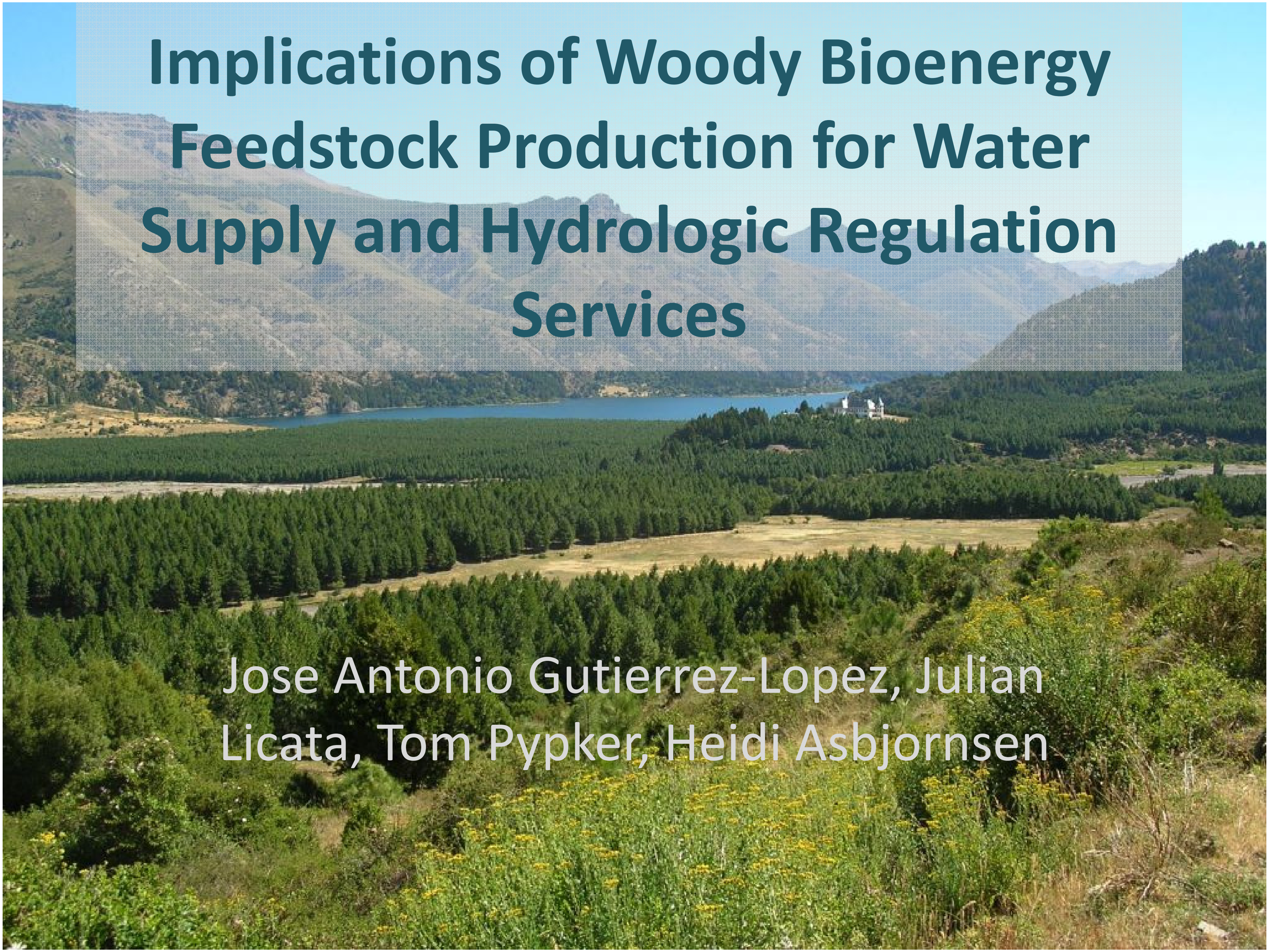


Implications of Woody Bioenergy Feedstock Production for Water Supply and Hydrologic Regulation Services

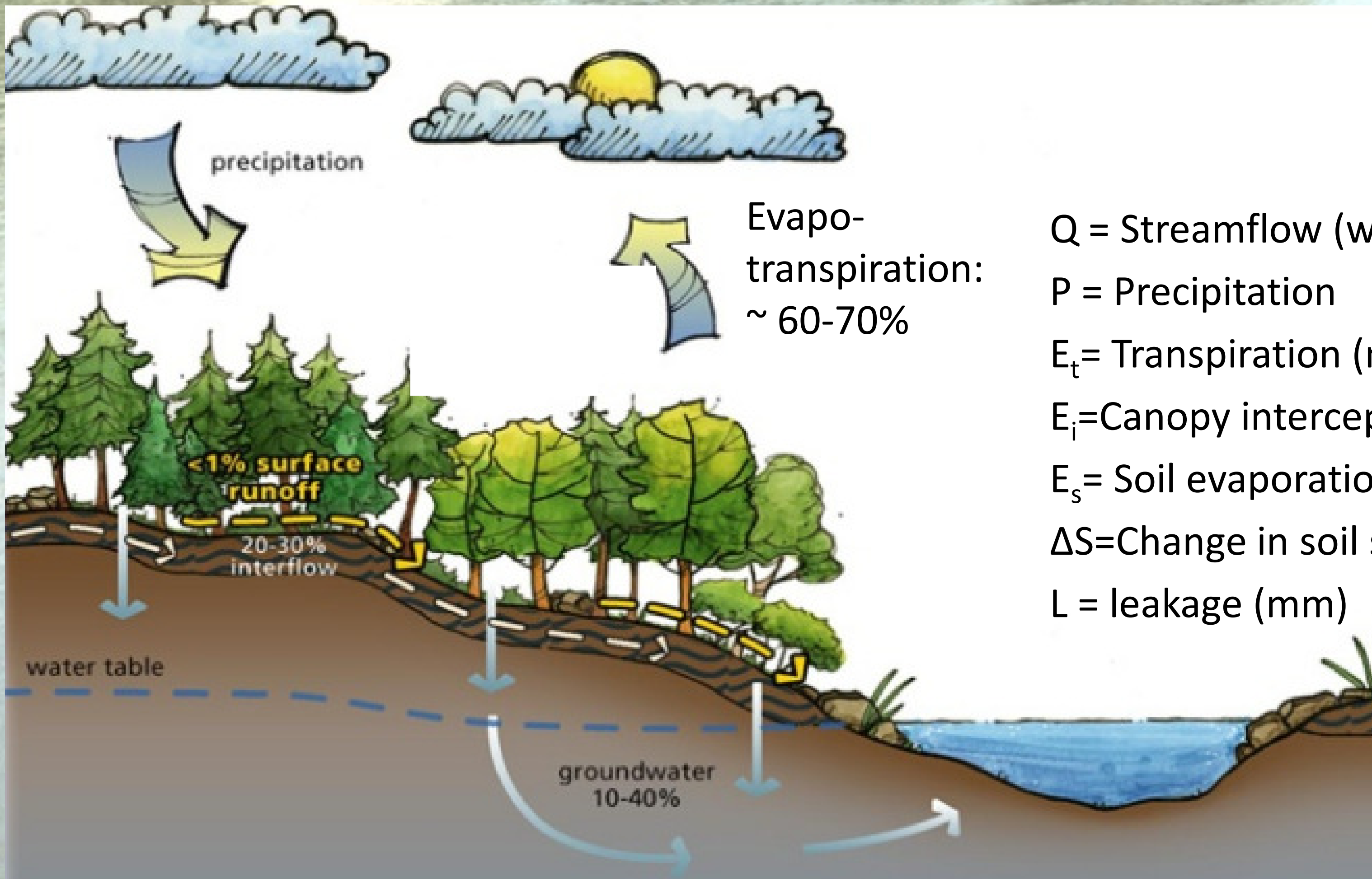
Jose Antonio Gutierrez-Lopez, Julian Licata, Tom Pypker, Heidi Asbjornsen

