Expansion of Rubber (Hevea brasiliensis) and its Implications for Water and Carbon Dynamics in Montane Mainalnd Southeast Asia

Jefferson Fox — East-West Center
Thomas Giambelluca — University of Hawai‘i at Mānoa
Ryan Mudd — University of Hawai‘i at Mānoa
Alan Ziegler — National University of Singapore
Maoyi Huang — Battelle Pacific NW National Laboratory
Wen Liu — University of Hawai‘i at Mānoa
Michael Nullet — University of Hawai‘i at Mānoa
Qi Chen — University of Hawai‘i at Mānoa

March 2011

EAST-WEST CENTER
COLLABORATION · EXPERTISE · LEADERSHIP

UNIVERSITY OF HAWAI‘I AT MĀNOA

NASA

NUS National University of Singapore

U.S. DEPARTMENT OF ENERGY

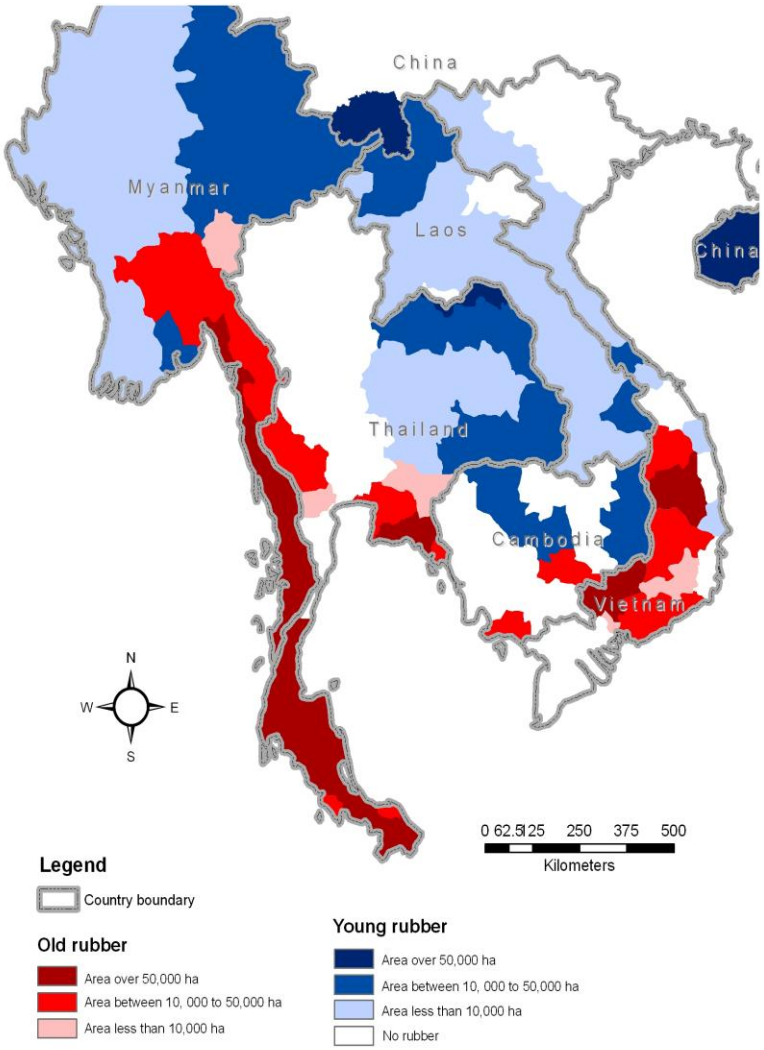

Jeff Fox, EWC, 2010

NR price forecasts to 2011
(It's the global market . . . 'stupid')

3/22/2011
$5.15

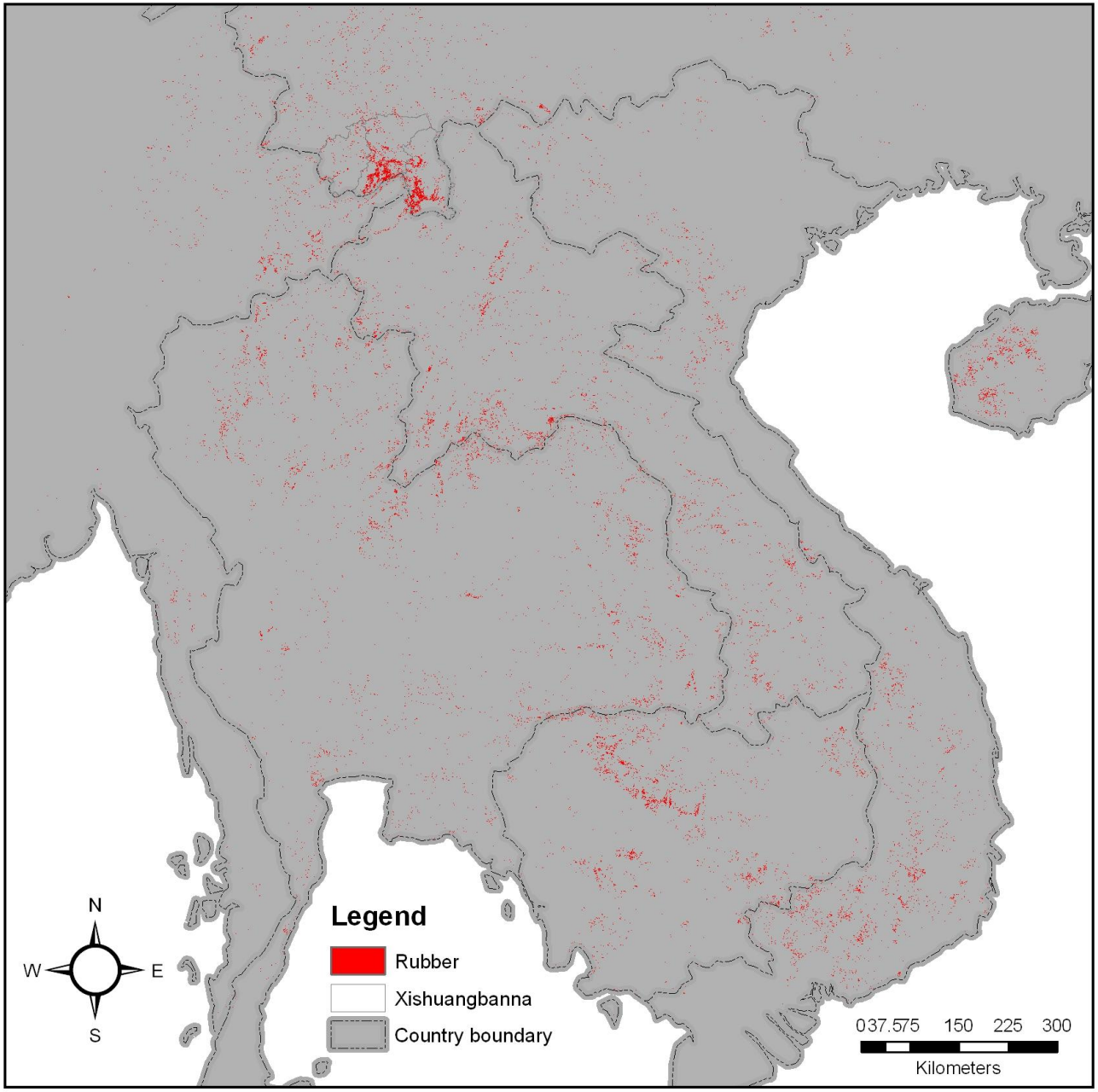
Prachaya. 2009.

