# Effects of large scale tree plantations on local climate. What potential for rubber tree plantations?

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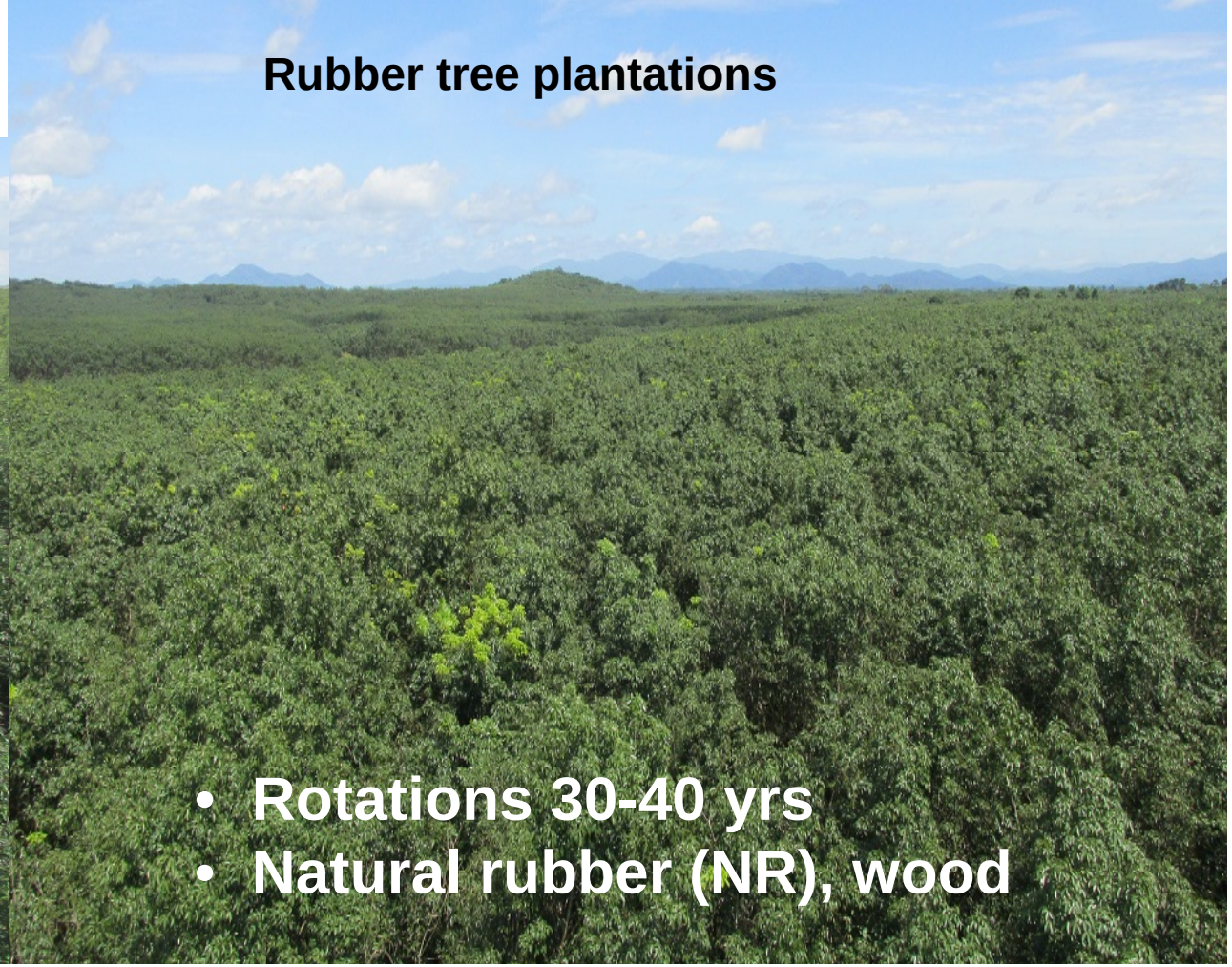
## Fast growing plantations (Eucalyptus)


## Rubber tree plantations




- **Global impacts on climate through their effects on atmospheric CO2 concentrations:**
  - **Increases in C stocks if plantations are established on grasslands or croplands: even if plantations are clearcut at the end of the rotation, C stocks are increased at the landscape scale (plantations of different ages)**
  - **Wood can be used as a substitute of wood from natural forests (avoid deforestation), or as a substitute of fossil carbon (e.g. coke) in the steel industry or energy facilities => avoid fossil C-CO2 emissions**
  - **Using natural rubber (renewable product) as a subtitute synthetic rubber (fossile C) => avoid fossil C emissions**
- **Local effects (evaporating cooling): biophysical factors, such as reflectivity, evaporation, and surface roughness can alter temperatures much more than carbon sequestration does** (Jackson et al., 2008)

# Large-scale plantations can strongly impact the water and energy cycle => local climate

**e.g. Eucalypt plantations in Brazil**

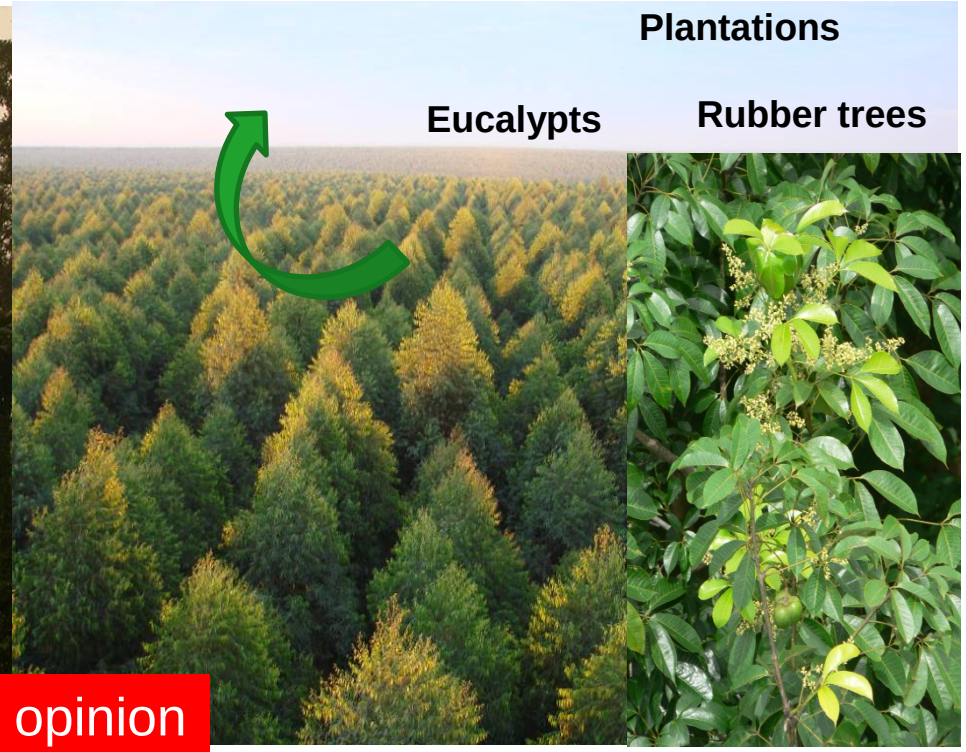
**High AET associated with high productivity**