Introduction: Why should we care about bioenergy and water resources?

- Water scarcity quickly becoming the world's most critical issue for human well-being and ecosystem sustainability: UN "International Decade Water for Life 2005-2015"
- Growing global pressure to increase bioenergy crop production: major consequences for water resources, often not considered!
- Current understanding? Important knowledge gaps?

WATER FOR LIFE
2005-2015

Background: The Water Cycle



Evapo-
transpiration:
~ 60-70%

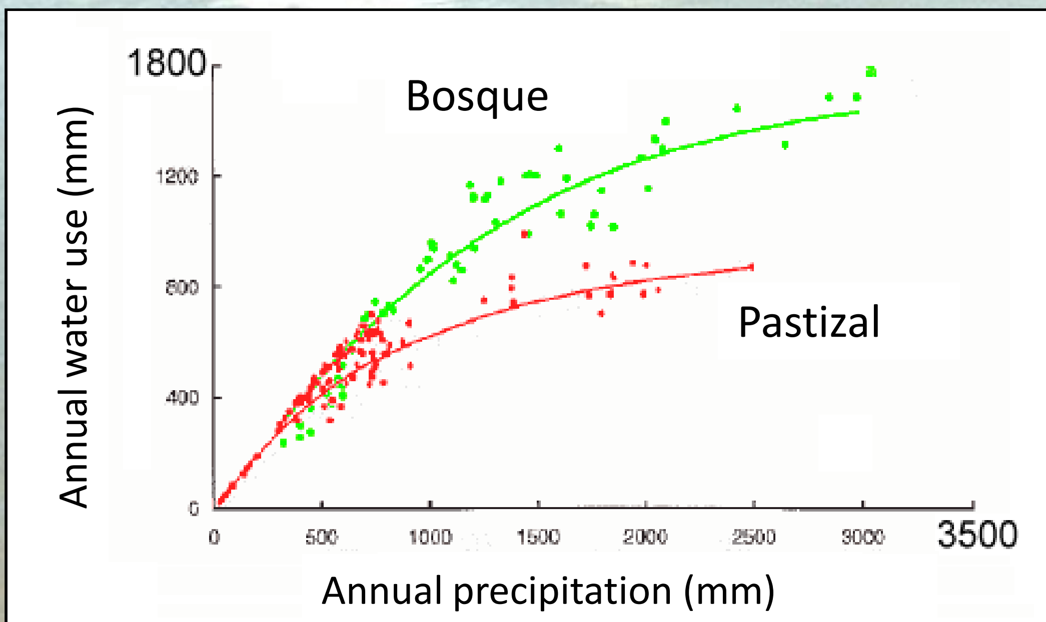
Q = Streamflow (water yield)
P = Precipitation
E_t= Transpiration (mm)
E_i=Canopy interception (mm)
E_s= Soil evaporation (mm)
ΔS=Change in soil storage
L = leakage (mm)

Streamflow (water yield) = Inputs - Outputs ± Storage

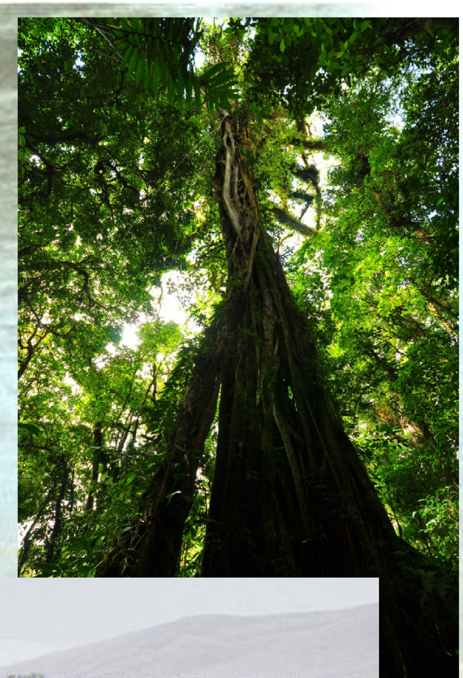
$Q\ (WY) = P - E_t + E_i + E_s + \Delta S + L$

Land use change (LUC) impacts on vegetation water use

- Forests *almost always* use more water compared to shrubs, grasslands, or crops.
  - Deep roots
  - Higher leaf area
  - Longer growing season



Zhang 2004



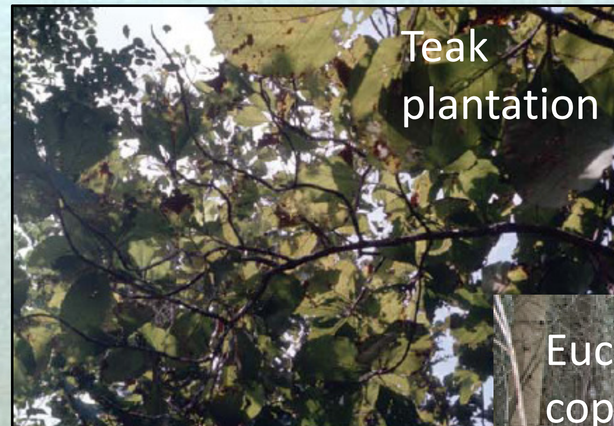
What's so unique about (woody) bioenergy plantations vs. other types of LUC?

