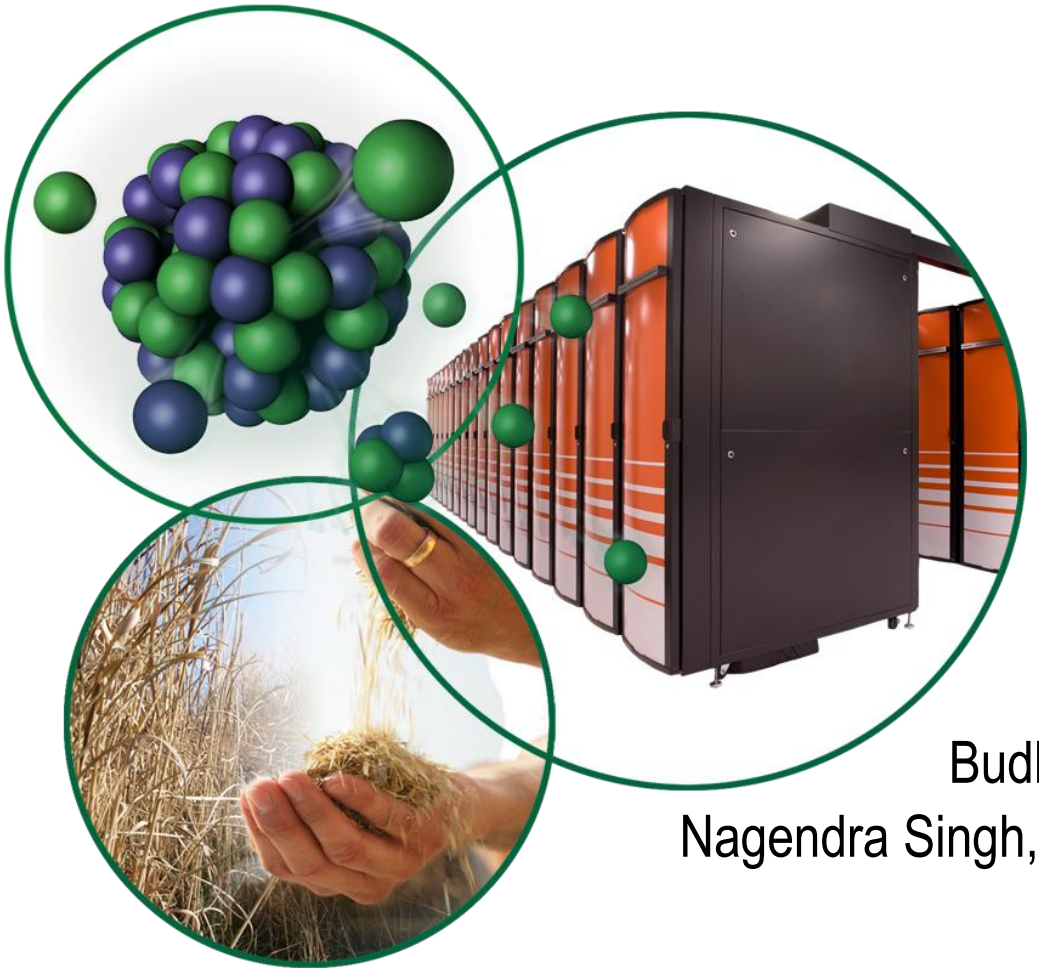
Project Review
Land Use Change Modeling Framework



April 4 2011
Analysis Platform Review

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Goal

Provide a development plan for a quantitative and spatially explicit land-use change modeling framework by scoping the data and design requirements assessing potential impact of US biofuel policies on land use from local to global scales

Background and Objective

Background

- Current land use land cover data and modeling approaches
  - Contain large uncertainties, fail to adequately incorporate the drivers of land use, and must be improved if they are to be applied for policy-making decisions

Objective

- The proposed modeling framework incorporating causal factors will provide
  - A systematic approach to quantify land use changes due to new bioenergy policy in a quantitative spatially explicit manner
  - Allow data driven validation of model predictions

