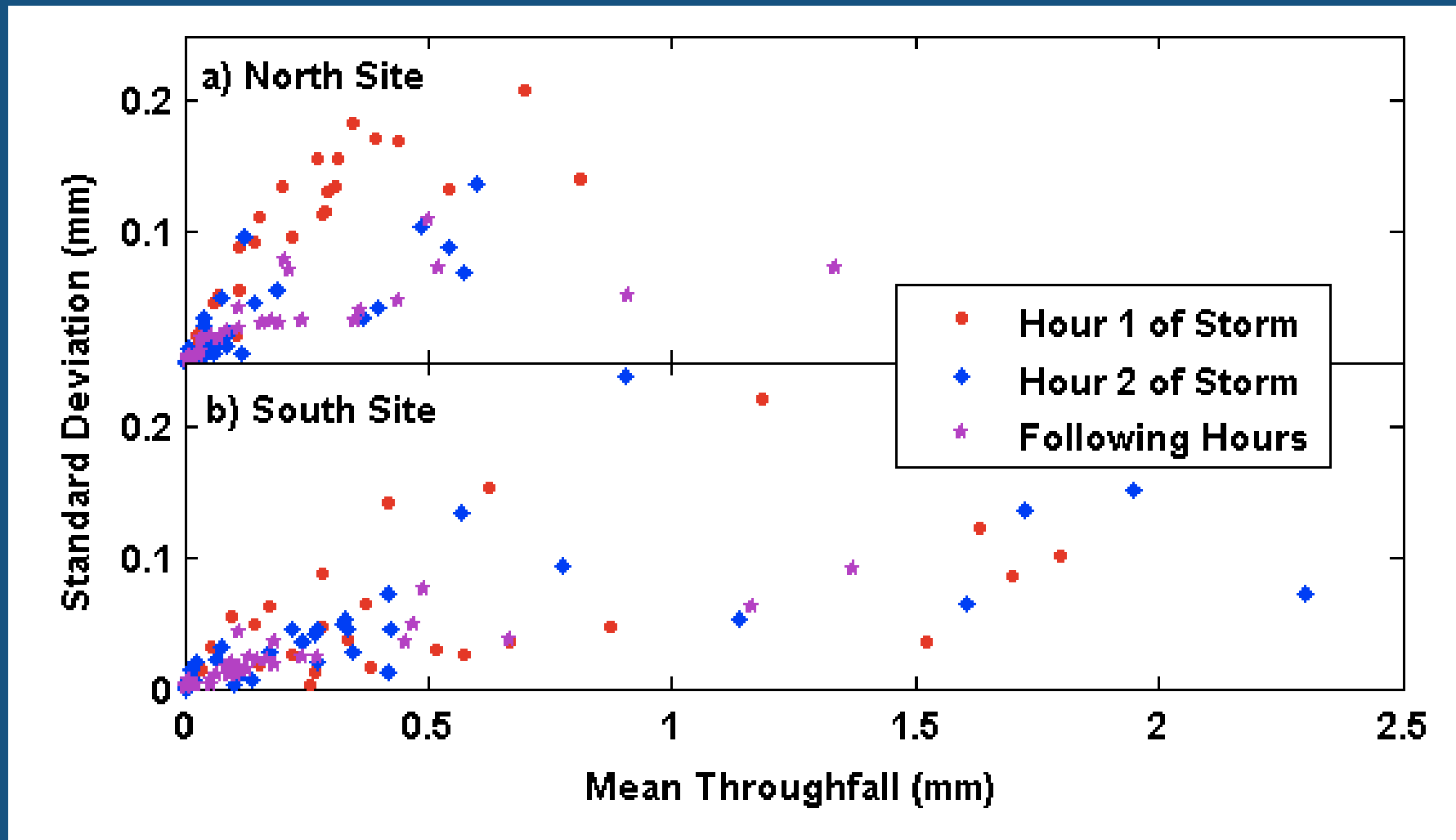




# Frequency with which each event type follows other event types at South site



# Changes in Within-Site Spatial Variation Over Time



# Outline



- Hydrologic Ecosystem Services in Kona, Hawai'i
- Rainfall and Throughfall
- Forest Structure