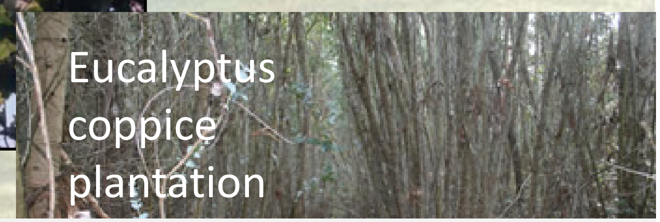
- Exotic species
- Rapid growth rates
- High planting density
- High leaf area index
- Short rotation length

High Productivity

- Water quantity
- Water "timing" (seasonal distribution)


Mature tropical rainforest


Teak plantation


Eucalyptus coppice plantation

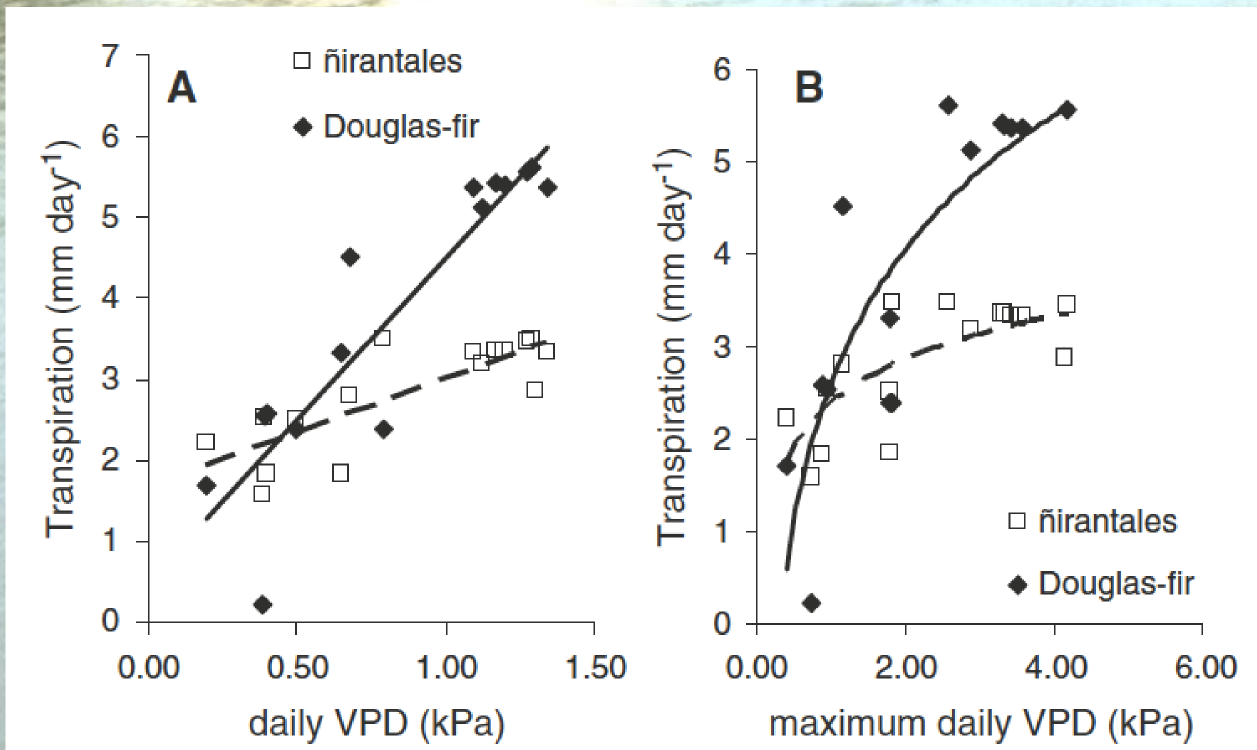
Few studies on woody bioenergy plantations and water use, but many similarities to other plantations

Water Quantity: Transpiration

Streamflow (water yield) = Inputs - Outputs ± Storage

$$\mathbf{Q\ (WY) = P - E_t + E_i + E_s + \Delta(S+G) + L}$$

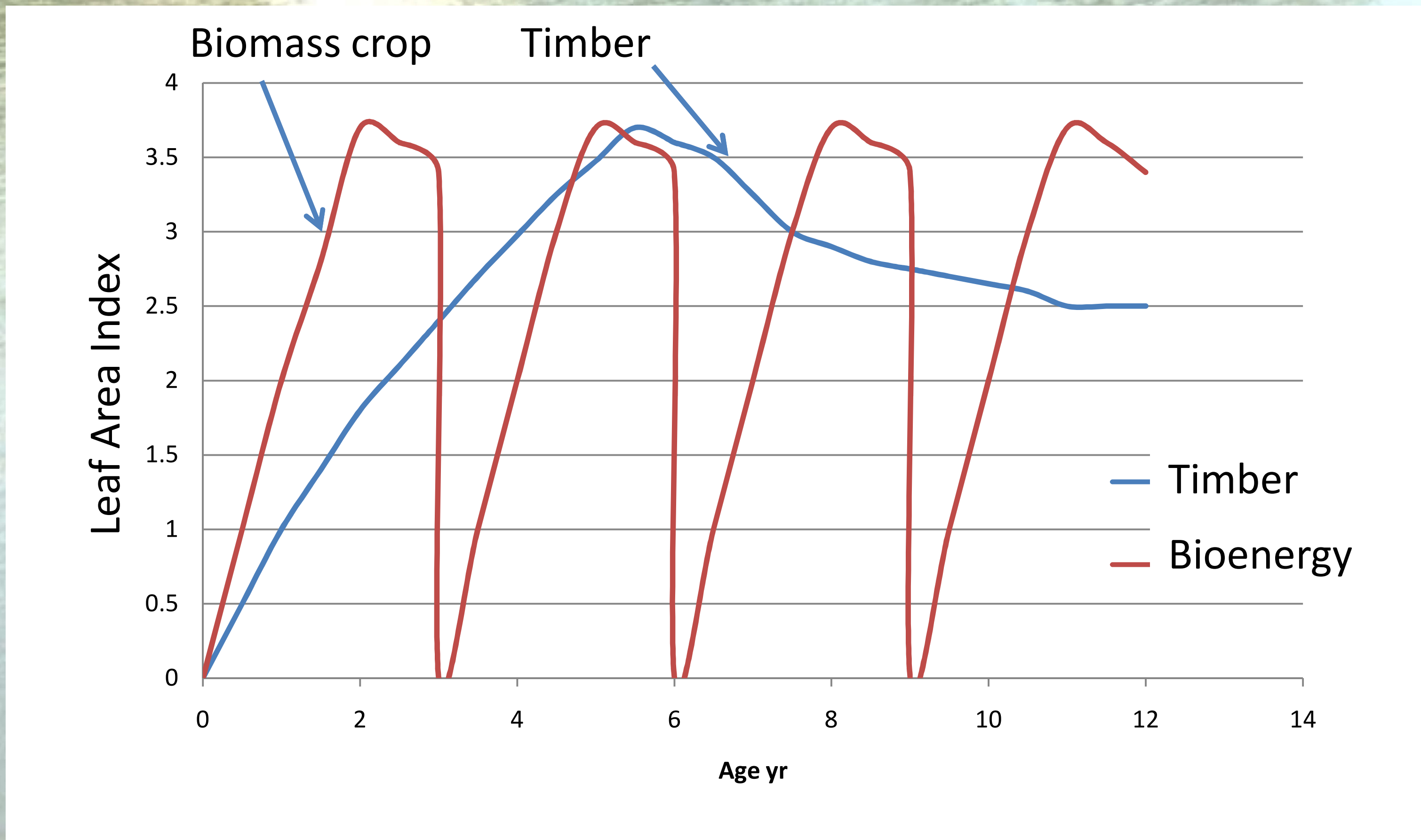
Transpiration rates for exotic species often greater than native forests: Douglas-fir plantations vs. native *Nothofagusantartica*forests: Patagonia, Argentina