**Rubber plantations act as water pumps in tropical China**

Zheng-Hong Tan,[1,2] Yi-Ping Zhang,[1,2] Qing-Hai Song,[1,2,3] Wen-Jie Liu,[1] Xiao-Bao Deng,[1] Jian-Wei Tang,[1] Yun Deng,[1] Wen-Jun Zhou,[1,2,3] Lian-Yan Yang,[1,2,3] Gui-Rui Yu,[4] Xiao-Min Sun,[4] and Nai-Shen Liang[5]

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L24406, doi:10.1029/2011GL050006, 2011

# High evapotranspiration (AET) : Good or bad?




Public opinion

**Natural forest** are often praised for their high AET (high AET = efficient recycling of rainfall to the atmosphere => positive feedback on climate, rainfall regime, decrease in air temperature, decrease in vpd, ect.), decreases flooding and losses of nutrients

By contrast, high AET for **Eucalypt or rubber tree plantations** is often seen as a sin…(accused of decreasing river flow, water table levels, and decreasing water availability for other users such as agriculture)

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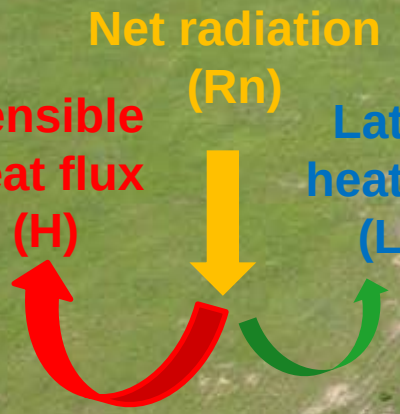
High AET = Good

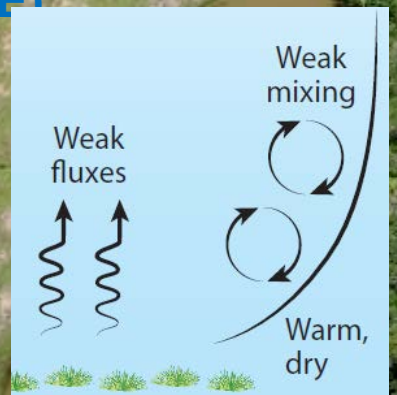
?

High AET = Bad?

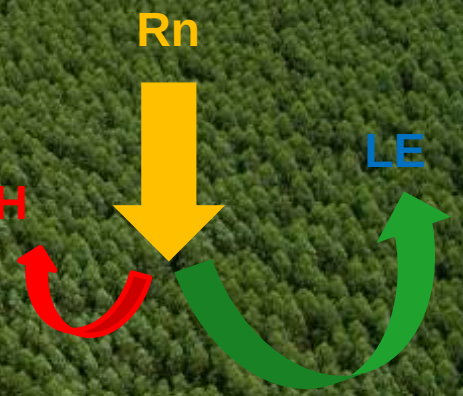
**“Policies for climate mitigation on land rarely acknowledge biophysical factors, such as reflectivity, evaporation, and surface roughness. Yet such factors can alter temperatures much more than carbon sequestration does”:** Jackson et al. (2008). Protecting climate with forests. Environ. Res. Lett. 3 (2008) 044006.

**The effect of land-cover on surface temperature mostly depends on albedo (which affects net radiation = available energy, Rn), and the partitionning of the available energy between latent heat flux (LE = evapotranspiration) and sensible heat flux (H)**




**The vaporisation of 1mm of water (1 liter water/m2) consumes 2.45 MJ/m$^2$**



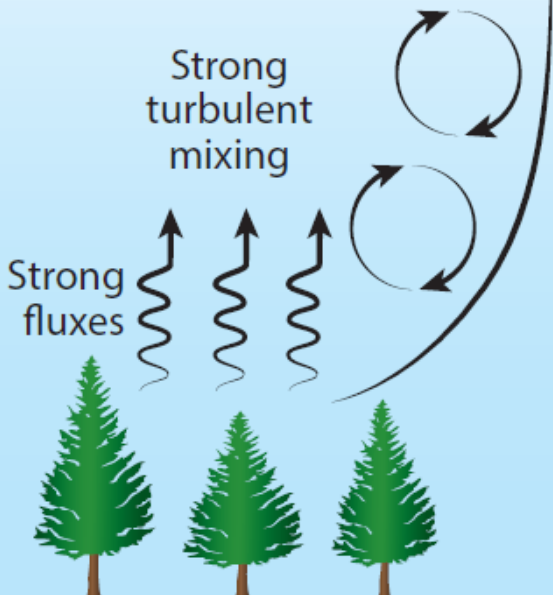

**Under the tropics, afforestation generally leads to lower surface temperatures (the effects of higher LE dominates the effects of lower albedo)**

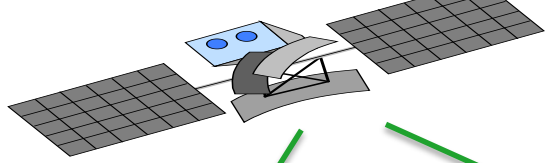
**Plantations => High evapotranspiration, due to:**