Traditional and non-traditional rubber-growing regions



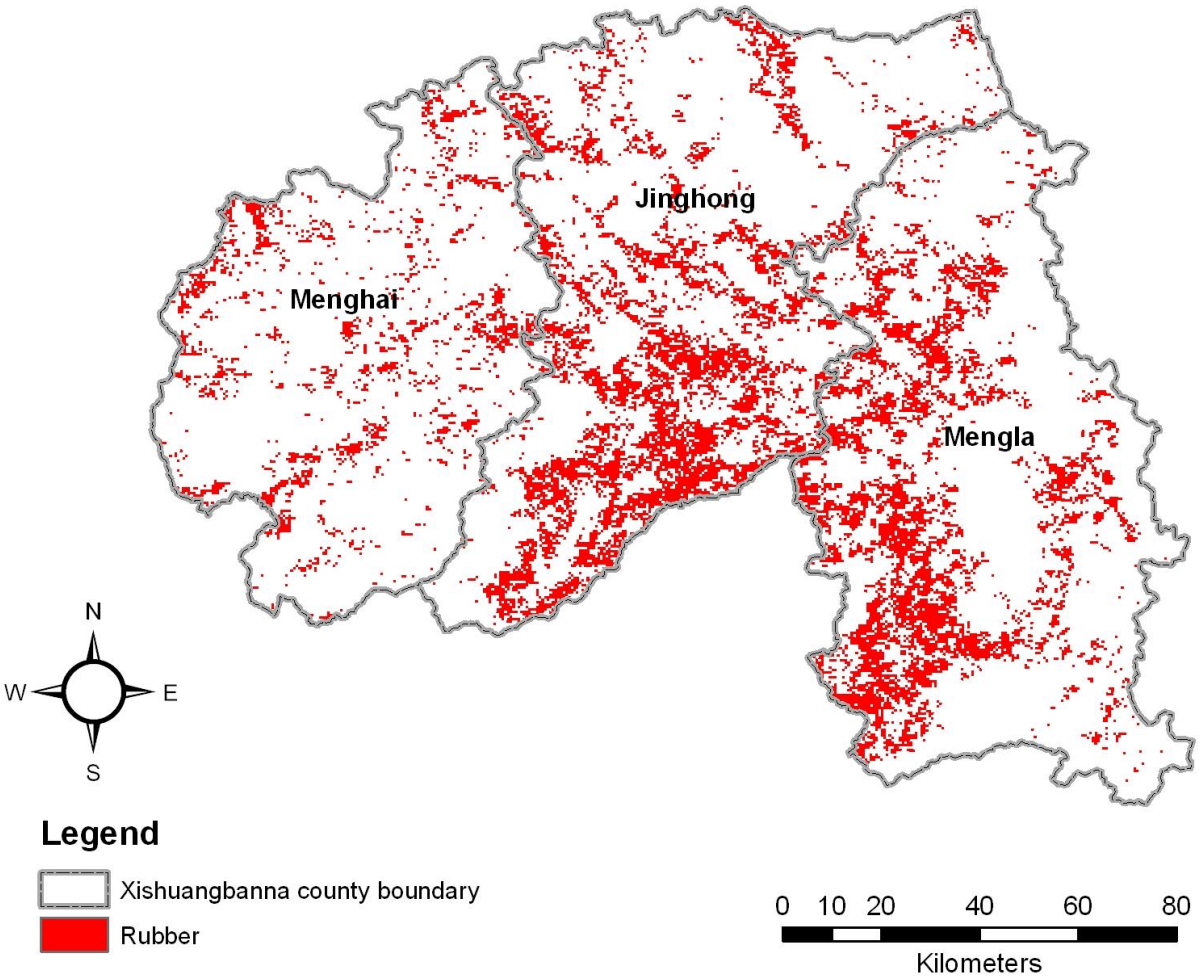
Jeff Fox, EWC, 2010

Rubber distribution in 2009 in MMSEA derived from MODIS 250m NDVI time series

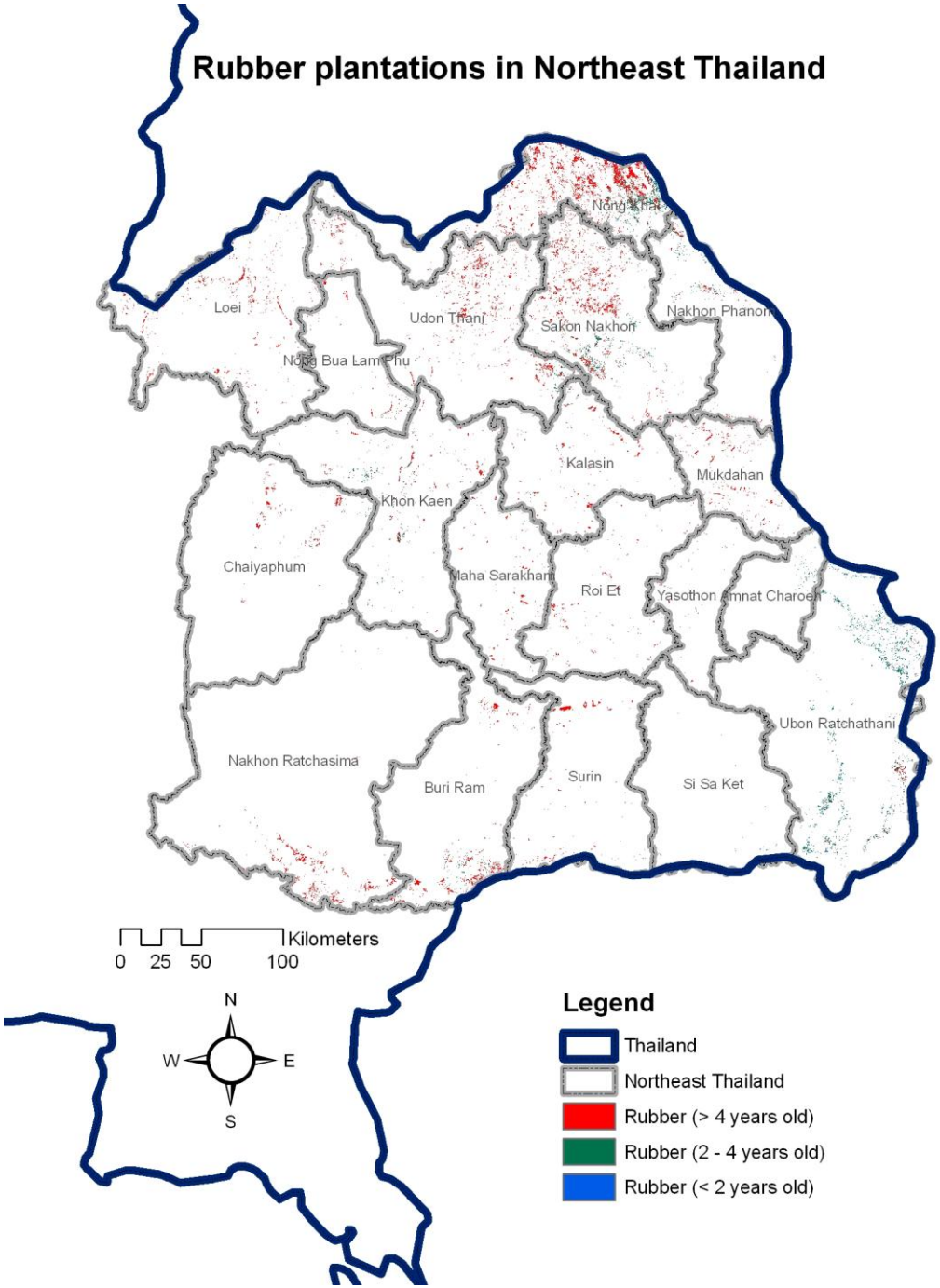


Jeff Fox, EWC, 2010

Rubber plantations in Xishuangbanna, Yunnan, China



Jeff Fox, EWC, 2010



Jeff Fox, EWC, 2010

Rubber Estimates (2008)
(non-traditional rubber areas)

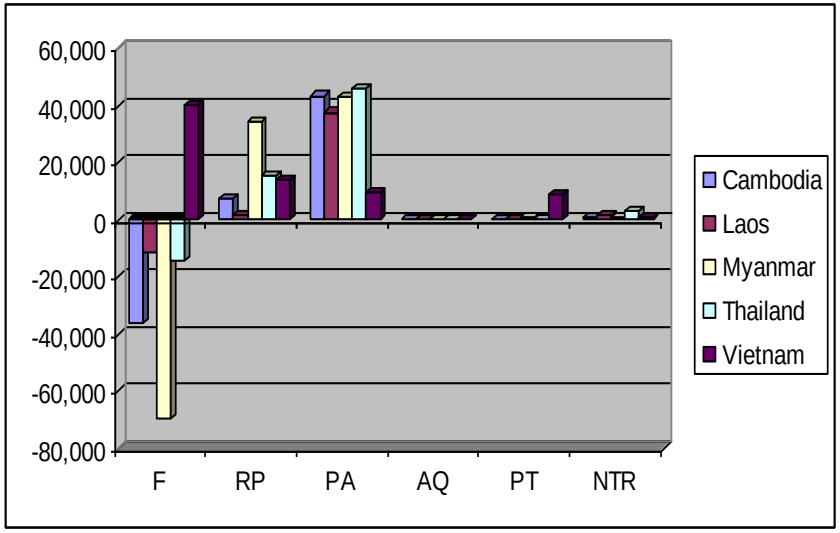
Country	Area (ha)
Northeast Thailand	348,063 (Thai Rubber 2007)
Xishuangbanna, China (1950s)	334,000 (Reuters 2008)
Laos (1994)	140,665 (NAFRI 2008)
Cambodia	107,901 (ANRPC 2009)
Northeast Myanmar (Kachin and Shan States)	68,723 (Hly Myint 2008)
Vietnam	58,100 (AgroInfo 2008)
Total	1,057,452

CLUE Land Cover / Land Use Simulations

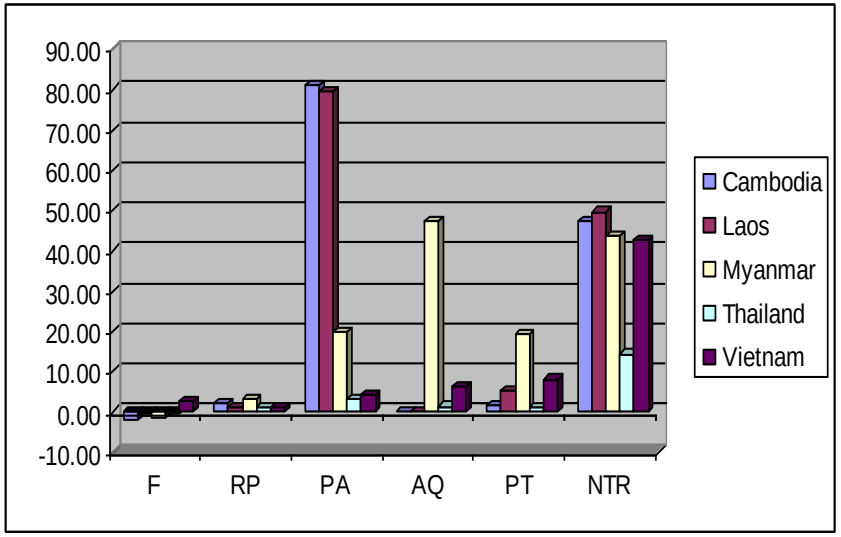
- Overall MMSEA **Results** Increase Decrease

Model Land Cover	% 2000	% 2050	% Change
Crops + Grass	12.38	14.81	2.43
Irrigated Crops	9.5	10.11	0.61
Shrubs	2.91	4.6	1.69
Deciduous Forest (rubber)	12.82	15.28	2.46 (4 mil ha)
Evergreen Forest	36.58	32.85	-3.73
Mixed Forest/ Mosaic	22.99	18.19	-4.8

Hotspots of LCLUC in Mainland Southeast Asia (1990 to 2008)



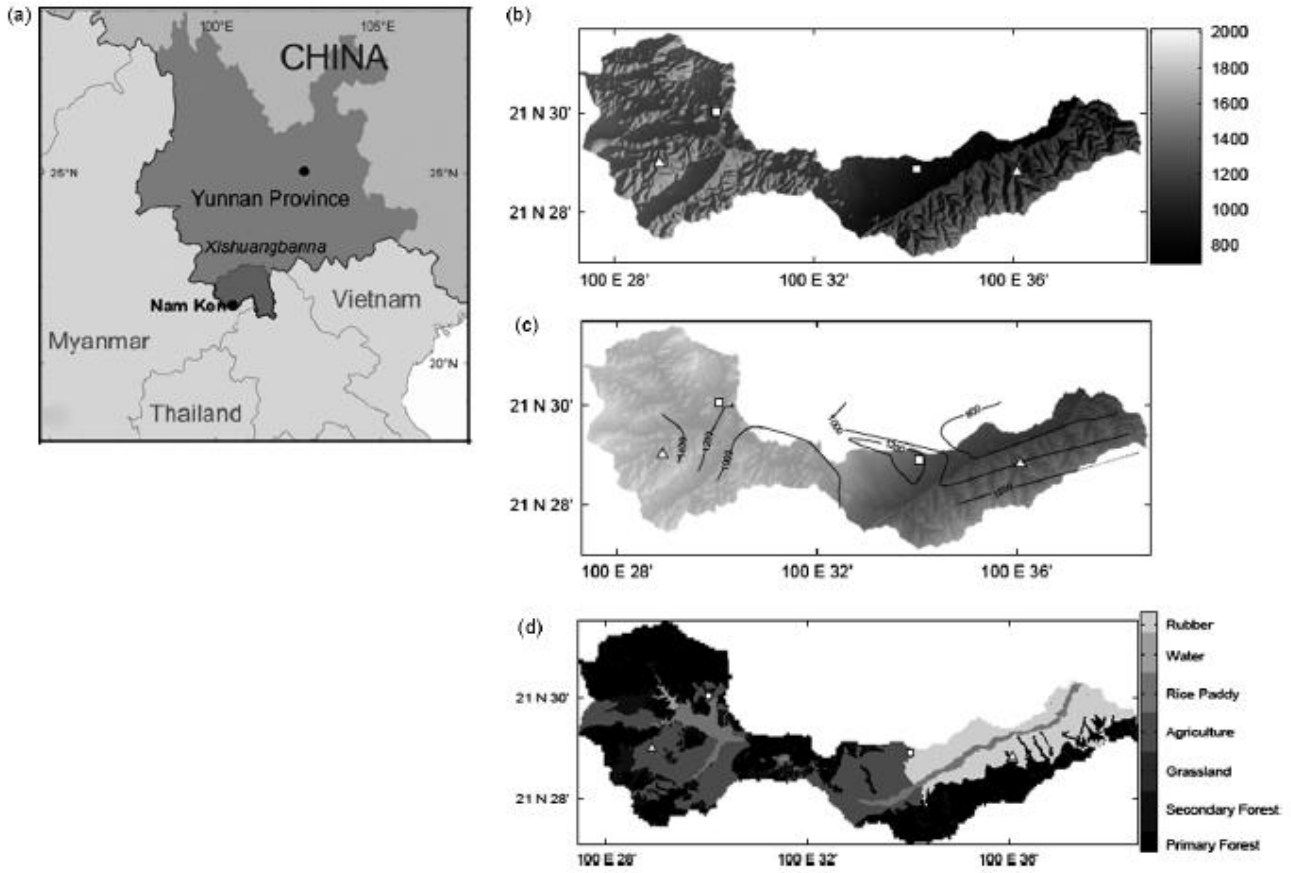
Total area in square kilometers



Annual rate of increase in %

F= forest; RP = rice/paddy; PA = protected area; AQ = Shrimp aquaculture; PT = Perennial trees; NTR = non-traditional rubber. Numbers from FAOSTAT; FAO World Forests; World Bank World Development Indicators; IUCN Protected Areas.

