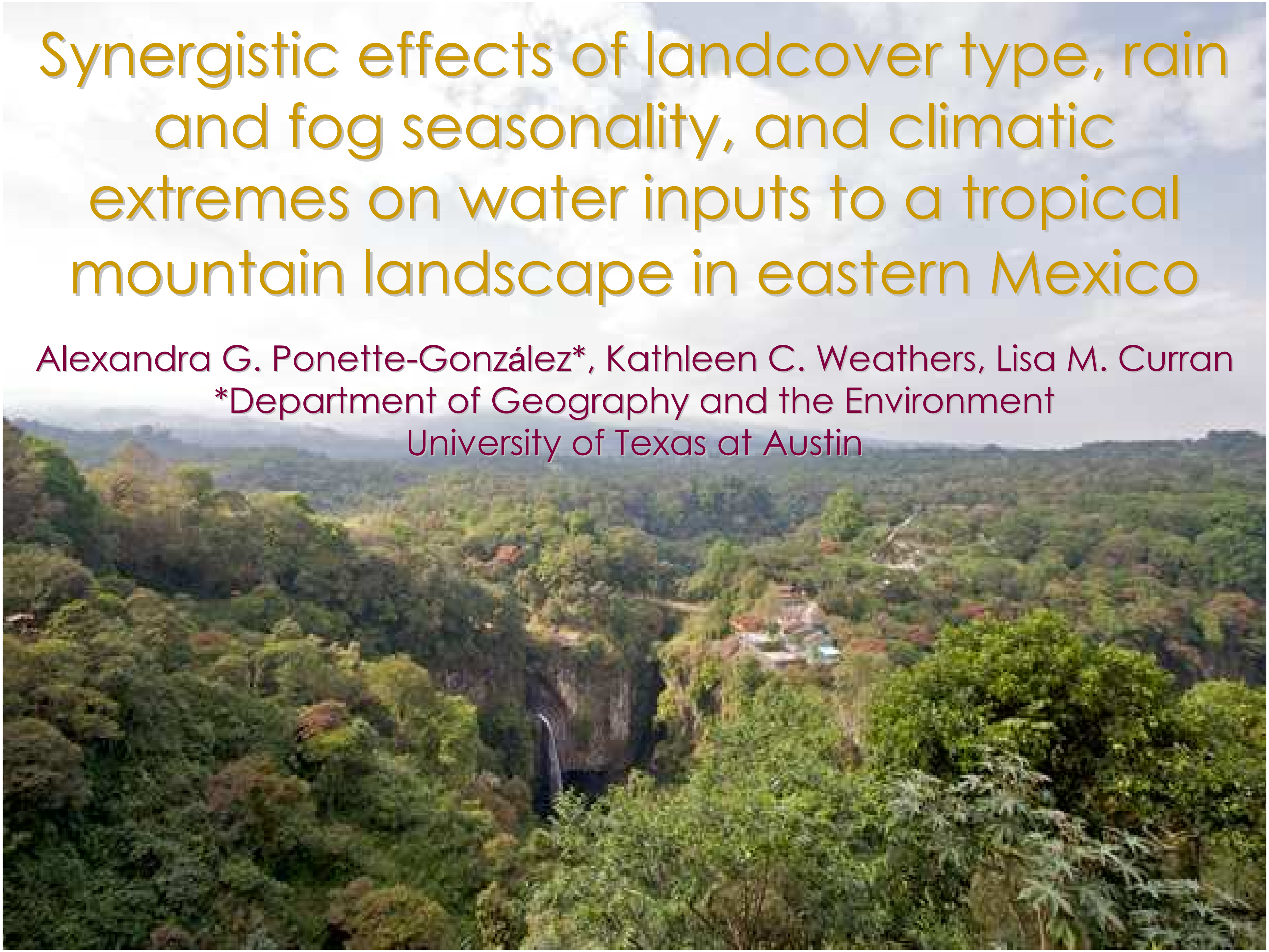
Synergistic effects of landcover type, rain and fog seasonality, and climatic extremes on water inputs to a tropical mountain landscape in eastern Mexico

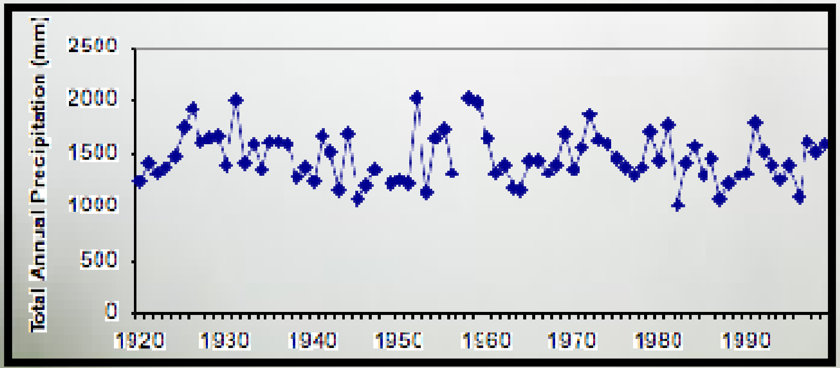
Alexandra G. Ponette-González*, Kathleen C. Weathers, Lisa M. Curran
*Department of Geography and the Environment
University of Texas at Austin