- Deep rooting
- Surface roughness
- High stomatal conductance
- Fertilisation

**=> surface cooling**

Fig.: Bonan, 2016, Annu. Rev. Ecol. Evol. Syst. 47:97–121





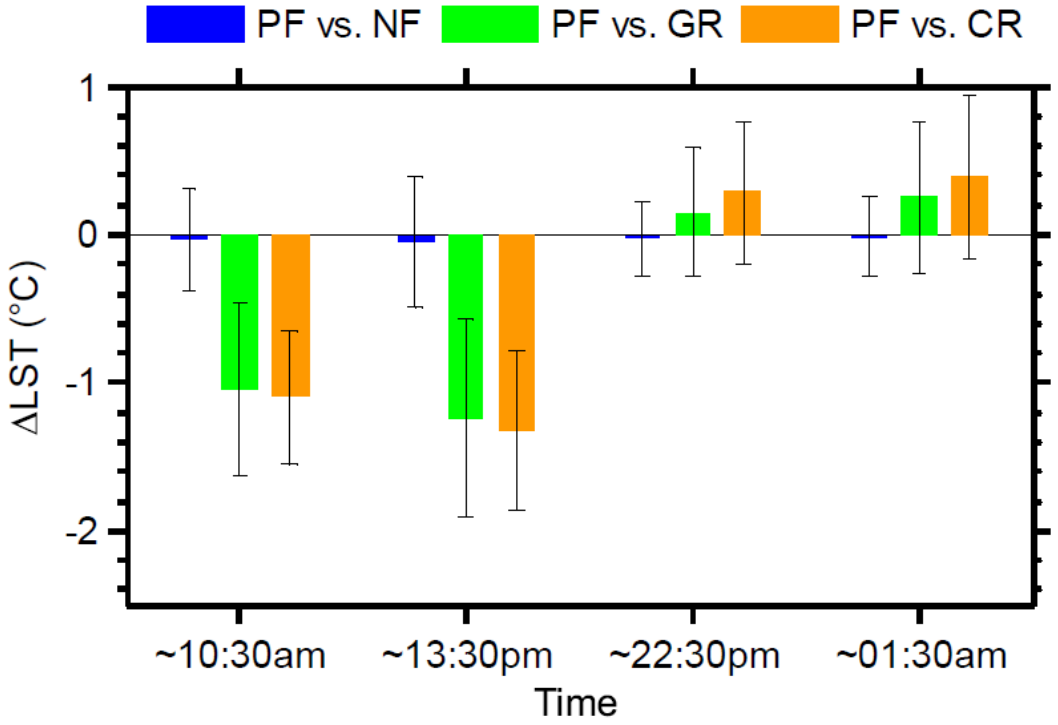
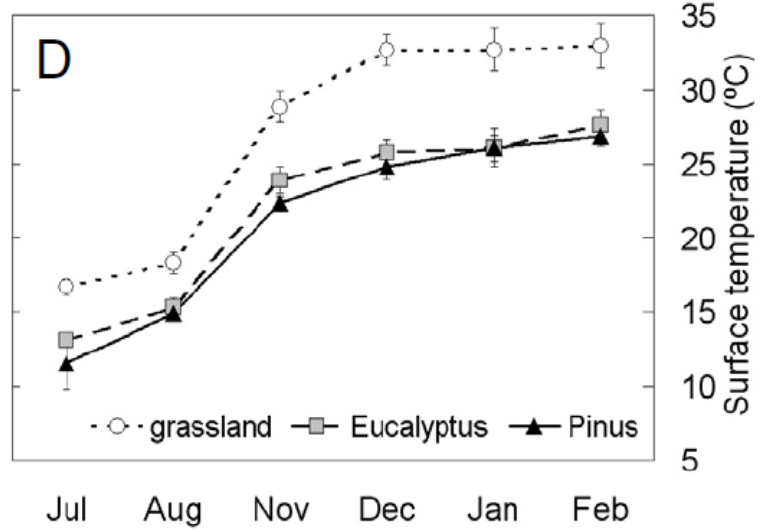
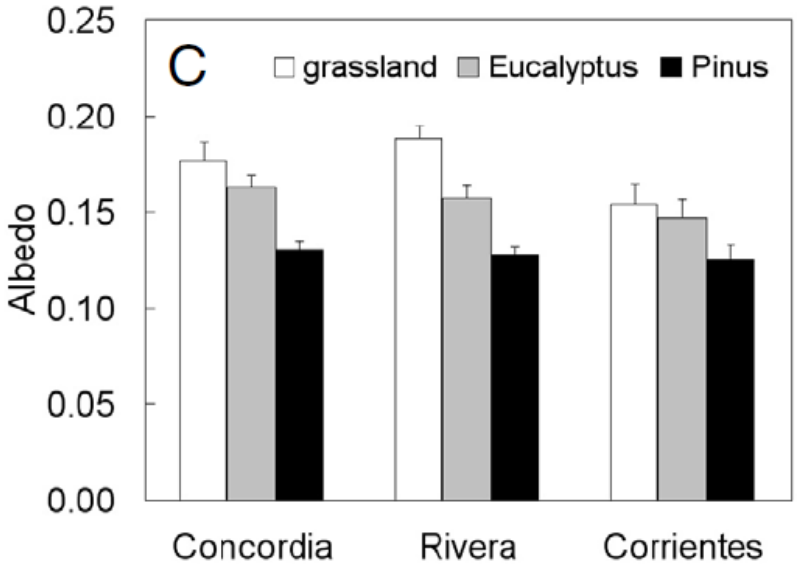



**Fig. 2.** Differences (mean ± SD) in annual LST between PF and the adjacent NF, GR, and CR during the daytime (~10:30 AM and ~13:30 PM) and nighttime (~23:30 PM and ~01:30 AM) in China during the period 2003–2010.

