Prognostic Land Use and Land Cover Change for a Coupled Climate-Biogeochemistry Model

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Objective

Improve knowledge of controls on future greenhouse gas concentrations and climate-biosphere feedbacks… by introducing predictions of human land use and land-cover change within a global climate-biogeochemistry model.
Important – but challenging

• Land use and land-cover change is the second-most important human source of CO$_2$ emissions (behind fossil fuel burning).
• Large uncertainty for historical emissions from land cover change (6%-40% of total radiative forcing from CO$_2$).
• Leads to large uncertainty in empirical estimates of land carbon sink.
Overview of coupling strategy
Prognostic biogeochemistry (CLM-CN)

Carbon cycle

Atm CO₂

photosynthesis

Plant

Internal (fast)

External (slow)

Nitrogen cycle

denitrification

N deposition

Soil Mineral N

assimilation

mineralization

N fixation

N leaching

respiration

litterfall & mortality

decomposition

Soil Organic Matter

Endogenous coupling

Exogenous coupling

Natural veg

Managed forest

Crop

Pasture

(wood harvesting)

Prognostic land allocation (IMAGE)
Project Summary

• Add prognostic land use / land cover change algorithms to CLM4
• Explore the interactions of carbon, water, nutrient, and energy components of the climate system with natural and anthropogenic changes in land cover and land use.
• Pragmatic step toward representing human dimensions in an Earth System Model.
Science Questions:

1. How do changes in land use and land cover influence feedbacks between the terrestrial biosphere and the global coupled climate system?

2. How sensitive are modeled climate-carbon cycle feedbacks to on-line vs. off-line representations of land use and land cover change?
Rationale (Why CLM and IMAGE?)

- Individual models are well-regarded in their respective communities.
- Complementary logical structures.
- Easily identified coupling points.
- Technical coupling issues are manageable in a two-year project.
- Enthusiastic collaboration.
Community Land Model with coupled Carbon and Nitrogen cycles (CLM-CN)

- Fully prognostic carbon and nitrogen cycles.
- Influence of land cover change on carbon, water, and energy budgets.
- Detailed treatment of natural vegetation types.
Integrated Model to Assess the Global Environment (IMAGE v2.4)

- Dynamic land allocation algorithm
- Detailed treatment of managed land types
- Crops (7), pasture (2), carbon plantations, bioenergy crops
- External nitrogen cycle
- 0.5 degree grid
Coupling Strategy

(a) IMAGE v2.4
- C-cycle
- External N-cycle
- Dynamic human land use
- Crop model
- C-plantations, bioenergy crops

CLM-CN v4.0
- C-cycle
- Internal N-cycle
- Dynamic natural veg (DGVM)
- Crop model
- Prognostic fire

(b) CLM-CN/IMAGE
- C-cycle
- External/internal N-cycle
- Dynamic human land use
- Crop model
- C-plantations, bioenergy crops
- Prognostic fire

(from IMAGE v2.4) (merged) (from CLM-CN v4.0)
Model Development Tasks

1. Bring new plant functional types into CLM-CN (crops, C-plantations, bioenergy crops).
2. Integrate internal N-cycle (CLM-CN) with external N-cycle (IMAGE).
3. Insert IMAGE land allocation as optional switch replacing current dataset drivers in CLM-CN.
4. Integration of historical datasets with expanded CLM-CN vegetation types from Task 1.
Simulation Experiments

• Phase 1: Historical (1500-2000) simulations driven by observed and modeled land use change datasets.
• Phase 2: Future scenario (2000-2100) driven by off-line IMAGE land use change dataset.
• Phase 3: Future scenario (2000-2100) driven by endogenously coupled IMAGE land use change algorithm.
Proposed work…

• Apply the same coupling strategy to another IAM
  – MiniCAM, Proposed collaboration with PNNL / JGCRI (Edmunds, Smith).

• Integrate operational forest management tools into CLM diagnostics and eventually CLM representation of stand dynamics
  – Forest Vegetation Simulator (FVS). Proposed collaboration with Forest Service (Moscow, ID).