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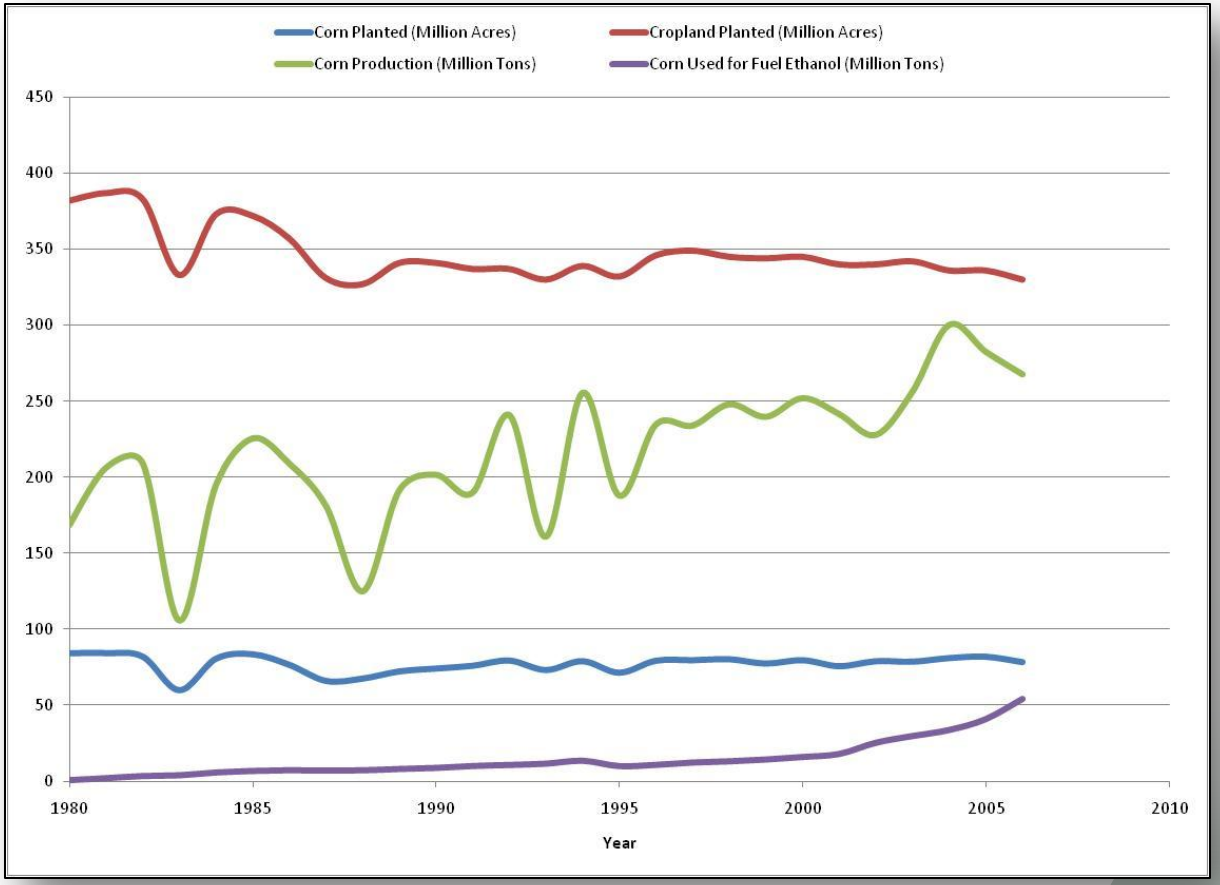
Aggregated statistical data are inconclusive for assessing LULC change

- Aggregated data (from county to national scales) do not provide a correlation between an increase in one land use category to a decrease in another land use category
- Land availability and corresponding crop production can be misleading because of
  - Geographic dispersed and fragmented land negatively impacts pragmatism and feasibility of production
  - (National) statistics lack realism



Project Overview

- Energy Independence and Security Act (EISA) 2007 mandates increase in biofuel production to 36 billion gallons by 2022, starting from 9 billion gallons in 2008
- Increasing demand for bioenergy crops can be met by (Kloverpris, 2008)
  - **Intensification:** Increasing yield from existing agricultural land
  - **Displacement**: Shifting existing agricultural land (displace other crops)
  - **Expansion**: Converting other non-agricultural land (pasture, forest, marginal, degraded, abandoned etc.)
- Land use change may involve one or a combination of displacement and expansion
- Availability of earth observation data with high spatial and temporal resolution should provide an effective way to observe, measure, and model land transitions and understand plausible correlation with biofuel policies

