# THE ROLE OF LAND-COVER CHANGE IN MMSEA IN ALTERING REGIONAL HYDROLOGICAL PROCESSES UNDER A CHANGING CLIMATE

## Participants, Affiliations & Project Roles

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  Land Cover / Land Use

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  Hydrological Field Observations

Co-I: Bart Nijssen, University of Arizona, Tuscon
  Watershed-scale Modeling

Co-I: Omer Sen, Istanbul Technical University, Turkey
  Regional-scale Climate Modeling

Istanbul Technical University
since 1773 pioneer through the ages

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Taikan Oki, Tokyo University;
Yuqing Wang, University of Hawaii

http://research.eastwestcenter.org/mmsea/

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## Science Questions

**How does LCLUC in MMSEA affect local and regional energy and moisture fluxes, and what are the consequences of those changes for continental-scale atmospheric circulation and climate, and local and regional hydrology, in the context of a changing global climate? More specifically,**

**1) How has LCLU changed in recent decades and what hydrologically-significant LCLUC is likely to occur in MMSEA in the coming decades?**

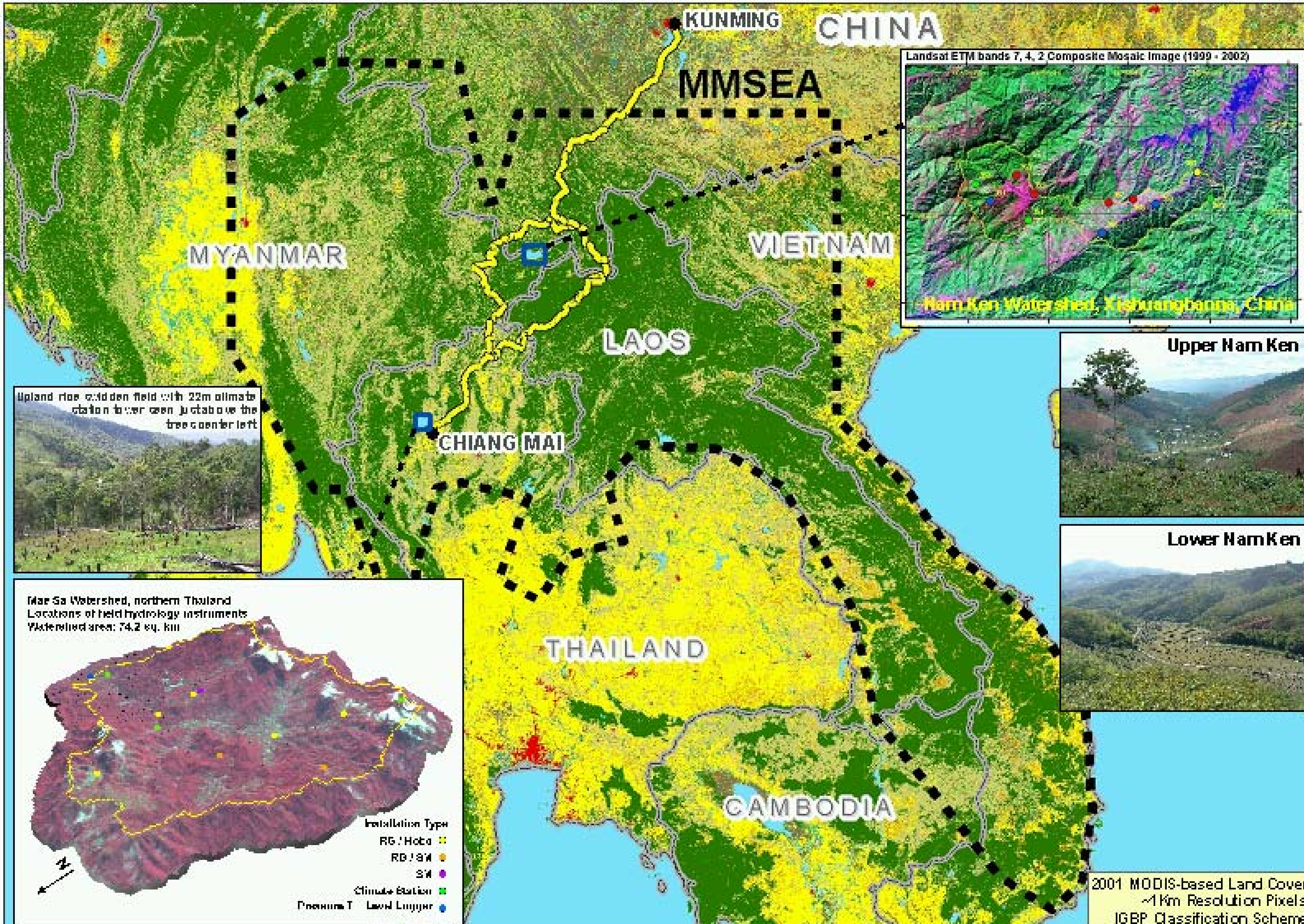
**2) How do changes in LCLU alter the hydrological functioning of watersheds in MMSEA? In particular, how will LCLUC affect the moisture and energy fluxes in these basins?**

**3) To what degree and over what spatial extent will these LCLU changes effect changes in atmospheric circulations and climate?**

**4) What are the separate and combined effects of LCLUC and global warming on the regional and local hydrology?**

## Abstract

The project is using multi-scale, multi-temporal remotely sensed and GIS data and derived products along with an array of ground-based, hydrological measurements and spatially-explicit, regional climate and watershed models to characterize and understand the relationships between land-cover/land-use change (LCLUC) and hydrologic processes in montane mainland Southeast Asia (MMSEA) and their interactions with the effects of global climate change. The project seeks to characterize land-cover, simulate LCLUC and measure and simulate climate and hydrology across a range of scales. The project is focused in two study watersheds, each approximately 100 km2, in the southern part of China's Yunnan Province, and in northern Thailand. These sites provide a cross-section of the varied political-cultural influences on land cover and land use (LCLU) in MMSEA, and represent a range of levels of current development and trajectories of future land-cover change. Moreover, the field sites are important nodes along the corridor of the proposed Chiang Mai-Kunming Highway, a major construction project certain to initiate rapid land-cover conversion and result in profound environmental and economic change in the MMSEA region and beyond.