**PF**=planted forest; **NF**=Natural forest; **GR**=grassland; **CR**=croplands
LST=Land surface temperature

**Peng, et al. (2014). Afforestation in China cools local land surface temperature. Proceedings of the National Academy of Sciences of the United States of America, 111 (8), pp. 2915-2919.**



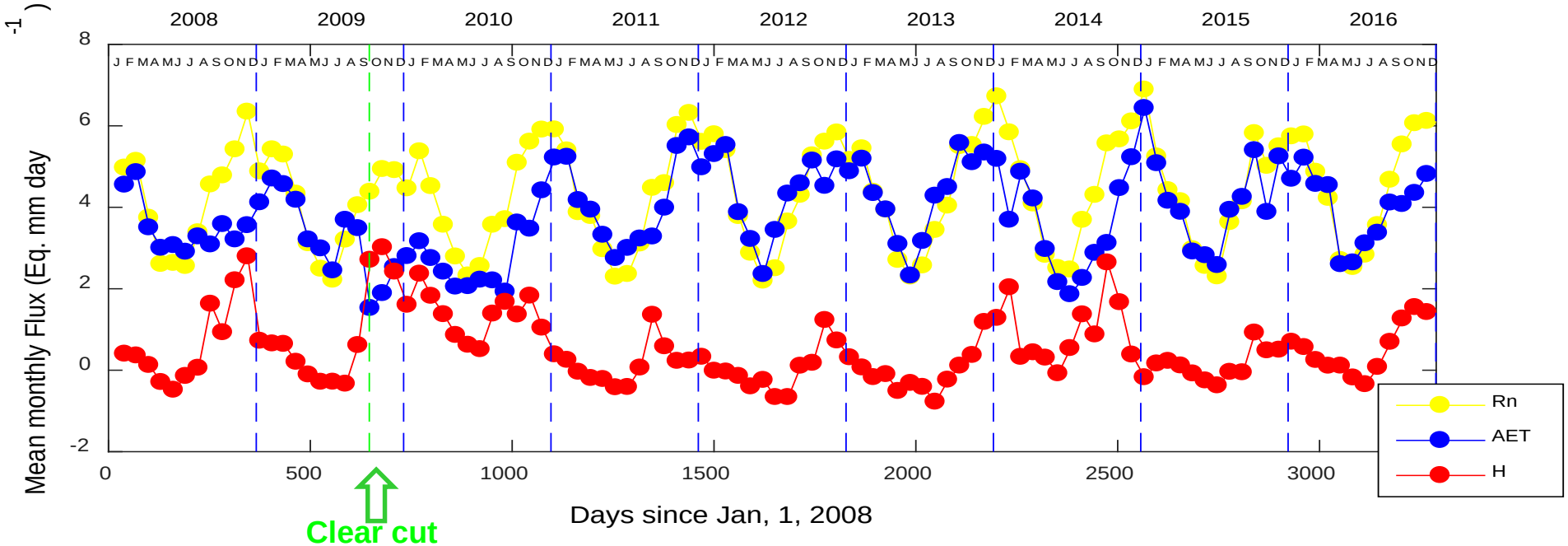

Argentina and Uruguay

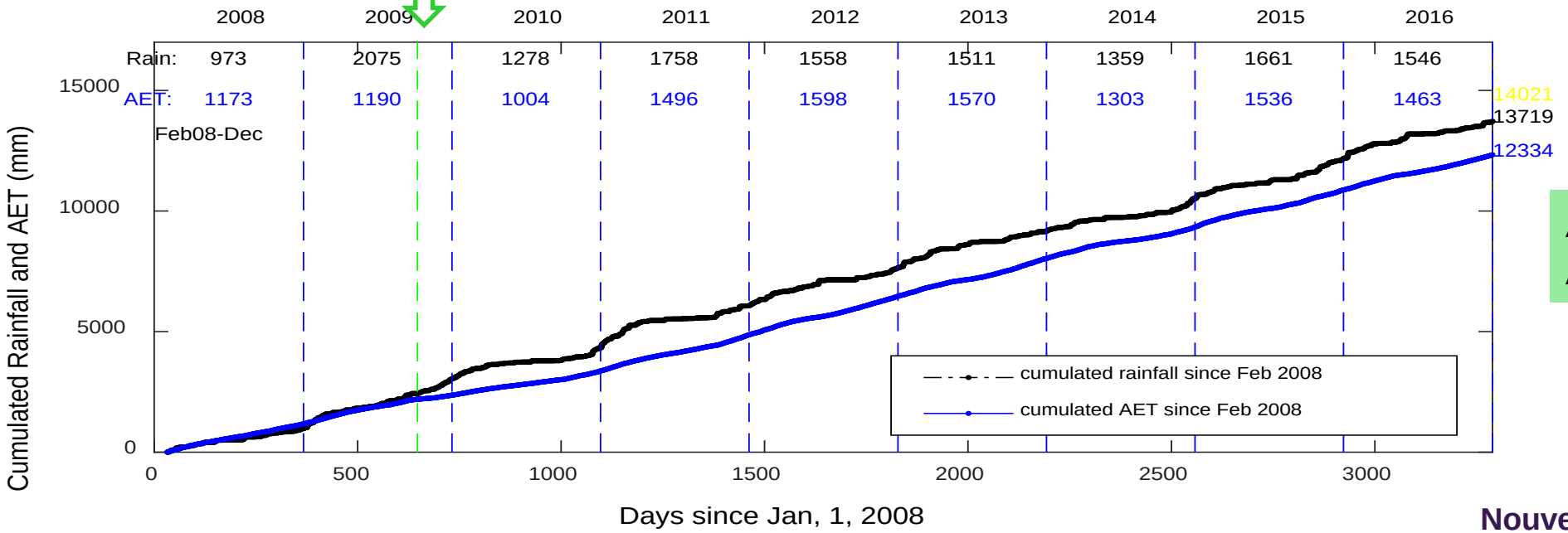
**Jackson et al. (2008). Protecting climate with forests. Environ. Res. Lett. 3 (2008) 044006.**

# Eddy-covariance measurements of evapotranspiration and energy fluxes

Thailand, rubber plantations

Brazil, Eucalypt plantations




**Eucalyptus stand (Brazil)**

Very high LE (AET)

