# CRC 990
# Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems Sumatra, Indonesia

A03

## Quantifying the effects of land use changes in Indonesia on carbon, water and energy fluxes to the atmosphere using remote sensing*1 and land surface modelling*2

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## Background

Tropical forests in South-East Asia (SEA) are essential agents in local and regional climate by recycling water, absorbing / releasing greenhouse gases, and transforming energy. Deforestation and forest degradation, especially in Indonesia, have been accelerated by economy-driven expansion of oil palm plantations. Changes of land surface properties (vegetation composition, soil property, surface albedo) associated with rainforest to oil palm conversion might alter the patterns of land-atmosphere energy, water and carbon fluxes. Remote sensing and earth system modeling provide a means for quantifying land surface dynamics and their effects on these fluxes across a variety of spatial and temporal scales.

This research is being conducted by Clifton Sabajo and Yuanchao Fan, using remote sensing and land surface modeling approaches, respectively.

## Objectives and Methods

***Remote Sensing***

Clifton uses a Surface Energy Balance Model to derive biophysical variables from remote sensing data (Landsat and MODIS). The biophysical variables which he studies are: land surface albedo (α), land surface temperature (Ts) and evapotranspiration (ET). The land surface albedo and the surface temperature are important variables to calculate the radiation balance.

Specifically, the aim is to:

- Quantify the biophysical variables (albedo, Ts, ET) of different land use types
- Study the biophysical variables and their changes in relation to changing LULC.

***Land surface modelling***

Yuanchao developed a new plant functional type (PFT) and sub-canopy strcuture for simulating oil palm in the Community Land Model (CLM 4.5), including new functions for its phenology, carbon & nitrogen allocation, yield, and radiative transfer and photosynthesis processes.

In this module, oil palm is represented as multiple layers of phytomers, each with its own prognostic leaf growth and fruit yield capacity. A total of 40 layers are stratified for sub-canopy phenological and physiological parameterization. Phenology and allocation operate on the different phytomers in parallel but at unsynchronized steps, so that multiple fruit yields per annum are enabled in terms of C & N outputs. A dynamic multilayer canopy stratification and integration scheme for radiative transfer and photosynthesis is also incorporated into CLM to better simulate this unique perennial evergreen oil palm system.

The model outputs are compared with oil palm yield data and eddy covariance flux data from a young and a mature plantations in Jambi. The model will allow to quantify LUC effects on carbon, water and energy fluxes in the forest to oil palm transformation system.