KUNMING
CHINA
MMSEA
Landsat ETM bands 7, 4, 2 Composite Mosaic Image (1999 - 2002)
Nam Ken Watershed, Xishuangbanna, China
MYANMAR
VIETNAM
LAOS
Upper Nam Ken
Lower Nam Ken
Upland rice swidden field with 22m climate station tower seen just above the tree center left
CHIANG MAI
THAILAND
CAMBODIA
Mae Sa Watershed, northern Thailand
Locations of field hydrology instruments
Watershed area: 74.2 sq. km
Installation Type
RG / Hobo
RG / SW
SW
Climate Station
Level Logger
N
2001 MODIS-based Land Cover
~1 Km Resolution Pixels
IGBP Classification Scheme

## Major Project Goals and Progress

(Research components are color-coded here and elsewhere on poster)

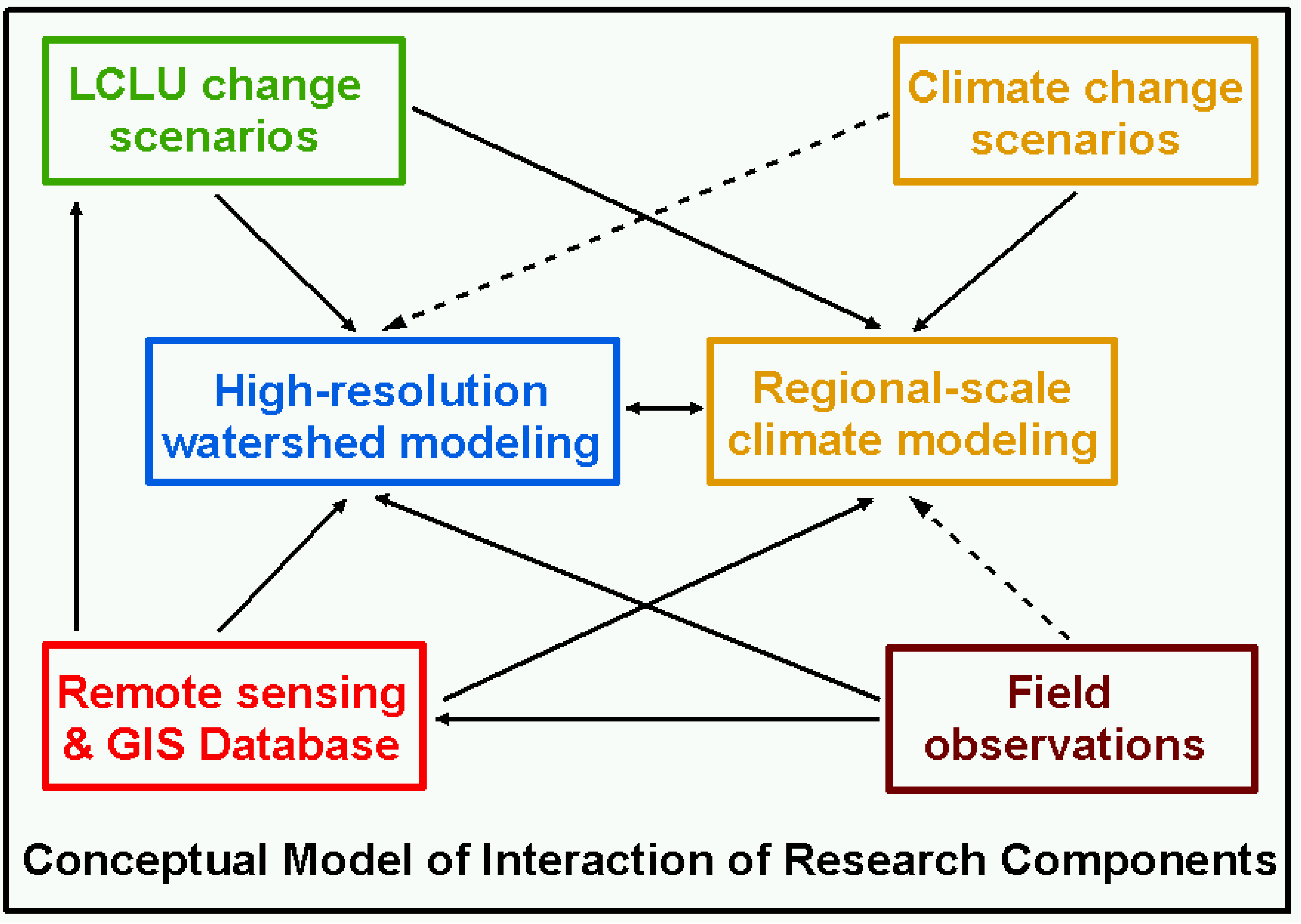
1) To develop a comprehensive, high-resolution database of recent and current land cover in MMSEA and to develop scenarios and simulations of LCLUC in the region to 2025 and 2050 to be used as data layers in a regional climate change model;

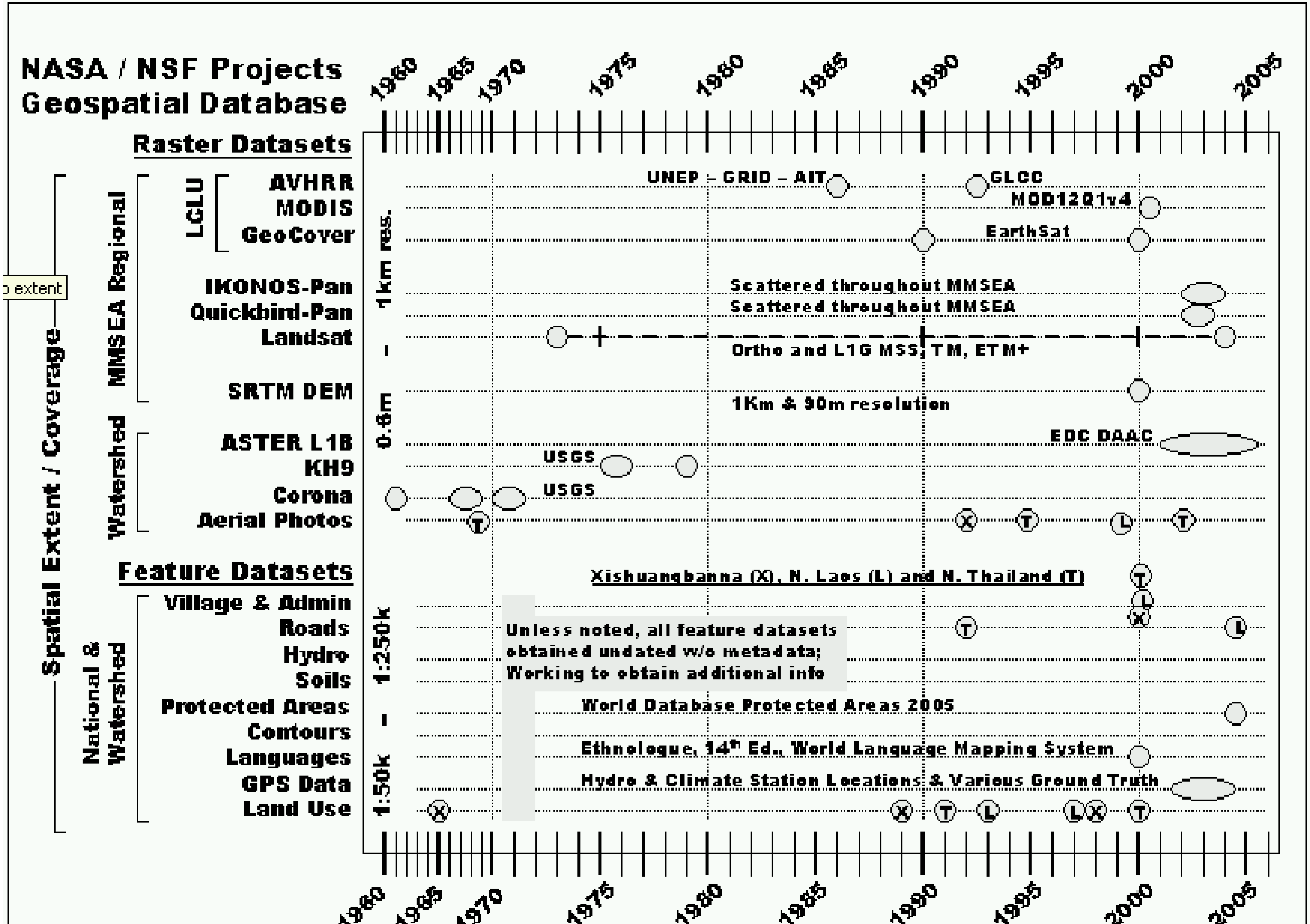
2) To make field measurements of key hydrological variables within two representative watersheds for the purposes of calibrating and validating hydrological and climatological models for the region;

3) To model hydrological processes within each study watershed to establish the role of land-cover change in altering watershed function.

