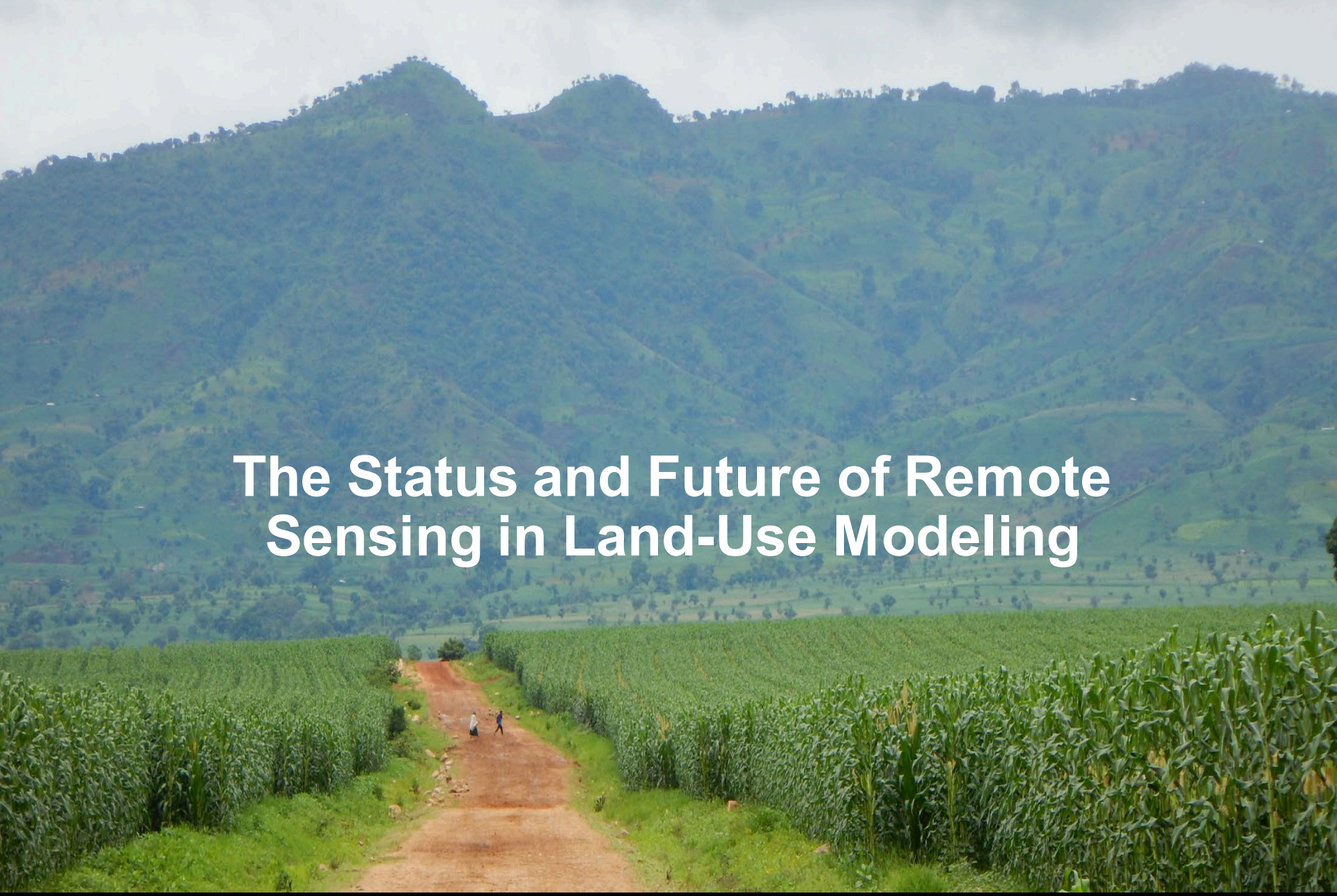


The Status and Future of Remote Sensing in Land-Use Modeling

Dan Brown
School of Environmental and Forest Sciences, University of Washington

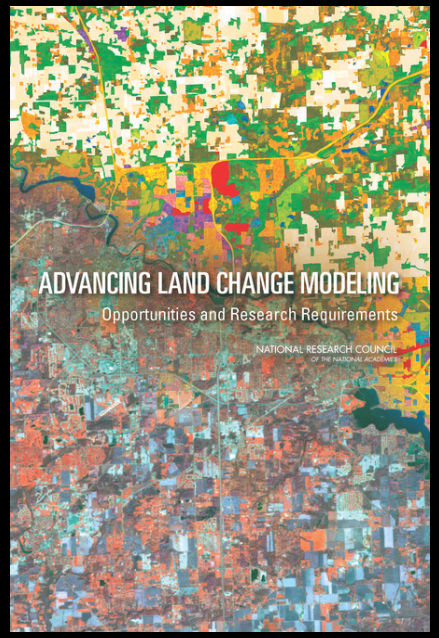
Modeling Approaches

Five overlapping approaches and hybrids were identified to evaluate their analytical capabilities and science and policy applications