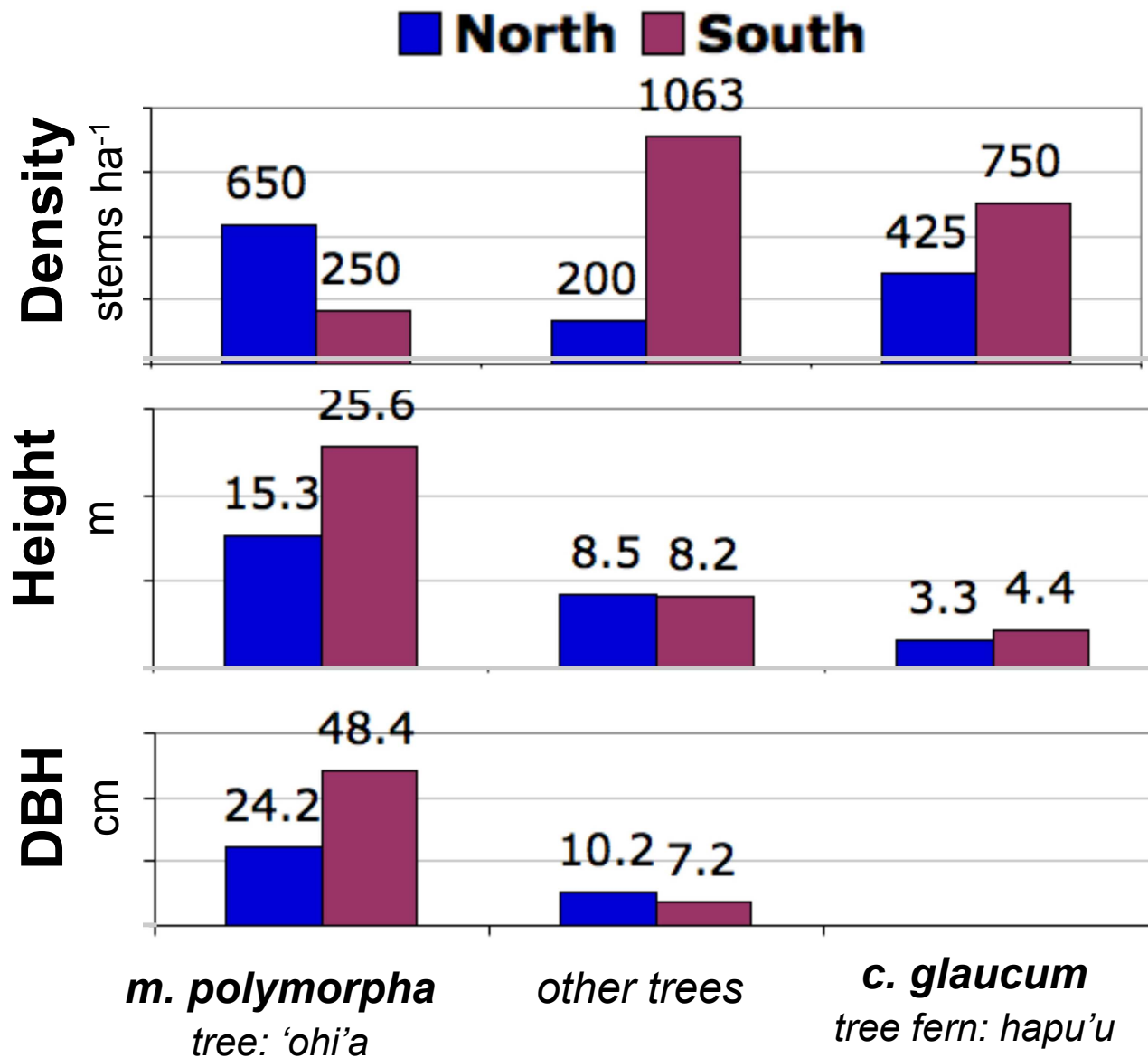
North Forest



South Forest



# Kona Forest Composition



# Forest Density



North Site LAI = 2.03



South Site LAI = 3.05





North Forest



South Forest



# Key Question



How does land cover in upland Kona affect coastal water resources?





# Conclusions

- Cloud interception can measurably increase ecosystem water availability
- Not all forests are the same: Vegetation structure, including canopy height and density, affects interception
  - Land-use history





# Acknowledgements

Funding: The Center for Conservation Biology, IPER Rudolf Research Fellowship, The Koret Foundation, The Moore Family Foundation, The Natural Capital Project, The Lucille and David Packard Stanford Graduate Fellowship, McGee Stanford School of Earth Sciences Research Funds, National Science Foundation Graduate Research Fellowship, Peter and Helen Bing, The William C. and Jeanne M. Landreth IPER Student Fellowship, and The Winslow Foundation