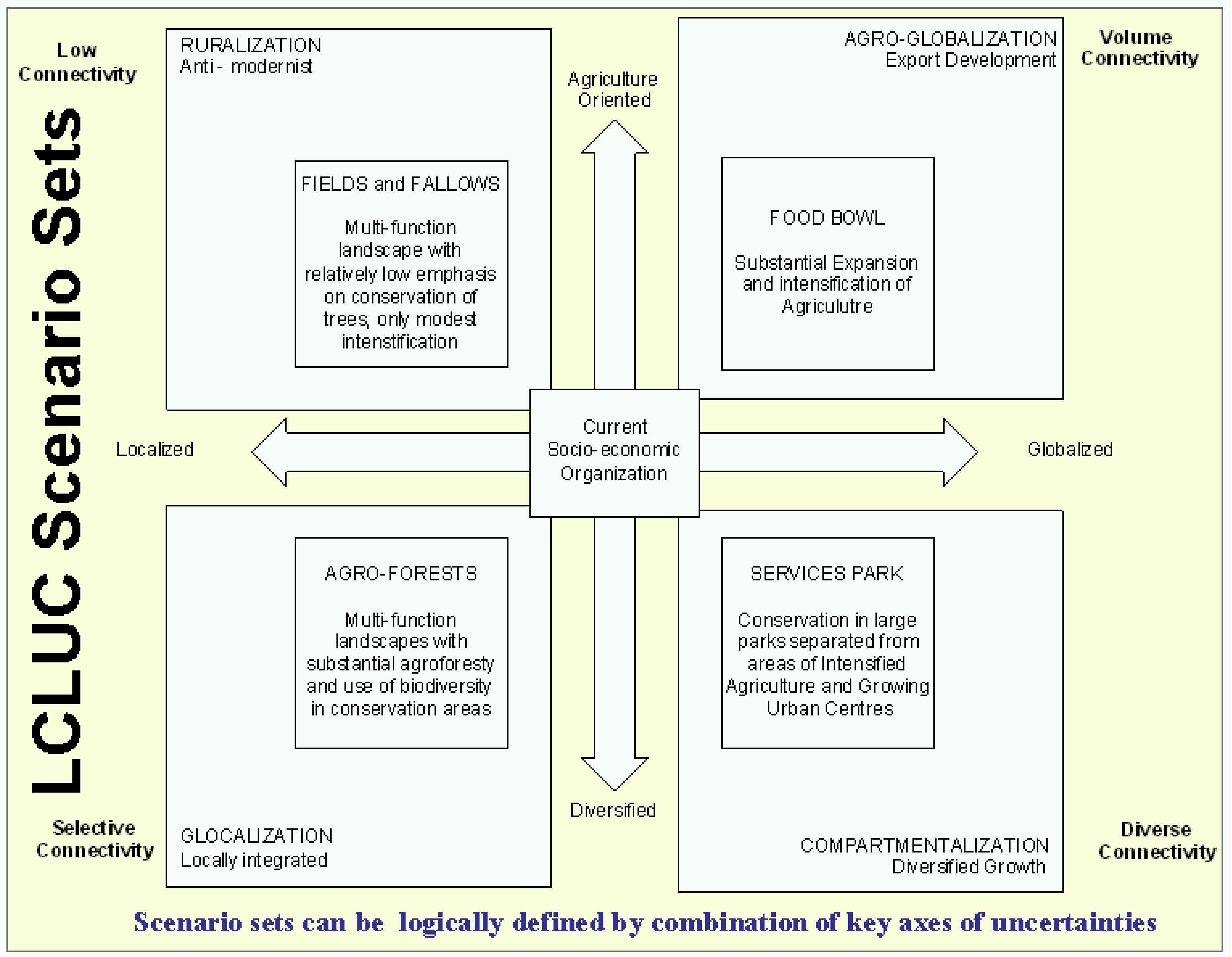
4) To simulate the climate and hydrology of the greater East and SE Asia region under scenarios of land-cover and climatic change.

5) To use climate model output to drive simulations of the watershed model to predict the effects of both land-cover and climatic change, including feedbacks, on MMSEA hydrology.