## CLM Modeling



### The Community Land Model

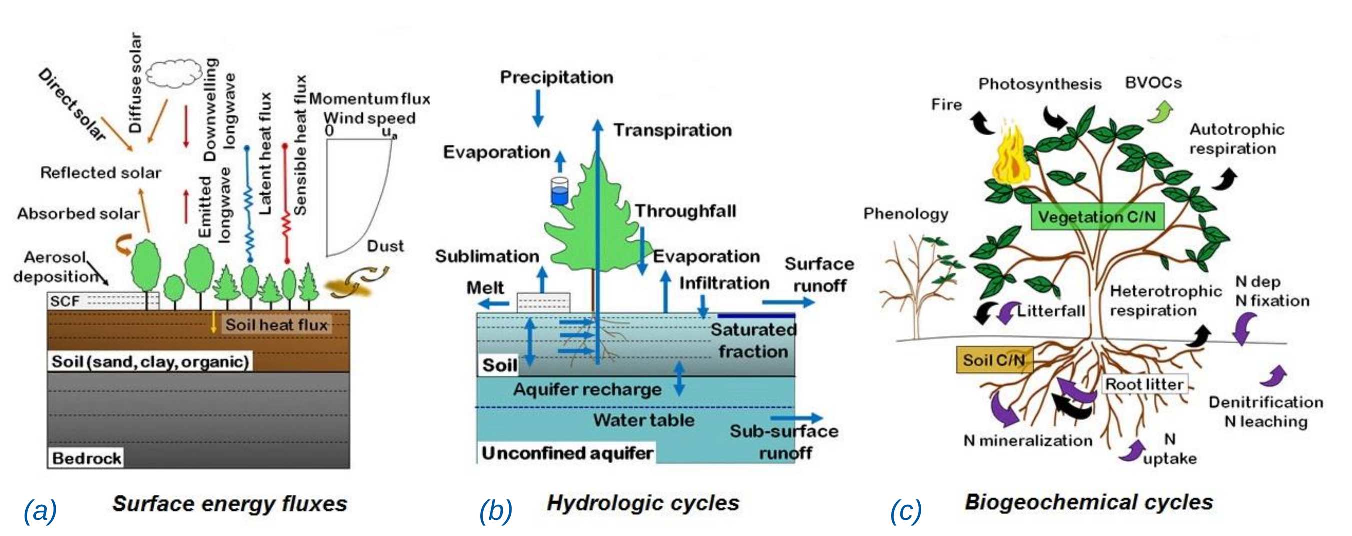



Fig.1. Processes Simulated by the Community Land Model 4.5: (a) energy fluxes, (b) water fluxes, (c) carbon fluxes.

### Simulate oil palm: phenology, allocation, yield

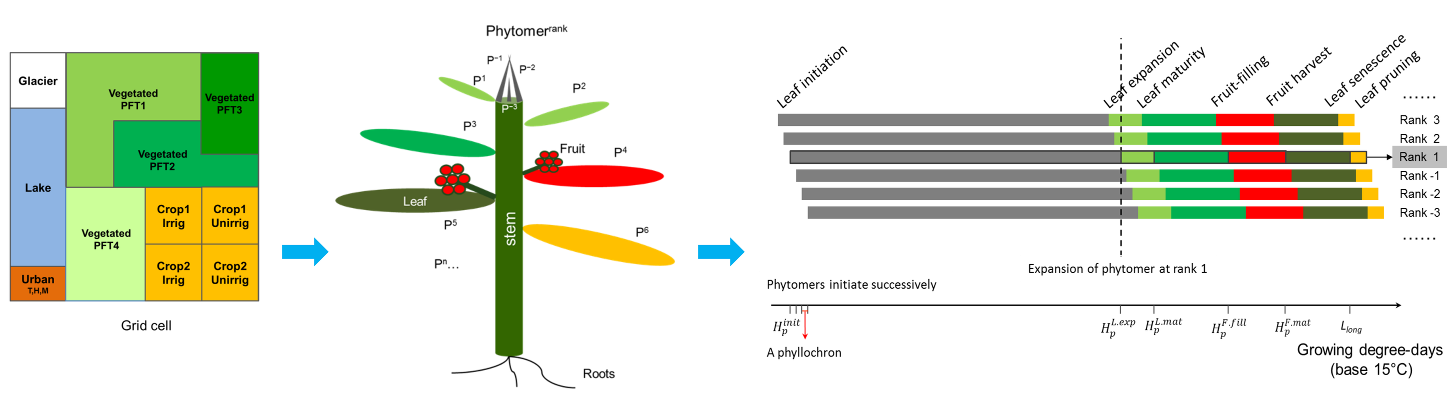



Fig.2. (a) New sub-canopy phytomer structure for the oil palm PFT within the CLM framework. $P^1$ to $P^n$ indicate expanded phytomers and $P^{-1}$ to $P^{-n}$ at the top indicate unexpanded phytomers packed in the bud. Each phytomer has its own phenology, represented by different colors corresponding to: (b) the 6-phase phytomer phenology: from initiation to leaf expansion, to leaf maturity, to fruit-fill, to harvest, to senescence and to pruning. Phytomers initiate successively according to phyllochron (in thermal time $GDD_{15}$).