Prior Study



Guardiola-Claramonte M, Troch Ziegler A, Giambelluca TW, Vogler JB, Nullet M (2008) Local hydrologic effects of introducing non-native vegetation in a tropical catchment. *Ecohydrology* 1: 13–22, DOI: 10.1002/eco.3.

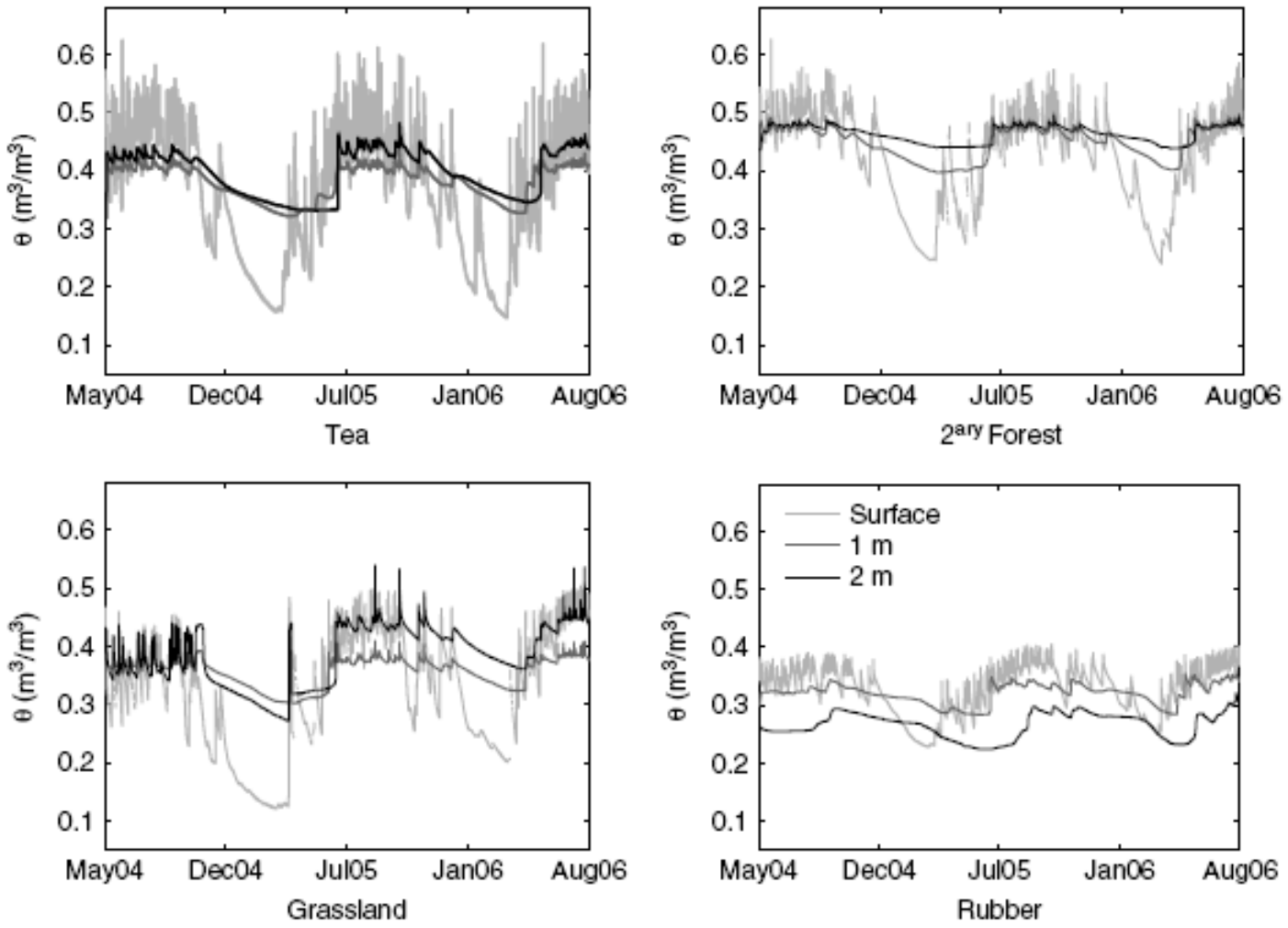
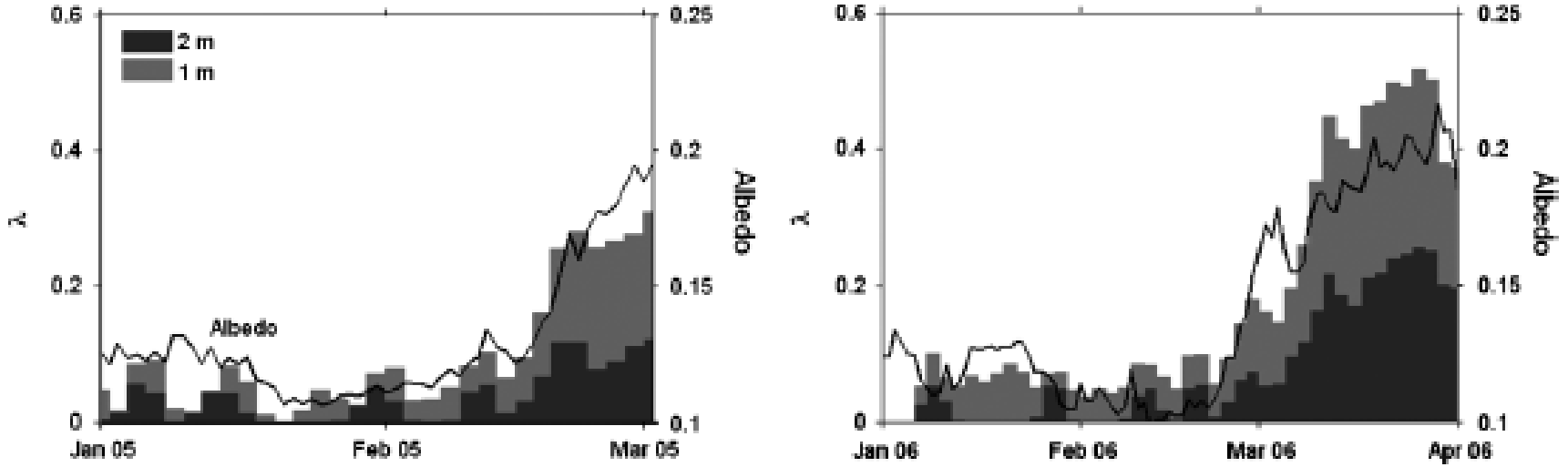


Figure 3. Soil moisture time series observed at the four land-cover sites.

Guardiola-Claramonte M, Troch Ziegler A, Giambelluca TW, Vogler JB, Nullet M (2008) Local hydrologic effects of introducing non-native vegetation in a tropical catchment. *Ecohydrology* 1: 13–22, DOI: 10.1002/eco.3.



Guardiola-Claramonte M, Troch Ziegler A, Giambelluca TW, Vogler JB, Nullet M (2008) Local hydrologic effects of introducing non-native vegetation in a tropical catchment. *Ecohydrology* 1: 13–22, DOI: 10.1002/eco.3.

Research Questions

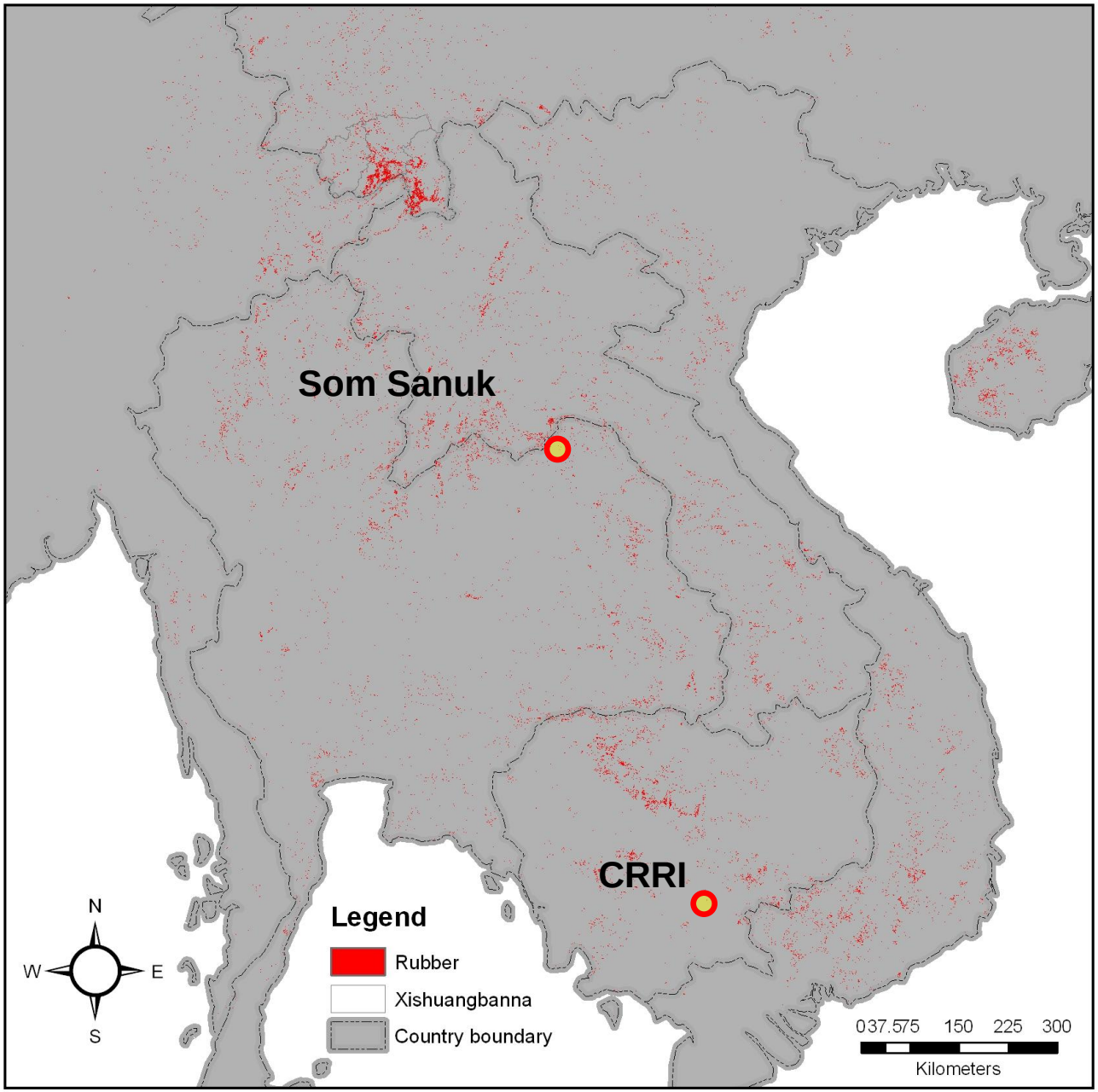
Hydrology of *Hevea brasiliensis* Plantations

- What are the hydrological and carbon **consequences of conversion** of land to rubber plantations in non-traditional rubber growing areas?