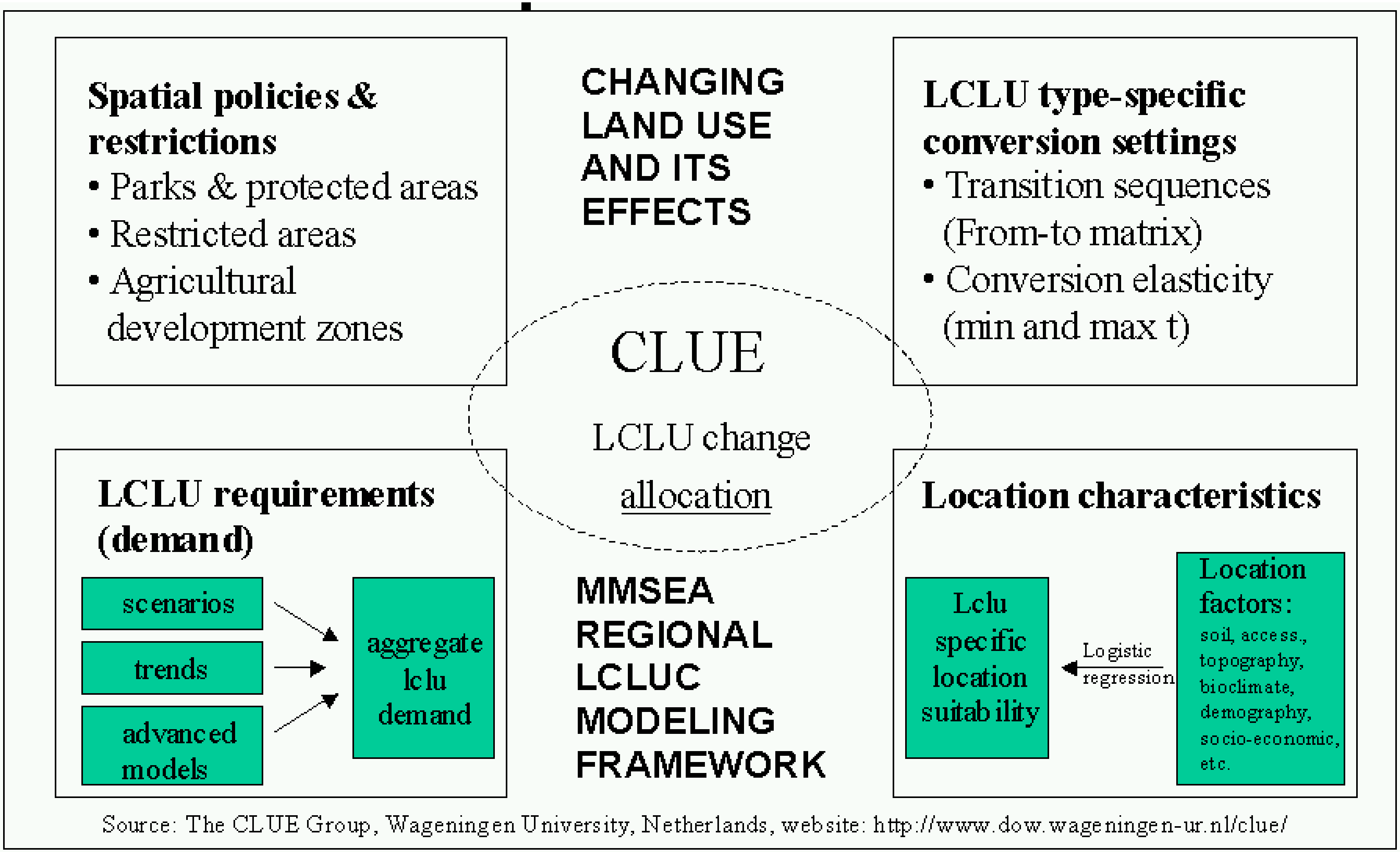

LCLU change scenarios
Climate change scenarios
High-resolution watershed modeling
Regional-scale climate modeling
Remote sensing & GIS Database
Field observations
Conceptual Model of Interaction of Research Components




http://research.eastwestcenter.org/mmsea/data.htm


LCLUC Scenario Sets
Low Connectivity
RURALIZATION
Anti - modernist
FIELDS and FALLOWS
Multi-function landscape with relatively low emphasis on conservation of trees, only modest intenstification
Agriculture Oriented
AGRO-GLOBALIZATION
Export Development
Volume Connectivity
FOOD BOWL
Substantial Expansion and intensification of Agriculutre
Localized
Current Socio-economic Organization
Globalized
AGRO-FORESTS
Multi-function landscapes with substantial agroforesty and use of biodiversity in conservation areas
SERVICES PARK
Conservation in large parks separated from areas of Intensified Agriculture and Growing Urban Centres
Diversified
Selective Connectivity
GLOCALIZATION
Locally integrated
COMPARTMENTALIZATION
Diversified Growth
Diverse Connectivity
Scenario sets can be logically defined by combination of key axes of uncertainties


Expansion of rubber tree plantation in southern China


Spatial policies & restrictions
• Parks & protected areas
• Restricted areas
• Agricultural development zones
CHANGING LAND USE AND ITS EFFECTS
LCLU type-specific conversion settings
• Transition sequences (From-to matrix)
• Conversion elasticity (min and max t)
CLUE
LCLU change allocation
LCLU requirements (demand)
scenarios
trends
advanced models
aggregate lclu demand
MMSEA REGIONAL LCLUC MODELING FRAMEWORK
Location characteristics
Lclu specific location suitability
Logistic regression
Location factors:
soil, access., topography, bioclimate, demography, socio-economic, etc.
Source: The CLUE Group, Wageningen University, Netherlands, website: http://www.dow.wageningen-ur.nl/clue/

| MMSEA Model Region | Observed | | Simulation | | Simulation | |
|---|---|---|---|---|---|---|
| (~1km cell resolution) | 2001 | | 2025 | | 2050 | |
| LC Type (BATS Scheme) | cells | % | cells | % | cells | % |
| Crops, Mixed Farming | 63816 | 3.69 | 103528 | 5.98 | 106182 | 6.13 |
| Short Grass | 51726 | 2.99 | 50654 | 2.93 | 59014 | 3.41 |
| Evergreen Needleleaf Trees | 5344 | 0.31 | 7411 | 0.43 | 5460 | 0.32 |
| Deciduous Needleleaf Trees | 25 | 0.00 | 18 | 0.00 | 18 | 0.00 |
| Deciduous Broadleaf Trees | 221978 | 12.82 | 246451 | 14.23 | 264610 | 15.28 |
| Evergreen Broadleaf Trees | 633363 | 36.58 | 582185 | 33.63 | 568824 | 32.85 |
| Tall Grass | 98737 | 5.70 | 93998 | 5.43 | 91185 | 5.27 |
| Desert | 11910 | 0.69 | 20683 | 1.19 | 39947 | 2.31 |
| Tundra | N/A | N/A | N/A | N/A | N/A | N/A |
| Irrigated Crops | 165063 | 9.53 | 174793 | 10.10 | 175123 | 10.11 |
| Semidesert | 17236 | 1.00 | 12638 | 0.73 | 12638 | 0.73 |
| Ice Caps and Glaciers | N/A | N/A | N/A | N/A | N/A | N/A |
| Bogs and Marshes | 1904 | 0.11 | 1904 | 0.11 | 1904 | 0.11 |
| Inland Water | 11105 | 0.64 | 11105 | 0.64 | 11105 | 0.64 |
| Ocean | 677 | 0.04 | 677 | 0.04 | 677 | 0.04 |
| Evergreen Shrubs | 39867 | 2.30 | 55781 | 3.22 | 68046 | 3.93 |
| Deciduous Shrubs | 10527 | 0.61 | 11663 | 0.67 | 11663 | 0.67 |
| Mixed Forest | 88824 | 5.13 | 77472 | 4.47 | 67414 | 3.89 |
| Forest/Field Mosaic | 309230 | 17.86 | 280372 | 16.19 | 247523 | 14.30 |
| Total | 1731333 | 100.00 | 1731333 | 100.00 | 1731333 | 100.00 |