- Rooting depth and access to water
- Stomatal sensitivity to drought (conservative strategy)

Gyenge et al. 2008, 2009

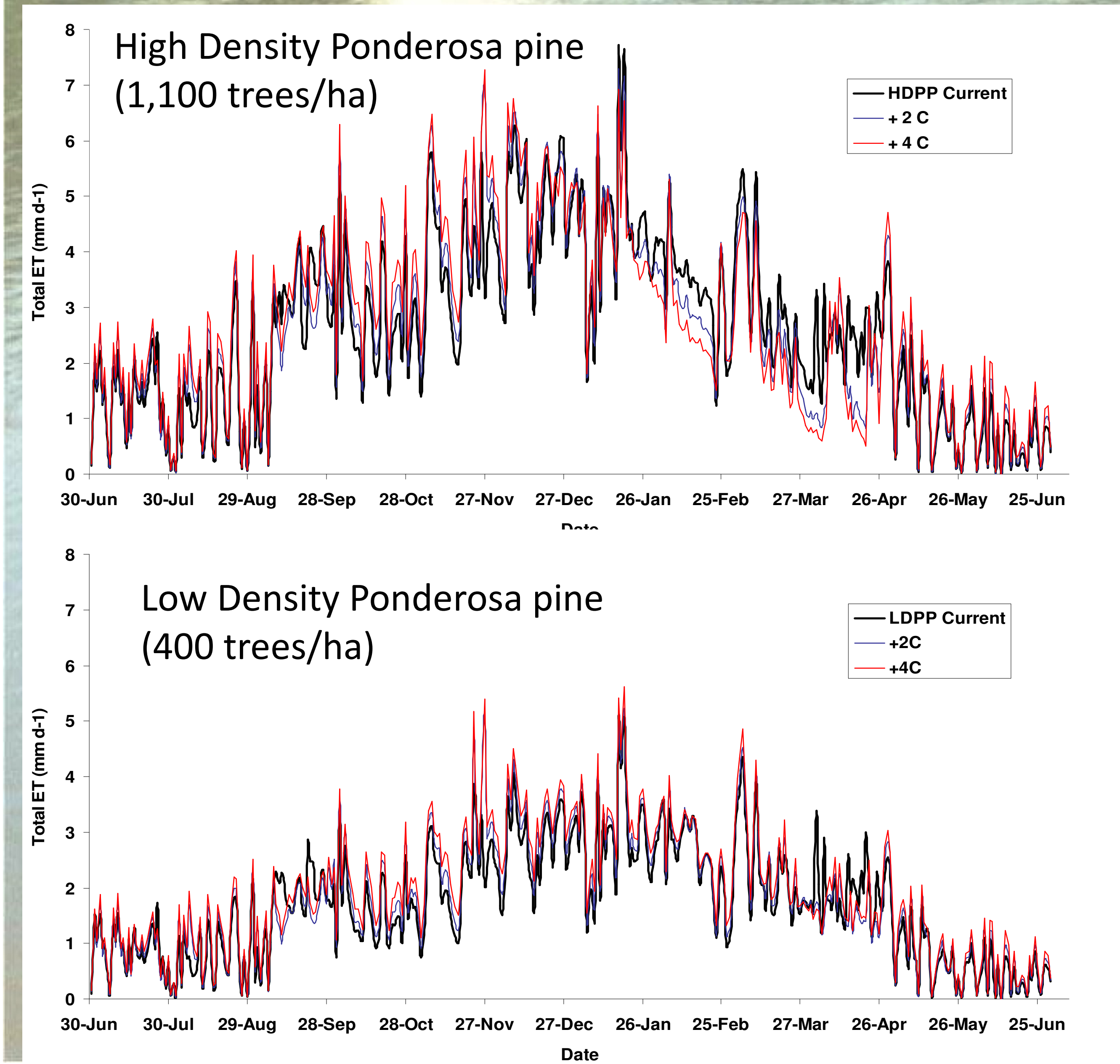
Rotation time for woody biomass crops may affect total water use: Conceptual model



- Woody biomass crops often have higher growth rates and leaf area indices, **<u>but shorter rotation times</u>**
- Potential for higher total water use over time

Licata et al., unpubl.

Biomass crops often planted at high density: Modeled effects of high vs. low density on transpiration



Temperature change current, +2 C and +4 C

Biomass crops may be less resilient to future climate change

Licata et al., unpubl.

