Socioecological Carbon Production in Managed Agricultural-Forest Landscapes

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Challenges, Questions, Objectives & Hypothesis

Land use, land cover changes, and ecosystem-specific management practices are recognized for their roles in mediating the climatic effects on ecosystem structure and function, (e.g., C cycle). A **major challenge** is to understand and forecast ecosystem C fluxes, we cannot rely solely on conventional biophysical regulations from the local ecosystem to the global scale. A **second challenge** is to quantify the magnitude of the C fluxes from managed ecosystems/landscapes over the lifetime of the C cycle, and to deduct the various energy inputs during management. **Our objective** is to quantify the landscape-scale C footprint of both managed agricultural-forest landscapes and people (Fig. 1).

Questions:

- What are the quantitative contributions of land cover change, specific management practices, and climate changes (means and extremes) to the social and physical C fluxes of managed ecosystems and landscapes?
- What are the spatial and temporal changes of their contributions in managed agricultural-forest landscapes; and
- How will future land use changes (including alternative management practices) impact C sequestration in an upper, mid-latitude managed ecosystem?

Hypothesis: Social C flux is more responsible than physical C flux for the dynamics, and especially the uncertainty, of the cumulative CO_2^{eq} production of these intensively-managed landscapes. However, their proportions vary significantly among the landscapes and over history because of the great variations in land conversions, land use practices, climatic changes and extremes in the watershed.

Study Landscapes and Approaches

The Kalamazoo Watershed (5261 km^2) includes portions of 11 counties (Allegan, Ottawa, Van Buren, Kent, Barry, Kalamazoo, Calhoun, Eaton, Jackson, and Hillsdale) in SW Michigan. Currently, it is dominated by cultivated crops (32.9%), deciduous forest (20.0%), pasture-hay prairies (15.1%), lakes and wooded wetlands (14.7%), and urban areas (6.8%) (Fig. 2).

The mechanisms from both human activities and biophysical changes on ecosystem C dynamics at different temporal and spatial scales will be explored by modeling total net ecosystem C production (*physical and social C fluxes*), exploring the relationships through Bayesian structural equation modeling (SEM), and performing a spatially-explicit life cycle assessment (LCA) on the total C production. Remote sensing technology, available geospatial data, records of management practices, survey of historical practices, a land surface model (CLM), *in situ* measurements of C fluxes will be used.