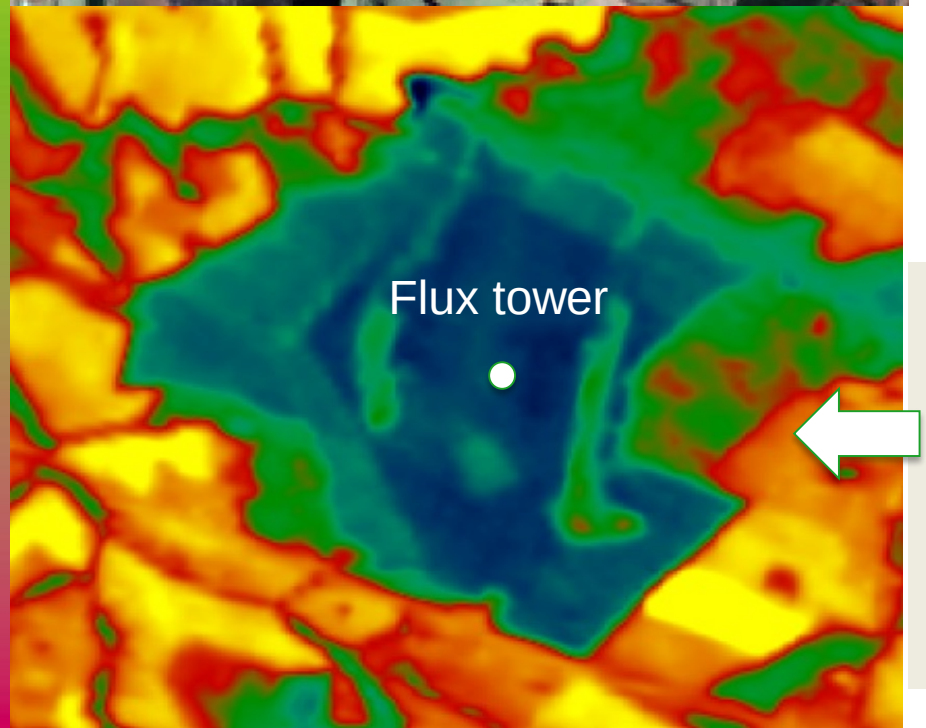
Very low sensible heat flux (H)