### Validate model output with field data

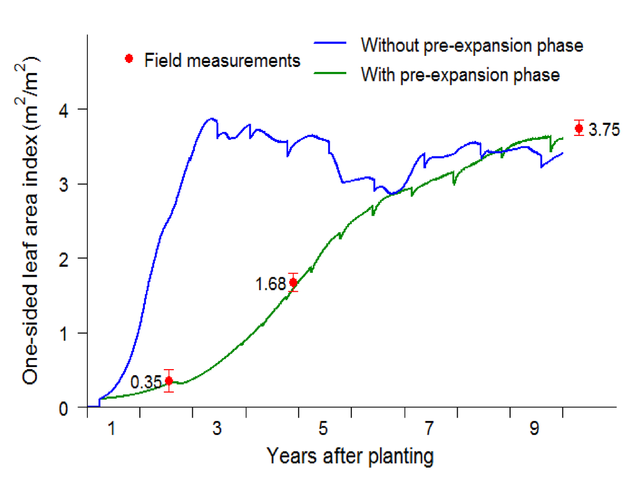



Fig. 3. PFT-level LAI simulated by the oil palm model, with and without the pre-expansion growth phase in the phytomer phenology. The initial sudden increase represents transplanting from nursery. The sharp drops mark pruning events.

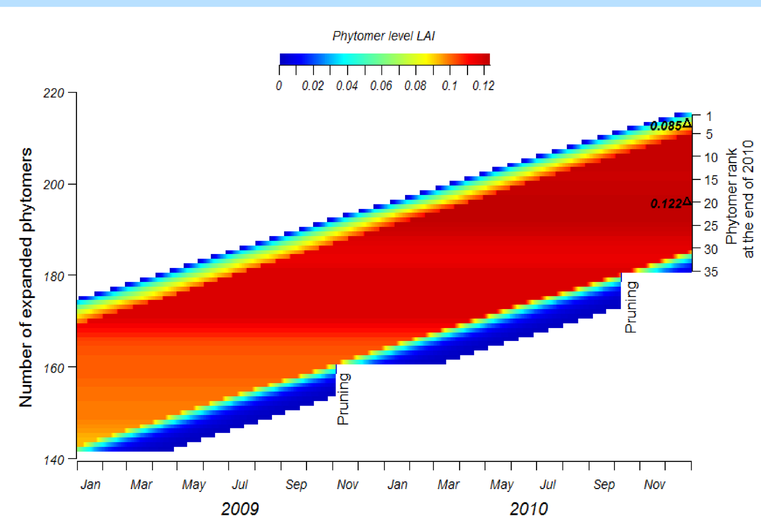



Fig. 4. Simulated phytomer level LAI dynamics compared with field observations. The latest expanded phytomer at a given point of time has a rank of 1. Each horizontal bar represents a part of the life cycle of a phytomer within years 2009-2010. The one-sided LAIs of two phytomer samples at rank 3 and rank 20 of a mature oil palm are within the range of simulated values.

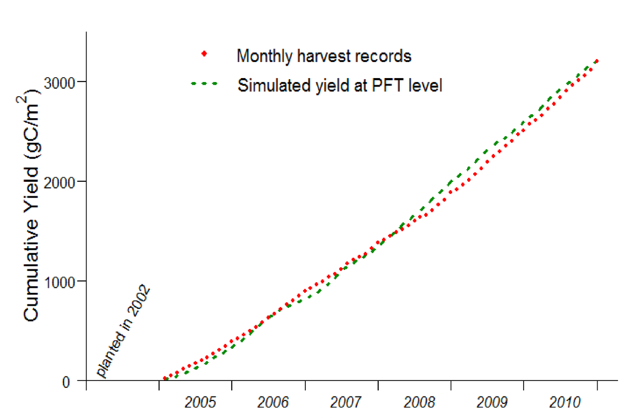



Fig. 5. (Left) Simulated yield compared with monthly harvest data (2005-2010) from an oil palm plantation (PTPN-VI) in Jambi, Sumatra. The oil palm model represents multiple harvests (about twice per month) from different phytomers throughout time. The cumulative harvest amount from the model matches well with field records.