- Machine learning & Statistical
- Cellular
- Economic
  - Sector-based
  - Spatially disaggregated
- Agent-based

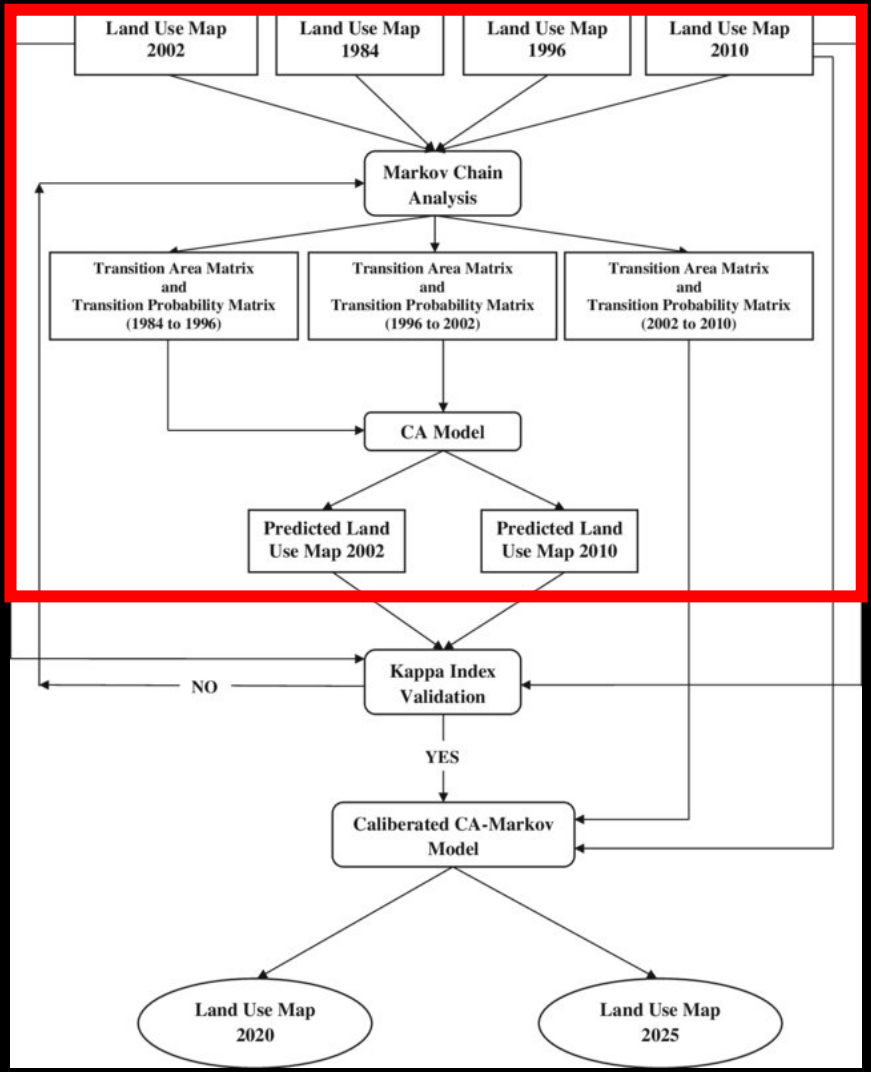
Land Cover

Land Use

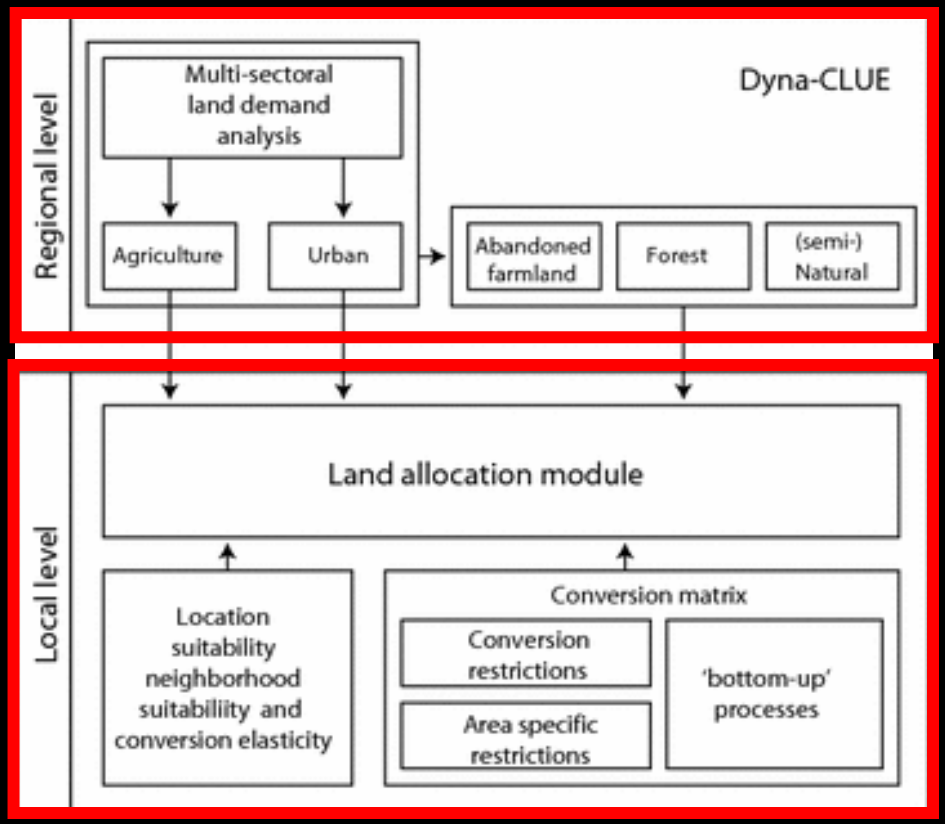


NRC, 2013

Cellular Models



Al-sharif and Pradhan, 2014. *Arab. J. Geosci*.