- What are the **rates of ET in rubber** stands, and how does it compare with other land-cover types in the region?

- To what extent are **dry-season basin water storage** affected by water use of rubber?

Tower Sites



Jeff Fox, EWC, 2010

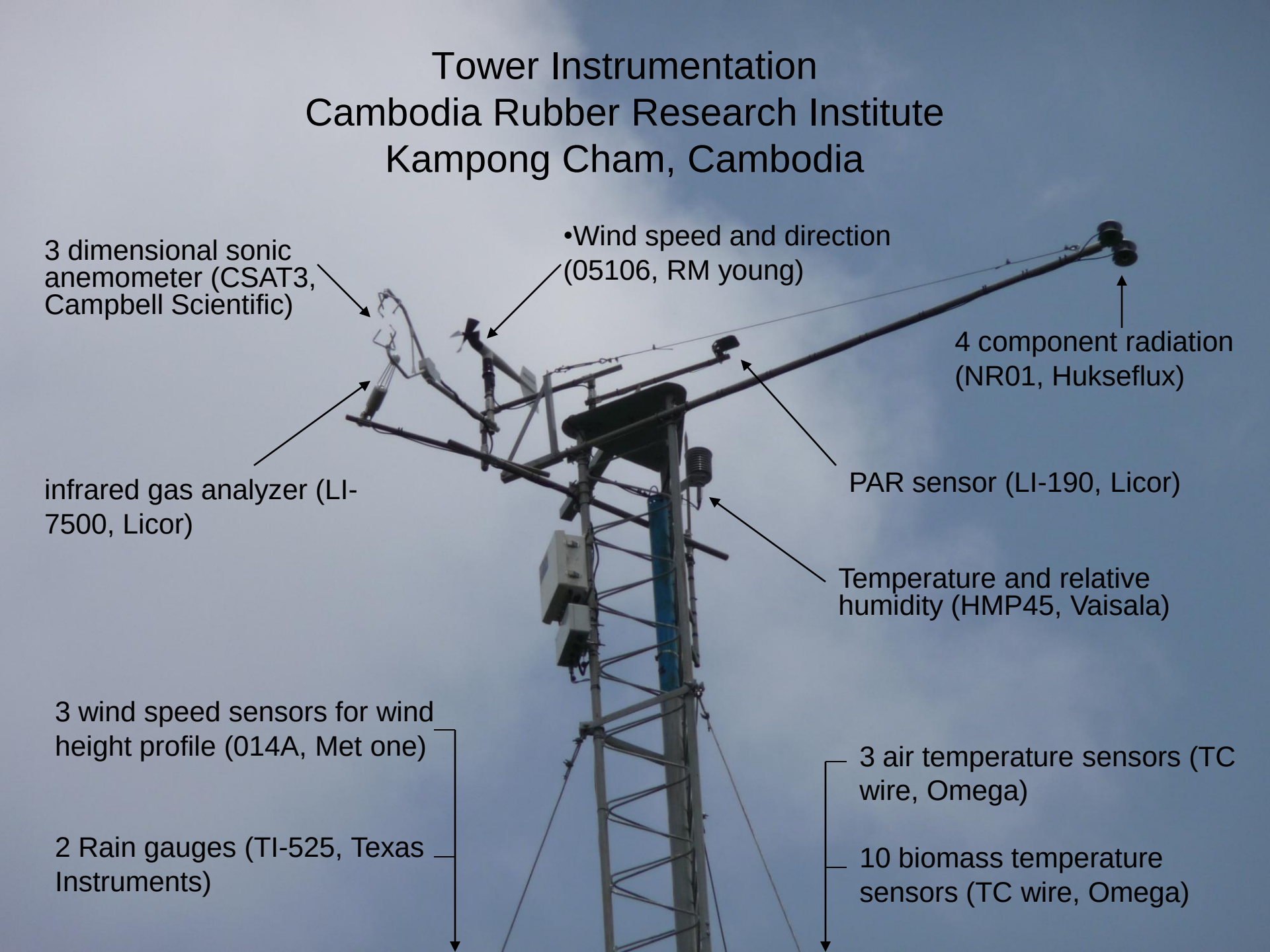
Instruments and Observations

Micrometeorological instruments installed at two rubber (*Havea brasiliensis)* plantations to measure water, energy, and carbon exchange

Som Sanuk, Nong Khai, NE Thailand
Trees planted in 1992
Tower installed February 2009

CRRI, Kampong Cham, Cambodia
Trees planted in 2004
Tower Installed September 2009

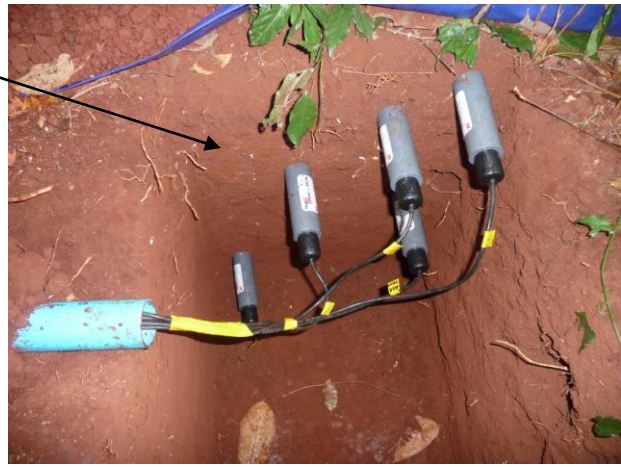
Tower Instrumentation
Cambodia Rubber Research Institute
Kampong Cham, Cambodia



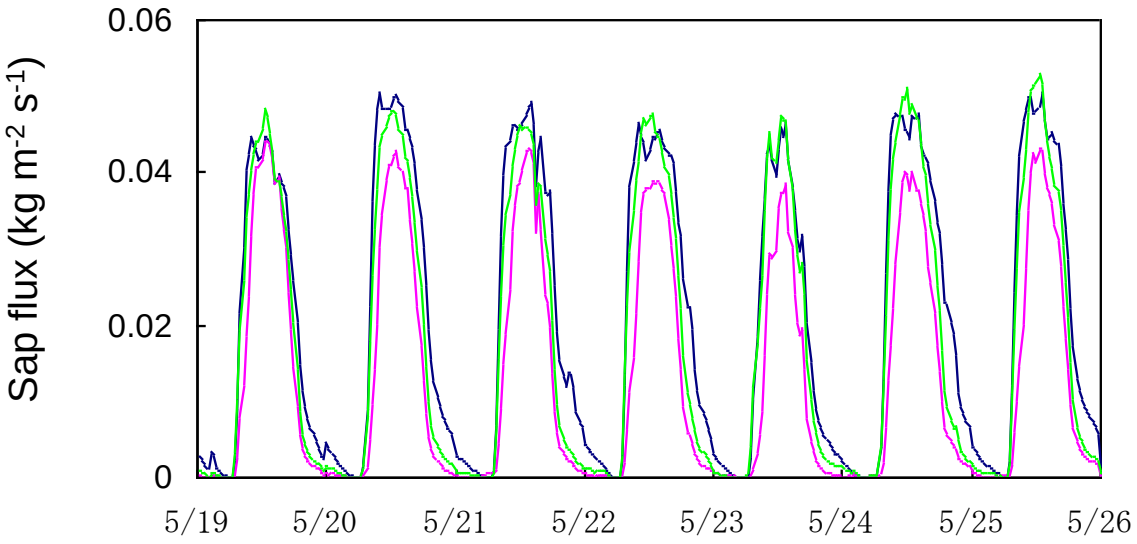
Underground sensors

- 2 **soil temperature** sensors (20 cm TC probes, Campbell Scientific)
- 4 **soil heat flux** plates (HFP01, Hukseflux)
- 5 TDR **soil moisture** probes – 30 cm (CS616, Campbell Scientific)
  - 4 cm horizontal
  - 30 cm vertical
  - 1 m vertical
  - 2 m vertical
  - 3 m vertical

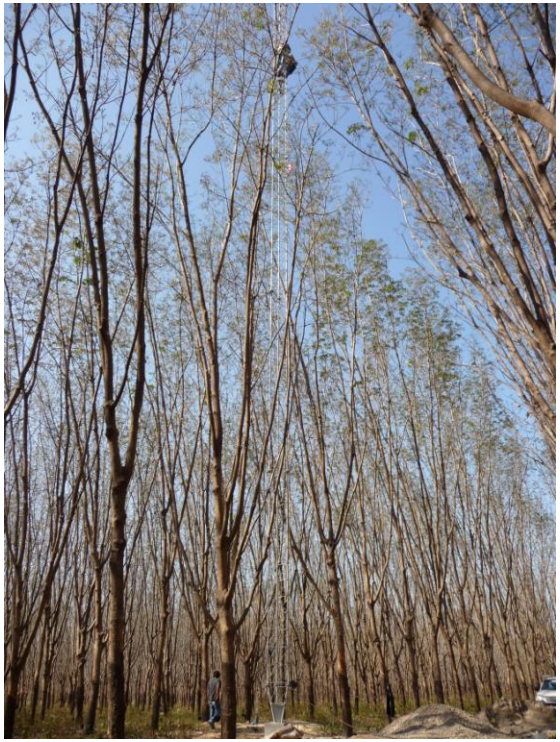
- 5 ADR **soil moisture** sensors (Theta Probe, DeltaT)
  - in 2 stands (2001 and 2004)
  - 5, 10, 20, 30, and 50 cm all horizontal