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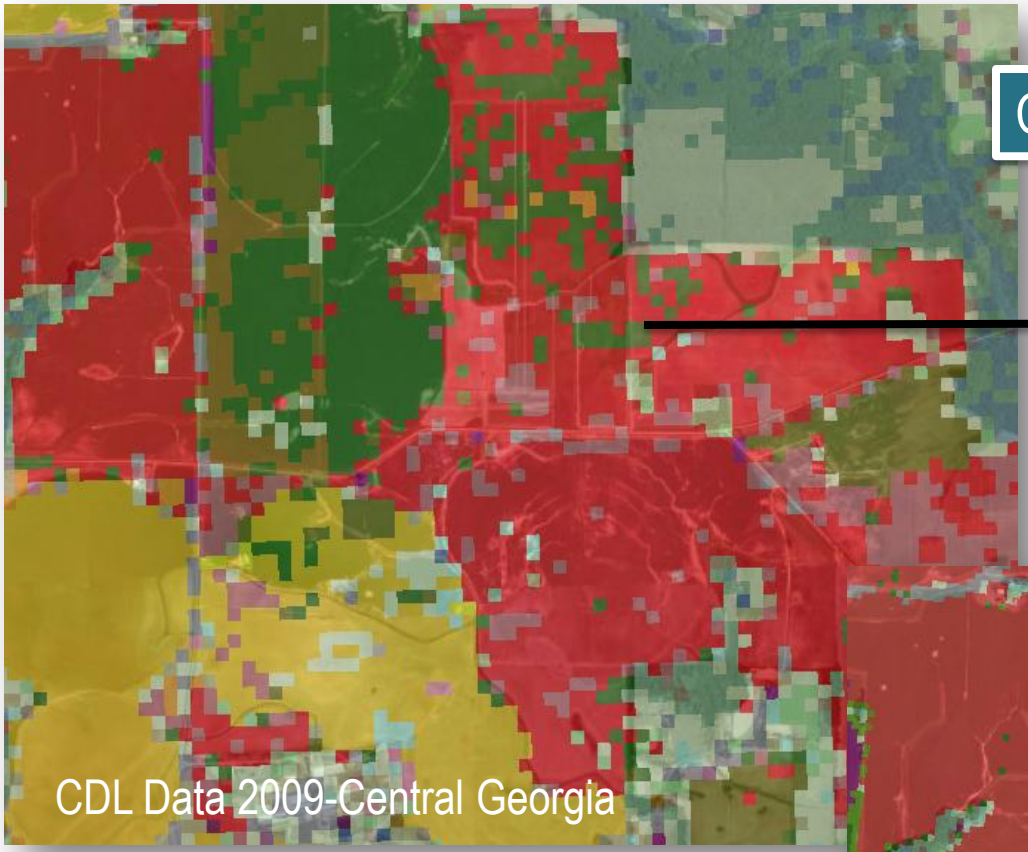
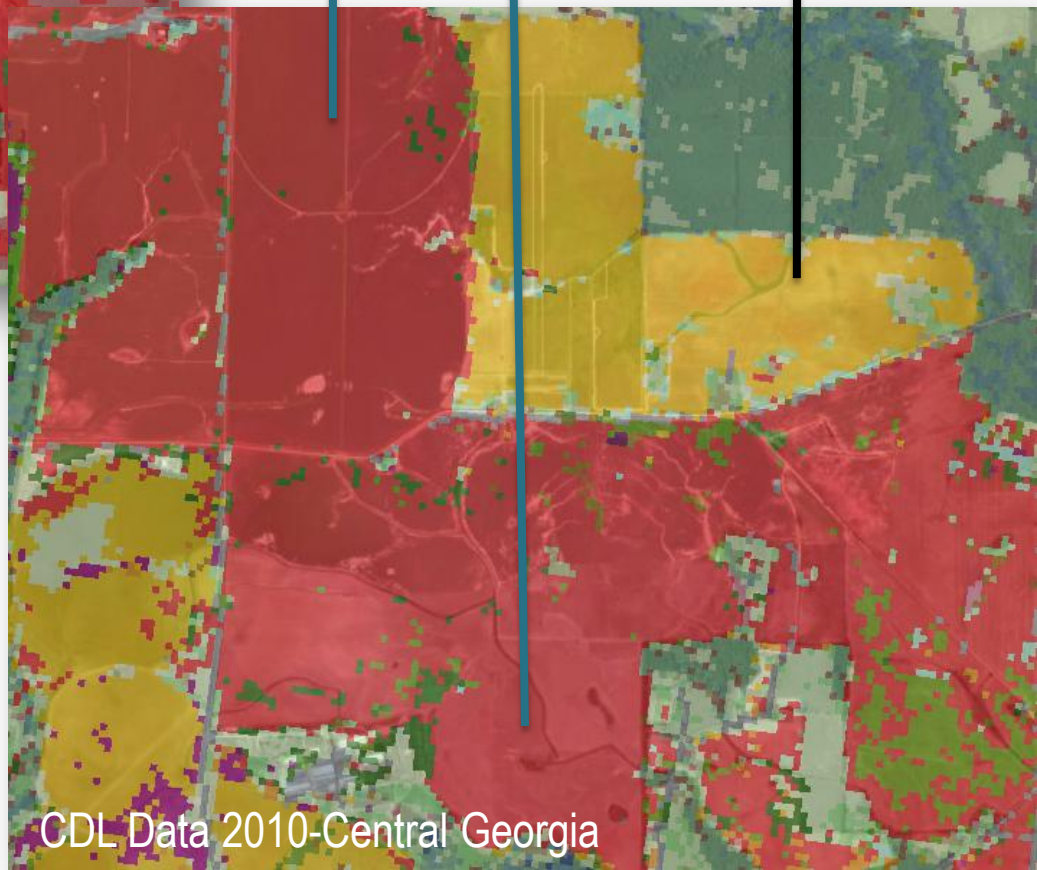


Cotton Replacing SOY & Corn

Corn Replacing Cotton



Land displacement is complex and depends on a variety of socio-economic factors

Did higher cotton prices in 2010 drive these changes?

Misaligned models and data sets

- Most datasets (GLC 2000, Ramakutty, FAOSTAT, CDL etc.) used in models and literature were assessed and analyzed for their suitability to estimate land use change due to biofuels.
- Problems arise not due to the inherent inaccuracy in the datasets but the way these data are used.
  - Subjective interpretation of land use categories
  - Inconsistent definitions of certain land use categories
- Large uncertainties are introduced in datasets by spatial aggregation, interpolation and merging classes which are used to prepare the data so it can be used in models and tools
- Land use change models are often developed independent of data
  - Mismatch between the theoretical framework of a model and available land use land cover data

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Technical Accomplishments

- Developed conceptual and functional designs of the modeling architecture, describing the key modeling components and their functional relationships.

- Assessed the gaps and uncertainties in available data and tools.

