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Where we use or plan to use CLM

1. Tropical Lowland Rainforest Transformation Systems (Sumatra, Indonesia) (Yuanchao Fan)

2. Effects of management/composition on forest response to extreme climate events (Rijan Tamrakar)

3. Introducing process based representations of soil C dynamics (myself)
Tropical Lowland Rainforest Transformation (Sumatra, Indonesia)

The background

• Tropical lowland forests are experiencing the strongest losses worldwide, with regions in Sumatra seeing some of the fastest transformations.

• These natural lowland forests are transformed into rubber and oil palm plantations.

• Similar intensive land use change is expected to continue happening extensively in Indonesia.
Tropical Lowland Rainforest Transformation (Sumatra, Indonesia)

Upscaling of carbon fluxes to landscape level
- Remote sensing various land use types (B05)
- Land surface modelling (A03)
- Integrated modelling (B10)

Four target rainforest transformation systems
Lowland rainforest, jungle rubber, rubber and oil palm plantation
Tropical Lowland Rainforest Transformation (Sumatra, Indonesia)
Simulating the Oil Palm (Yuanchao Fan)

- Evergreen phenology
- Seasonal-deciduous phenology
- Stress-deciduous phenology
- Annual crop phenology
- **Perennial evergreen crop phenology**
  - Oil Palm phenology
Palm Phenology

- Planting to leaf initiation
- Leaf expansion
- Leaf maturity
- Fruit fill
- Fruit harvest and output
- Leaf senescence and pruning
The oil palm PFT structure

1. leaf growth
2. fruit-fill
3. harvest
4. leaf pruning

P = Phytomer

Leaf
Fruit
P1
P2
P3
P4
P5
P6

Roots

3/9/2015
Palm Phenology

Phytomer rank

Initiation Expansion Maturity Fruit-fill Harvest Death/Pruning

A Phyllochron

Growing degree days (base 15°C)
The spear leaf

- The “spear” leaf develops for nearly 2 years before it expands to be a photosynthetically active leaf.
Leaf area index

Field Measured
With pre-expansion phase
Without pre-expansion phase

One-sided leaf area index (m²/m²)

Year

2002 2003 2004 2005 2006 2007 2008 2009 2010

(2014) 3.7

0.35

1.68
Pruning

Phytomer LAI

Feb 2005

Phytomer (L)

0.00 0.01 0.02 0.03 0.04 0.05 0.06

PLAI [indgrid=0, phytomer=*, time=*]
Trophic Competition

• Vegetative demand and reproductive demands compete under stress conditions

• *Supply: Demand* ratio affects inflorescence gender ratio and abortion rate

\[ RSD = \frac{C_{avail}}{D_{veg} + D_{rep}} \]

• \( r_{sex} = m_1 (1 - RSD) \); when \(-27 \leq \text{Rank} \leq -21\)
• \( r_{abort} = m_2 (1 - RSD) \); when \(7 \leq \text{Rank} \leq 12\)
Carbon and Nitrogen Allocation

- Annual crops: allocation to leaf/stem/root decreases continuously until grain-fill, whereas allocation to grain increases from grain-fill till harvest.
Carbon and Nitrogen Allocation

- The oil palm maintains LAI and produces continuously throughout its entire life cycle
- Allocation to leaf/stem/root and fruit needs to be balanced
Two-step allocation

• Plant level: allocate available C and N to root, stem, and overall leaf (vegetative) + overall fruit C/N pools (reproductive)

• Phytomer level: allocated C and N to the leaf and fruit pools are partitioned between all phytomers
Objectives

Understand and model changes in:

- Albedo
- Water/Energy Fluxes
- Carbon Cycle

Then scale up to the region and predict for different future scenarios
Introducing process based representations of soil C dynamics

• A theory based approach is the better option, even if agreement with data shows little improvement
• Enough theory and evidence is available to know that we can do better
• Land Use Change (e.g. Indonesia) = Big Experiment
Introducing process based representations of soil C dynamics

Temperature

\[ r_{\text{soil}} = Q_{10} \left( \frac{T_{\text{soil},j} - T_{\text{ref}}}{10} \right) \]

Q10 = 1.5

Moisture

\[ r_{\text{water}} = \sum_{j=1}^{5} \left\{ \begin{array}{ll}
0 & \text{for } \Psi_j < \Psi_{\text{min}} \\
\log\left(\frac{\Psi_{\text{min}}/\Psi_j}{\Psi_{\text{max}}/\Psi_j}\right) & \text{for } \Psi_{\text{min}} \leq \Psi_j \leq \Psi_{\text{max}} \\
1 & \text{for } \Psi_j > \Psi_{\text{max}}
\end{array} \right. \]
Introducing process based representations of soil C dynamics

Temperature

• Soil Incubations show higher Q10 (>=2)
• Several studies suggest a higher sensitivity for slower pools.
• Slow pools have low contributions to $R_{eco}$, therefore will not noticeably influence short term $R_{eco}$ T sensitivity
• However, they will respond to T changes in longer time periods - new equilibrium

Lefevre, Barre, Moyano, et al. GCB, 2014

• In agreement with theory
• Relates T-sensitivity to pool turnover time
Introducing process based representations of soil C dynamics

**Moisture**

**Priming Effect**
- Michaelis-Menten Kinetics: dependence on [S]
- SOM-Mic distance

**Birch Effect**
- enzyme activity and diffusion dependence on moisture not equal
- adsorption/desorption

**SOM-Enzyme Reaction Site**

**SOM-Microbe Distance**

- Enzymes
- Litter, SOC
- Enzymatic Reactions
- DOC
- Adsorption - Desorption
- Mineral Surface

- Diffusion
- M, t

- Enzymes
- Microbes
- Enzymatic Reactions
- DOC
- Adsorption - Desorption
- Mineral Surface
- Microbes
- Uptake
- M, t

**T-response variability**
- Chemical quality (intrinsic T resp)
- [S] (Michaelis-Menten)
- Diffusion interactions

**Negative Priming Effect**
- adsorption/desorption

**Soil Texture**
- SOM Quality
- pH

Manzoni, Moyano, et al. in prep.
Introducing process based representations of soil C dynamics

Moisture

Moisture effect through C and enzyme diffusion:

\[ F_S = h_S \left( C^w_S - C^w_{S,0} \right) \]

\[ h_S(\theta) = \frac{vD_S(\theta)}{\delta^2} \]

\( \delta \) : characteristic distance between microbial cells and C substrate
That’s it

=============== SUCCESSFUL TERMINATION OF CPL7-CCSM ================
=============== at YMD,TOD = 10106 0 ================
=============== # simulated days (this run) = 5.000 ================
=============== compute time (hrs) = 0.001 ================