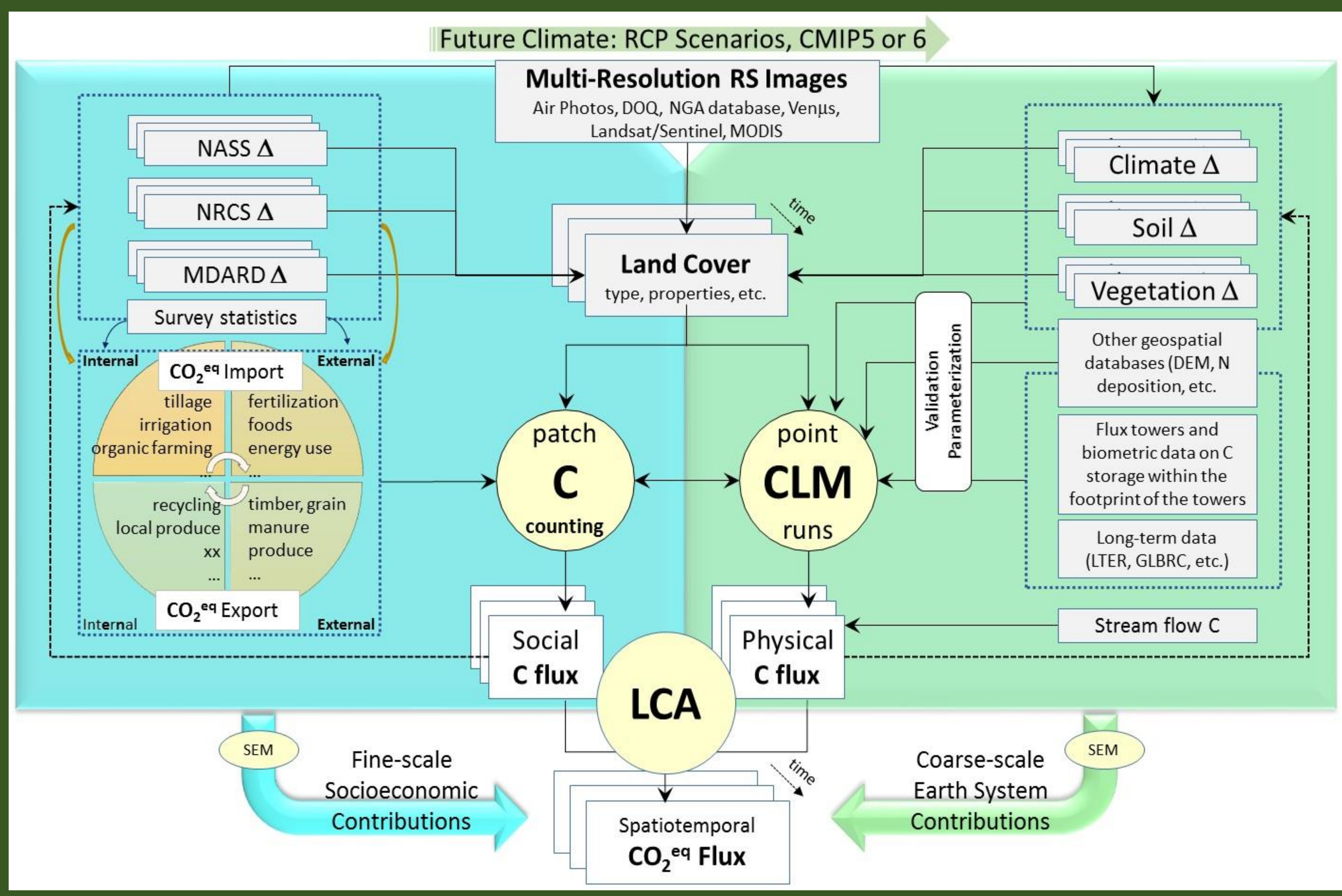


Fig. 1. Research components and their linkages for process-based predictions of the spatiotemporal changes in CO_2^{eq} production that will be quantified by estimating "social C flux", and "physical C flux" at contrasting landscapes (Fig. 2) within the Kalamazoo Watershed.

Research Tasks

We will take a bottom-up approach to quantify landscape C fluxes and a top-down scaling effort to characterize the contributions of climatic change, land use, and site-specific management practices at two spatial scales: Midwest, USA landscapes with contrasting structure and composition and the entire Kalamazoo Watershed (Fig. 2).

Three specific tasks to be performed are:
Task 1: Model the long term dynamics of the physical C fluxes of the watershed and landscapes;
Task 2: Estimate the social C fluxes for the same time period; and
Task 3: Diagnose the effects that mechanisms from land use, land cover changes, management practices, climatic change, and climatic extremes have on total CO_2^{eq} fluxes at the two spatial and temporal scales (40-year and 80-year) through LCA. Physical C will be quantified through a CLM after ecosystem-specific parameterization and independent validation.

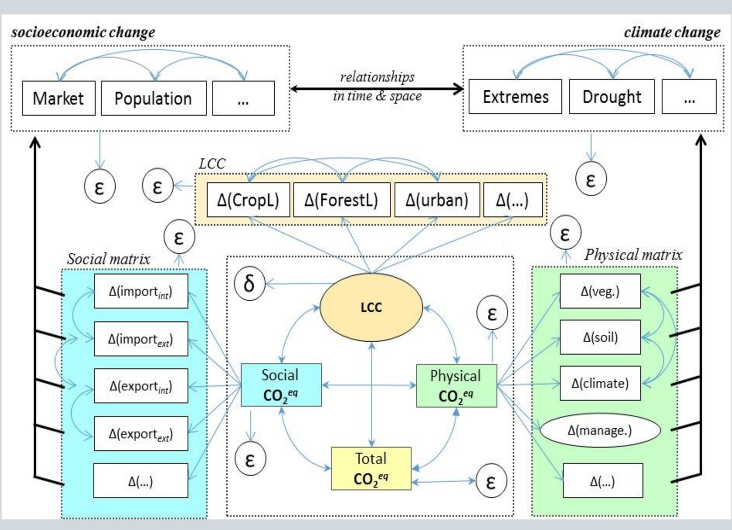


Fig. 3. Proposed comprehensive Bayesian structural equation modeling (B-SEM) translated from our conceptual framework (Fig. 1). This structure will be modified for a regrowth SEM, representing the 80-year and 40-year time series, respectively, at the two scales. The "error" or "disturbance" terms are not presented, but illustrated as ε and δ as an example in the circles, respectively. This B-SEM will be applied for each of the four landscapes, and the entire watershed.