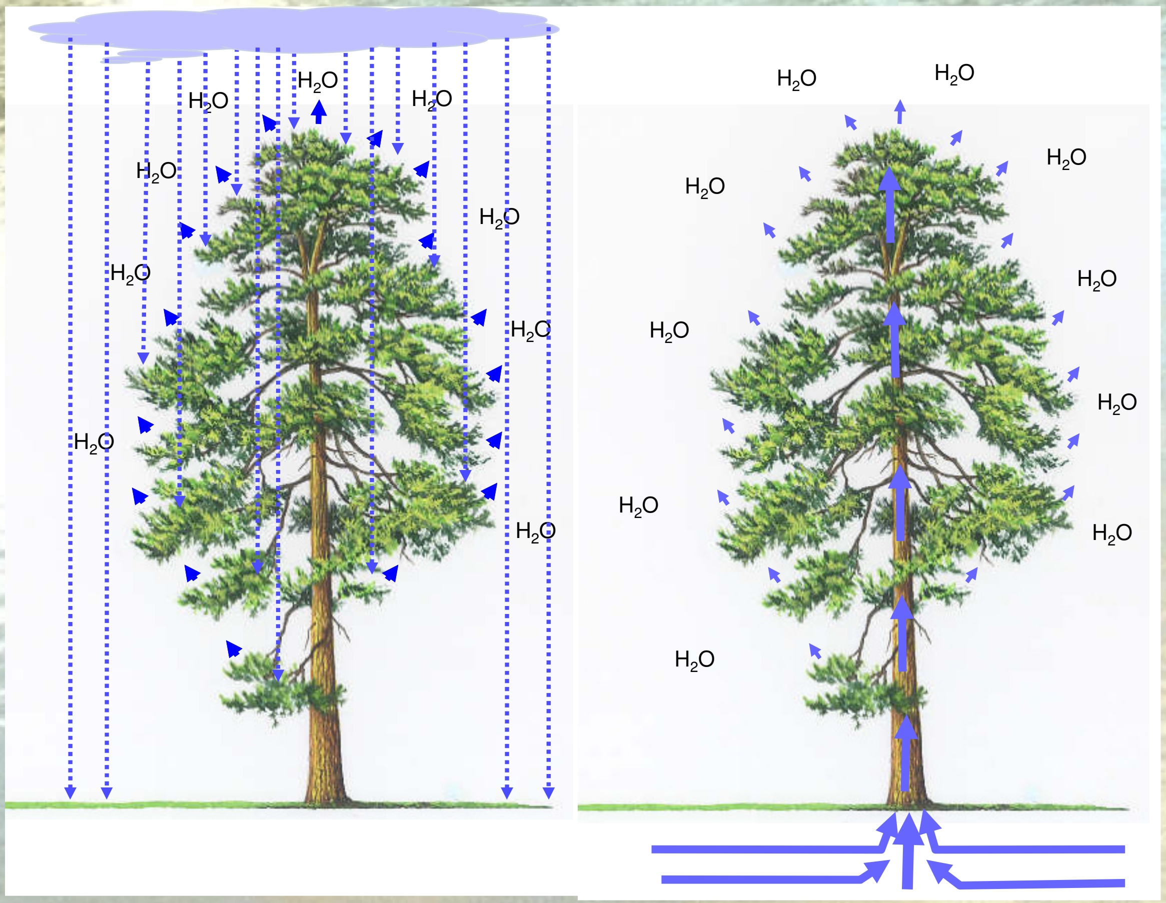
Water Quantity: Canopy Interception

Streamflow (water yield) = Inputs - Outputs ± Storage

$$Q\ (WY) = P - E_t + E_i + E_s + \Delta(S+G) + L$$

Canopy Interception (E_i):

Productive vs. non-productive water use

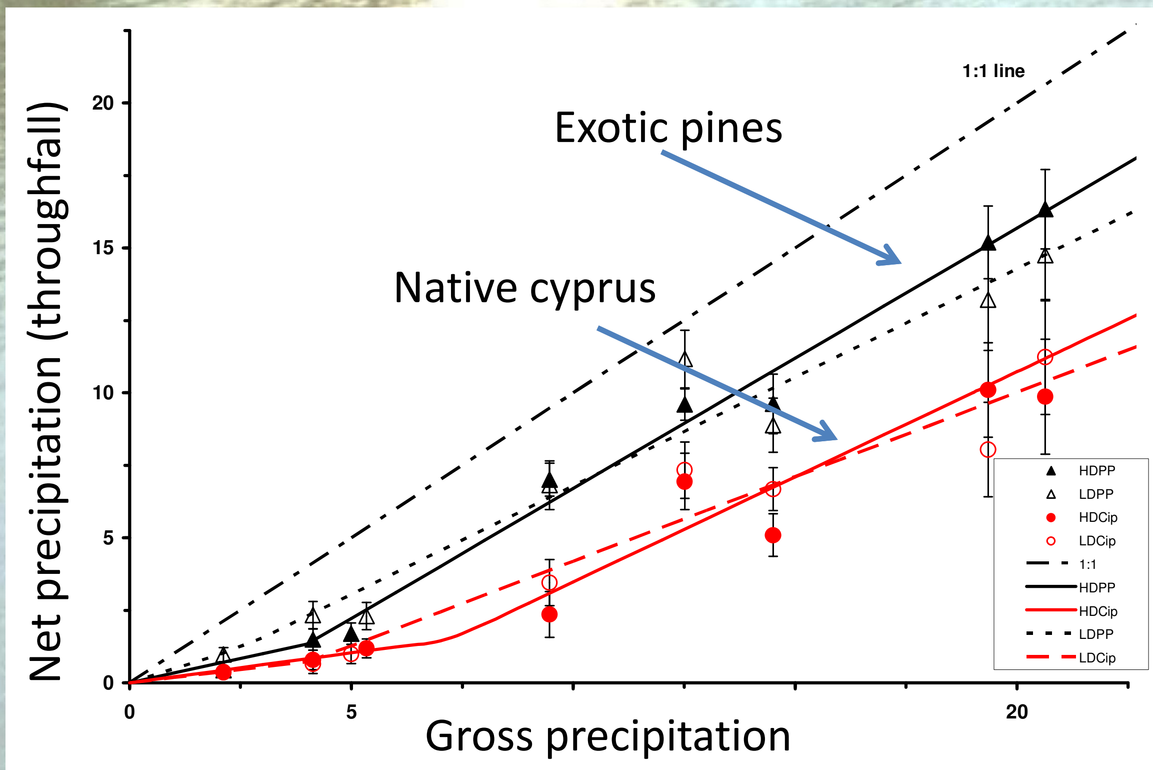


(Licata et al., 2010)

- E_i(usually) =non-productive water loss
- Throughfall = productive water use if infiltrated into the soil (if transpired by vegetation and not lost via runoff)

Canopy Interception (E_i): Patagonia

Morphological and structural traits of leaves and branches are critical determiningE_iLosses



- Exotic pines had lower E_i losses and higher soil water recharge than native cypress forests.
- Exotic pines had higher E_t AND productivity.
- Species selection important!

Licata et al., 2010

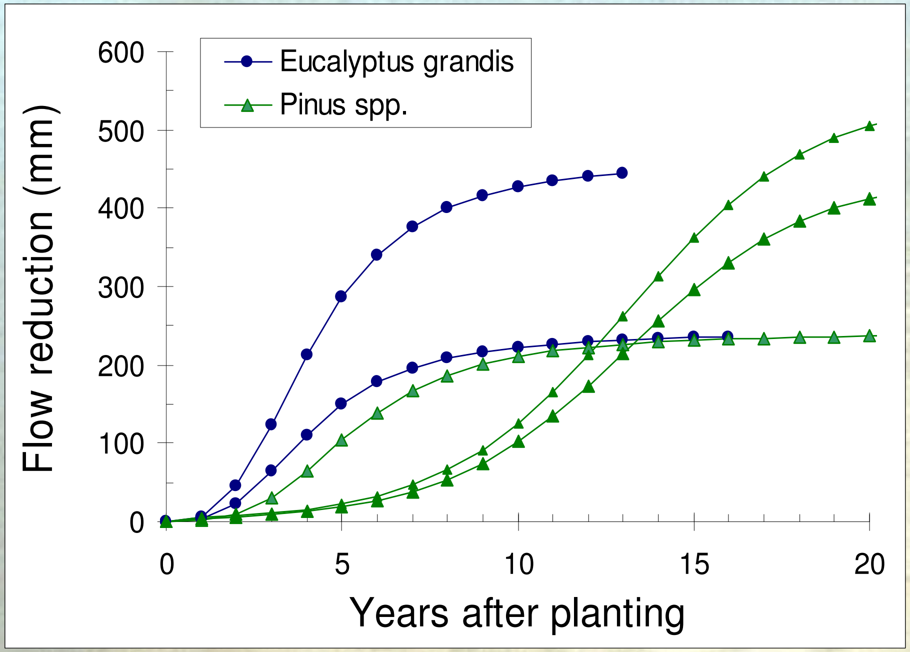
Water Quantity: ET and Streamflow

Streamflow (water yield) = Inputs - Outputs ± Storage

$$Q\ (WY) = P - E_t + E_i + E_s + \Delta(S+G) + L$$

$$= ET$$

Establishing plantations on former (non-degraded) grasslands in South Africa:Effects on streamflow