- Developed a draft framework for causal analysis of land-use change

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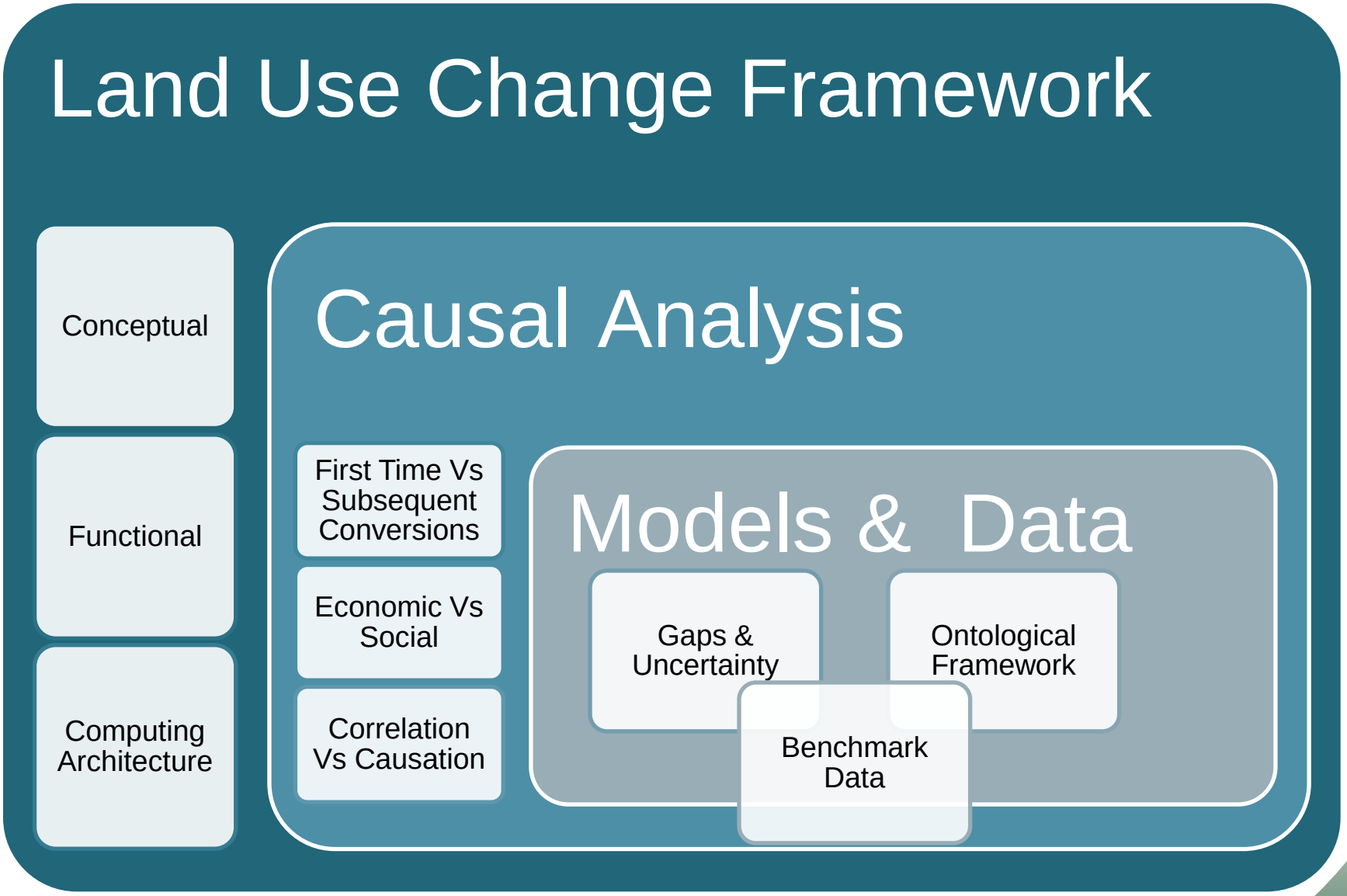
Approach