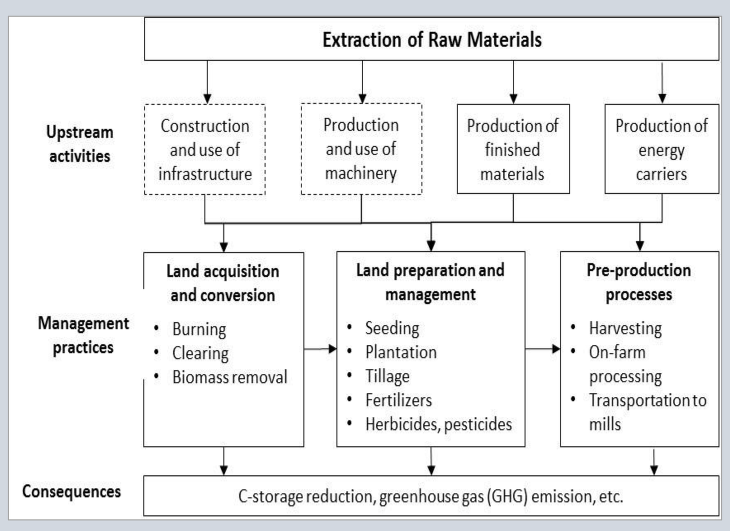


Fig. 4. Proposed system boundary for our LCA, both upstream activities and management practices will be included in the calculation. LCA will be used to calculate the CO_2^{eq} flux across time and over space by considering management practices (e.g., land conversion, tillage, etc.) and industrial activities (e.g. production of fertilization, pesticides, and herbicides). The dynamics during the two stages of LCA—the life cycle inventory (LCI) and the life cycle impact assessment (LCIA)—will be realized.