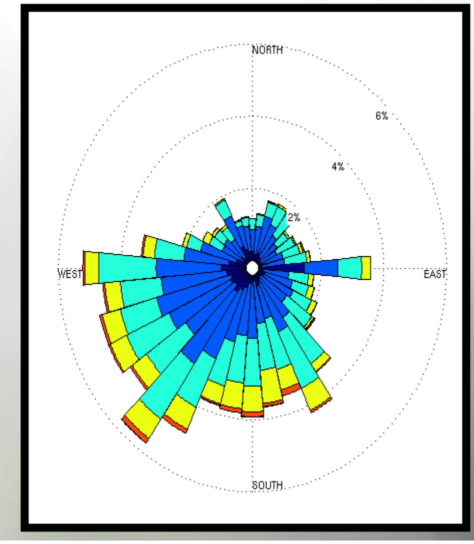


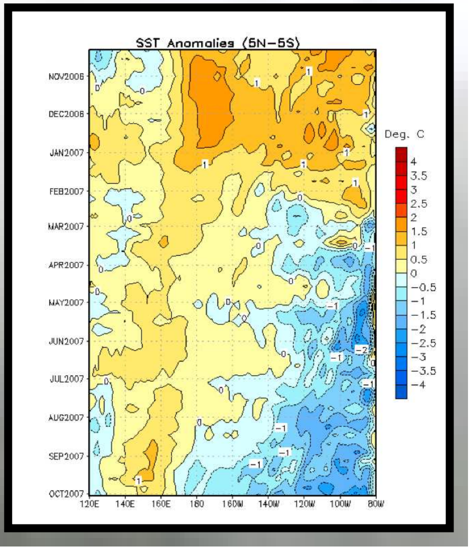
Controls on Water Fluxes

Vegetation

Climate

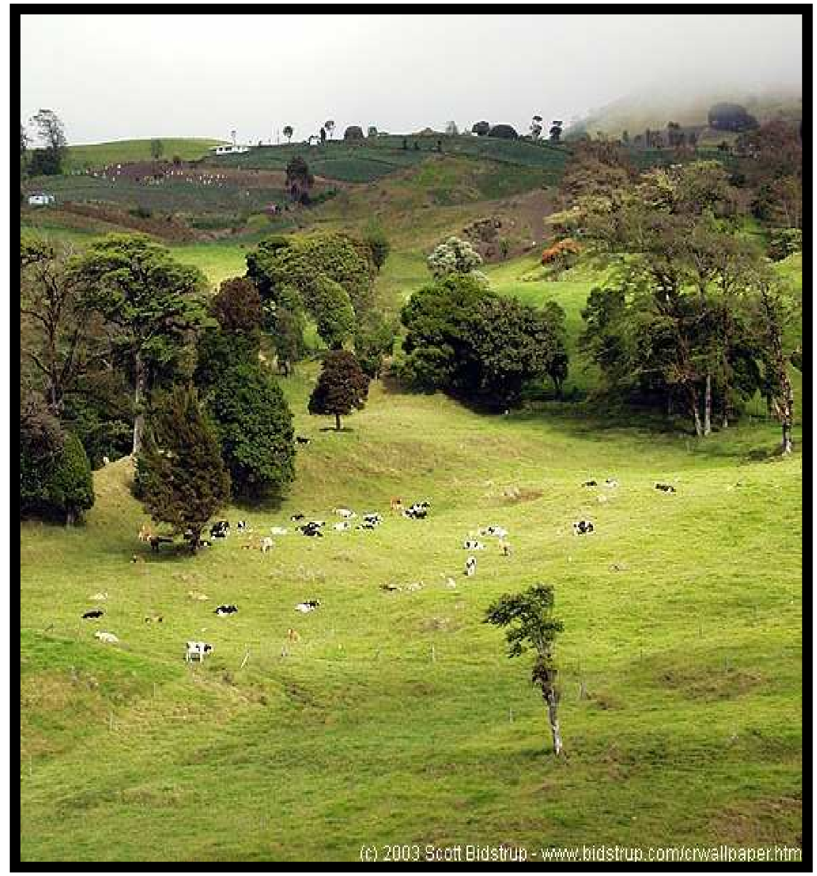






Land Cover & Water Redistribution

latent vs sensible heat flux, cloud formation



Land Cover & Water Redistribution

water delivery to soil

Land Change

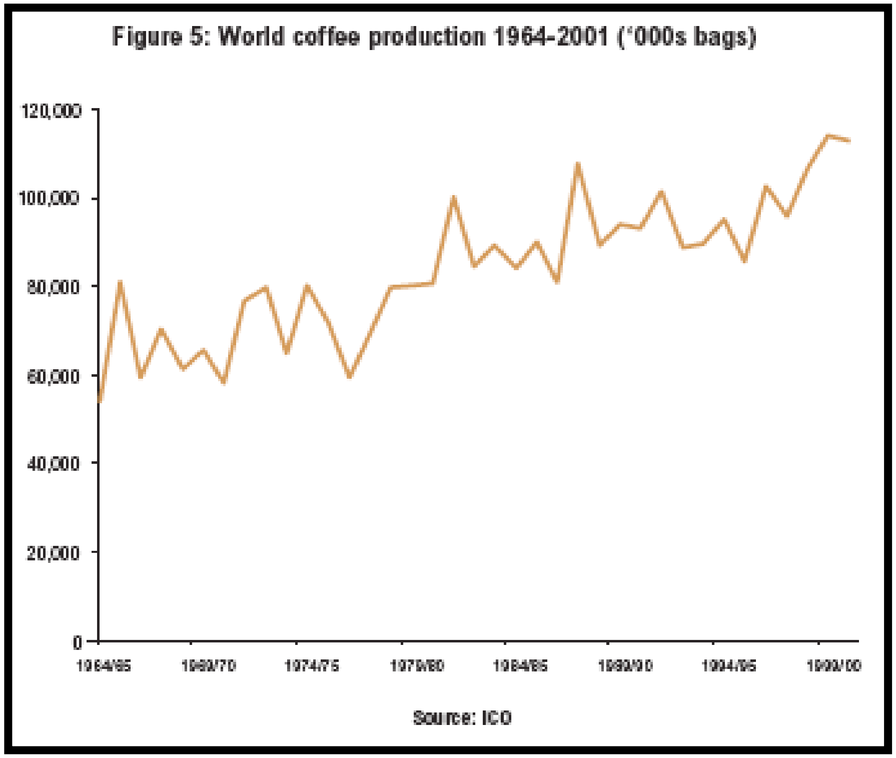


Figure 5: World coffee production 1964-2001 ('000s bags)
120,000
100,000
80,000
60,000
40,000
20,000
0
1964/65
1969/70
1974/75
1979/80
1984/85
1989/90
1994/95
1999/00
Source: ICO

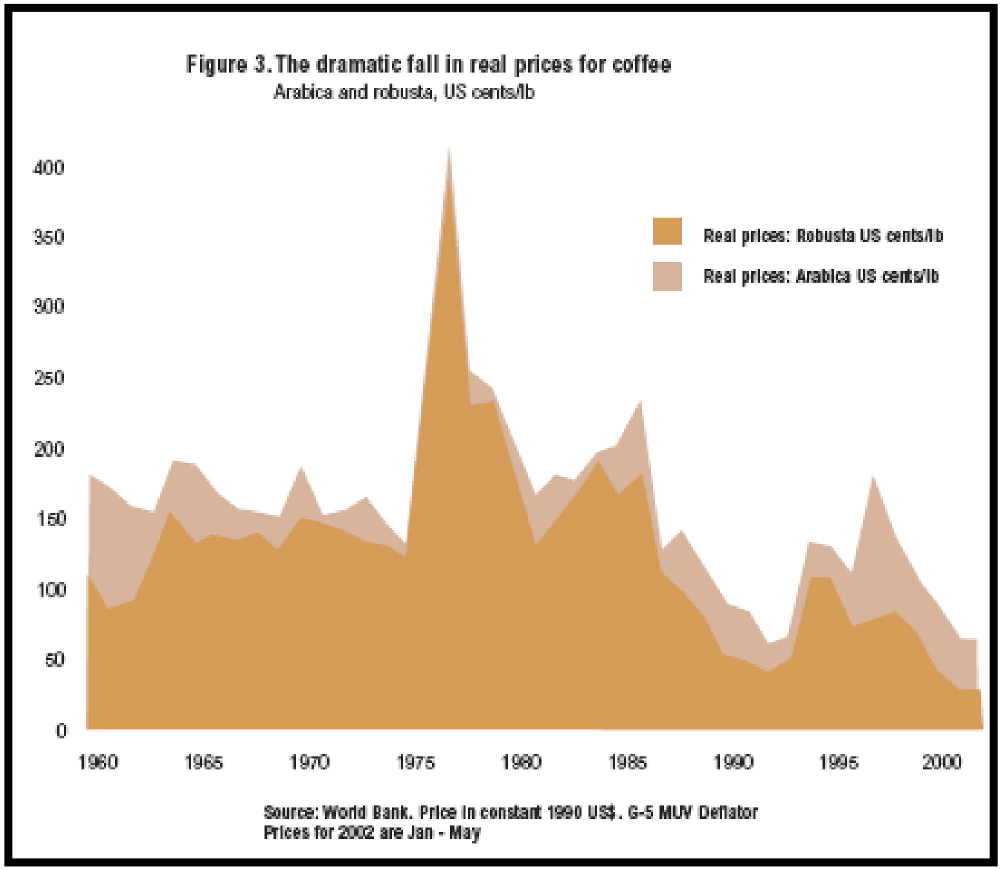


Figure 3. The dramatic fall in real prices for coffee
Arabica and robusta, US cents/lb
400
350
300
250
200
150
100
50
0
Real prices: Robusta US cents/lb
Real prices: Arabica US cents/lb
1960
1965
1970
1975
1980
1985
1990
1995
2000
Source: World Bank. Price in constant 1990 US$. G-5 MUV Deflator
Prices for 2002 are Jan - May

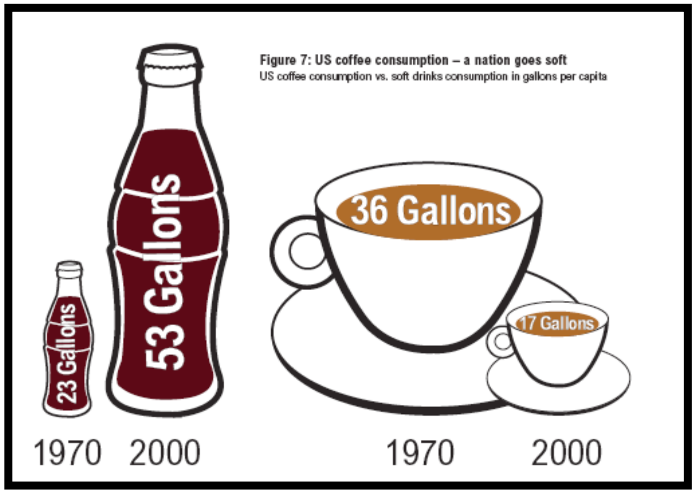


Figure 7: US coffee consumption – a nation goes soft
US coffee consumption vs. soft drinks consumption in gallons per capita
23 Gallons
53 Gallons
36 Gallons
17 Gallons
1970
2000
1970
2000

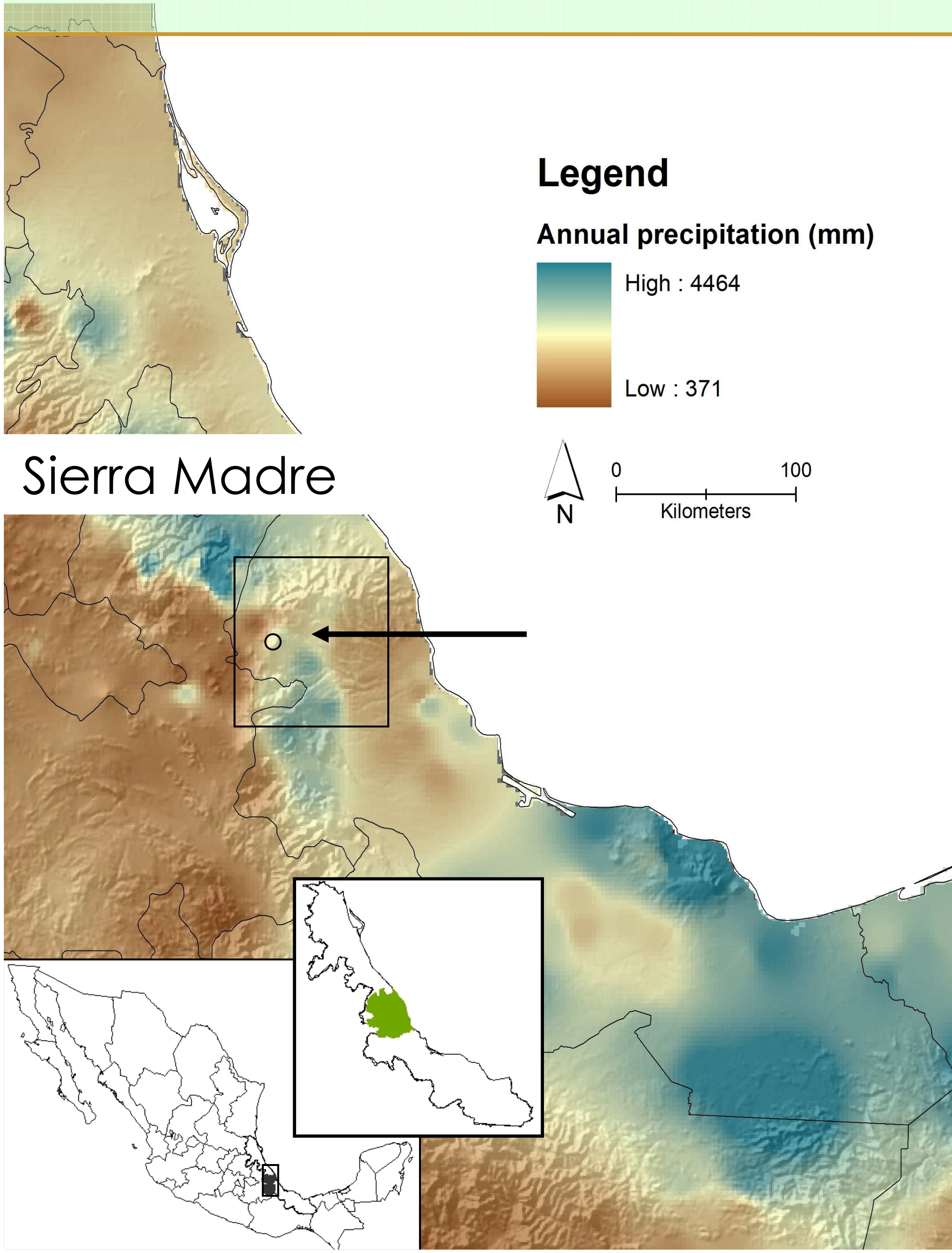
Research Questions

(1) How does land-cover type—forests, coffee agroforests, pastures—affect the partitioning of rainfall into throughfall & stemflow fluxes?