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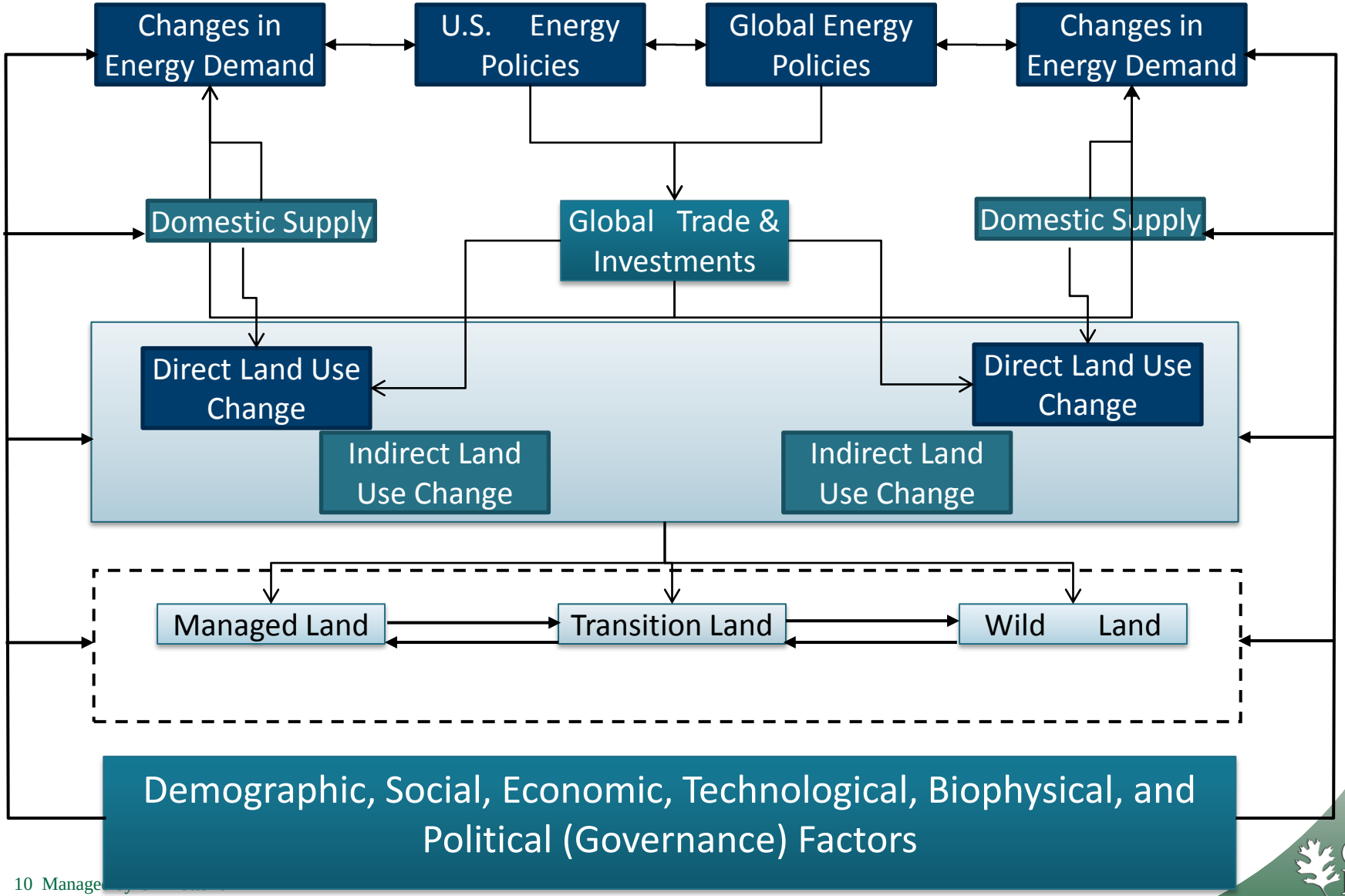
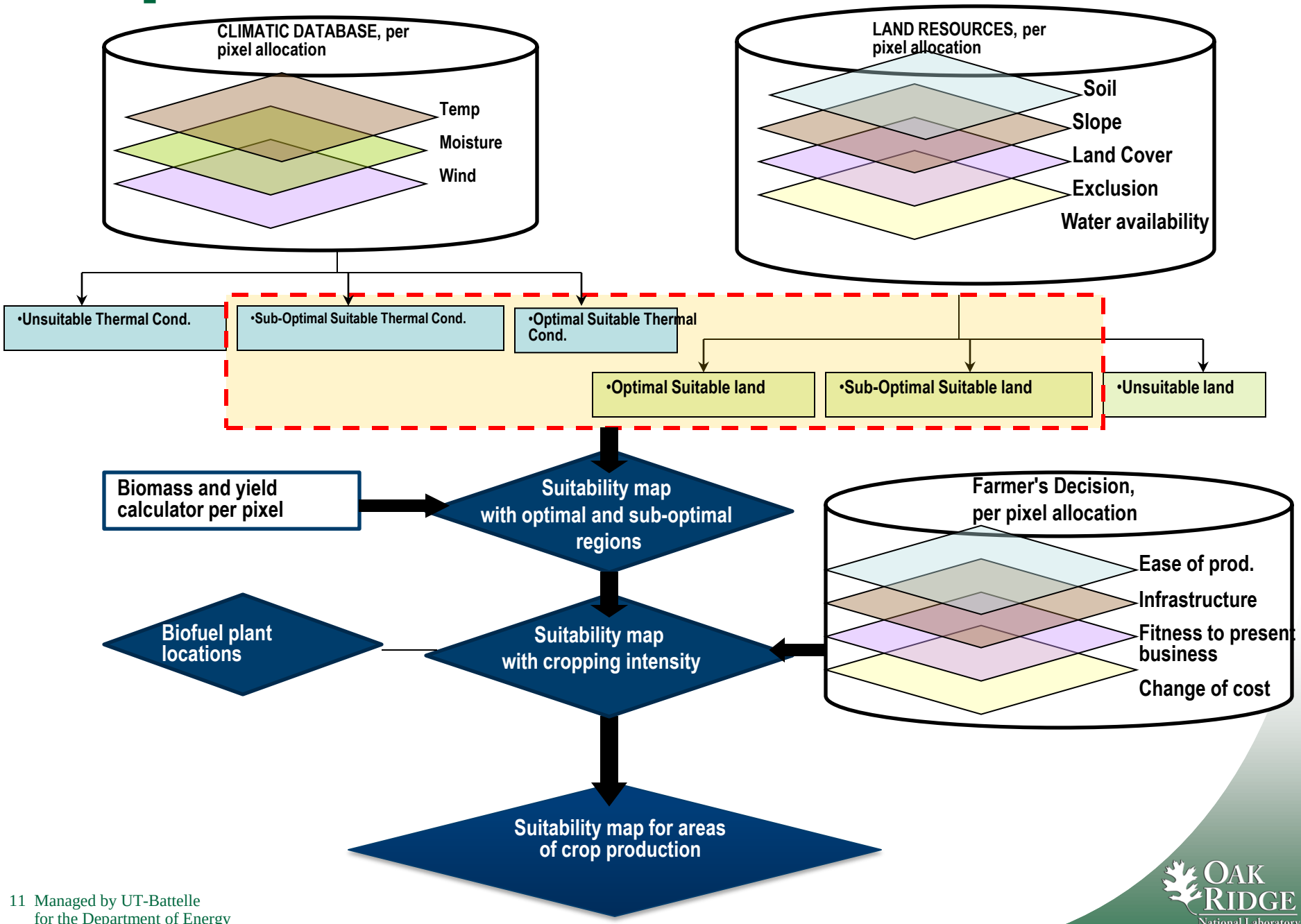
Conceptual Framework