# Final MMSEA CLUE Simulations

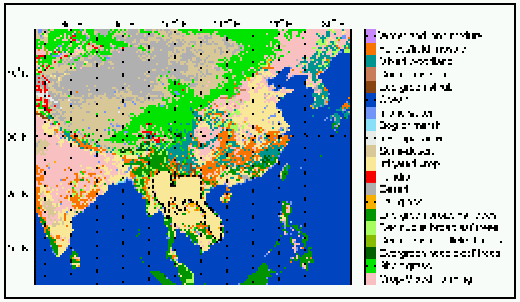
INCREASE

DECREASE

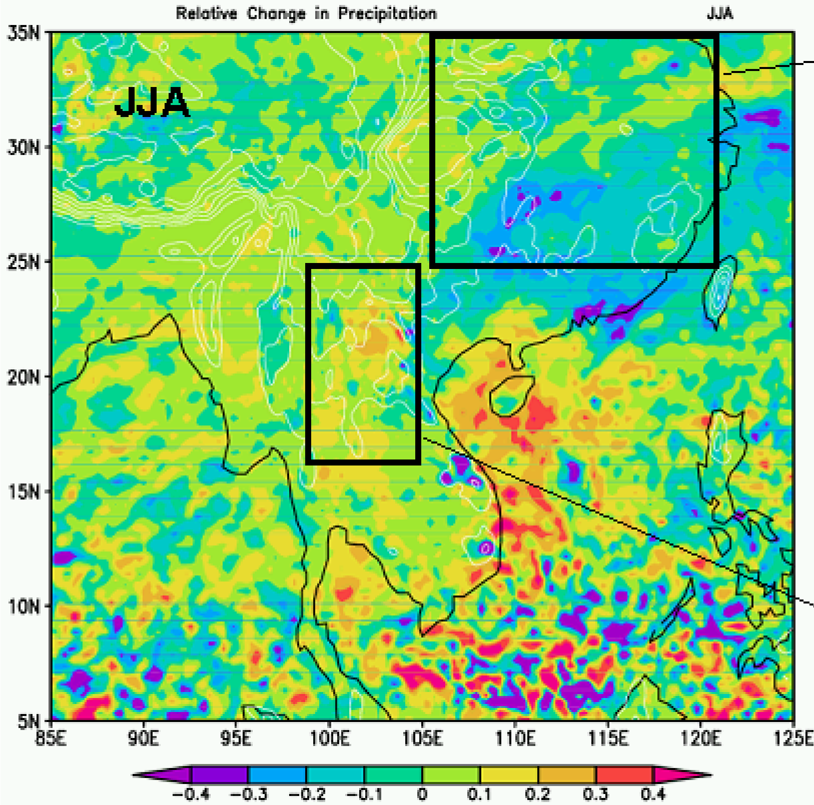
LITTLE CHANGE/
OR NOT MODELED

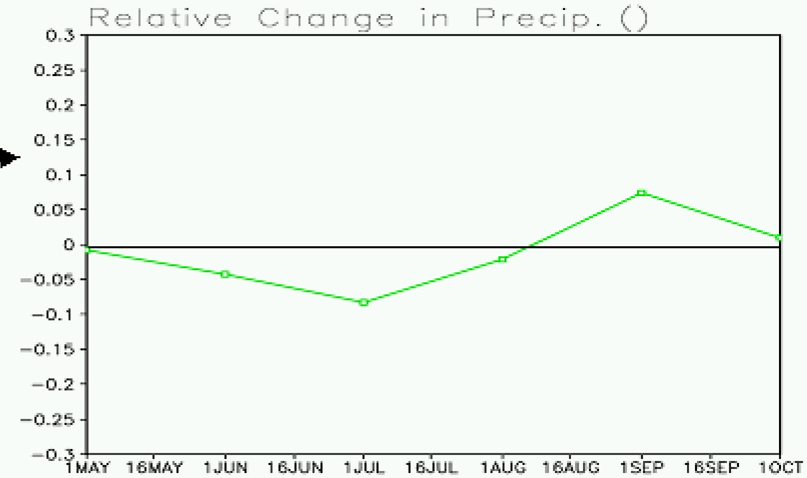
- LCLU simulations run at annual time steps using LCLU requirements (Demand) that are scenario-driven.

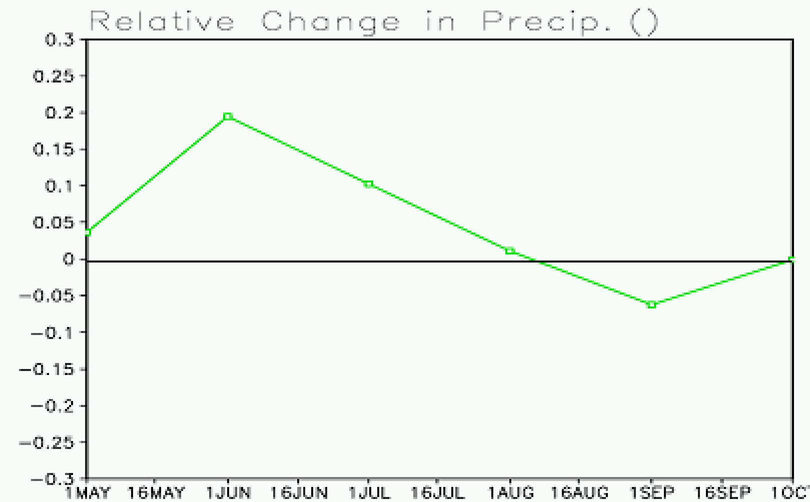
- Key output years 2025 and 2050 are being input into regional climate model.



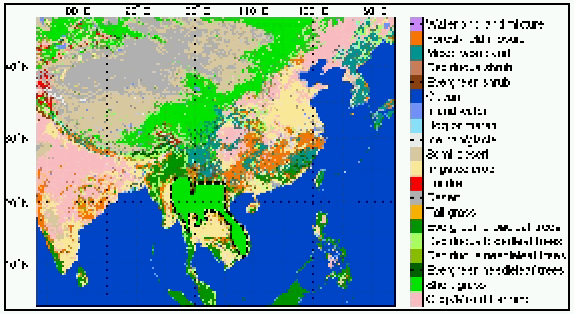
# June-July-August Relative Change in Precipitation from Extreme Deforestation (All Irrigated Crop) minus (-) Control Land Cover (2001)