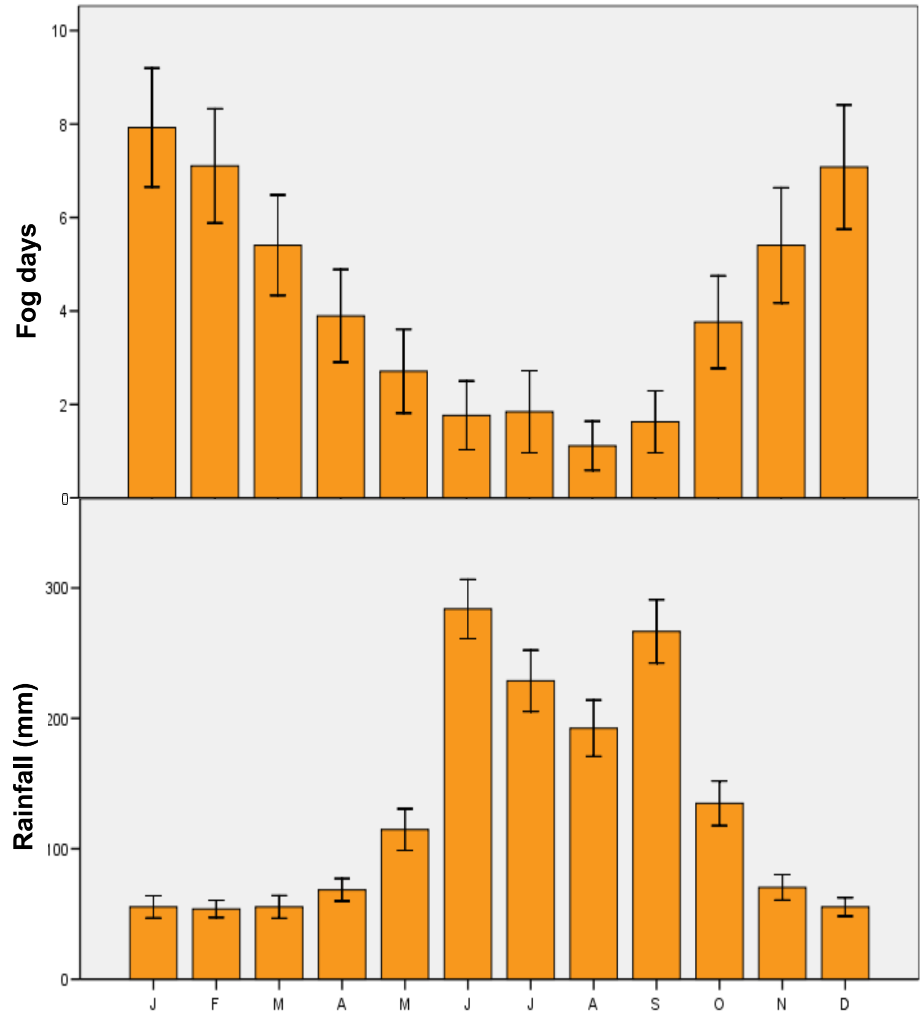
(2) How does vegetation stand structure influence the amount, type, timing, and spatial distribution of water fluxes to soils?

(3) How do tropical storms and hurricanes and El Niño-related changes in seasonal precipitation affect throughfall water fluxes to dominant land-cover types?