- Trees have higher water use than grasses
- Streamflow reduced
- Effects observed sooner for eucalyptus vs. pine plantations

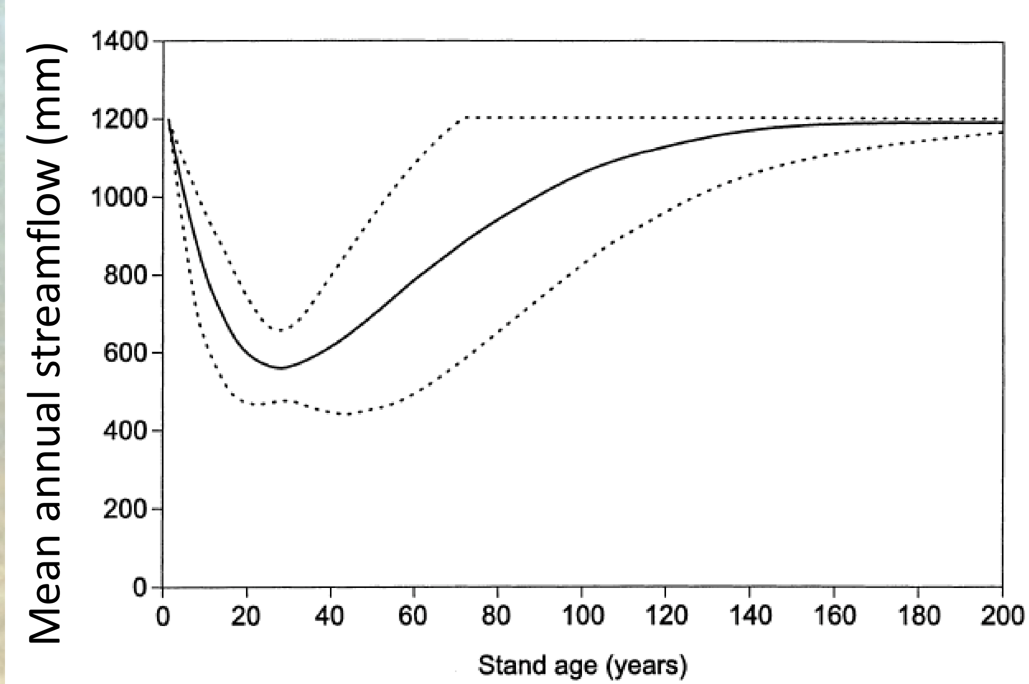
Scott et al. 1997

Conversion of mature forest to eucalyptus plantations in New Zealand: Effects on streamflow

- Young rapidly growing plantations have higher transpiration rates than mature forest.
- Streamflow reduced under eucalyptus during early stand development.
- Streamflow returns to pre-conversion levels after 80-100 y

Age	Plottranspiration (mm/day)
14	2.2 mm
45	1.4 mm
160	0.8 mm

Roberts et al. 2001

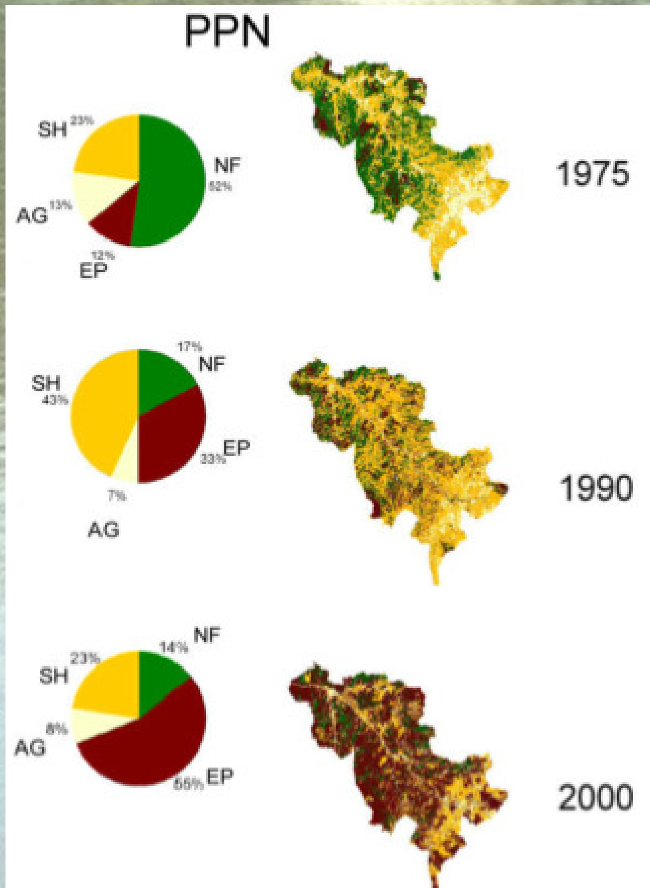


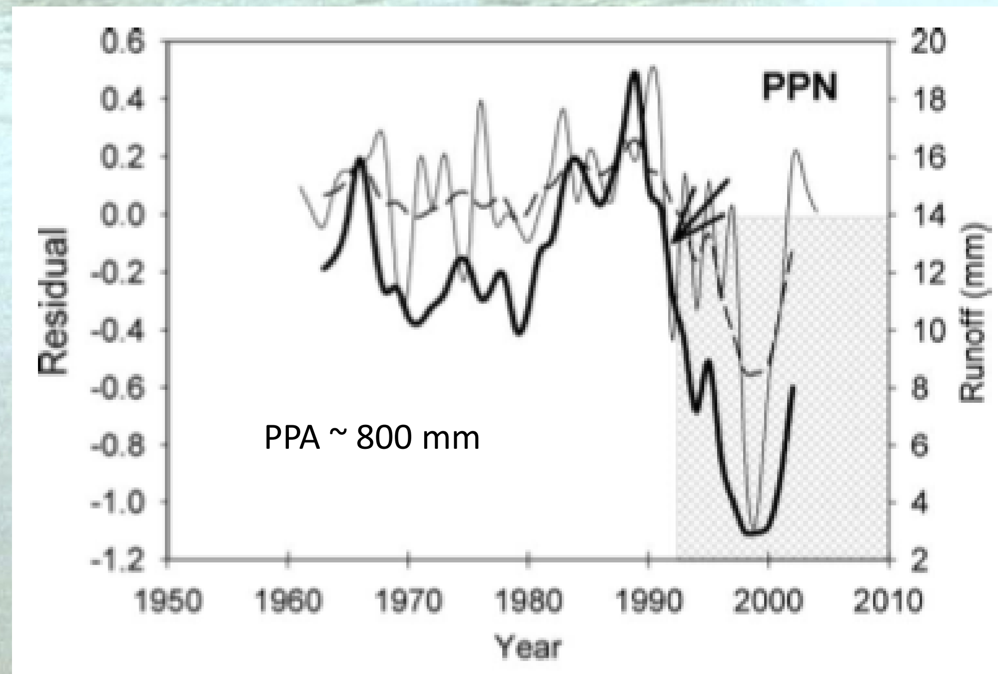
Kuczera1985

Water Timing (seasonal distribution)

Dry Season Flows:
Critical for downstream hydrologic services!