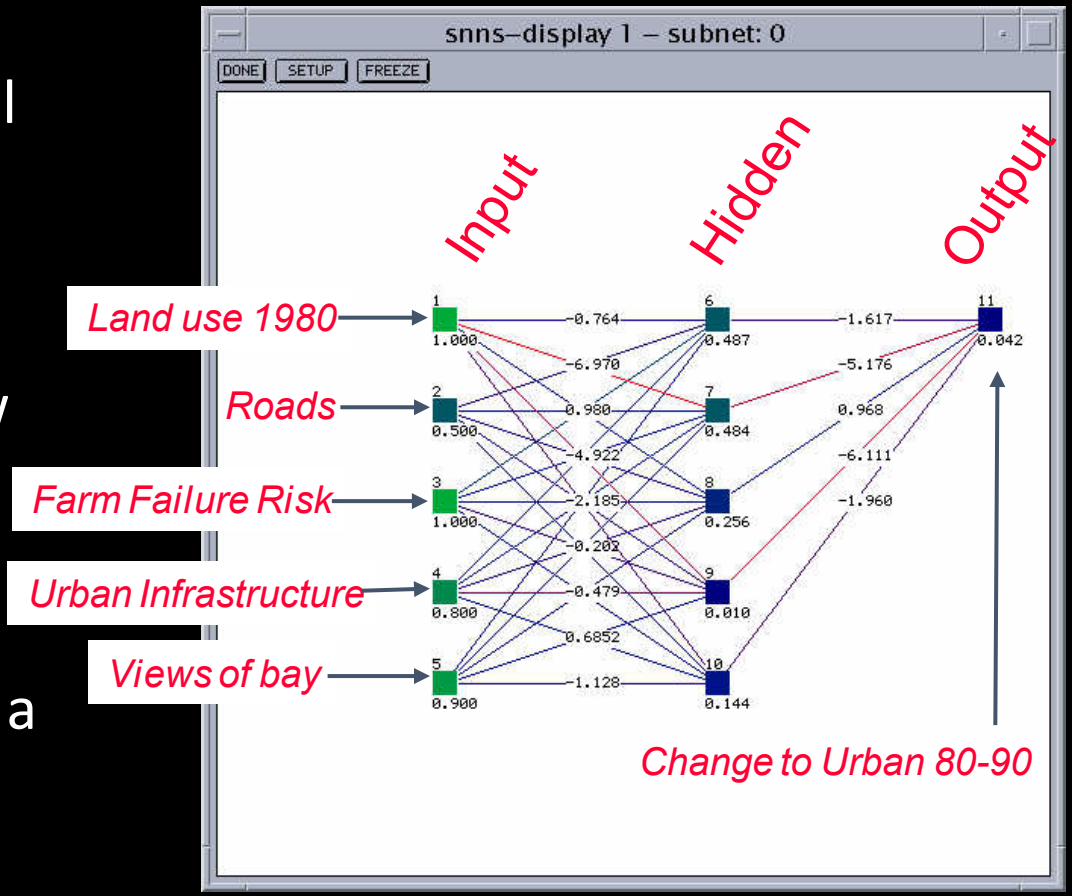


Verburg and Overmars, 2009. *Landscape Ecol*.