Central Veracruz, Mexico



Seasonal water inputs



Land-Cover Change Pathways


Cattle grazing

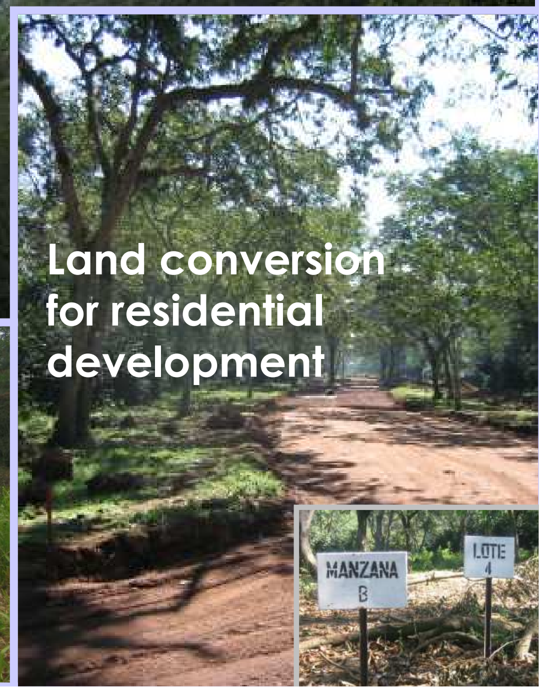

Shade coffee cultivation


Material mining


A tropical montane cloud forest landscape in Central Veracruz


Sugarcane farming

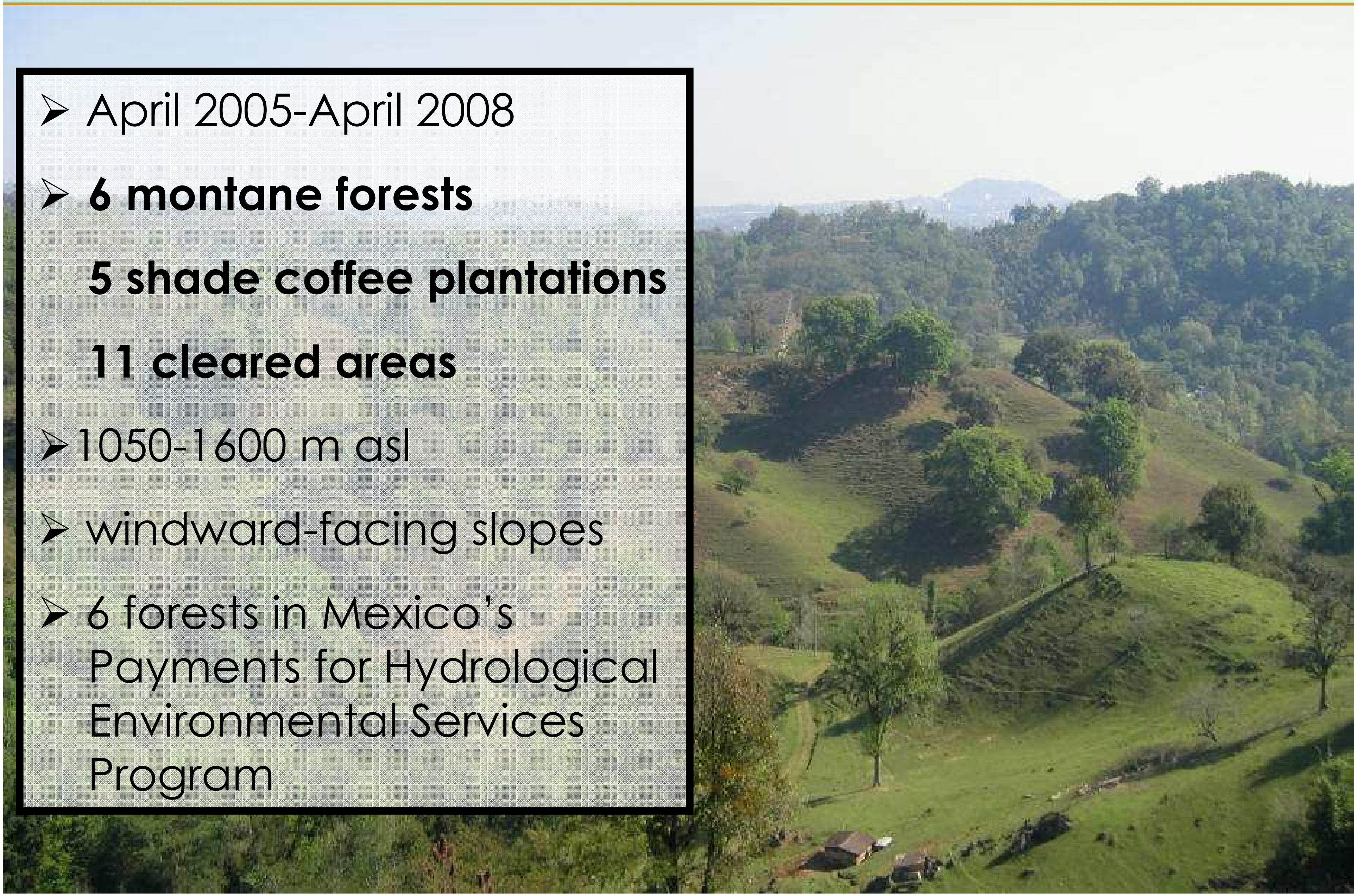
Sugar cane burning before harvest



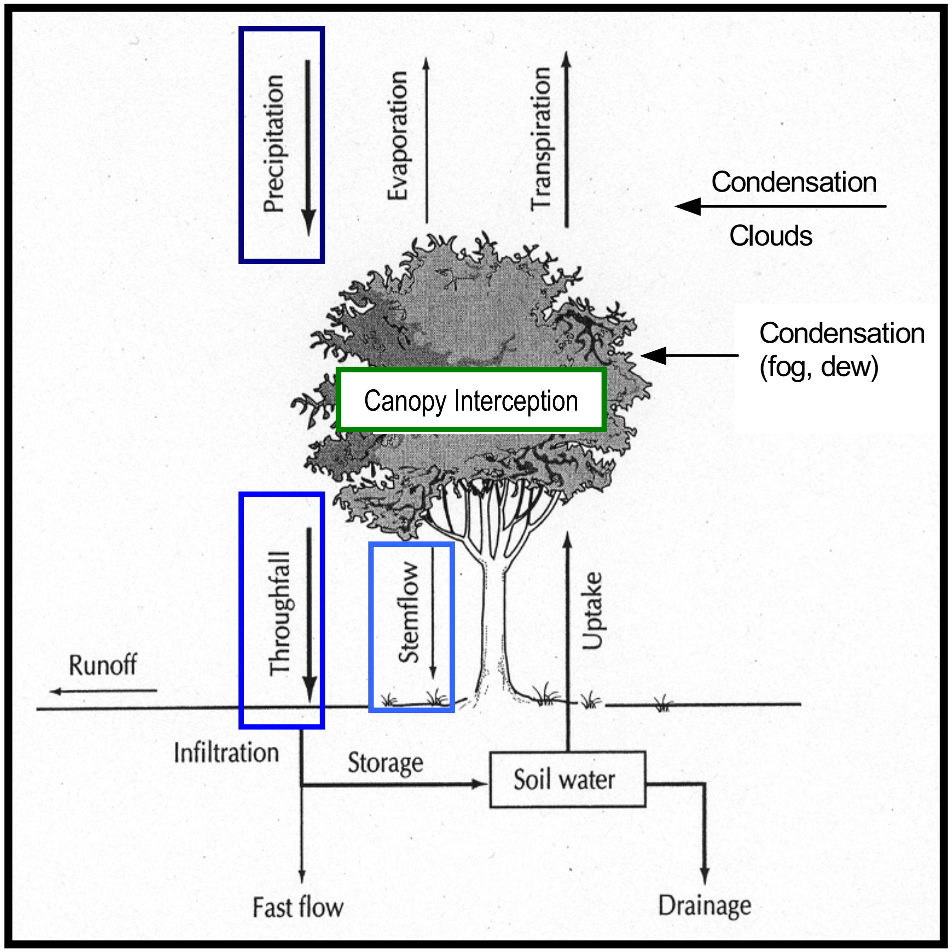
Land conversion for residential development

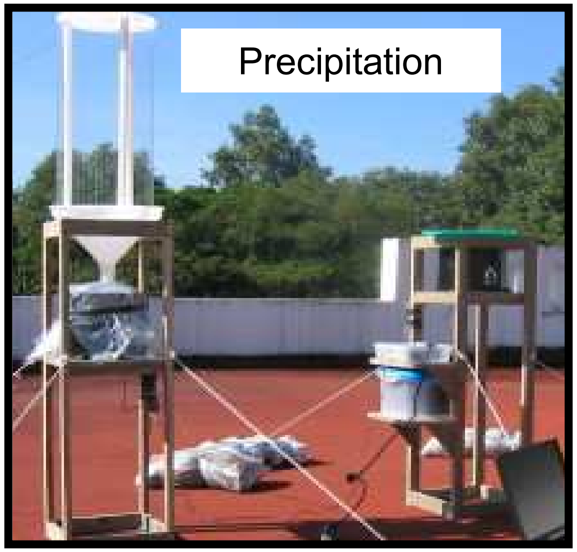
Experimental Design

- April 2005-April 2008
- **6 montane forests**
  5 shade coffee plantations
  11 cleared areas
- 1050-1600 m asl
- windward-facing slopes
- 6 forests in Mexico's Payments for Hydrological Environmental Services Program



Methods: Water Delivery





Methods: Vegetation-Water

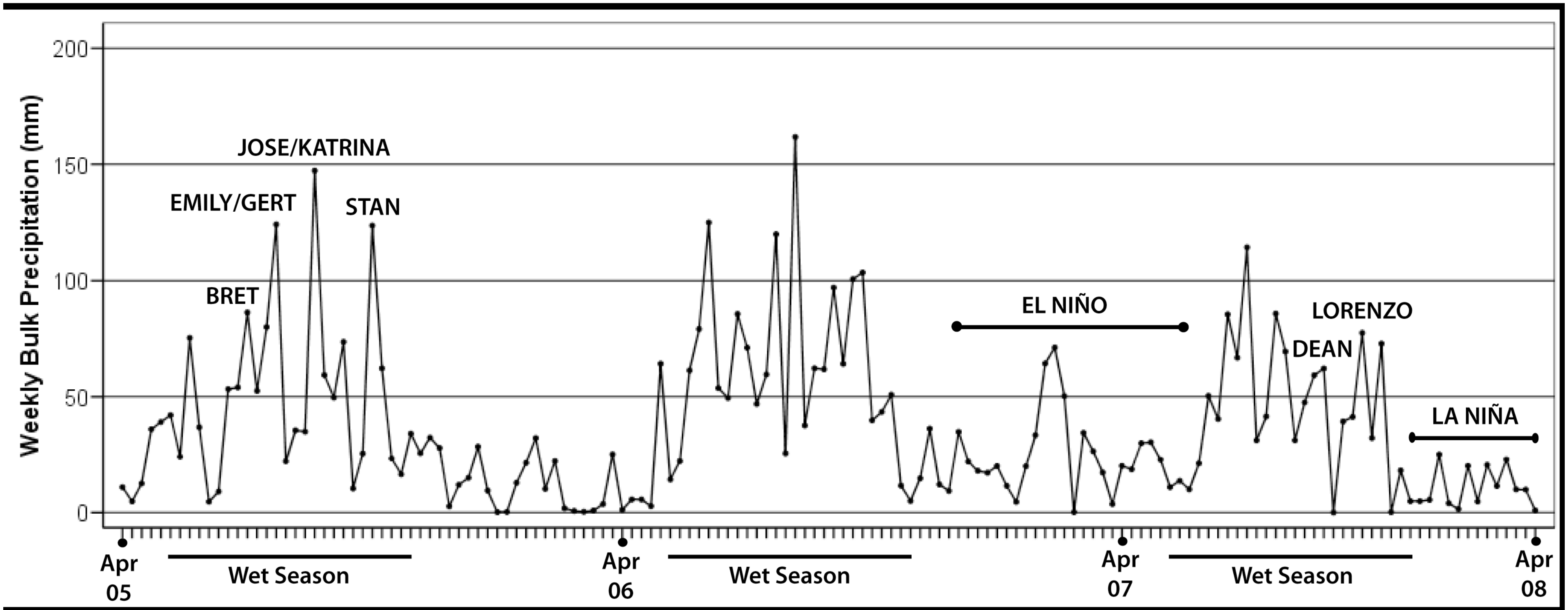
throughfall (TF) - bulk rainfall =

net throughfall (NTF)

IF NTF > 0 (throughfall > rainfall) THEN
fog water deposition

IF NTF < 0 (throughfall < rainfall THEN
canopy interception

Precipitation Patterns



Alexandra Ponette-González, Kathleen C. Weathers, and Lisa M. Curran. In press. Water inputs across a tropical montane landscape in Veracruz, Mexico: synergistic effects of land cover, rain and fog seasonality, and interannual precipitation variability. *Global Change Biology* doi: 10.1111/j.1365-2486.2009.01985.x.

Vegetation

Site	Tree ha^{-1}	Basal Area $m^2\ ha^{-1}$	Mean Ht (m)	Mean Min Ht (m)	Mean Max Ht (m)	Crown Projection (m^2)	Wet Season LAI	Dry Season LAI	Trees with Epiphytes (%)
Forest									
1	755±91[b]	40±8[a]	12±1[ab]	7±1[b]	19±2[a]	283±38[ab]	4.5±0.5[ab]	3.4±0.2[b]	56±9[ab]
3	1103±143[b]	40±6[a]	11±1[b]	5±0.3[bc]	19±1[a]	247±26[b]	5.1±0.2[a]	5.6±0.2[a]	44±7[b]
5	1621±125[a]	36±3[a]	13±0.3[a]	7±0.3[a]	20±1[a]	359±35[a]	4.2±0.2[b]	2.5±0.1[c]	60±6[ab]
7	891±109[b]	29±6[ab]	10±1[b]	6±0.4[bc]	15±2[bc]	150±19[c]	3.3±0.3[c]	ND	32±9[b]
8	399±53[c]	18±3[b]	11±1[b]	8±1[a]	13±1[c]	118±24[c]	ND	ND	73±9[a]
10	849±121[b]	24±4[ab]	11±1[b]	7±1[ab]	15±1[b]	138±17[c]	ND	ND	36±9[b]
Shade Coffee									
2	374±50[a]	8±2[b]	10±1[b]	7±1[a]	13±1[a]	90±14[a]	1±0.2[a]	1.9±0.3[a]	28±9[a]
4	155±33[b]	13±3[ab]	13±1[ab]	12±1[b]	15±2[a]	107±26[a]	1.9±0.4[ab]	2±0.2[a]	17±10[a]
6	430±35[a]	13±3[ab]	10.6±1[b]	8±1[a]	13±1[a]	93±10[a]	1.9±0.2[b]	1.8±0.2[a]	20±8[a]
9	239±33[b]	20±6[a]	14±1[a]	11±1[b]	15±1[a]	147±26[a]	ND	ND	47±10[a]