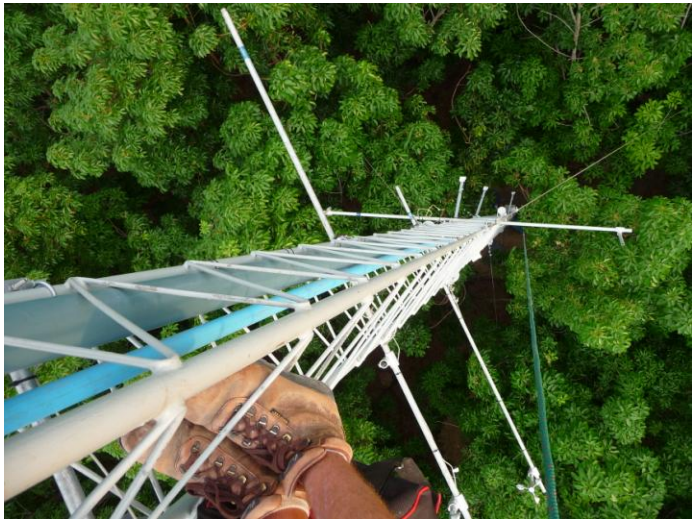


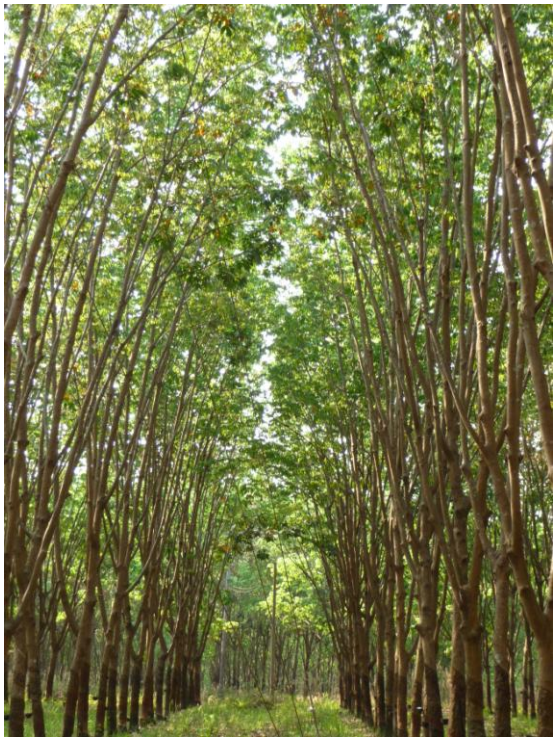
Collaboration with Kumagai Lab of Kyushu University for sap flow measurements



Som Sanuk, Thailand

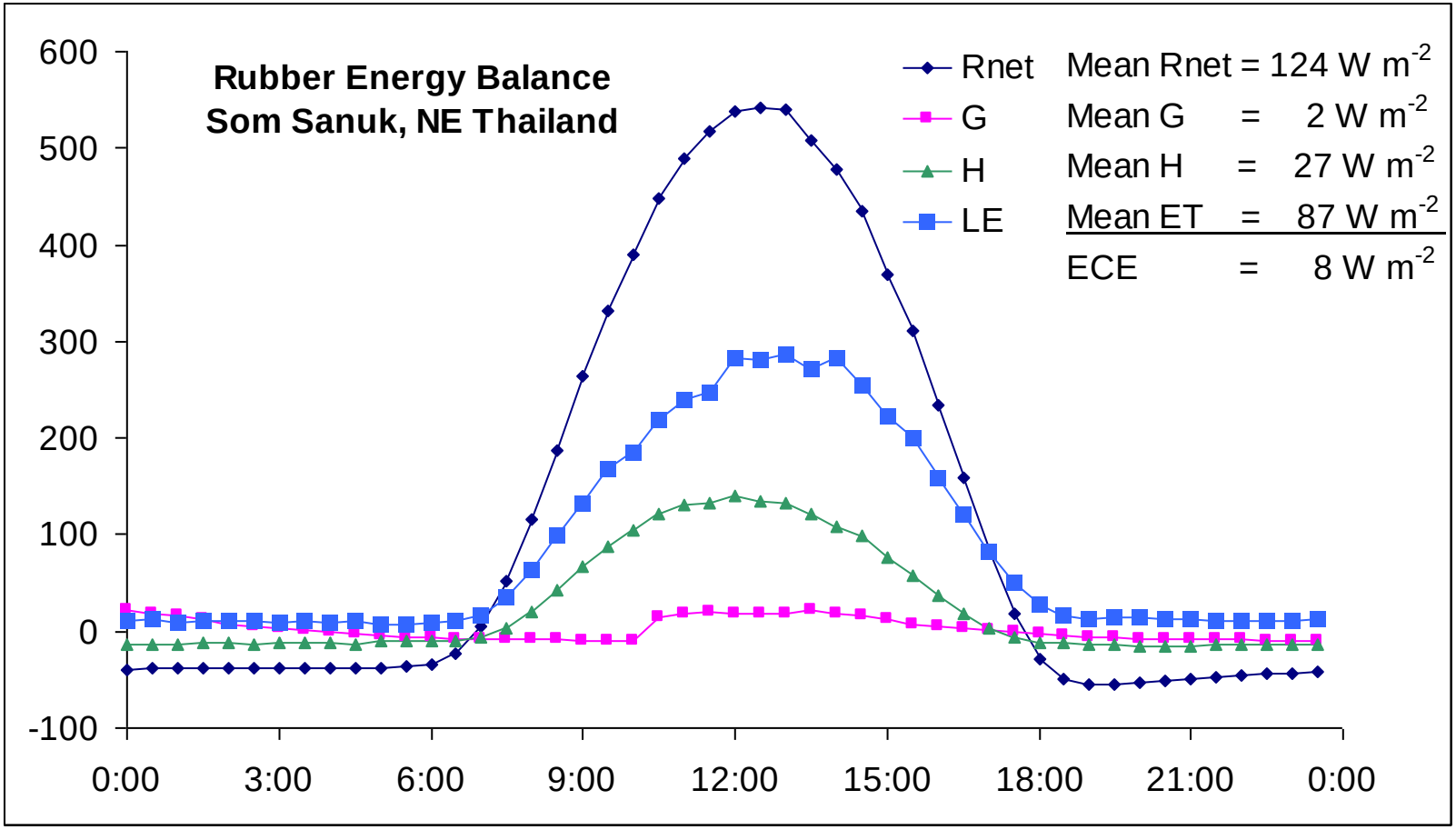




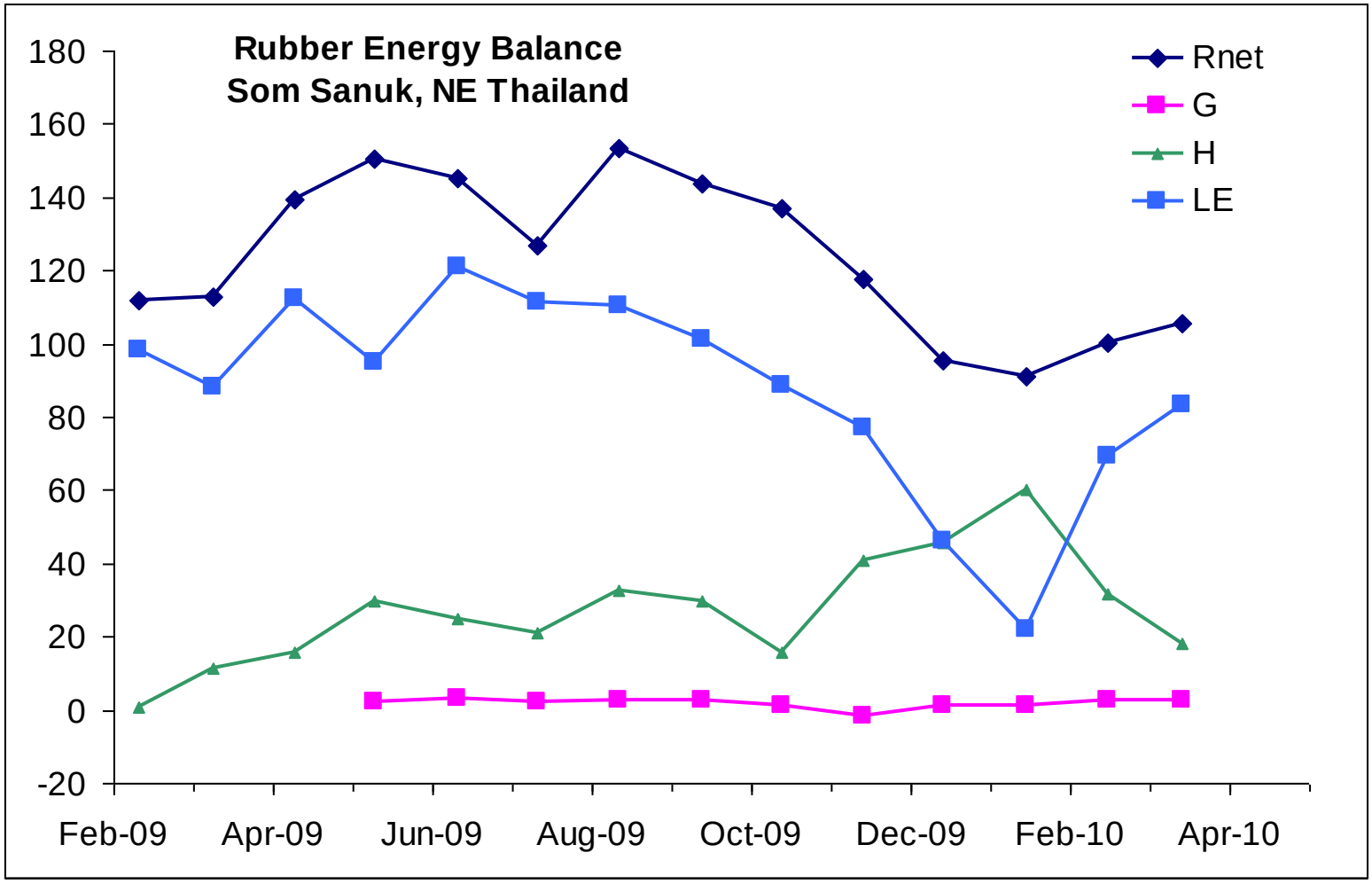


Som Sanuk, Thailand

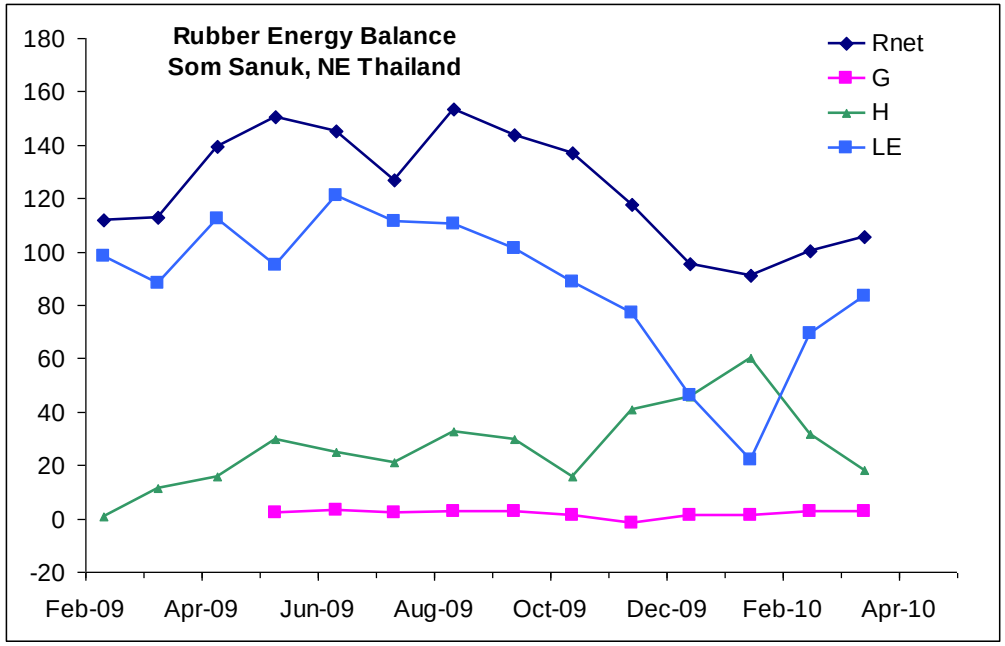
Preliminary Eddy Flux Results from Som Sanuk
Annual Mean Diurnal Cycles