Conversion of native forest to pine plantations in Chile: Effects on dry season streamflow





- Watershed in Chile: 250 km2
- Approximately 50% of native forest converted to radiata pine plantations between 1978 and 1997

- Dry season streamflow reduced by 40%
- Greater water use during wet season by pines.

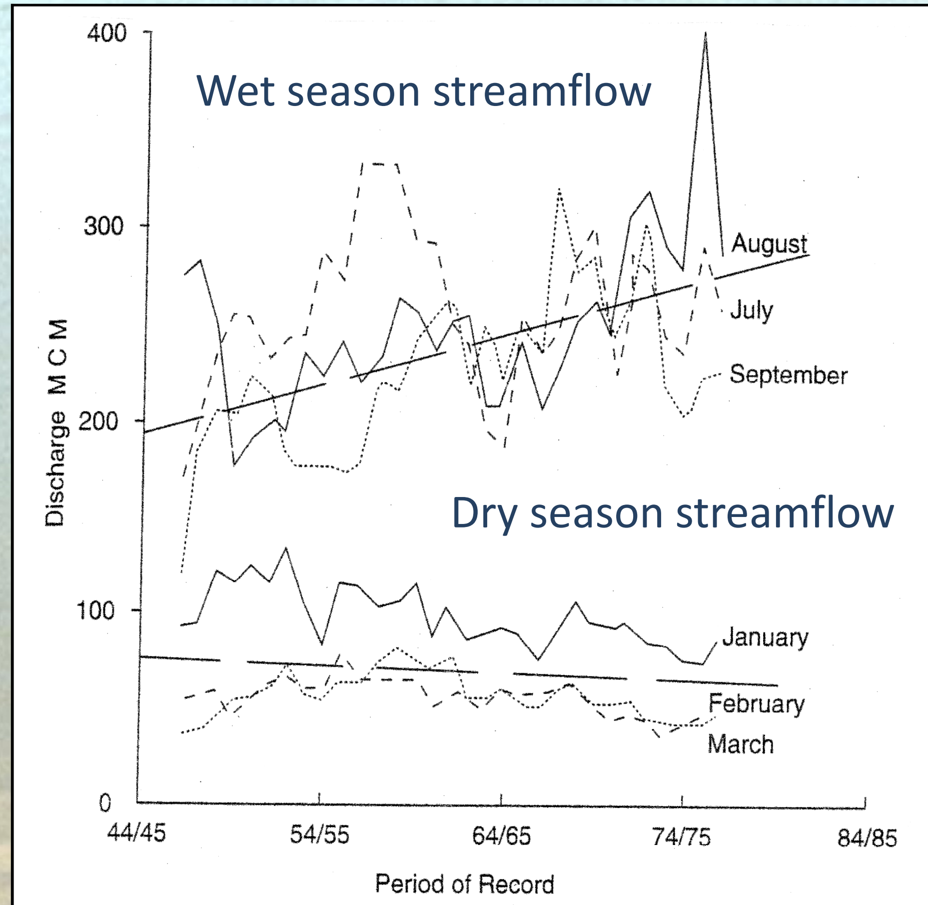
Little et al. 2009

Water Timing (seasonal distribution)

Can planting trees ***on degraded soils*** increase dry season streamflow?

- Net balance between the amount of increased water loss (due to increased ET) and gains in groundwater water recharge (due to increased soil infiltration rates).
- Key: soil hydraulic properties & recharge

Deforestation + soil degradation = higher annual streamflow but lower dry season flows

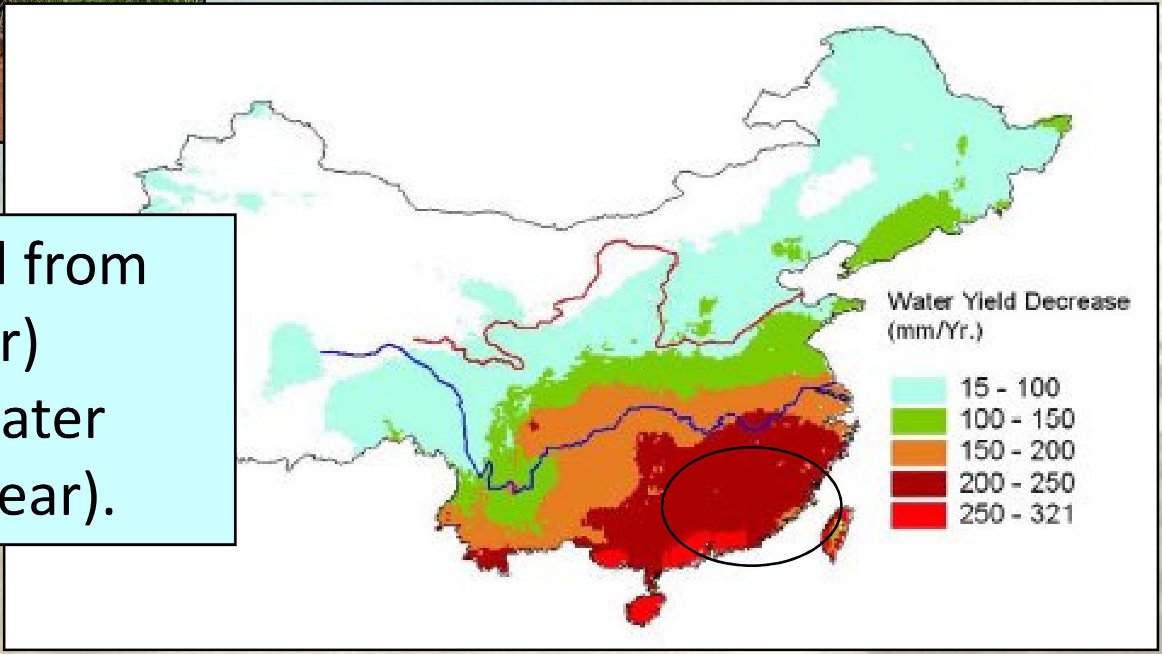


MaddumaBandara 1997

Reforestation on degraded soils: balance between outputs (transpiration) and inputs (infiltration)