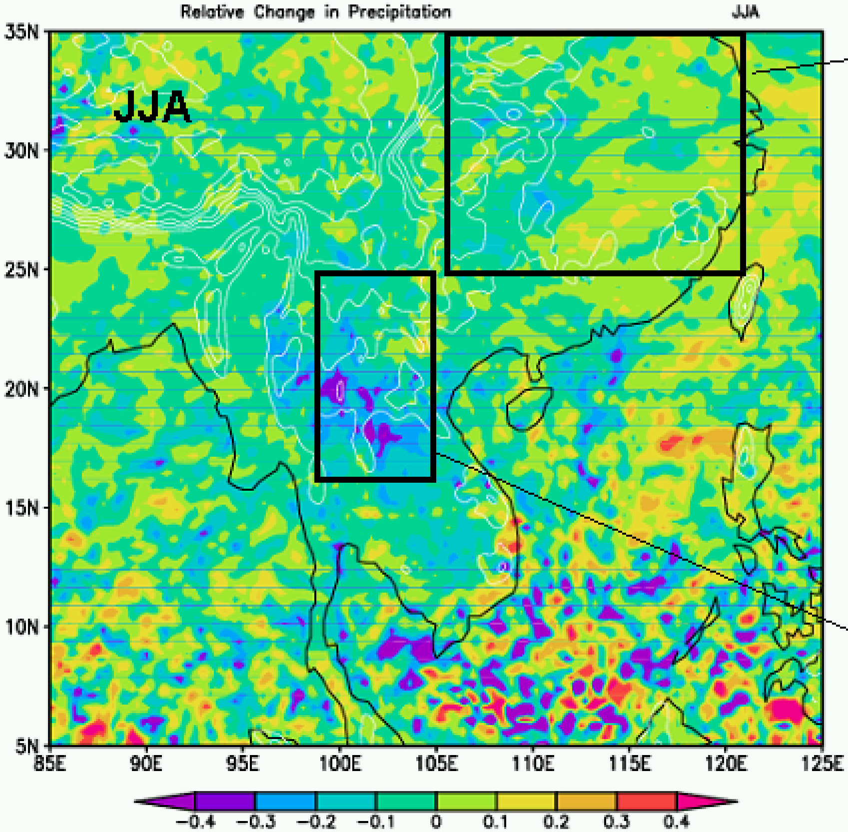


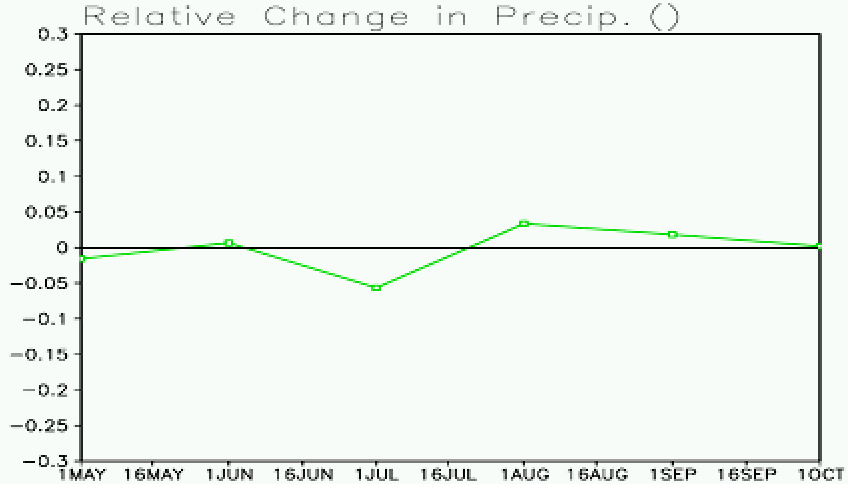



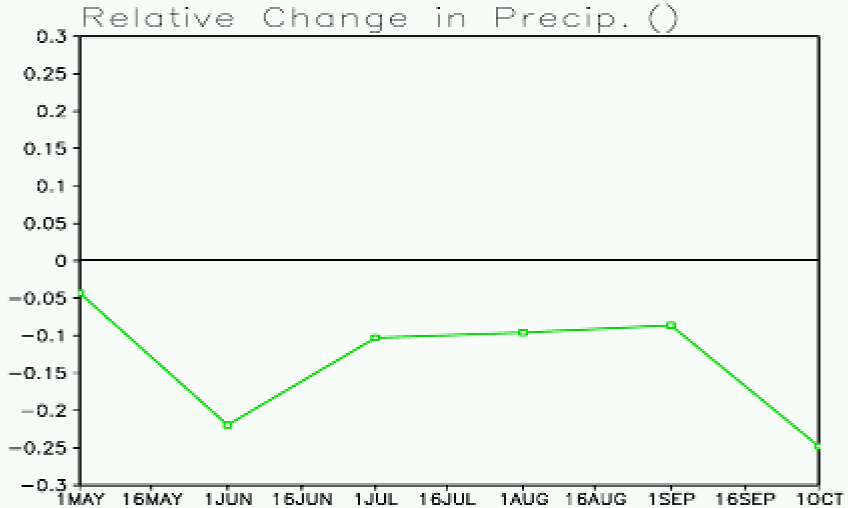



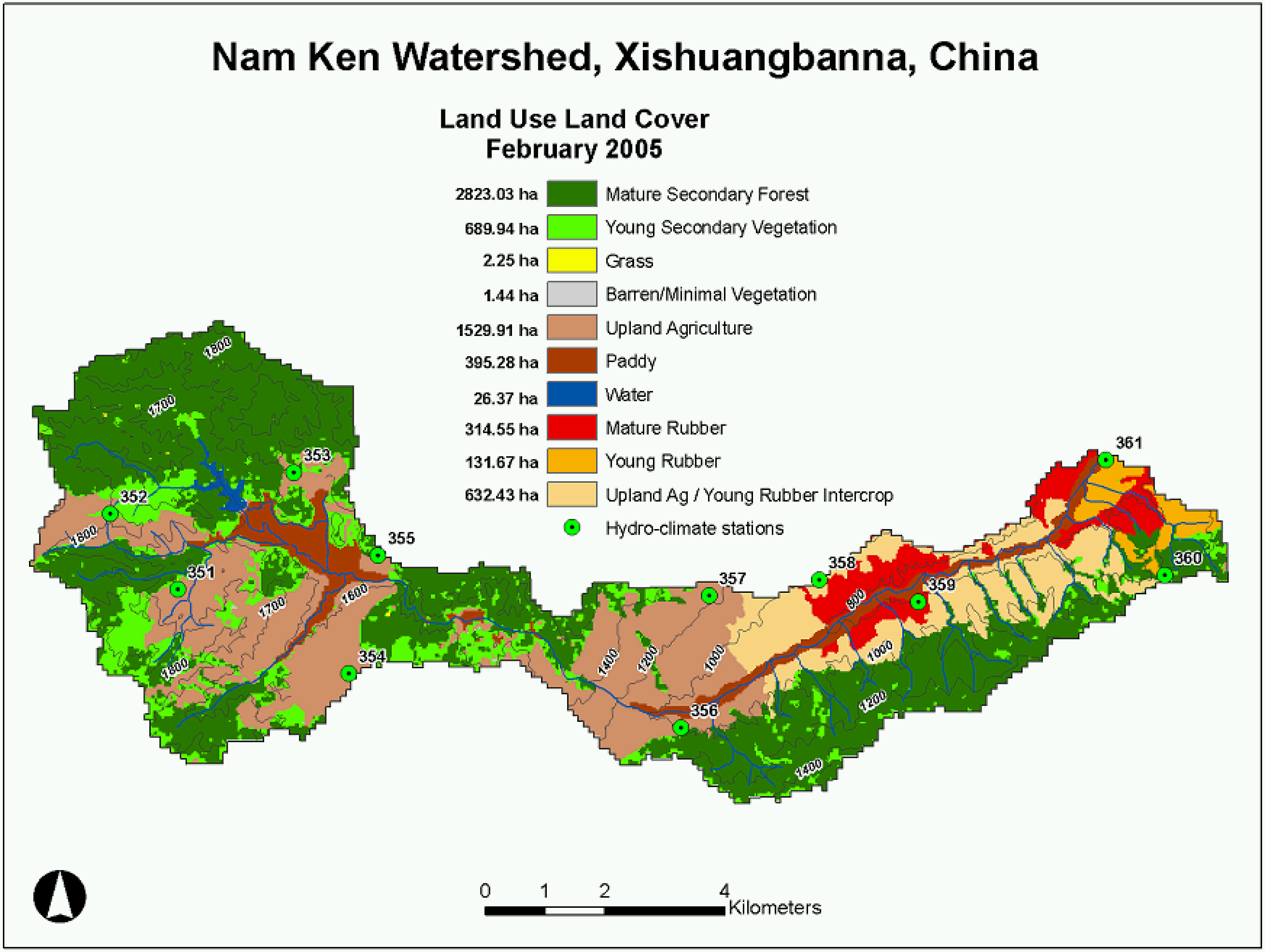
# June-July-August Relative Change in Precipitation from Extreme Deforestation (All Grass) minus (-) Control Land Cover (2001)