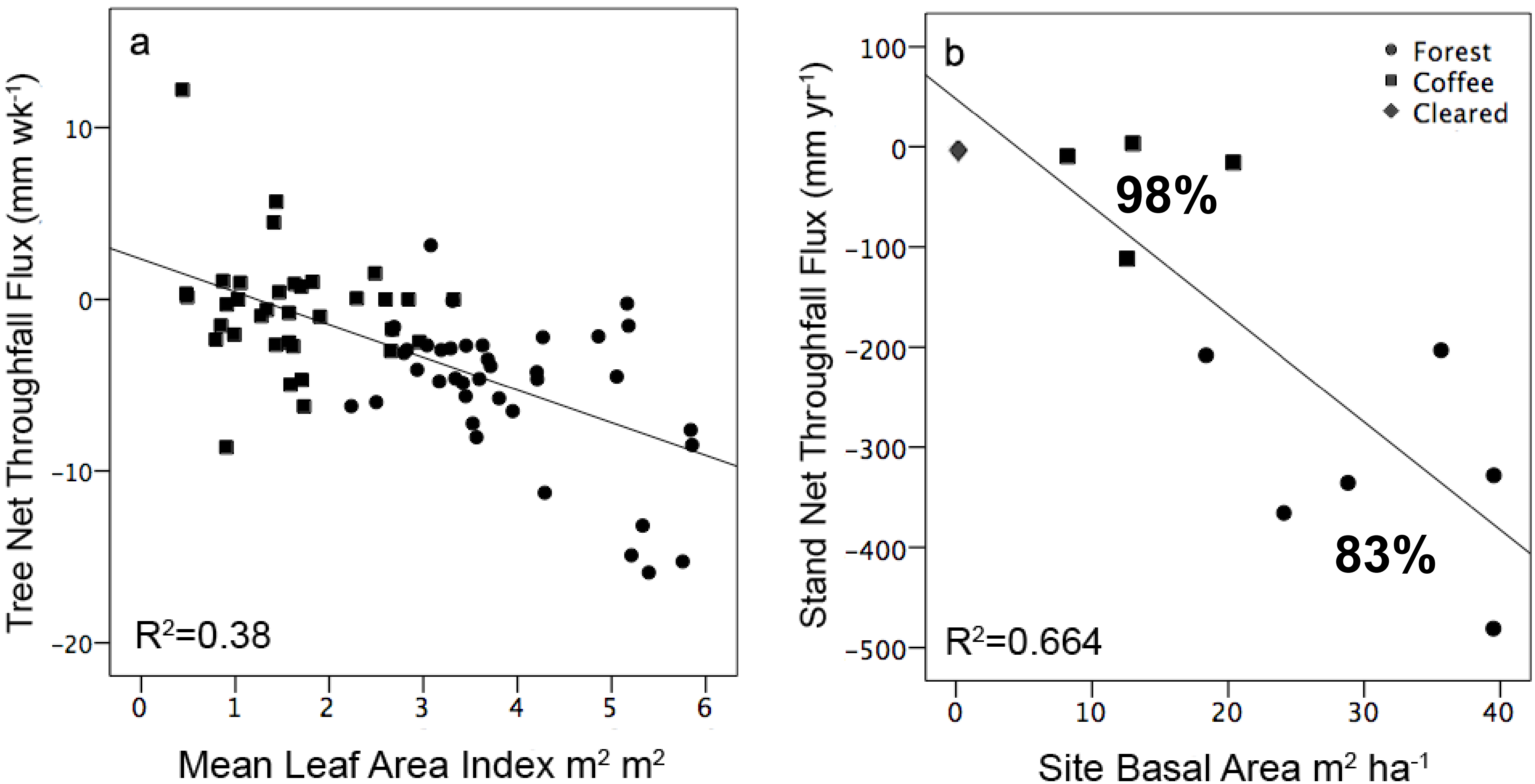
*Forest - semi-deciduous

*Shade coffee - evergreen

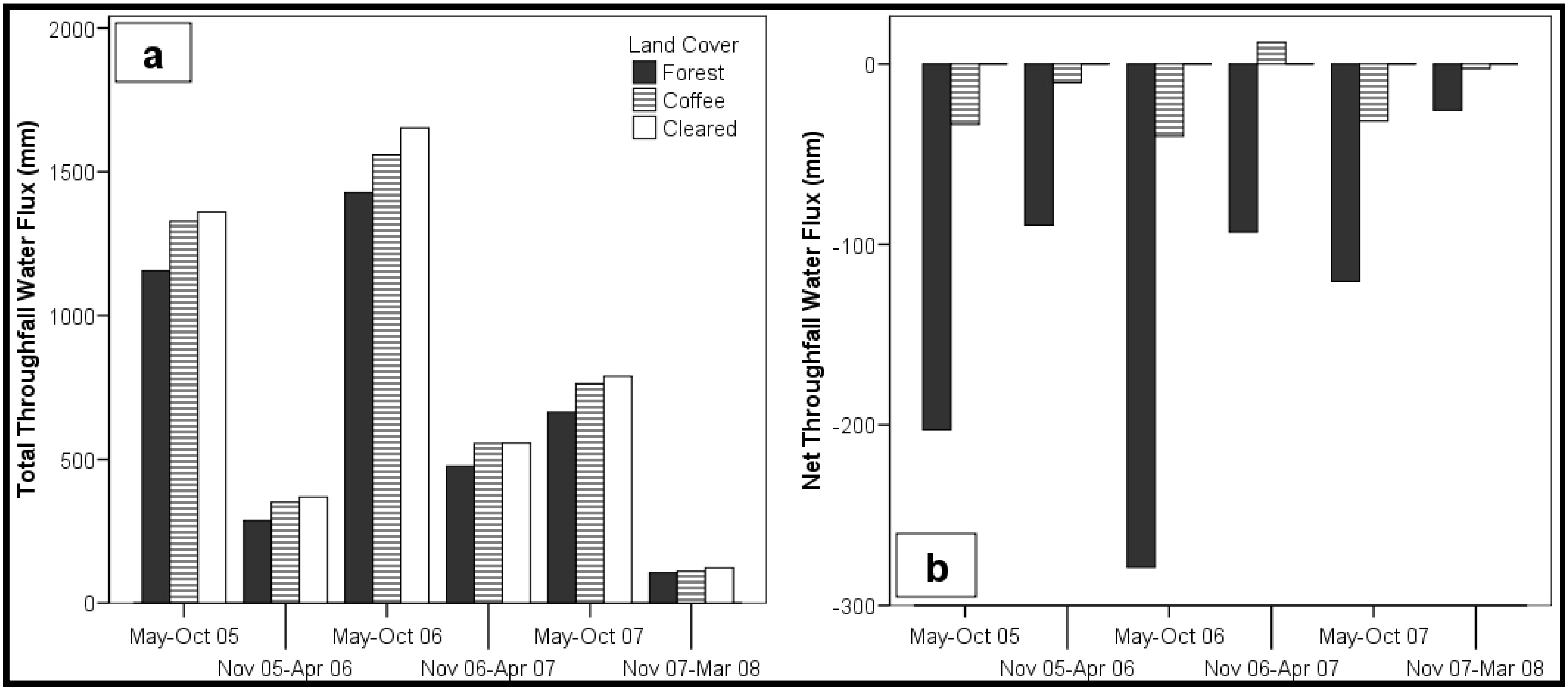
Throughfall Flux

cleared > coffee > forest

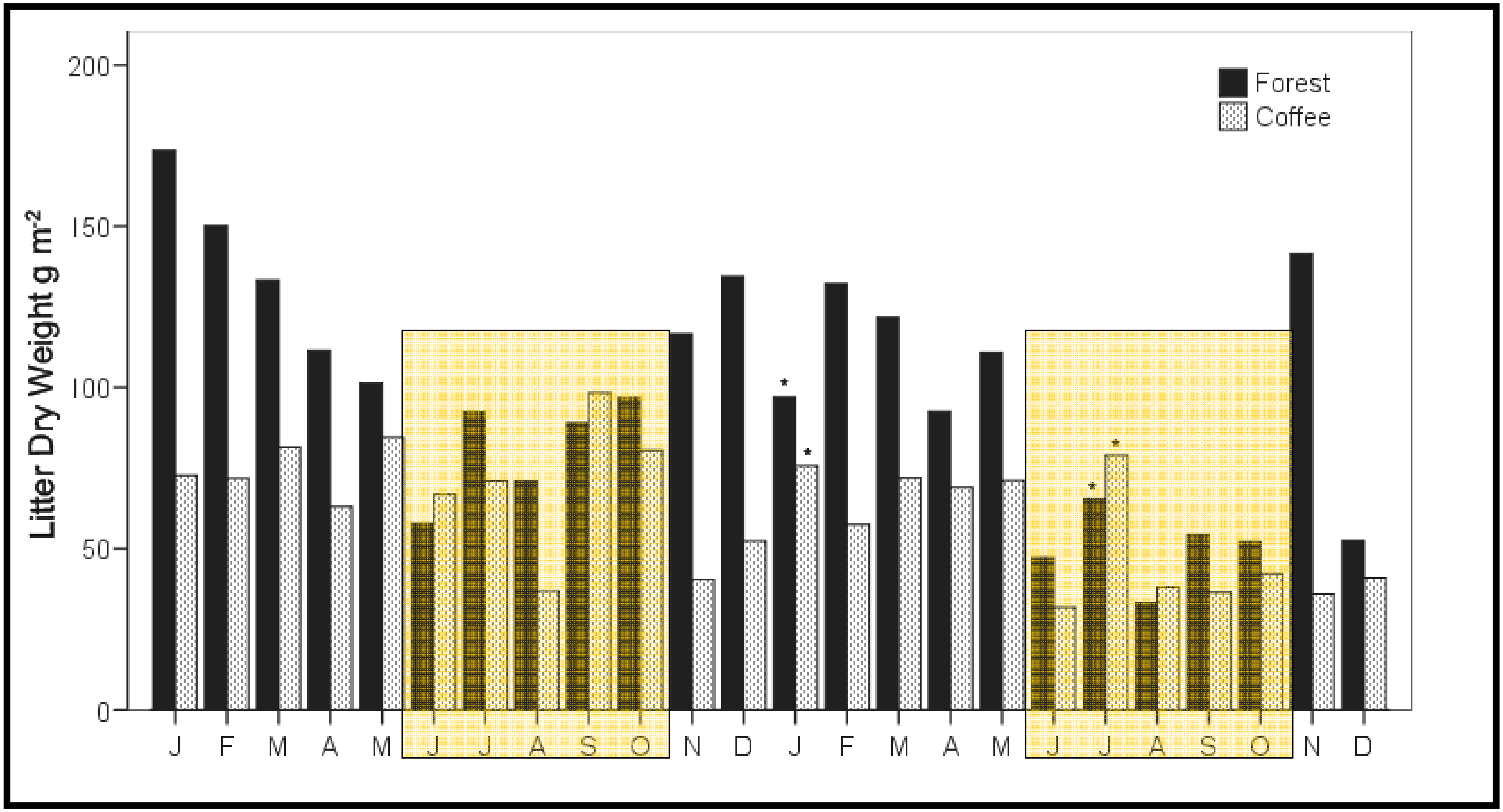
Max change in throughfall water flux = 17%