Advisors and Colleagues: Greg Asner, Joe Berry, Berry Brosi, T. Ka'eo Duarte, Dale Fergerstrom, Chris Field, Milton Garces and the UH Infrasound Lab, Rebecca Goldman, Josh Goldstein, Larry Goulder, Flint Hughes, Aurora Kagawa, Robin Martin, Guillermo Mendoza, Liba Pejchar, Heather Tallis, Buzz Thompson, Peter Vitousek, Adam Wolf

Landowners: Kamehameha Schools, Kealakekua Ranch, Palani Ranch

Research Assistant: Jody Fergerstrom



# Mahalo!

# Questions?

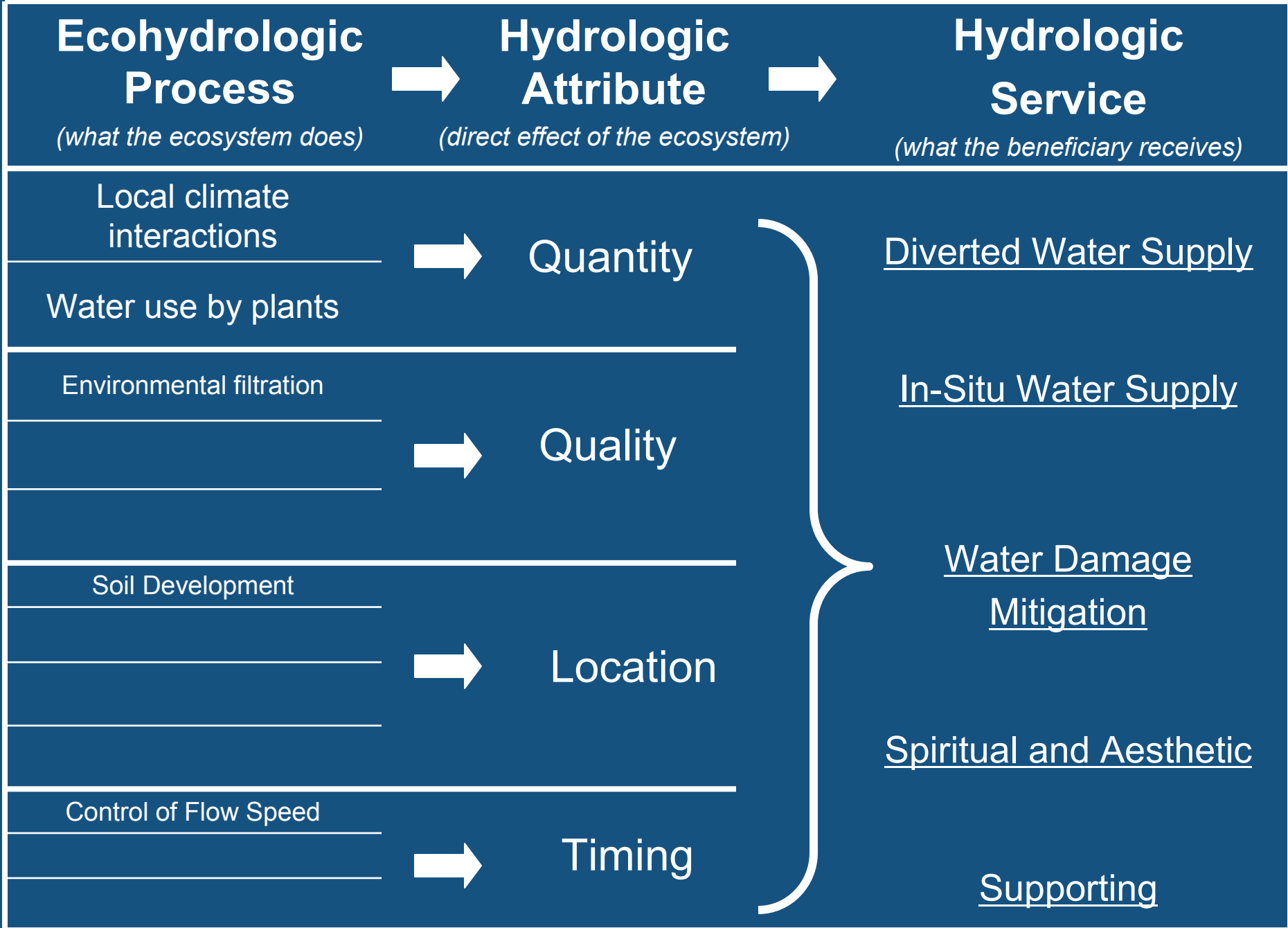


Figure adapted from Brauman et. al. ARER 2007