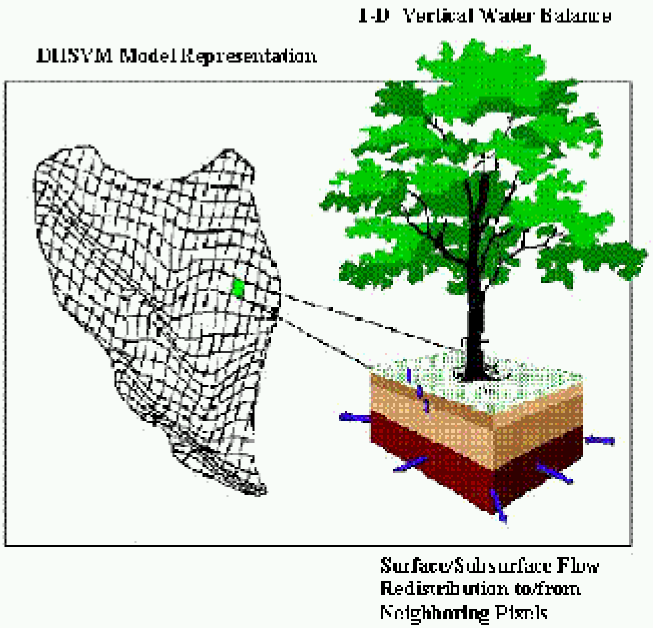





Nam Ken Watershed, Xishuangbanna, China
Land Use Land Cover
February 2005
2823.03 ha Mature Secondary Forest
689.94 ha Young Secondary Vegetation
2.25 ha Grass
1.44 ha Barren/Minimal Vegetation
1529.91 ha Upland Agriculture
395.28 ha Paddy
26.37 ha Water
314.55 ha Mature Rubber
131.67 ha Young Rubber
632.43 ha Upland Ag / Young Rubber Intercrop
Hydro-climate stations
351
352
353
354
355
356
357
358
359
360
361
0 1 2 4
Kilometers

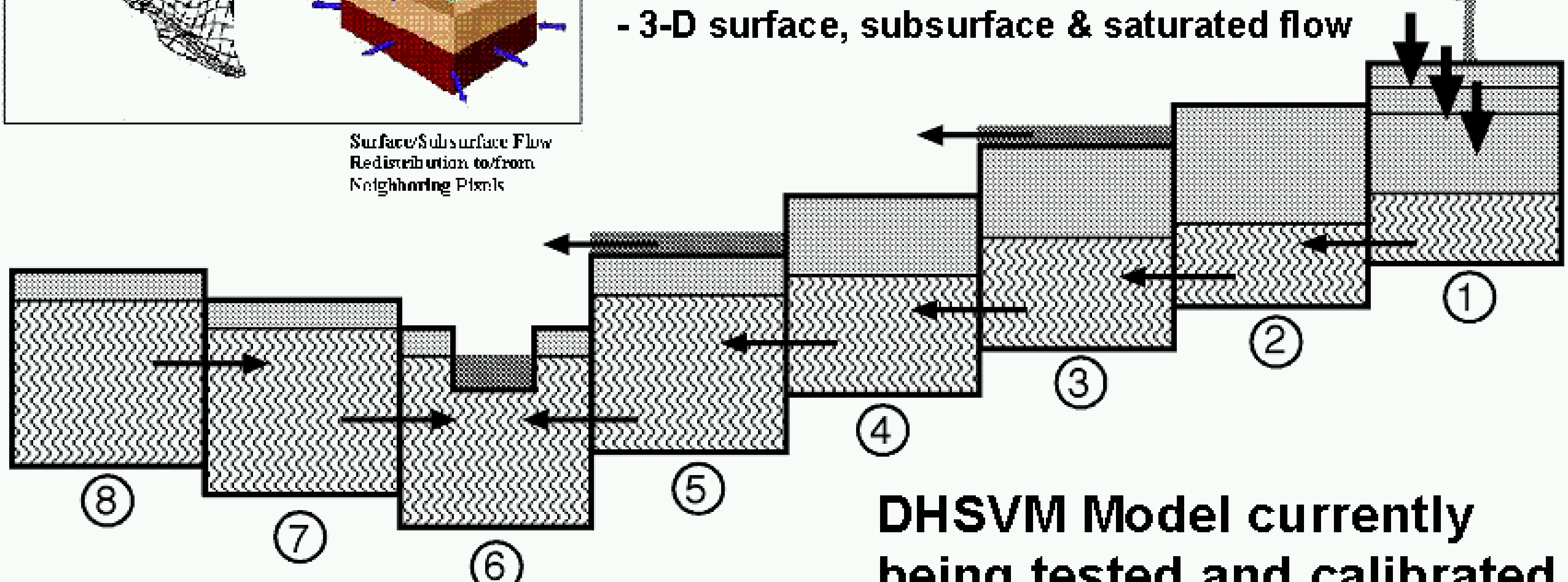



## Distributed Hydrology Soil Vegetation Model

Incorporates:

- Overstory / Understory (Land Cover Veg Types)
- 3 layers of rooting zone
- Saturated subsurface flow

- Unsaturated flow > Darcy (Unit gradient)
- Lower root zone > Water table
- 3-D surface, subsurface & saturated flow