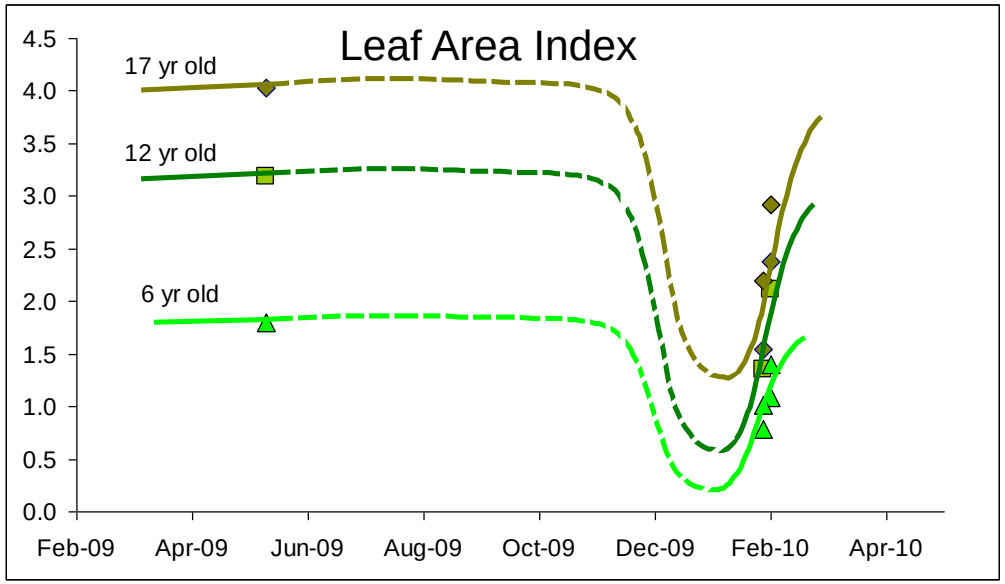


Preliminary Eddy Flux Results from Som Sanuk

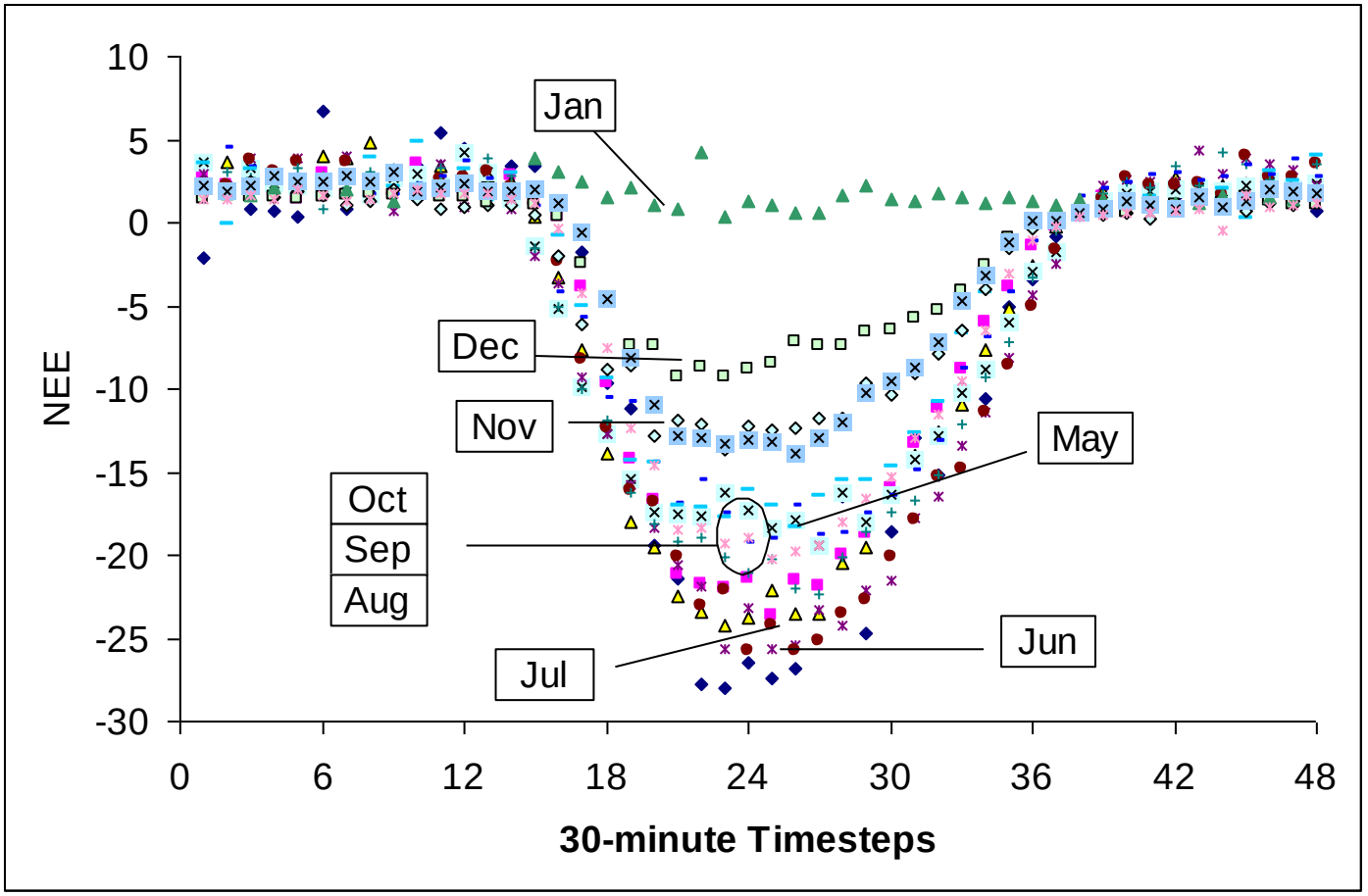


Seasonal Cycle Related to Leaf Area



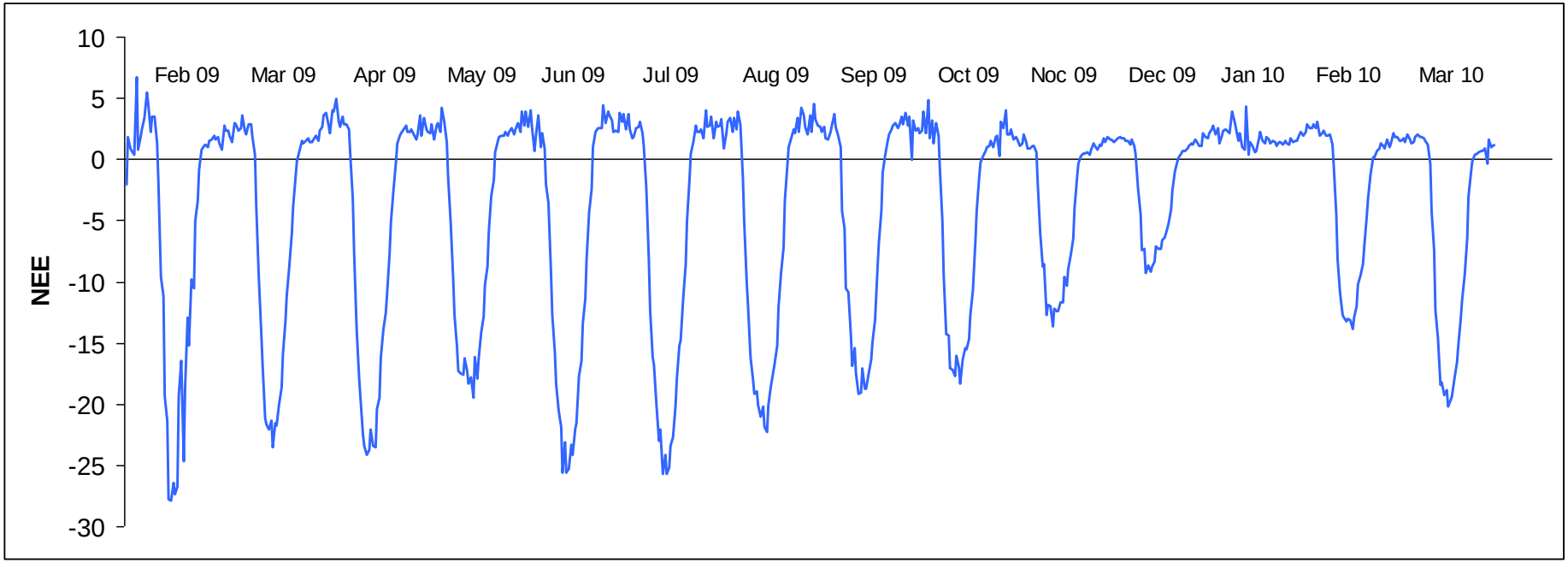


Preliminary Eddy Flux Results from Som Sanuk: Mean Diurnal NEE Cycles



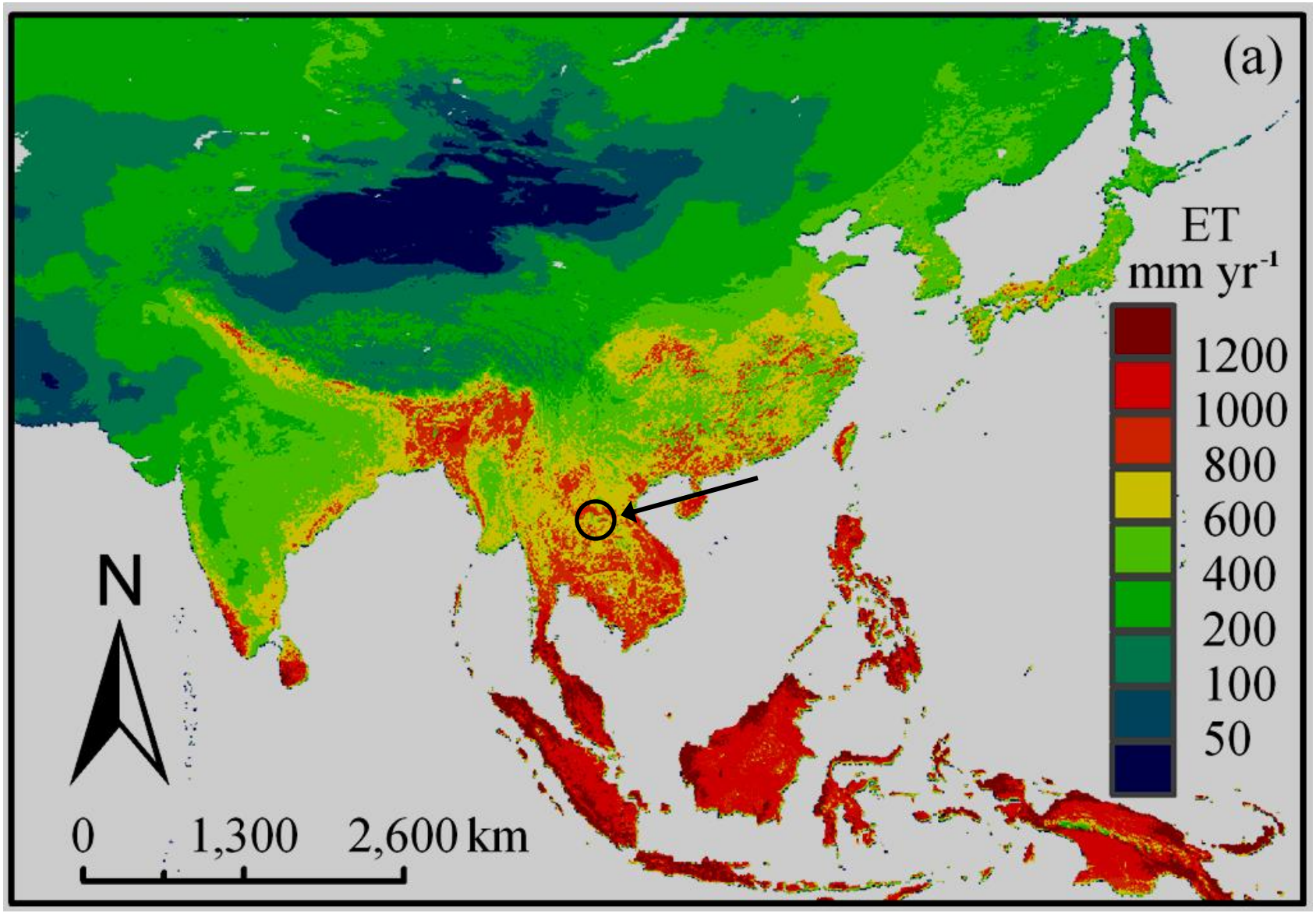
Preliminary Eddy Flux Results from Som Sanuk: Mean Diurnal NEE Cycles