Computational Framework



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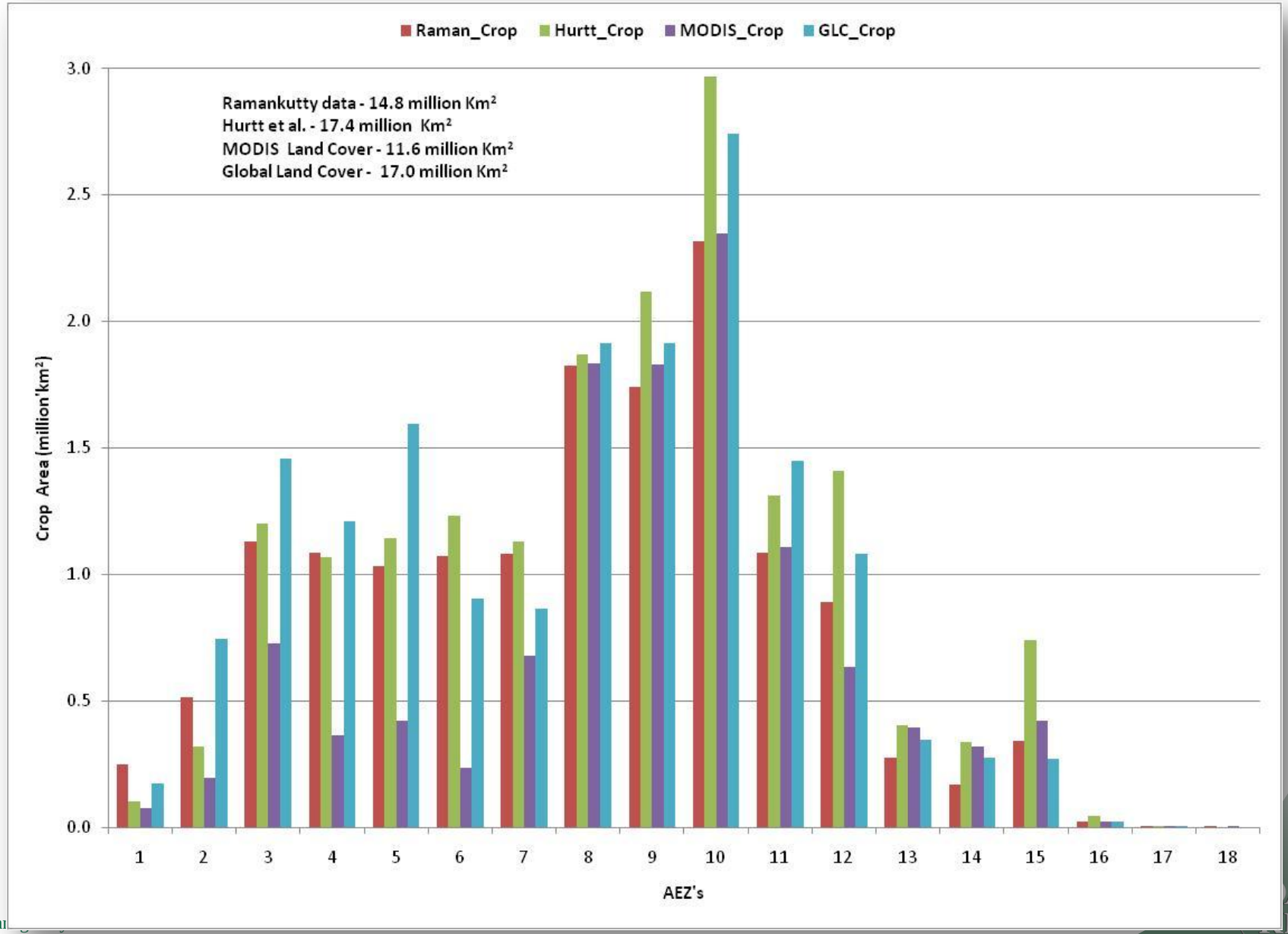
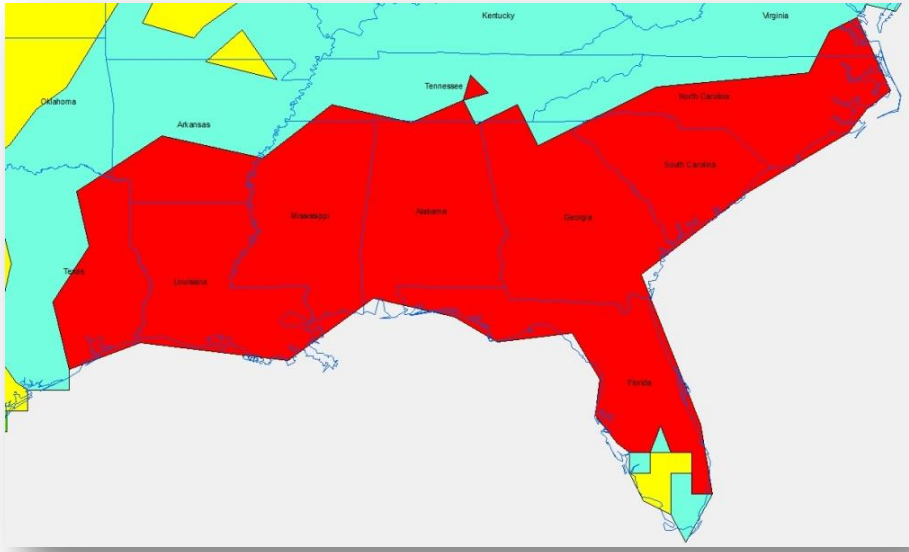
Uncertainty from different datasets