**DHSVM Model currently being tested and calibrated**


# Root Zone Water Balance

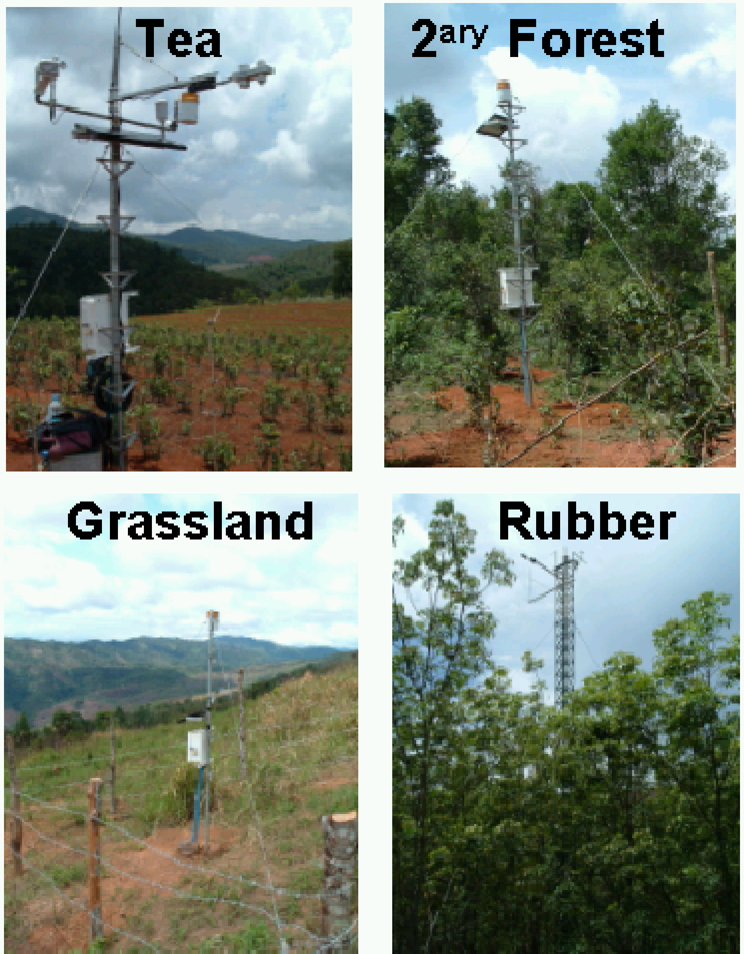
$$\frac{d\theta}{dt} Z = P - E - R$$

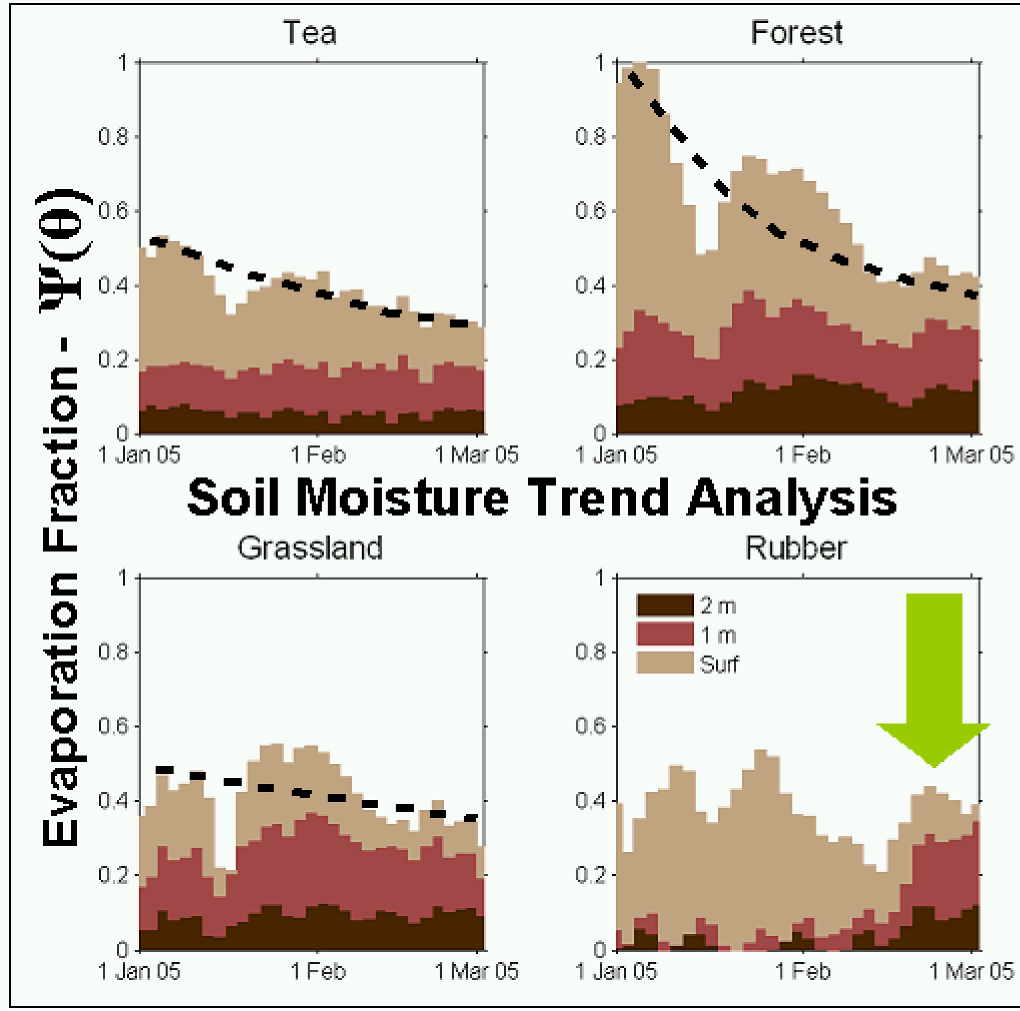
$$E = -\frac{d\theta}{dt} Z$$

**Dry season assumptions:**

Negligible
- Precipitation
- Deep percolation
- Net lateral inflows

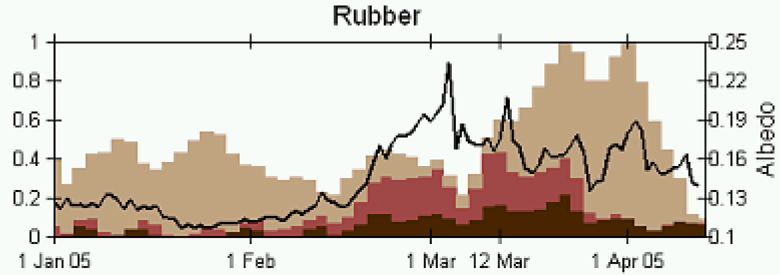
Homogeneous soils


Tea
2ary Forest
Grassland
Rubber


Soil Moisture Trend Analysis
Evaporation Fraction - Ψ(θ)
Tea
Forest
Grassland
Rubber
2 m
1 m
Surf
1
0.8
0.6
0.4
0.2
0
1 Jan 05
1 Feb
1 Mar 05

*Why Root-water uptake during shedding?*


Rubber




NOV – DEC – JAN – FEB – MAR – APR – MAY

## Leaf flushing during the dry season:

1) New leaves during hottest & driest season
2) Trees rely heavily on subsurface water
3) Climate is not the primary control of phenology, but rather Day Length

## Conclusions from Soil Moisture Trend Analyses

1) Rubber appears to be a Spring Flushing tree
2) Soil moisture increases with depth for all vegetation types EXCEPT rubber
3) Rubber exhibits a deep rootzone water uptake during the dry season that other vegetation types do not
4) Rubber phenology responds strongly to Day Length whereas other vegetation respond primarily to temp. & precip.
5) In terms of ET, rubber and native vegetation behave very differently
6) At larger scale, introducing rubber could shift the demand for water to a time when there is already a water deficit!

**Conversion to rubber is occurring rapidly and extensively in the region!**

## Geospatial Datasets and Project Timelines

Collect and analyze existing and new remotely sensed and GIS data, mapping and field observations for generating biophysical variables, hydroclimate data, thematic layers and understanding LCLUC at multiple scales

Response to NRA-03-OES-03

1980 — Landsat 5 TM → 1990 — NOAA AVHRR → 2000 — Landsat 7 ETM+, ASTER, MODIS →

- Remote sensing analysis and field observations for LC characterization and LCLUC dynamics
- → CA and CLUE model development, implementation, validation for LCLU simulations
- Field climate & hydrology equipment installation, calibration and field observations
- → Watershed model construction, implemention, simulation and scenario evaluation
- RegCMs using present/control/projected climates with present LCLU and extreme deforestation scenarios
- → RegCMs using present/control/projected climates with 2025 and 2050 LCLUC simulations

2004 — 2005 — 2006 — 2007

→ NASA Project Duration →

Climate & Hydrology Field Data Online at: http://webdata.soc.hawaii.edu/hydrology/projects/res_NASA/data.htm

Annual, multi-res LCLU simulations derived from LCLUC scenarios and CA and CLUE modeling provide input for high-res watershed simulations (DHSVM model) and regional climate simulations (NCEP/NCAR/ECHAM5), respectively, to years 2025 and 2050.

2007 — 2025 — 2050

→ → Simulation Period —

Prepared for
NASA LCLUC
Science Team Meeting
April 4-6, 2007
Washington, DC

## Future Steps

1) Continue to obtain field climate/hydrological data and soil, vegetation, and physical parameters for forcing, parameter setting, and calibration of watershed and climate models

2) Simulate hydrological processes in study watersheds under various land cover scenarios using distributed model DHSVM

3) Simulate climate and hydrology of East-SE Asia region for future land cover and future global climate scenarios

4) Use regional climate output to drive simulations of hydrological processes in study watersheds under future land-cover and climate conditions