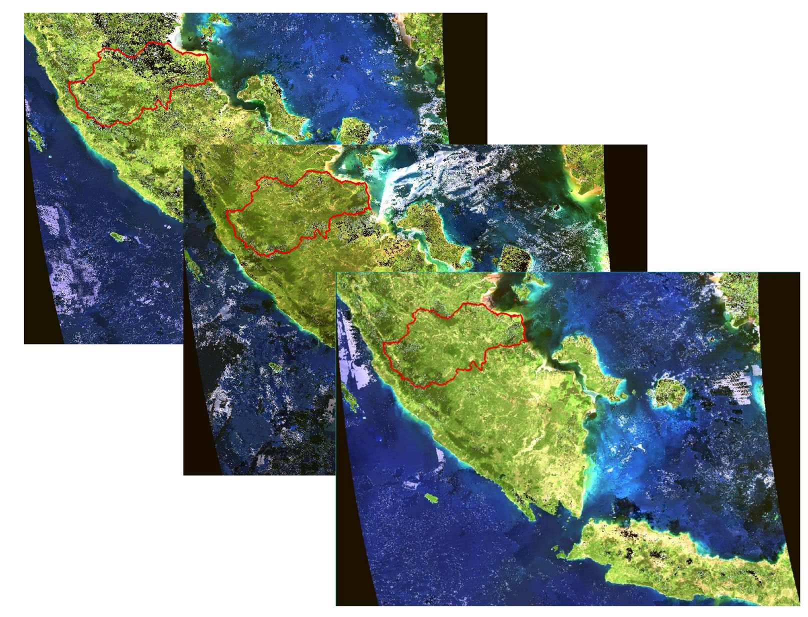
### Simulate LUC effects: historical and scenario

To do:

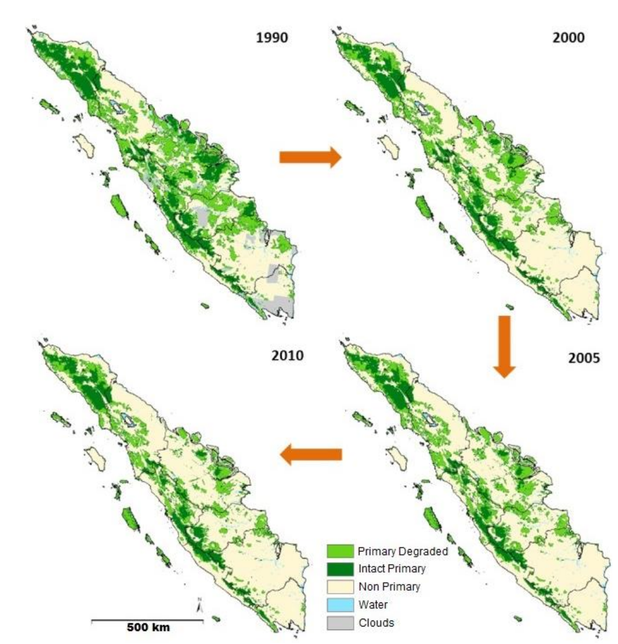
- Construct and represent historical LUCs from rainforests to oil palm plantation (create transient PFT datasets)
- Run historical simulations and compare with findings from other studies.
- Design future LUC scenarios: business-as-usual, food production, forest preservation, carbon conservation, hybrid scenarios, etc.
- Climate scenarios: SRES and/or RCP scenarios
- Scenario simulations and analysis