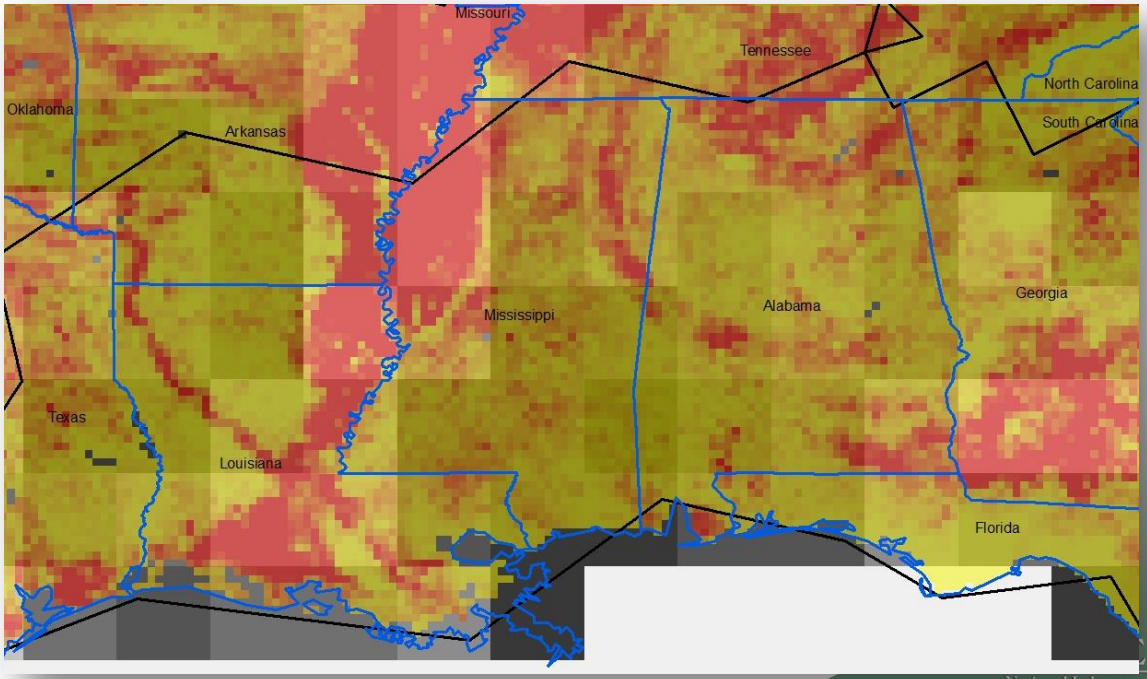


Uncertainty from disparate data resolution



Global agro-ecological zone (AEZs) boundaries used by the Global Trade Analysis Project (GTAP). These 18 zones are based upon length of growing period (LGP) and climatic zone. Areas marked in red are all included in AEZ 12 due to a temperate climate and a humid, year round growing season with LGP > 300 days/year. Note that small triangular inclusions of a particular AEZ may show up within another AEZ as a result of converting a continuous grid to polygonal boundaries.

A portion of AEZ 12 in the USA (southern part of Texas and Louisiana), the black line is the AEZ boundary, black, white pixels are 1 degree pixels (resolution of Hurtt) while red and yellow are 5 min pixels (resolution of Ramankutty).



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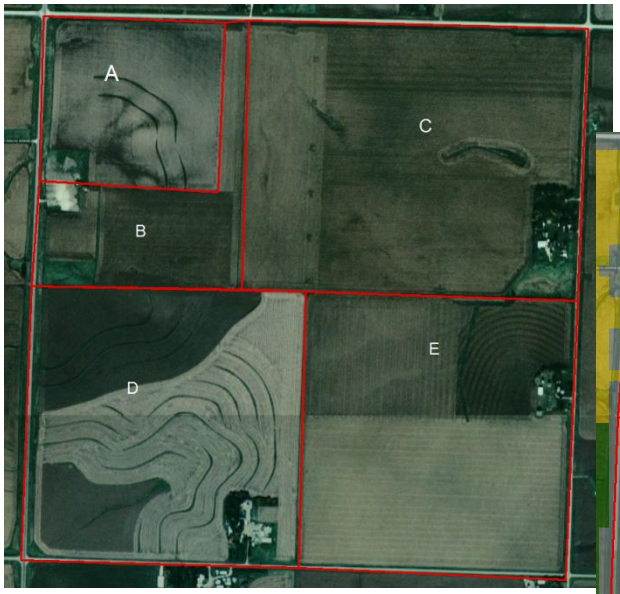
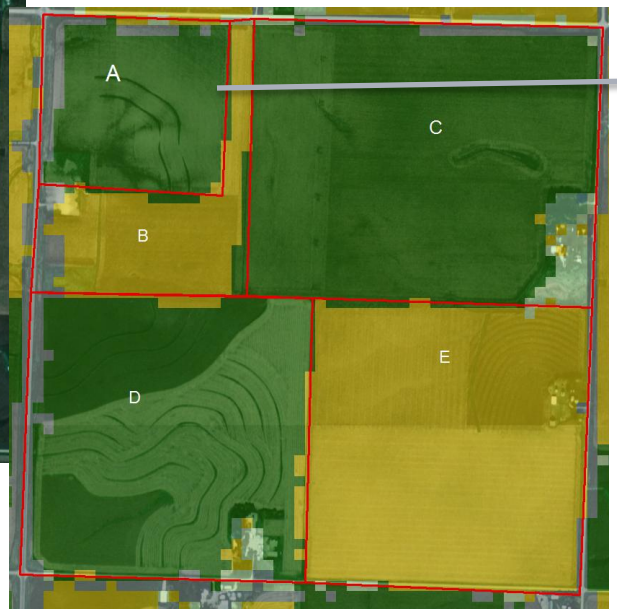
Pixel mathematics are often misleading