88% of available energy used for evapotranspiration

=> Surface cooling

AET ~ 90% of rainfall
AET ~ 88% of Rn

**Nouvellon et al., in prep**

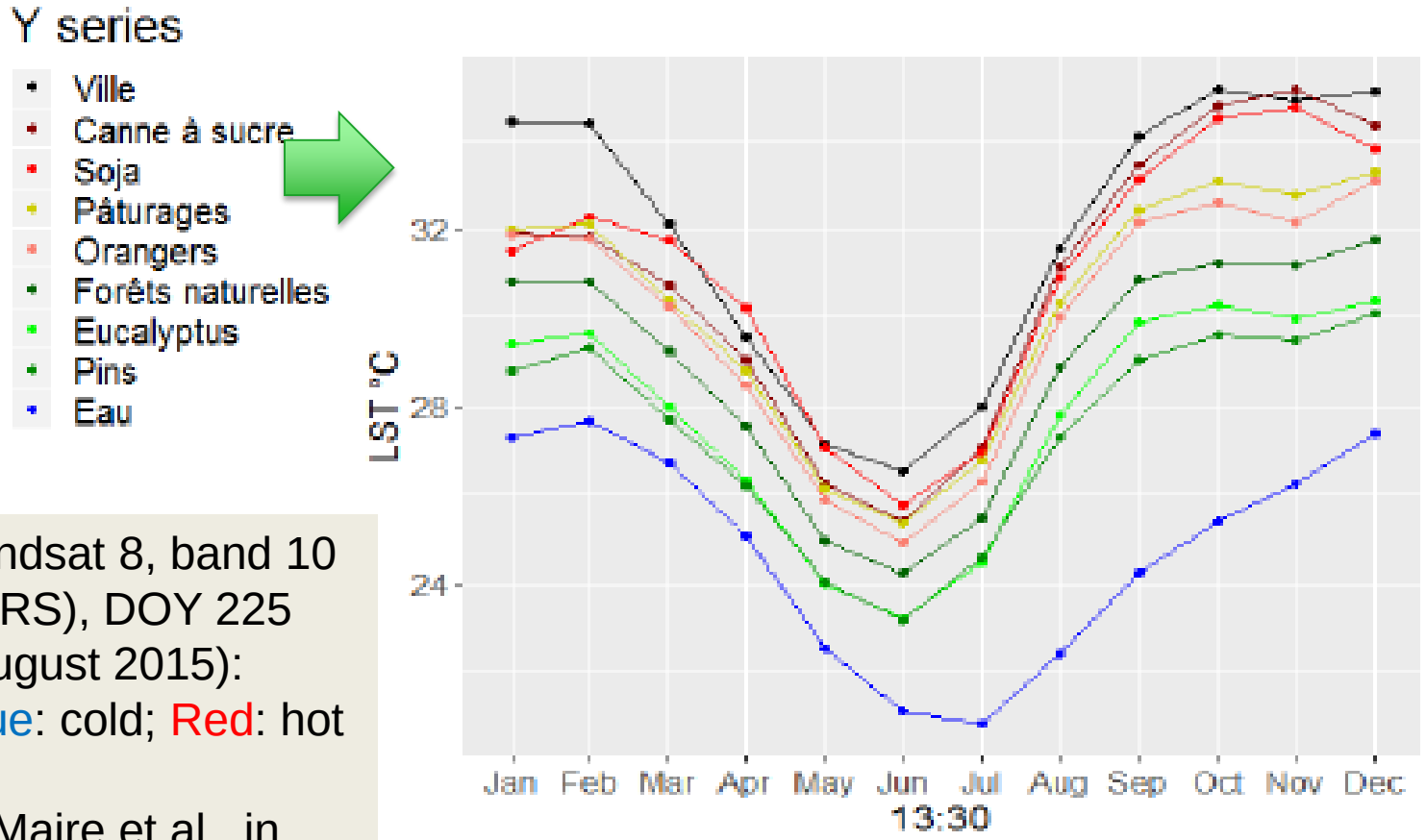




Landsat 8, band 10 (TIRS), DOY 225 (August 2015):
Blue: cold; Red: hot

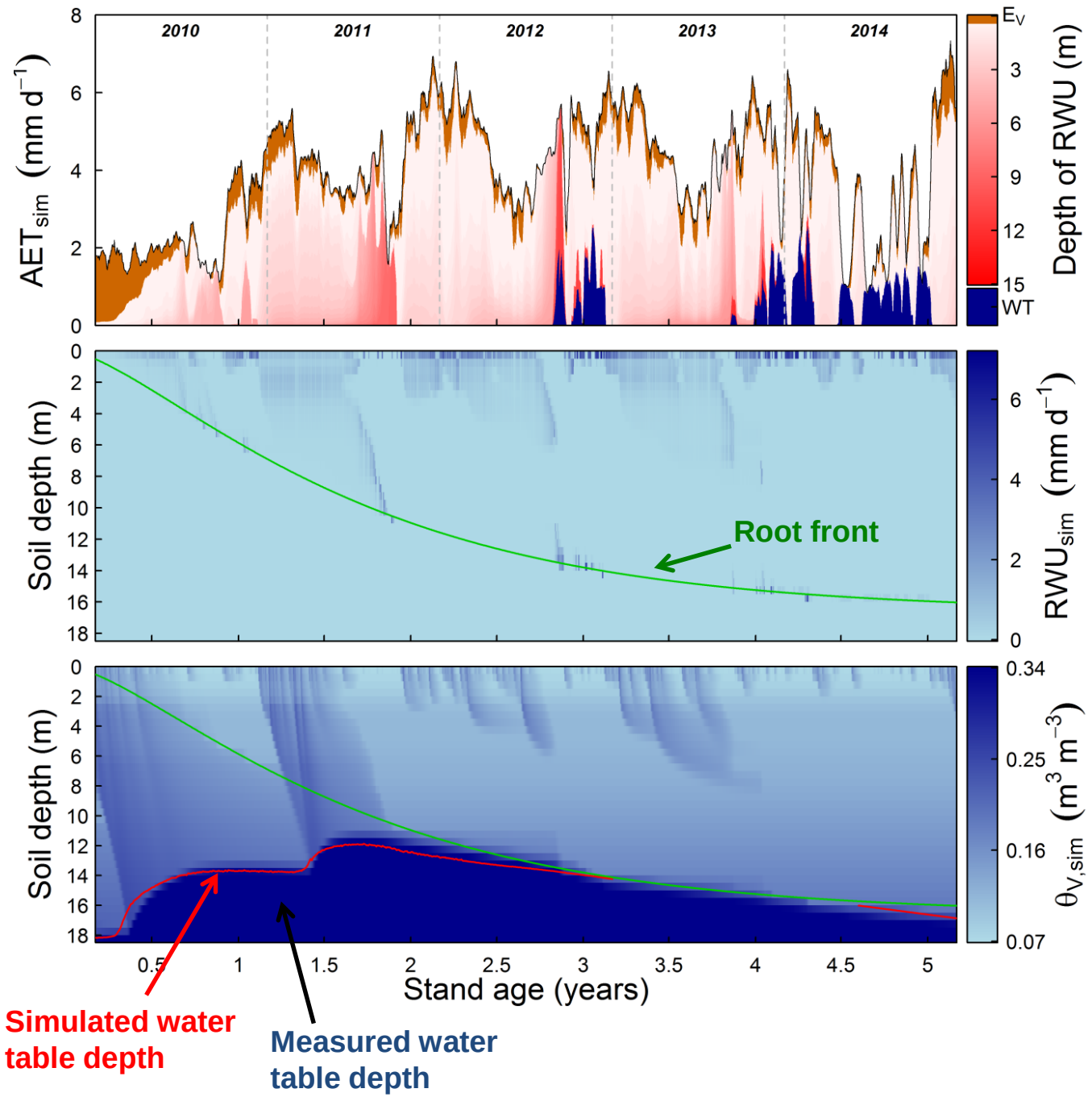
le Maire et al., in prep

**This Evaporative cooling** is associated with high AET can be seen from satellites

- positive effect on local climate
- might also avoid over-heating and thermal damage of the leaves => thermo-protection, and might allow leaves to operate at more optimal temperatures




MODIS (regional scale); le Maire et al., in prep




**The high evapotranspiration in these brazilian plantations are partly due to deep soil and deep rooting**

**=> Allow the trees to use water stored in deep soil layers and water from the water table**

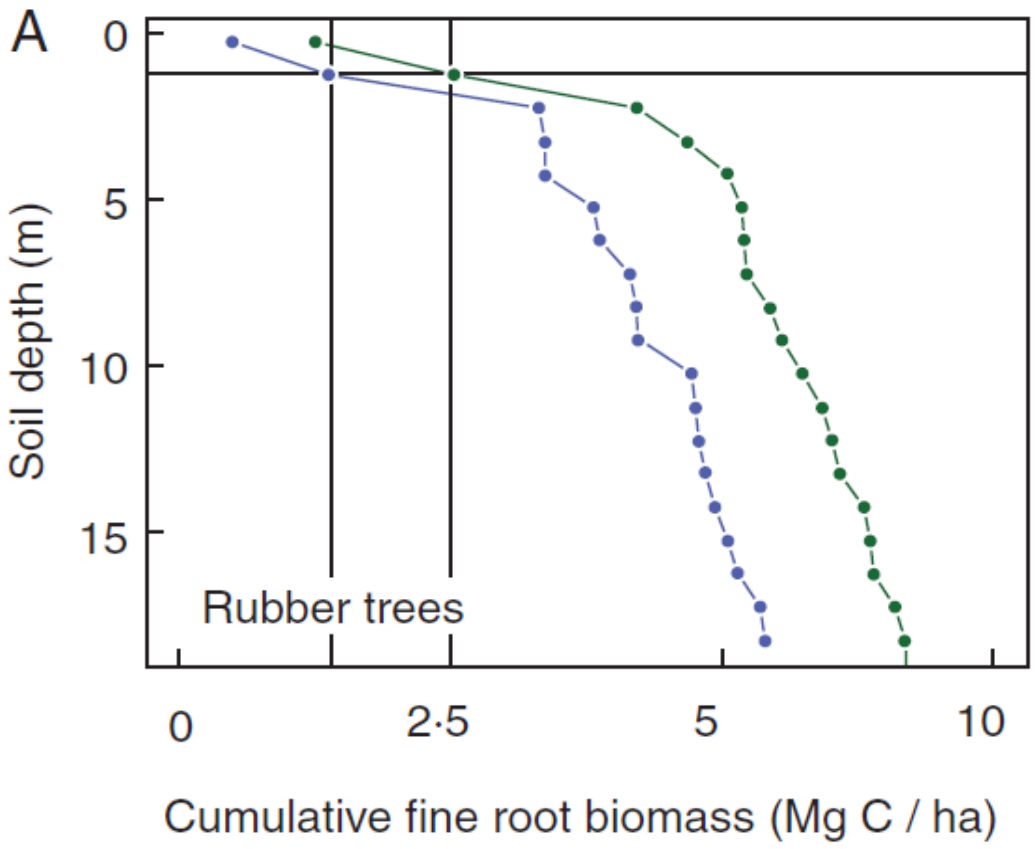
Christina et al. (2017). Importance of deep water uptake in tropical eucalypt forest. Functional Ecology, 31: 509–519.