Seasonality of Water Inputs



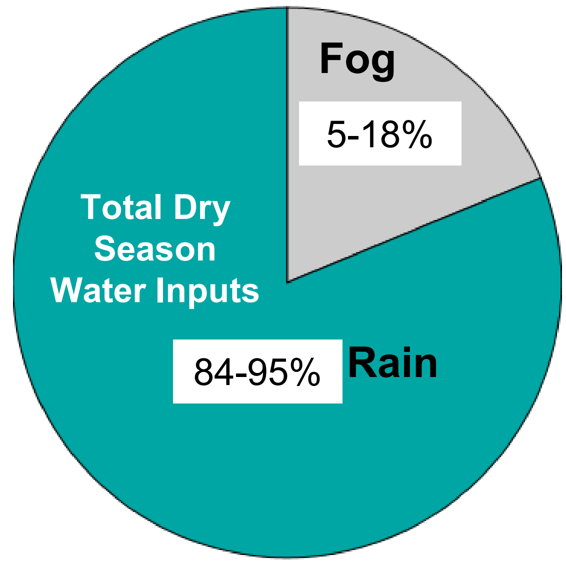
Litterfall Patterns

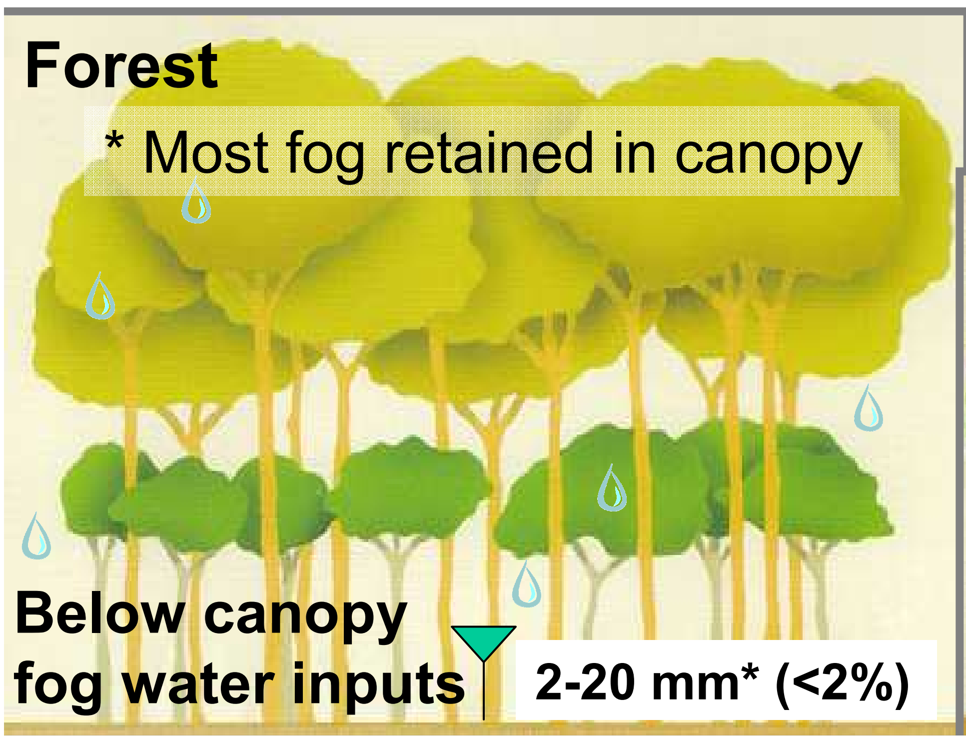


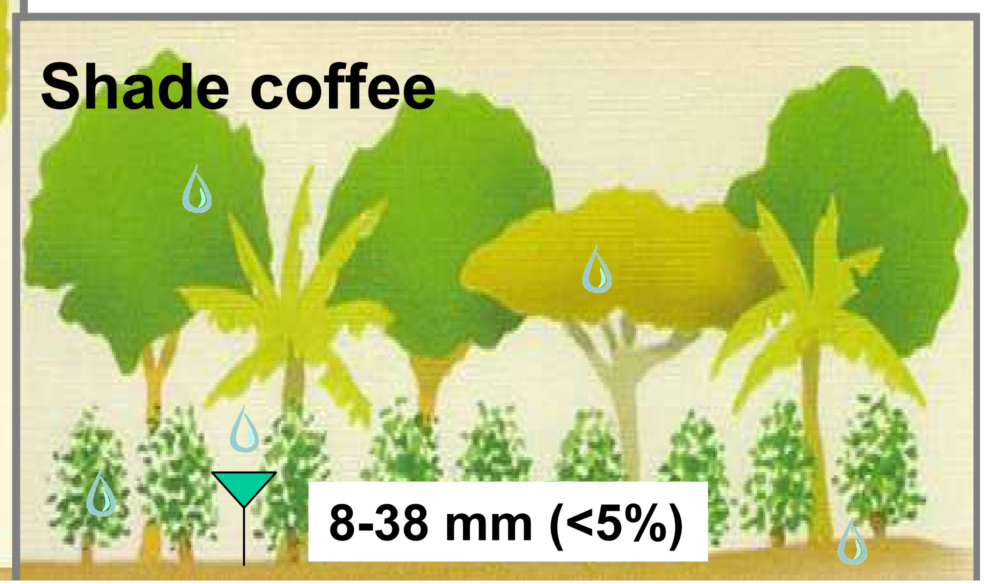
- wet season - maximum difference in LAI
- dry season - partial forest leaf abscission

Precipitation Type & Intensity - Fog

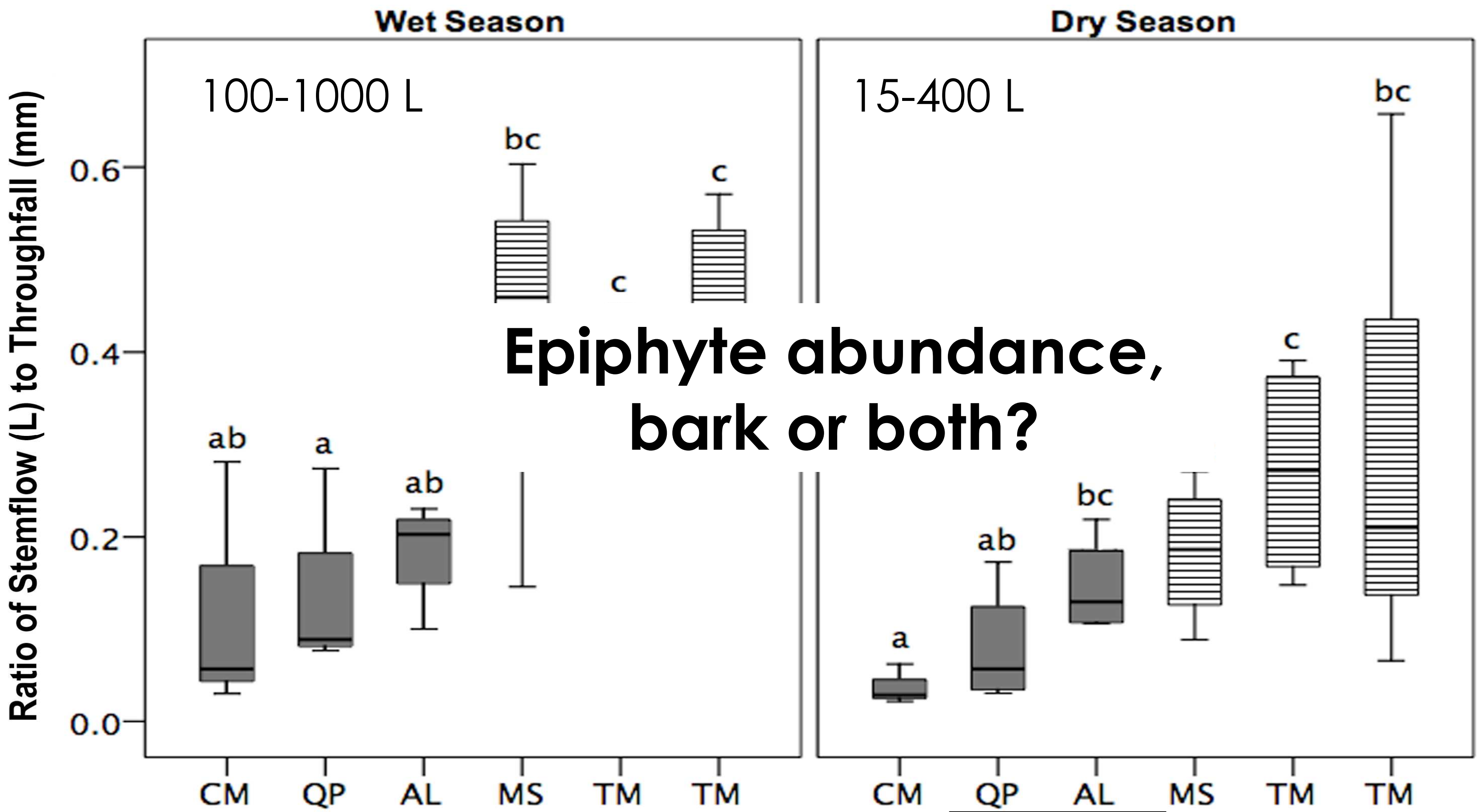
Above Canopy
Dry Season Fog Inputs
33 mm (Xalapa)
100 mm (Coatepec)