THROWBACK SLIDE FROM LCLUC 2000

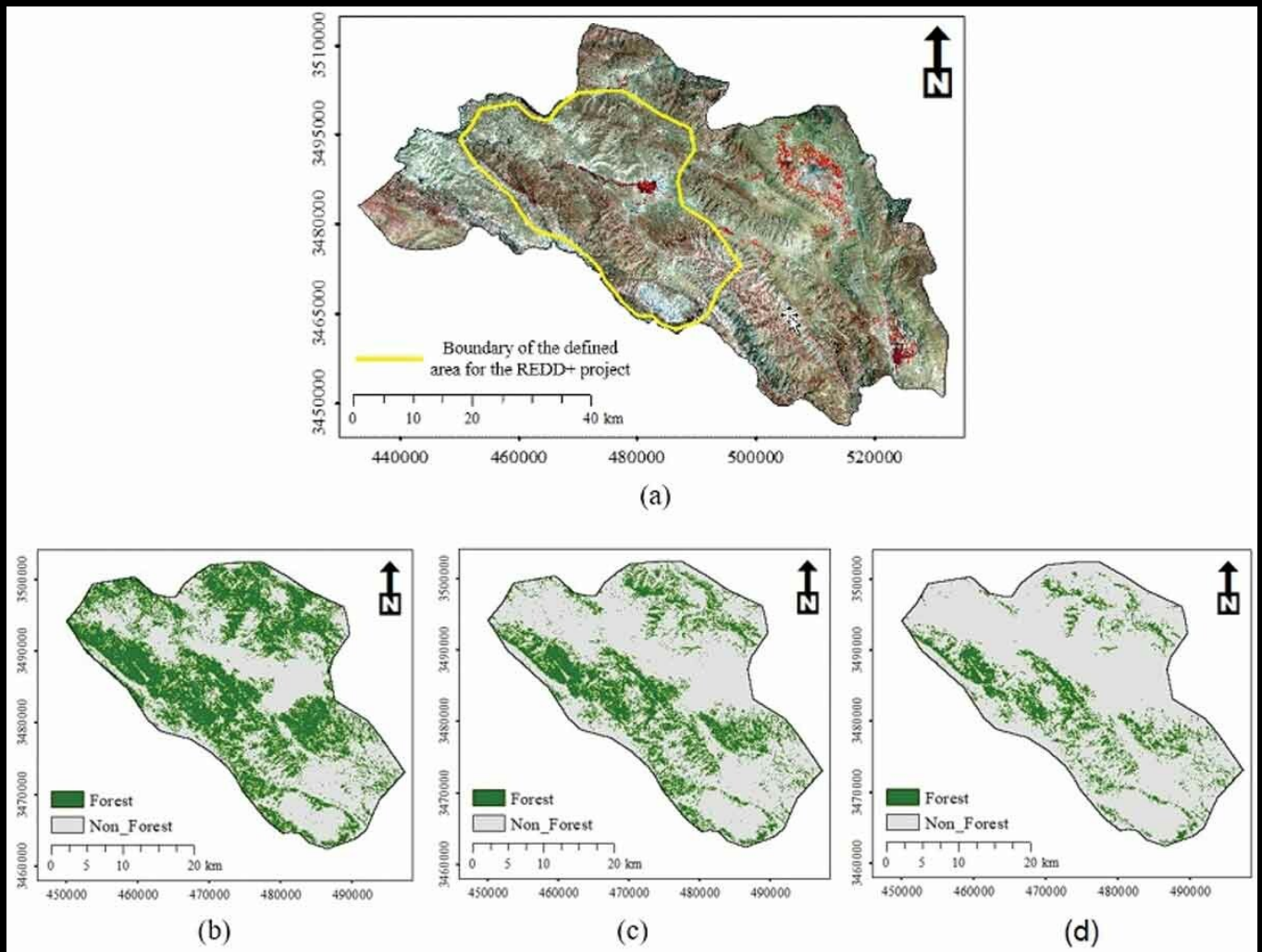
Artificial Neural Net (ANN) Modeling

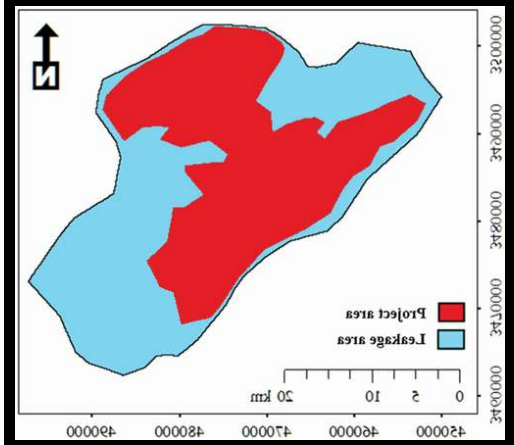
- Use ANN to learn how factors influenced spatial pattern of historical land use change
- Software link written between LTM in ArcView and SNNS neural net software.