**Evapotranspiration is also increased by fertilization**

Christina et al..(2018). Simulating the effects of different potassium and water supply regimes on soil water content and water table depth over a rotation of a tropical Eucalyptus grandis plantation. Forest Ecology and Management, 418: 4-14.

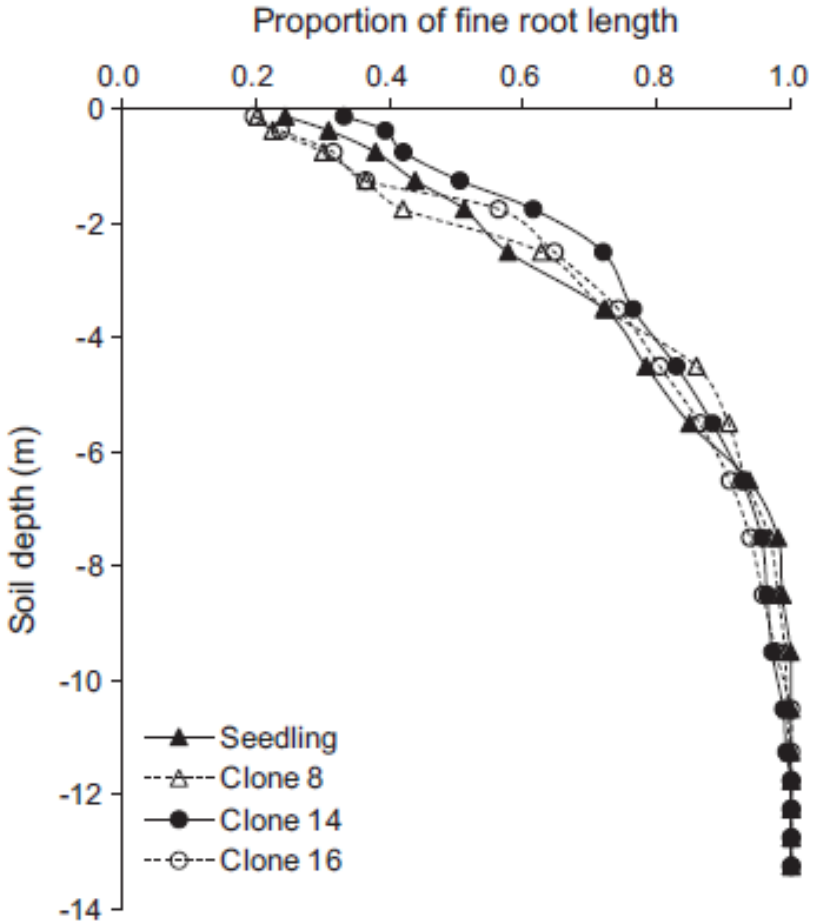
# Deep rooting, a factor contributing to the high AET, high productivity, and tree ability to cope with seasonal drought, is also common in rubber tree plantations

## Rubber trees, southern Thailand




Pierret et al., 2016 Annals of Botany 118: 621–635, 2016

## Eucalypt trees (2 yrs-old)




Pinheiro et al., 2016 Forest Ecology and Management 366 (2016) 143–152

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# Evapotranspiration of rubber (*Hevea brasiliensis*) cultivated at two plantation sites in Southeast Asia

Thomas W. Giambelluca[1,2], Ryan G. Mudd[1], Wen Liu[1], Alan D. Ziegler[3], Nakako Kobayashi[2], Tomo'omi Kumagai[2], Yoshiyuki Miyazawa[1,4], Tiva Khan Lim[5], Maoyi Huang[6], Jefferson Fox[7], Song Yin[5], Sophea Veasna Mak[5], and Poonpipope Kasemsap[8]