Degraded red soils in humid SE China
Annual P: 1,450 – 1,950 mm

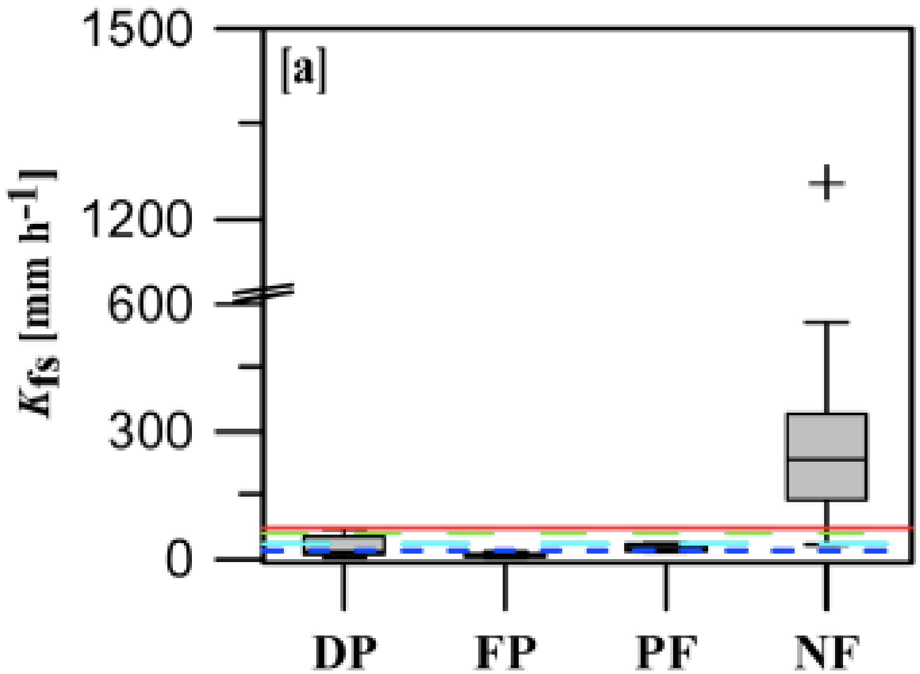
- The “extra” water gained from infiltration (> 450 mm/year) exceeded the additional water used by trees (<300 mm/year).



Zhang et al. 2004, Sun et al. 2006

Pine Reforestation of Degraded Lands: Nepal

Field saturated soil hydraulic conductivity



DP = Degraded Pasture (DP)
FP = Foot Path (FP)
PF = Pine Reforestation (PF)
NF = Native Forest (NF)

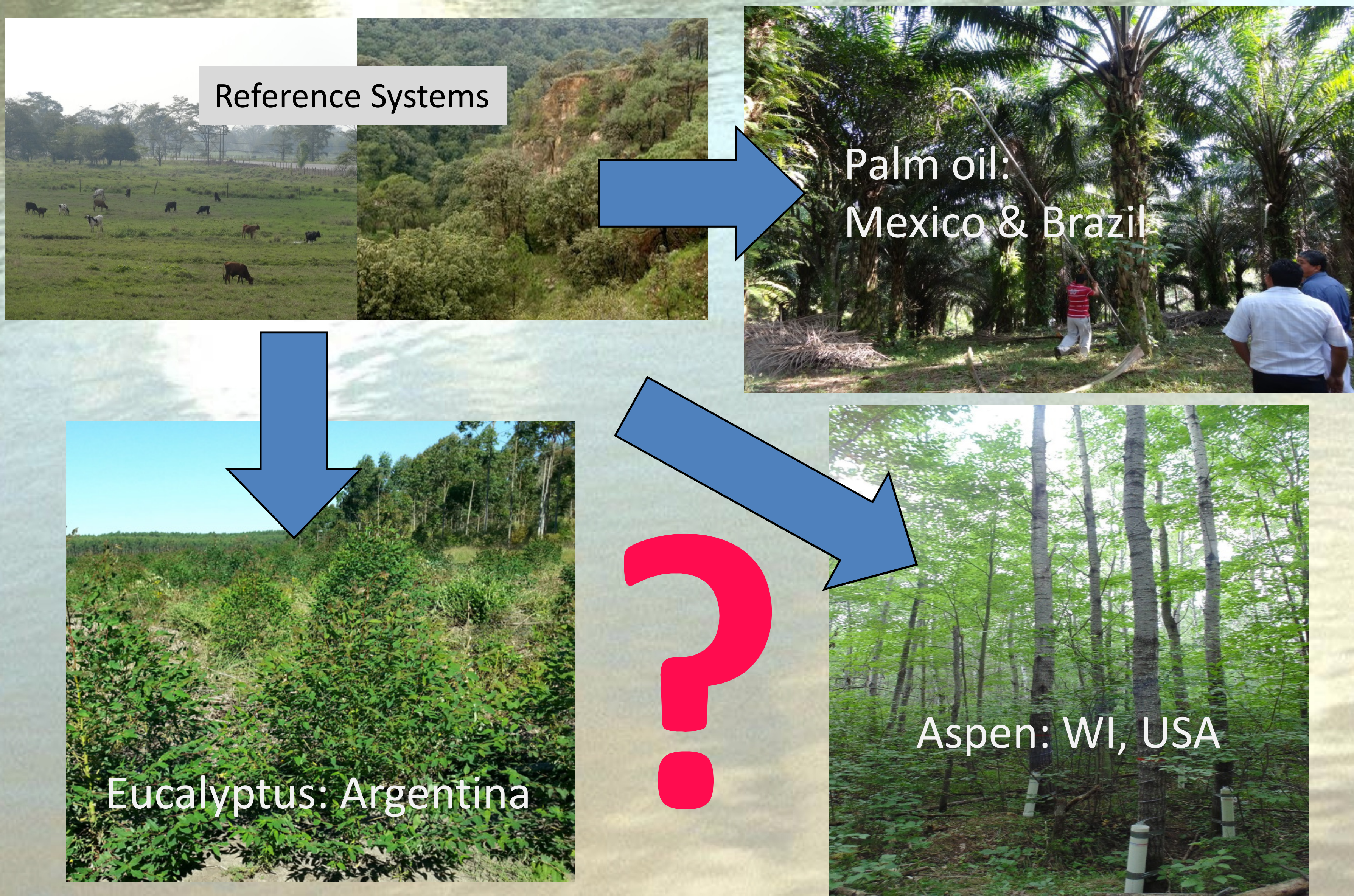
- Pine reforestation did not improve soil hydraulic properties after 25 years.

Ghimire et al. 2013

Opportunities for managing biomass plantations for hydrologic services

- Rotation length
- Stand density
  - planting
  - thinning
- Genetic improvement:
  - Productivity
  - Water use efficiency
- Species selection
- Species combinations

Current Research: Effects of bioenergy production on water supply and hydrologic services?



Acknowledgements:

Funding: NSF-PIRE, NSF-RCN

Obrigado! Obrigada!
Perguntas?