NEE (μmol $m^{-2}s^{-1}$)



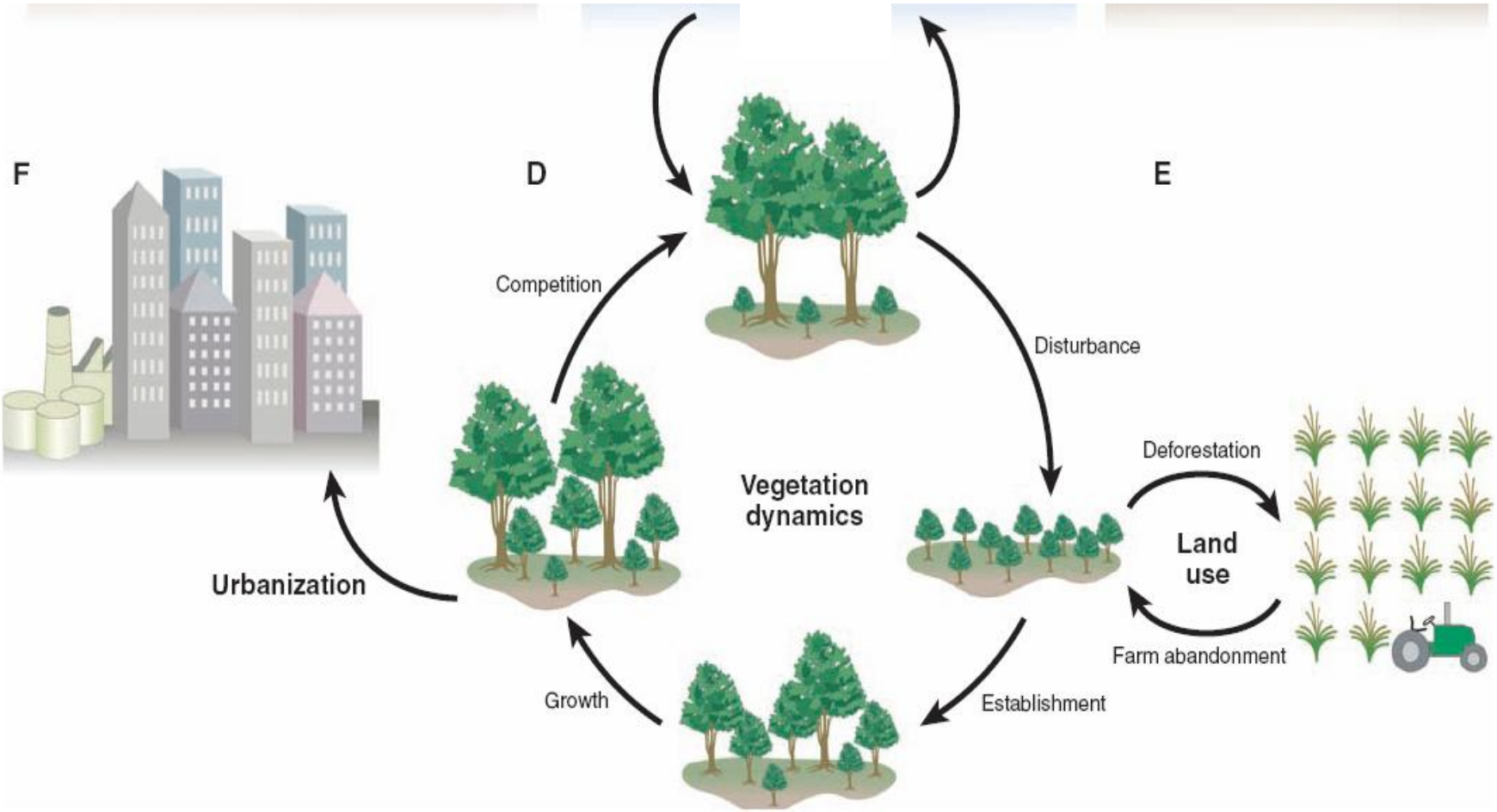
Mean Annual ET: 1100 mm

Site	Land Cover	LE:Rnet
Borneo	Tropical rainforest	0.89
Amazon	Tropical rainforest	0.86
Som Sanuk	**Rubber plantation**	**0.70**
Chiang Mai	Hill evergreen	0.60
Mato Grosso	Transitional forest	0.66



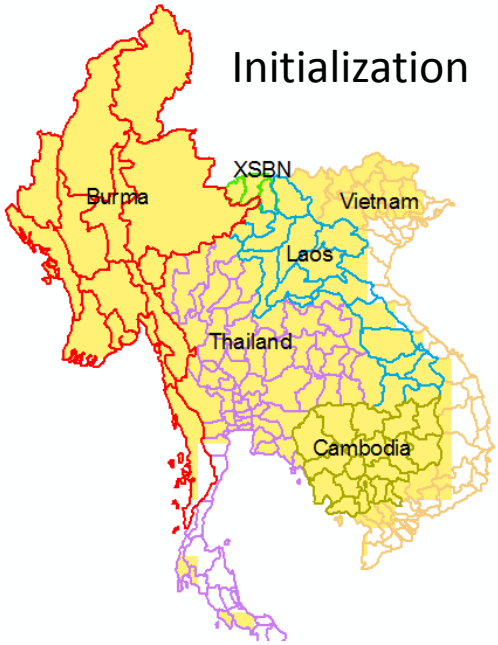
Weimin Ju，Fangmin Zhang, Jingming Chen, Shuanghe Shen, Shaoqiang Wang, Guirui Yu, Xinquan Zhao, Shijie Han, J. Asanuma (2010) Trends of evapotranspiration in East Asia from 1982 to 2006 simulated using a remote sensing-driven ecological model. Presented at HESSS2, 22 June 2010, Tokyo.

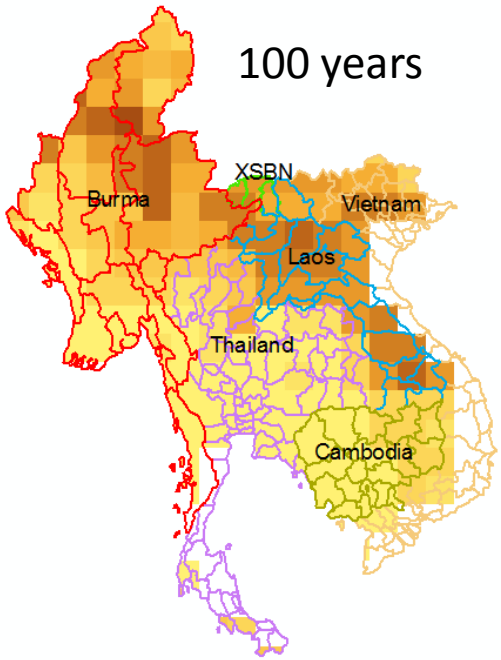
Ecosystem Model Must Incorporate Vegetation Dynamics

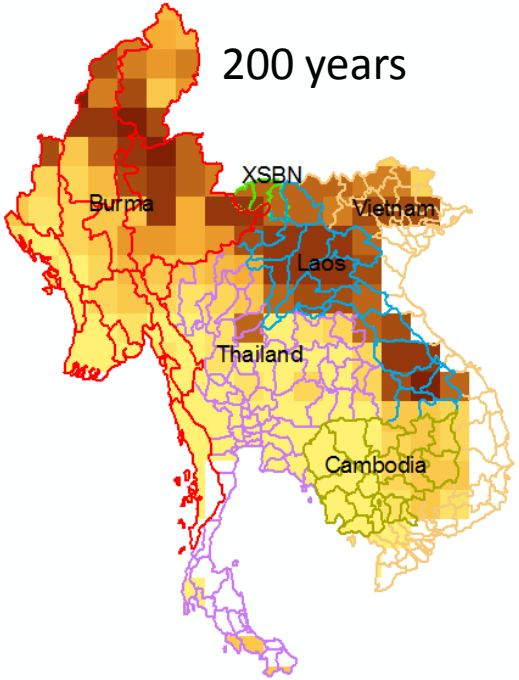


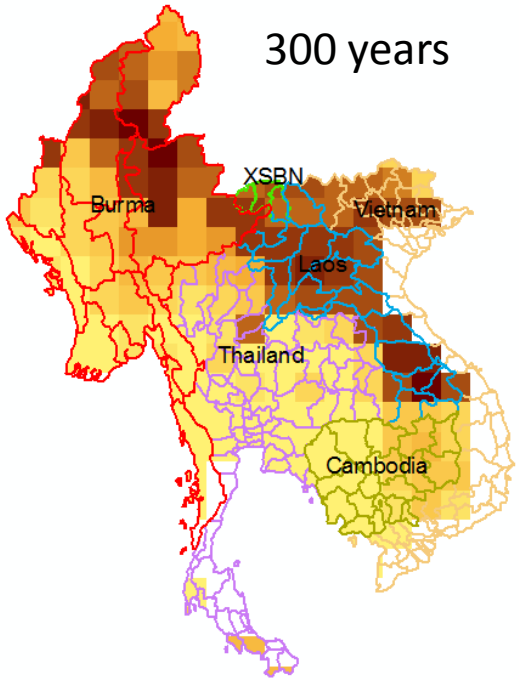
Bonan (2008, *Science* 320: 1444-1449)