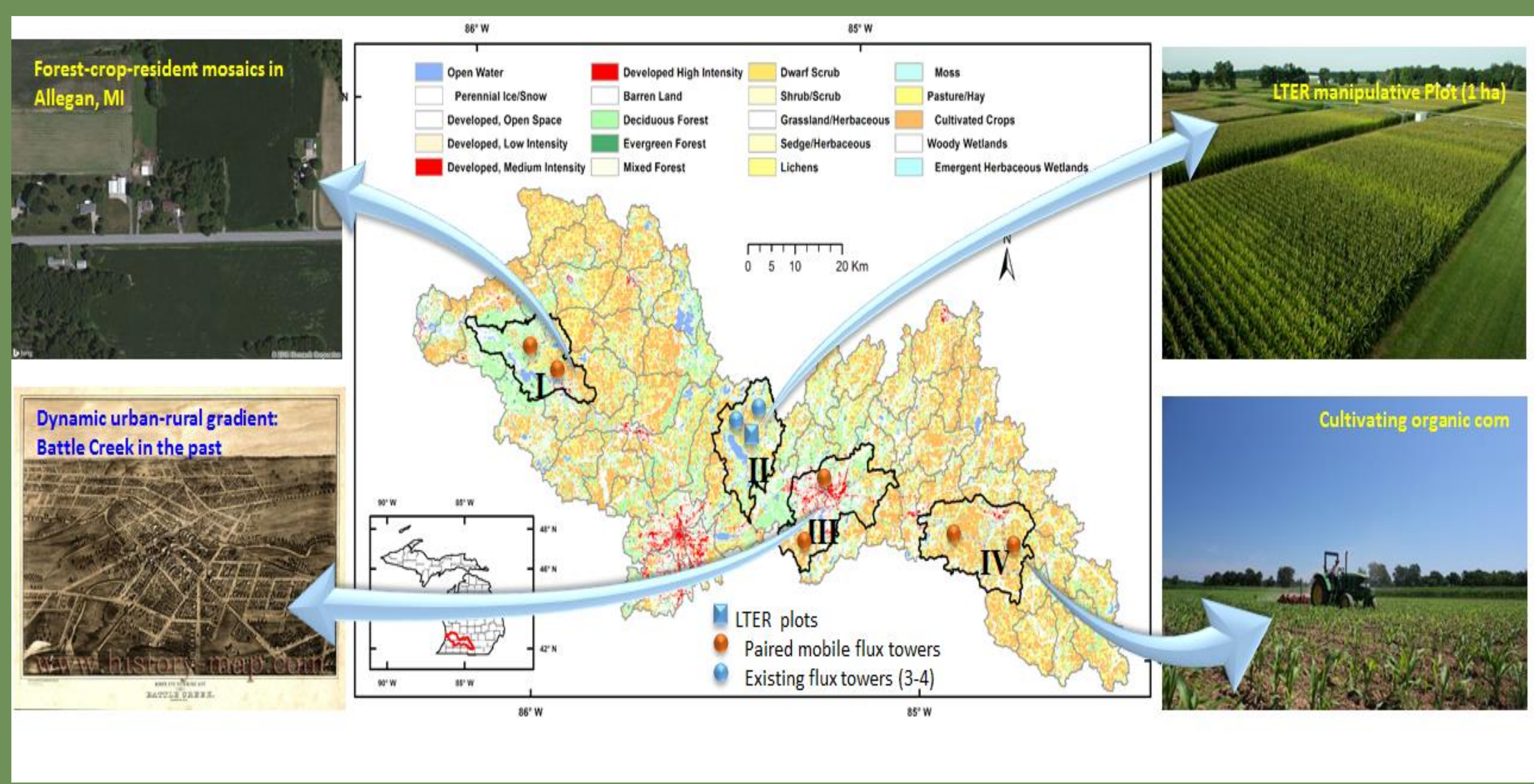
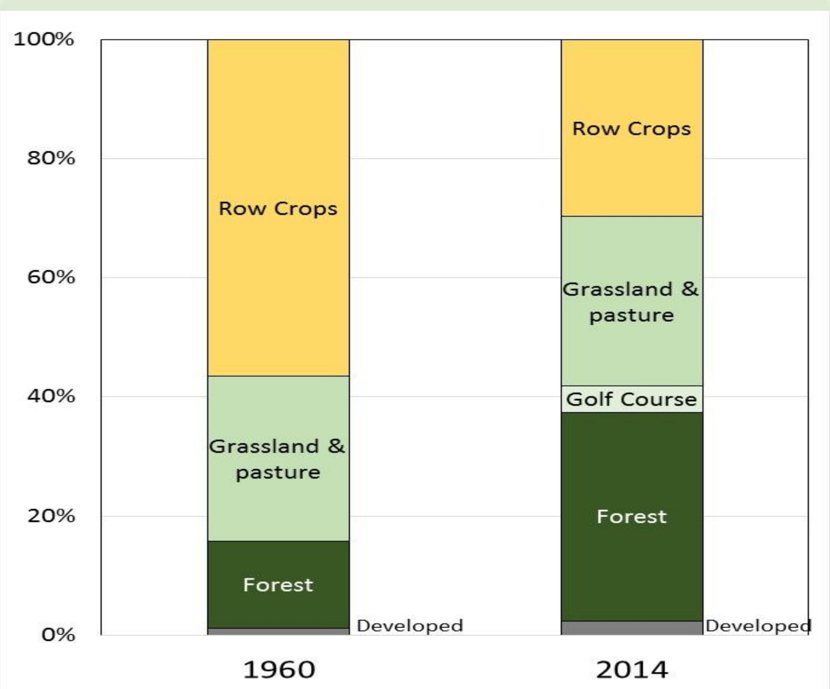
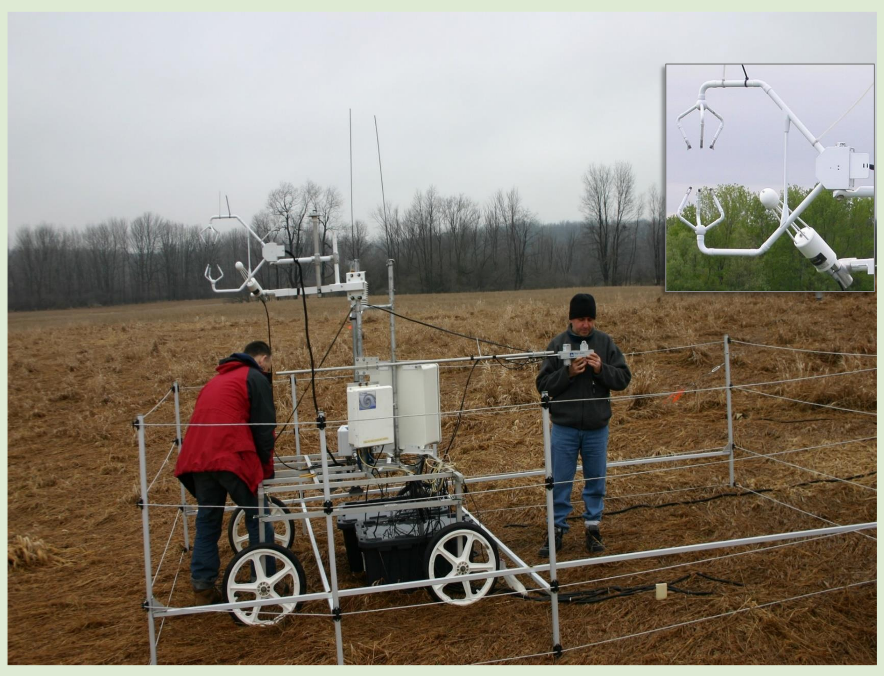