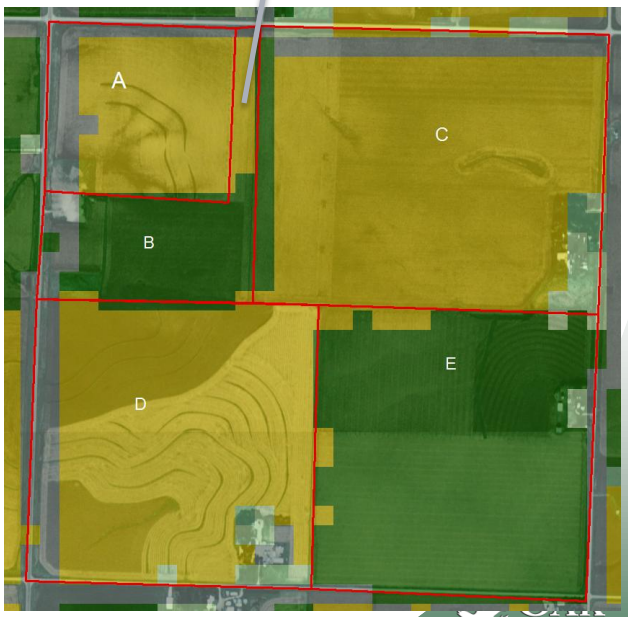
2010 Imagery (virtual earth)



2010 CDL

Per Pixel comparison and aggregation will show no crop rotation for some areas

2009 CDL



Example: Extent and importance of crop rotations are not captured using current methods

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Relevance

- There is considerable disagreement about how to estimate these implications, particularly how to quantify and qualify the Land-Use Change (LUC) that has occurred or is likely to occur in response to US biofuel policy
- This project addresses this need by designing an independent, integrated modeling architecture and methods to incorporate causal analysis to improve accuracy when assessing impacts of land-use change from US biofuel development.
- Debate of conversion of forest and native grassland into agricultural fields (as outlined in the MYPP) can only be accurately monitored by benchmark spatial data
- A spatially explicit land use change modeling framework with benchmark spatial land use dataset will
  - Improve understanding the GHG emissions associated with biofuels (Im-C)
  - Help estimate and understand land use change for environmental sustainability as outlined in the MYPP (FY12) and overcome barrier (ST-G)

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Benefits and Expected Outcome

- Incorporation of local/regional level detail and data will allow effective geographic scaling (regional to global analysis)
- Assessment and cross-comparison of remote sensing derived data will lead to community benchmark datasets at regional to continental scales that provide the most relevance for LULC change modeling in this context
- Availability of marginal, unused agricultural land can be accurately and consistently estimated by spatial data with required specification
- Ability to discern and allocate relative values of cause-and-effect among the different drivers of land-use change
- Ability to generate policy-based scenarios and sensitivity studies

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Summary

Reliable information on land - cover, use, productivity, soil qualities, C stocks, fluxes (C, nutrients), environmental services… - is essential

Misalignment between models and available data is a major hurdle for effective land use change assessment

- Evaluation of homogenized, averaged, and aggregated data at different scales
- Design theoretical and computational frameworks for land use change
- Characterization of global land cover data assets
- Develop operational linkages data and models that operate at different scales

Improved modeling requires better data and new community approach

- Community benchmark LULC data sets
- Causality data
- Values for measured stocks, flows, and services
- Increased temporal resolution of LULC data

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Future Work

- Develop approaches and alternative model structures for integrating multiple drivers with economic factors to better describe land-use change at different scales
- Develop hypotheses to test how observed drivers of land-use change respond to bioenergy policies and to estimate the effects of second generation feedstock production
- Testing, validation and sensitivity analysis of the proposed modeling framework.
- Develop benchmark dataset based on stakeholder input which can be used in future.
- Enhancement of the prototype modeling process to include, more variables and regions

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Additional Slides

Publications and Presentations

- Singh, N. & Bhaduri, B.L. 2009.*Suitability of Land Cover datasets for Feedstock Estimation.* Association of American Geographers (AAG) annual meeting, Las Vegas, NV.

- Singh,N. & Bhaduri B.L. 2010- *The Effect Of Biofuel on Land Cover Change Using Multi-Year MODIS Land Cover Data*. 2010 IEEE International Geoscience and Remote Sensing Symposium. Honolulu, Hawaii.

- Chaudhuri G, Bhaduri B.L., Singh N, & Clark K. 2011 *Expanding Bioenergy and Land Use Change: A Spatially Explicit Modeling Approach,* Association of American Geographers (AAG) annual meeting, Seattle, WA.

- Singh, N. & Bhaduri , B.L. - Cropland Change and Biofuels - Insights from Multiple Data Sources (manuscript under preparation)

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