Simulation of forest biomass density in Mainland Southeast Asia





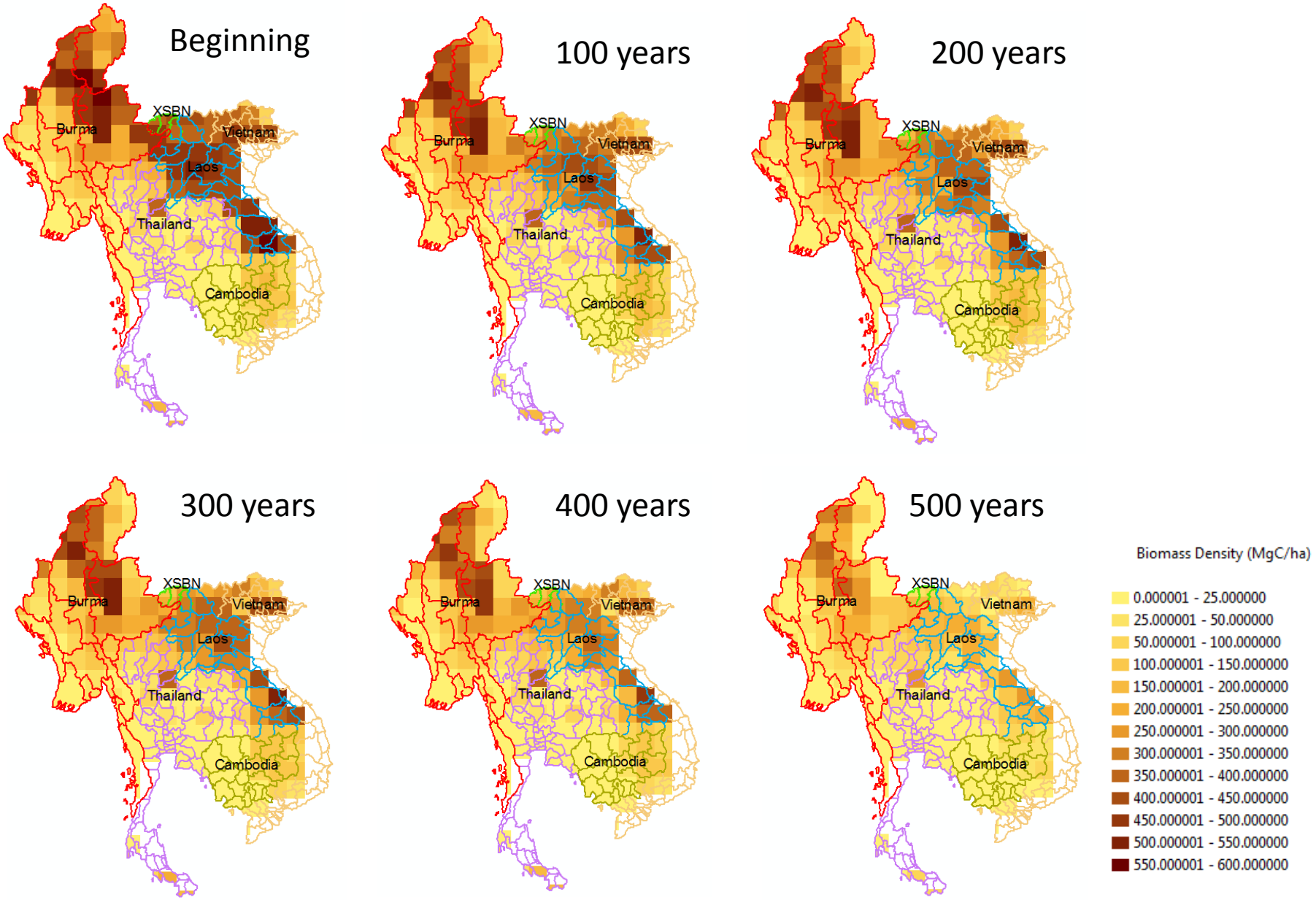




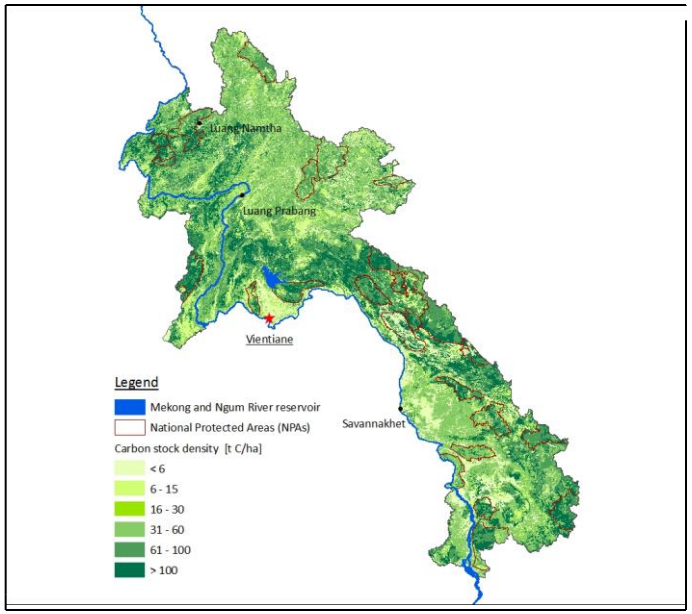
Biomass Density (MgC/ha)

- 0.000001 - 25.000000
- 25.000001 - 50.000000
- 50.000001 - 100.000000
- 100.000001 - 150.000000
- 150.000001 - 200.000000
- 200.000001 - 250.000000
- 250.000001 - 300.000000
- 300.000001 - 350.000000
- 350.000001 - 400.000000
- 400.000001 - 450.000000
- 450.000001 - 500.000000
- 500.000001 - 550.000000
- 550.000001 - 600.000000

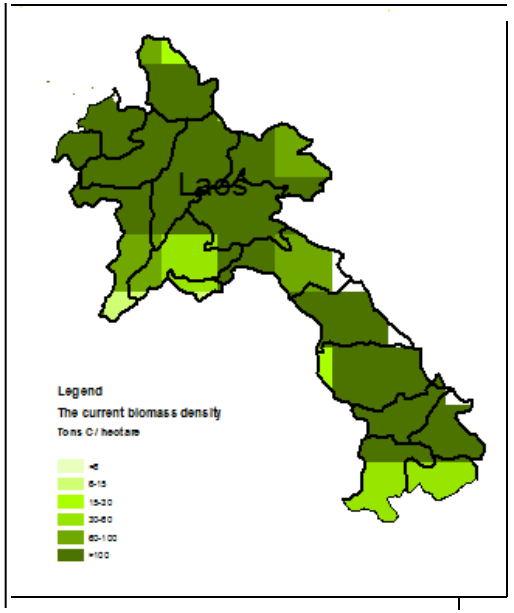
Simulations of the forest biomass density with the incorporation of land use/cover change



Preliminary verification of carbon



Carbon map of Laos 2010



Modeled carbon density after 500 years of land use

Summary

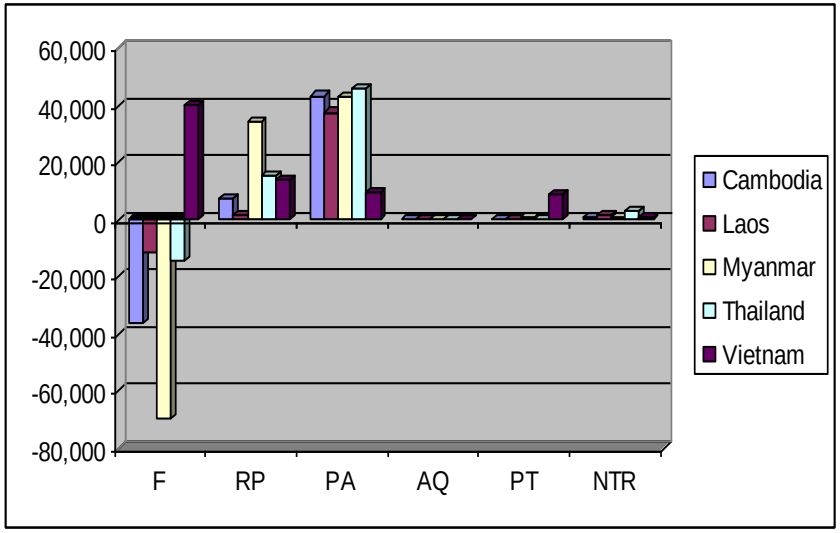
- Rubber ET may be higher than forest ET
- Seasonal cycle significantly changed with lower Sep-Jan ET and higher Mar-Jul ET
- Annual Carbon flux cycle strongly influenced by the phenology of rubber
- Question:
  - What effect does the altered annual cycle have on basin water storage and river discharge at the start of rain season?
  - How does the annual and long-term carbon budget of rubber plantations compare with those of land covers that rubber is replacing?
- Further work:
  - Continued monitoring-both sites
  - Integrate EC and Sapflux observations
  - Leaf level measurements
  - Installation of carbon profile monitoring equipment
  - Carbon stocks and budget


Thank You

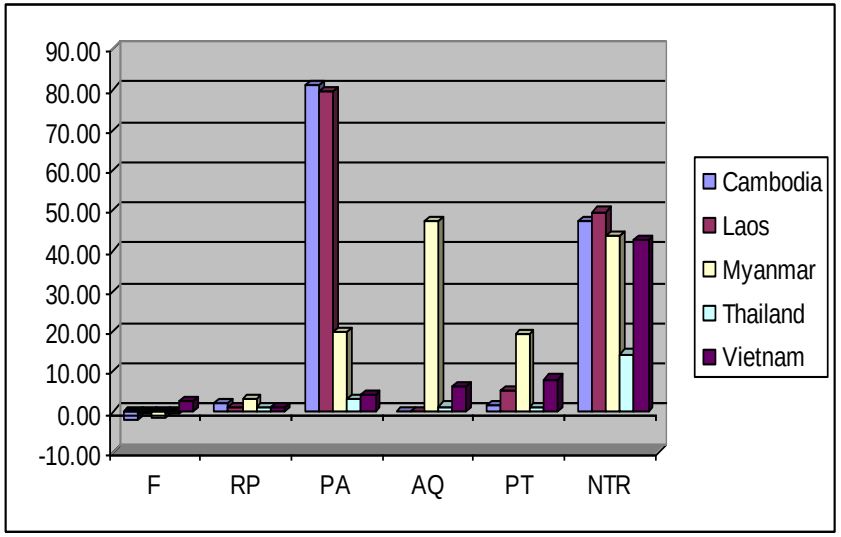
Rubber Estimates (2008)
(non-traditional rubber areas)

Country	Area (ha)
Northeast Thailand	348,063 (Thai Rubber 2007)
Xishuangbanna, China (1950s)	334,000 (Reuters 2008)
Laos (1994)	140,665 (NAFRI 2008)
Cambodia	107,901 (ANRPC 2009)
Northeast Myanmar (Kachin and Shan States)	68,723 (Hly Myint 2008)
Vietnam	58,100 (AgroInfo 2008)
Total	1,057,452

Hotspots of LCLUC in Mainland Southeast Asia (1990 to 2008)



Total area in square kilometers



Annual rate of increase in %

F= forest; RP = rice/paddy; PA = protected area; AQ = Shrimp aquaculture; PT = Perennial trees; NTR = non-traditional rubber. Numbers from FAOSTAT; FAO World Forests; World Bank World Development Indicators; IUCN Protected Areas.

CRRI