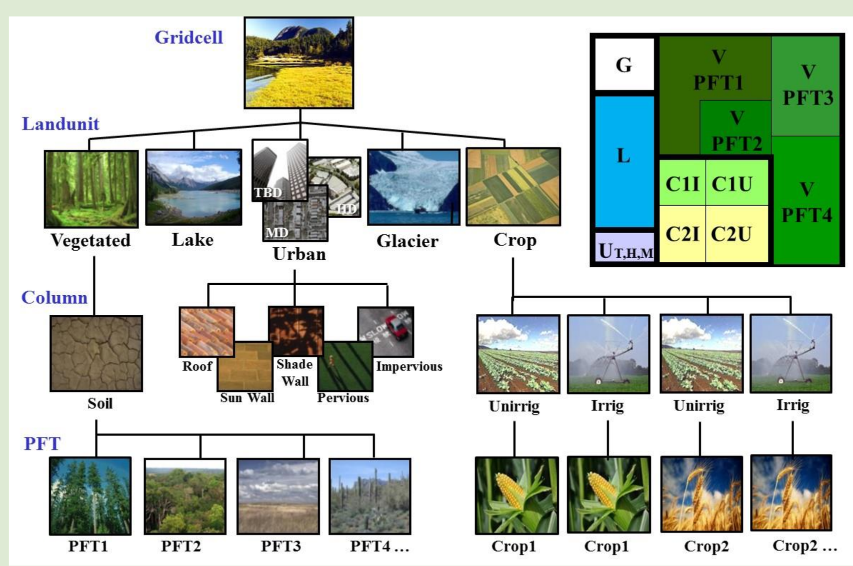
Fig. 2. Current land cover of the Kalamazoo Watershed (NLCD), which includes 127 sub-watersheds (USGS). The watershed will be examined for the changes of CO_2^{eq} during a 40-year period (1978–2018) using Landsat/Sentinel, with climate and human activities following our working framework (Fig. 1). Four contrasting landscapes will be quantified with high-resolution RS data, historical records, and survey statistics over an 80-year period (1938–2018).



Land cover change in the Augusta Creek watershed. Estimates are based on aerial photos and the Cropland Data Layer) (Hamilton *et al.*).



Permanent/mobile flux towers, chambers, and biometric sampling will be conducted for direct measurements of C fluxes.



CLM sub-gridcell structure will include pasture Landunit (in dashed line box), as will be the case in CLMv.5. In a PTCLM run, a "gridcell' is a point location with any spatial extent. Fractional cover is divided into Landunits, and soil properties are shared among natural PFTs and pasture, while croplands have a separate soil column.

Project Webpage http://lees.geo.msu.edu/research/NASA_carboncycle/