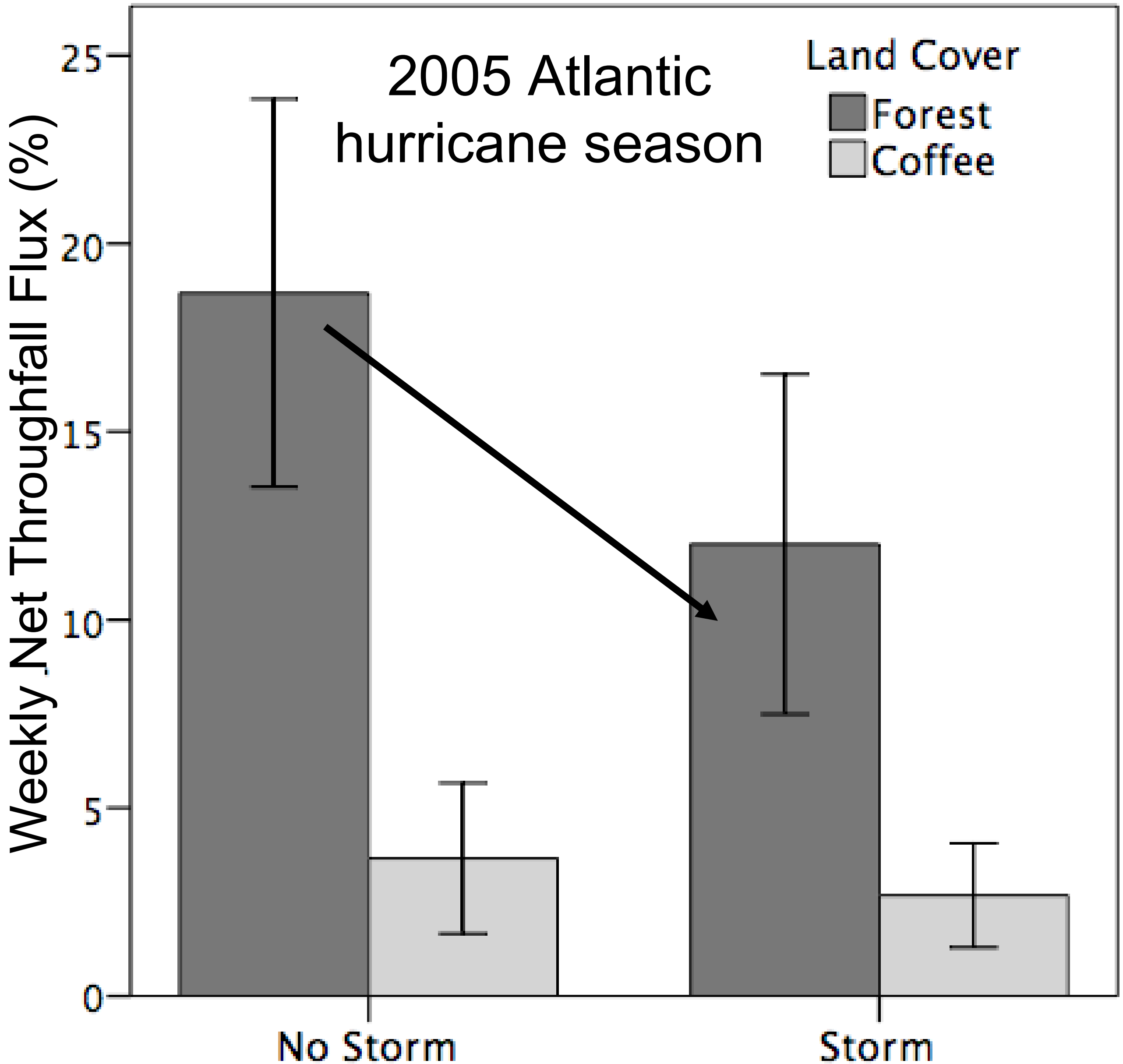


Stemflow



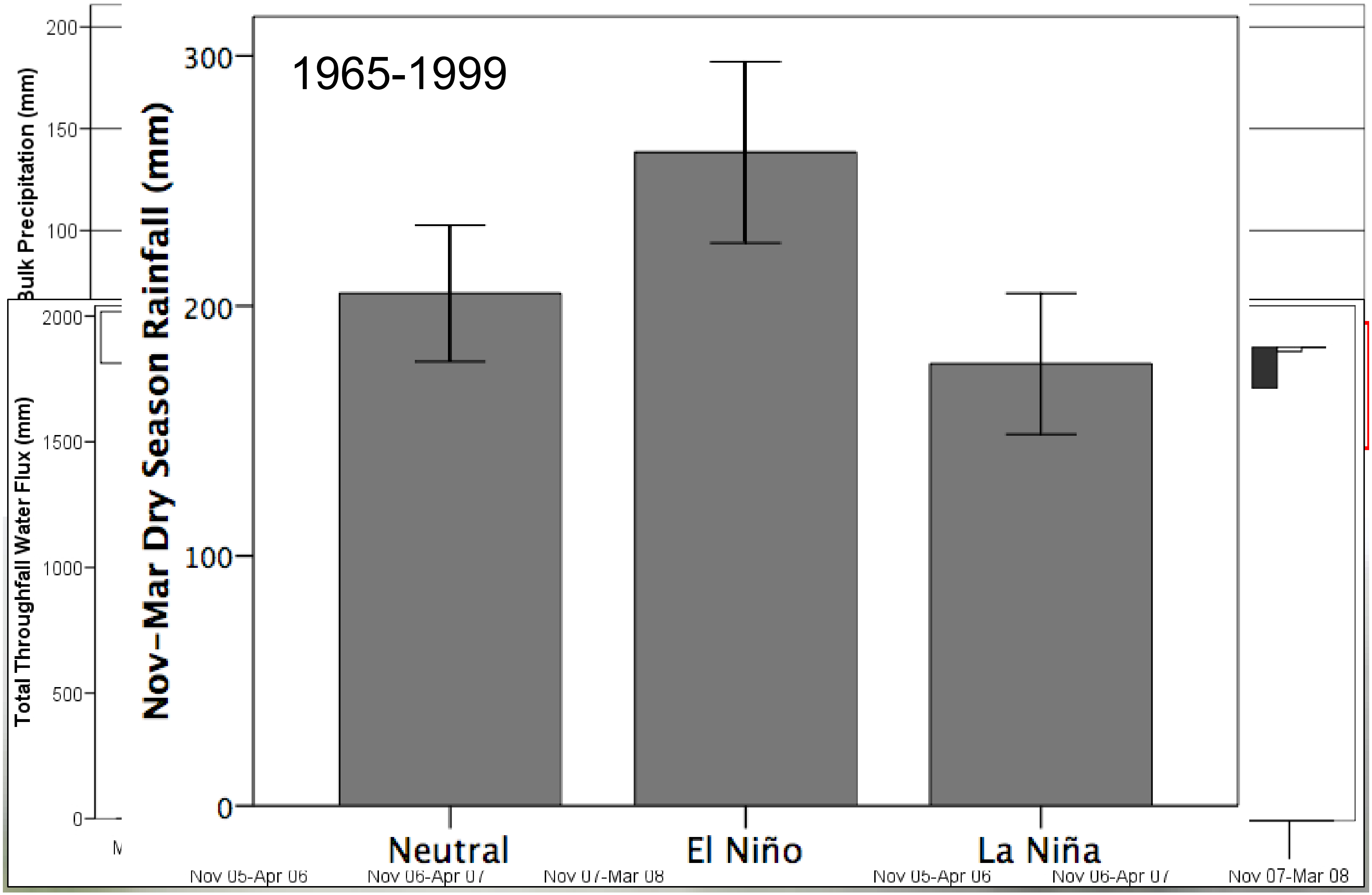
Epiphyte abundance, bark or both?