**Water Resources Research, 2016**

**Bueng Kan, Thailand**
**AET 1211 mm/yr**

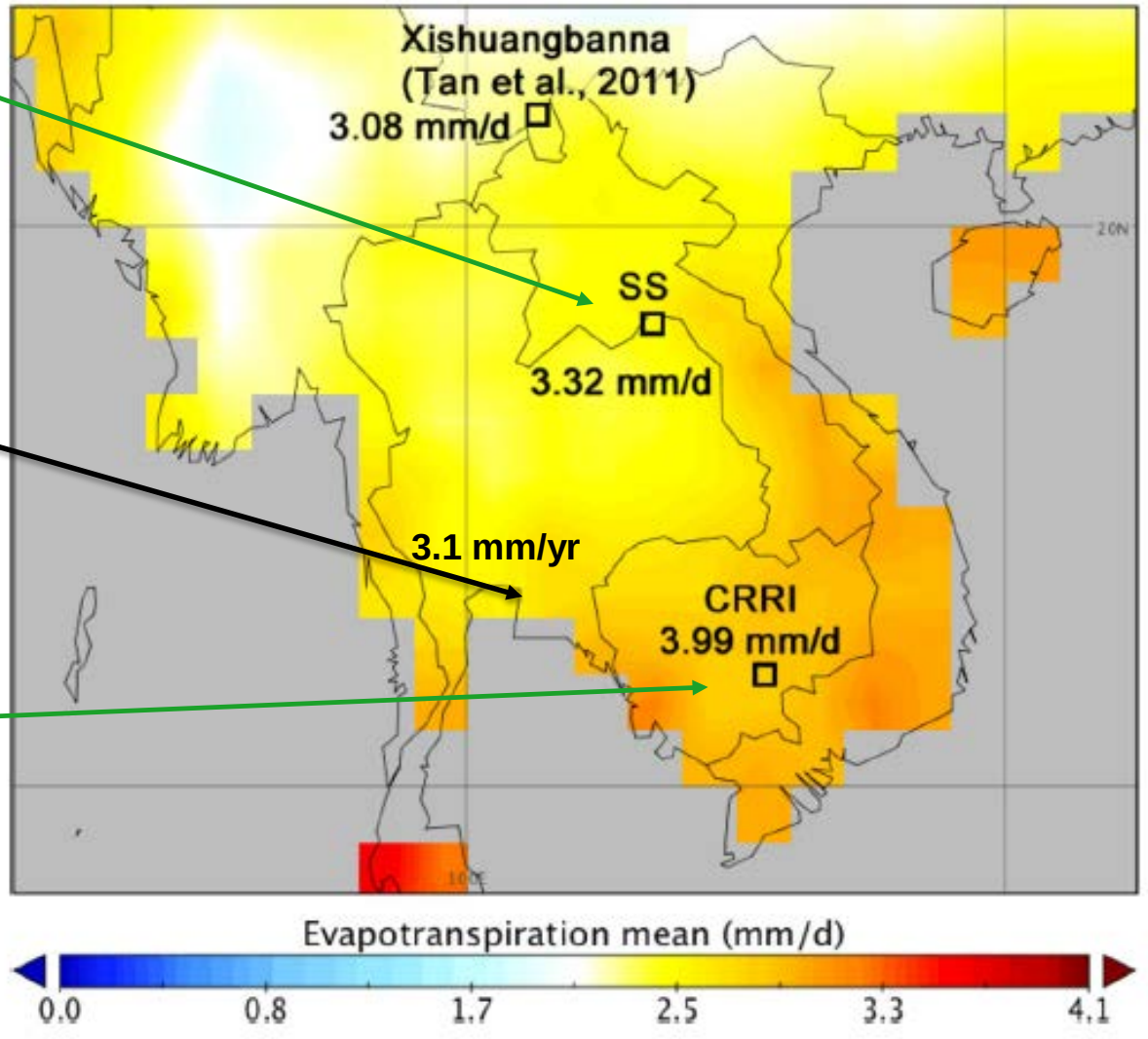
CRRC

**Chachoengsao;**
**AET 1150 mm/yr**
**About 73% of the available energy used for AET**

**Kampong Cham, Cambodia (CRRI), 1459 mm/yr**

**About 72% of the available energy used for AET**

**AET in rubber plantations higher than in nearby natural forests**

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# Conclusions and Perspectives

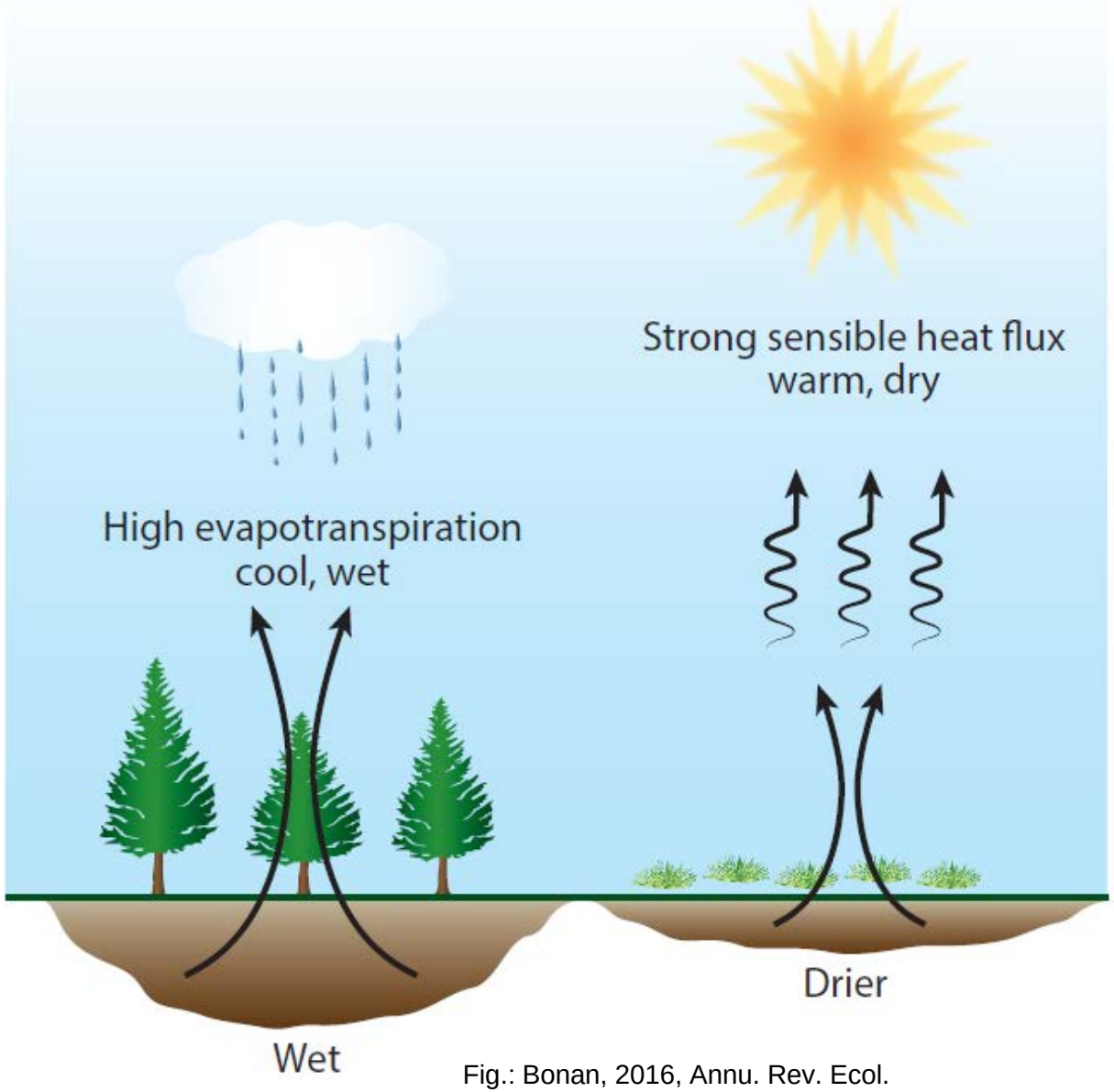


Fig.: Bonan, 2016, Annu. Rev. Ecol. Evol. Syst. 47:97–121

- **Cooling effect of afforestation in the tropics is well established**
- **Plantations and natural forests are likely to have similar cooling effects**
- **Management can influence the plantation effects on local climate: in general, factors that increase plantation productivity and water-use (genotypes, fertilization) increase the cooling effect**
- **Plantation effects on other meteorological variables, e.g. on rainfall, air humidity, VPD... have been less studied**
  - need for studies where ecophysiological process-based models simulating plantation carbon, water, and energy balances are coupled with regional atmospheric models

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