## Remote Sensing

### Remote sensing change detection of historical land cover dynamics

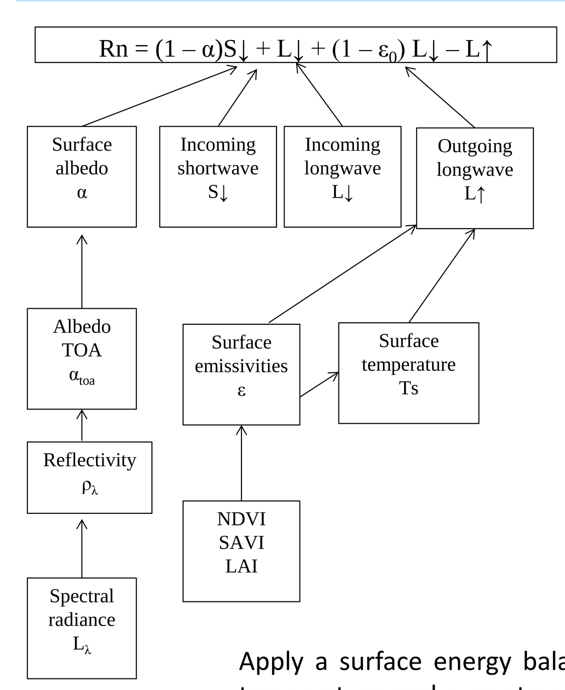


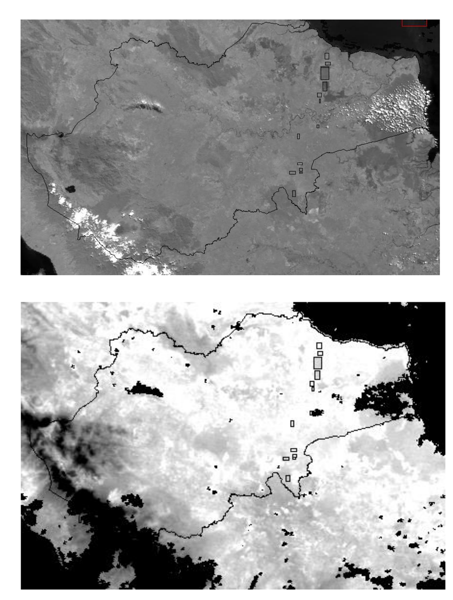
Change detection using MODIS or Landsat TM images.




LUC detection exemplary results

### Quantify biophysical variables for different land use types with a Surface Energy Balance Model

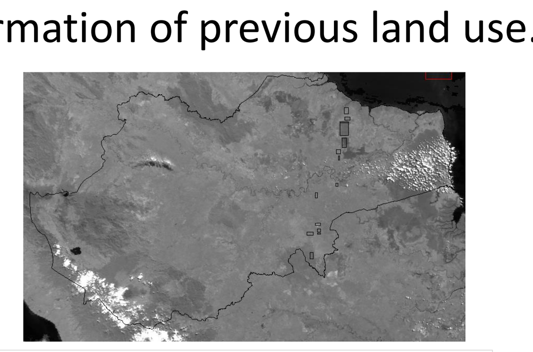


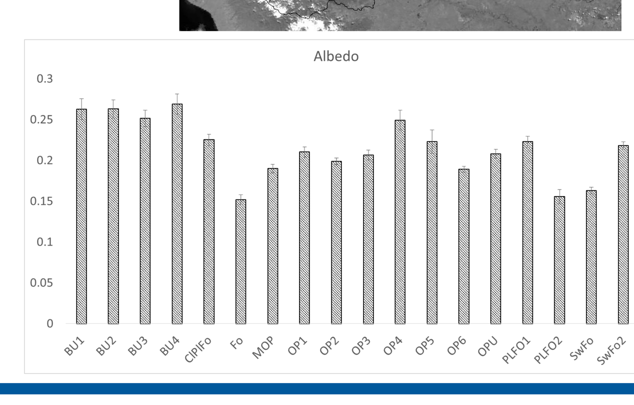



Apply a surface energy balance model to derive: albedo, surface temperature and evapotranspiration from satellite images. Upper satellite image: Landsurface albedo; Lower satellite image: Land surface temperature (both from MODIS).

### Study the biophysical variables and their changes in relation to Land use change

To do: Compare the biophysical variables of different land use types with each with information of previous land use.






Satellite image with different land use types selected. The average albedo of these areas is shown in the bar graph. (BU 1-4 = Urban areas, ClPlFo = cleared plantation forest, MOP = Mature Oil palm, OP 1 – 6 = Oil Palm, PLFo 1 – 2: Plantation Forest, SwFo = swamp forest)

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