Tropical Storms and Hurricanes

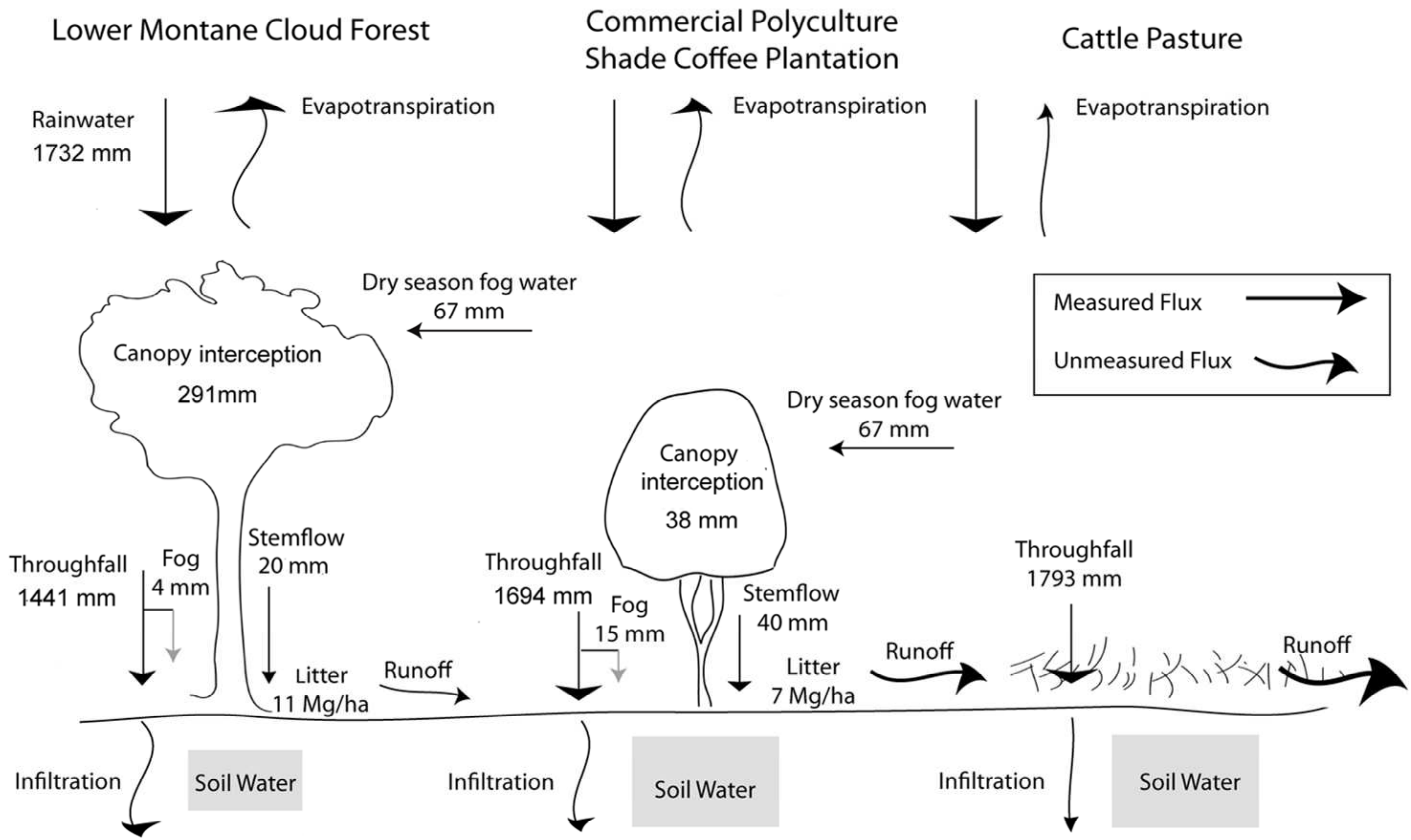


Max change in throughfall water flux = 10%

ENSO & Dry Season Precipitation



Summary



Lower Montane Cloud Forest
Commercial Polyculture Shade Coffee Plantation
Cattle Pasture
Rainwater 1732 mm
Evapotranspiration
Evapotranspiration
Evapotranspiration
Dry season fog water 67 mm
Measured Flux
Unmeasured Flux
Canopy interception 291mm
Dry season fog water 67 mm
Canopy interception 38 mm
Throughfall 1441 mm
Fog 4 mm
Stemflow 20 mm
Litter 11 Mg/ha
Runoff
Throughfall 1694 mm
Fog 15 mm
Stemflow 40 mm
Litter 7 Mg/ha
Runoff
Throughfall 1793 mm
Runoff
Infiltration
Soil Water
Infiltration
Soil Water
Infiltration
Soil Water

Global Change Implications

- Land-cover change alters the quantity, type, and timing of water inputs to soil.

- Basal area, leaf area, and canopy epiphytes are important controls on TF and SF.

- Forest to pasture conversion could result in a ~16% dry season reduction in fog deposition to plant canopies = max projected rainfall reduction for LA region by 2080.

Global Change Implications

- Change in throughfall water flux imparted by forest conversion (17%) > max change recorded in forests following tropical storms and hurricanes (10%).

- Increasing hurricane frequency/rainfall intensity may exacerbate human-mediated alterations in the water cycle.

- ENSO cycles decrease precipitation seasonality and increase antecedent soil moisture conditions before hurricanes.

Geographic Relevance

QuickTime™ and a
decompressor
are needed to see this picture.

BIODIVERSITY HOTSPOTS

COFFEE GROWING REGIONS

COCOA GROWING REGIONS

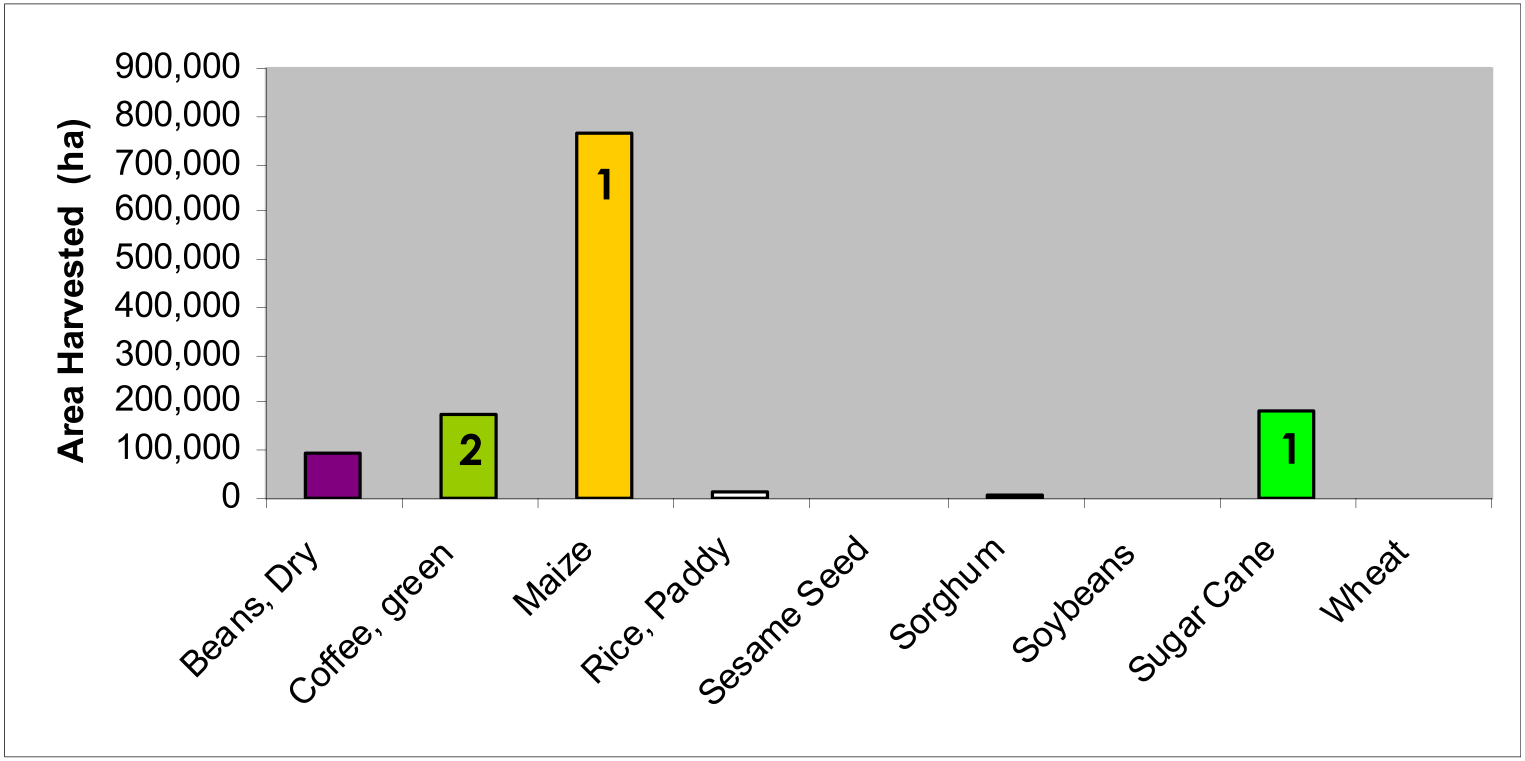
Hardner & Rice 2002

Thank you!

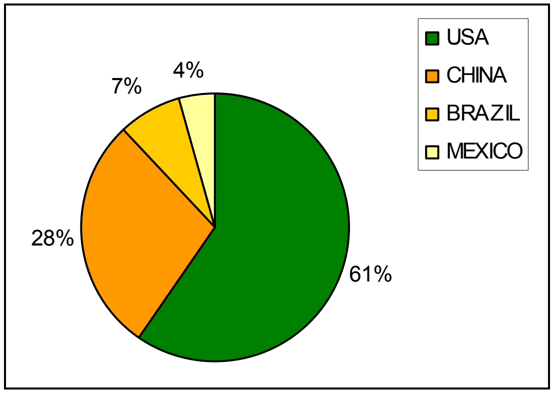
NASA Goddard Space Flight Center & GSRP, National Science Foundation, Fulbright-Hayes, Compton Foundation, Ford Foundation, Tinker Foundation, Yale Center for Earth Observation, Yale Institute of Biospheric Studies, Yale Tropical Resources Institute, Instituo de Ecología, A.C., Cary Institute of Ecosystem Studies

Kenneth R. Young, Graeme P. Berlyn, Mark Ashton, K. Jon Ranson, Robert H. Manson, Guadalupe Williams-Linera, Amanda Elliott, Milton Hugo Díaz Toribio, Matthew Fry, Romeo Vázquez Saldaña, Alejandra Tauro, and all landowners, caretakers, and field assistants.

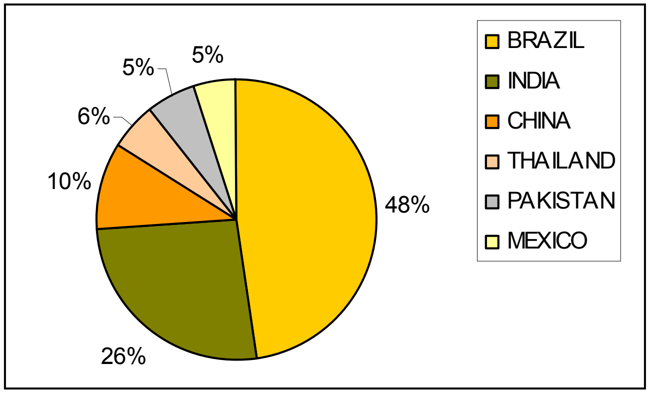
Agriculture



MAIZE PRODUCTION (MT)



SUGAR CANE PRODUCTION (MT)



COFFEE PRODUCTION (MT)