- Drivers are inputs, predicting probability of a particular land use change.

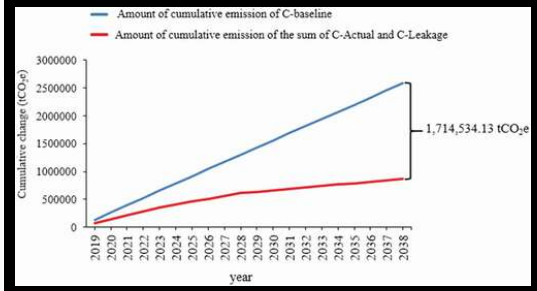


Cellular Counterfactuals and Baselines

- VCS Standard includes model-based baselines

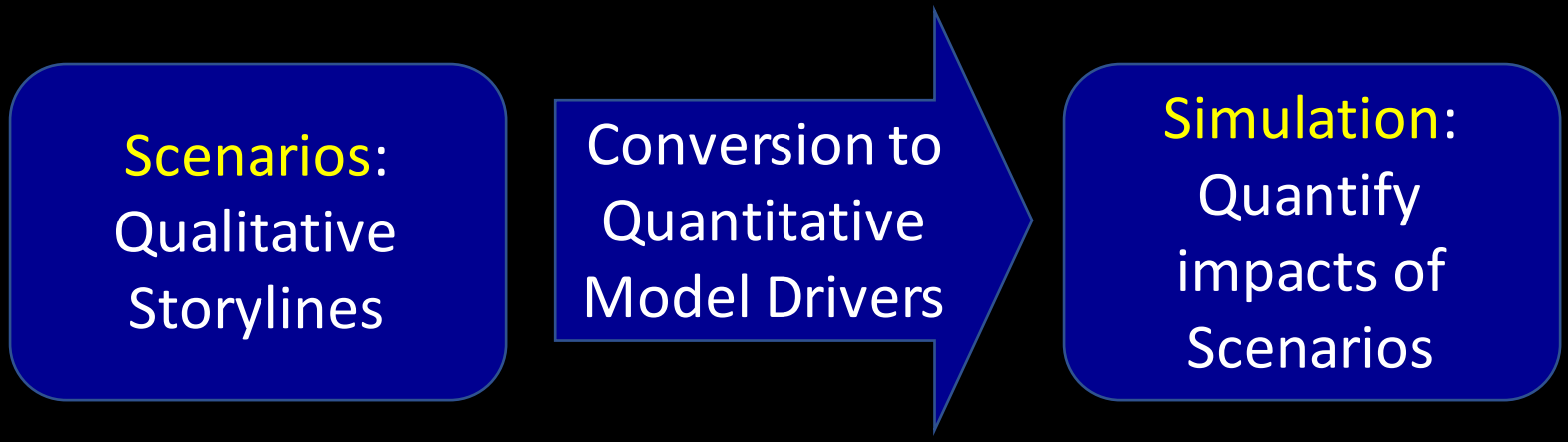






Delpasand et al. 2022.
J. Sust. Forestry

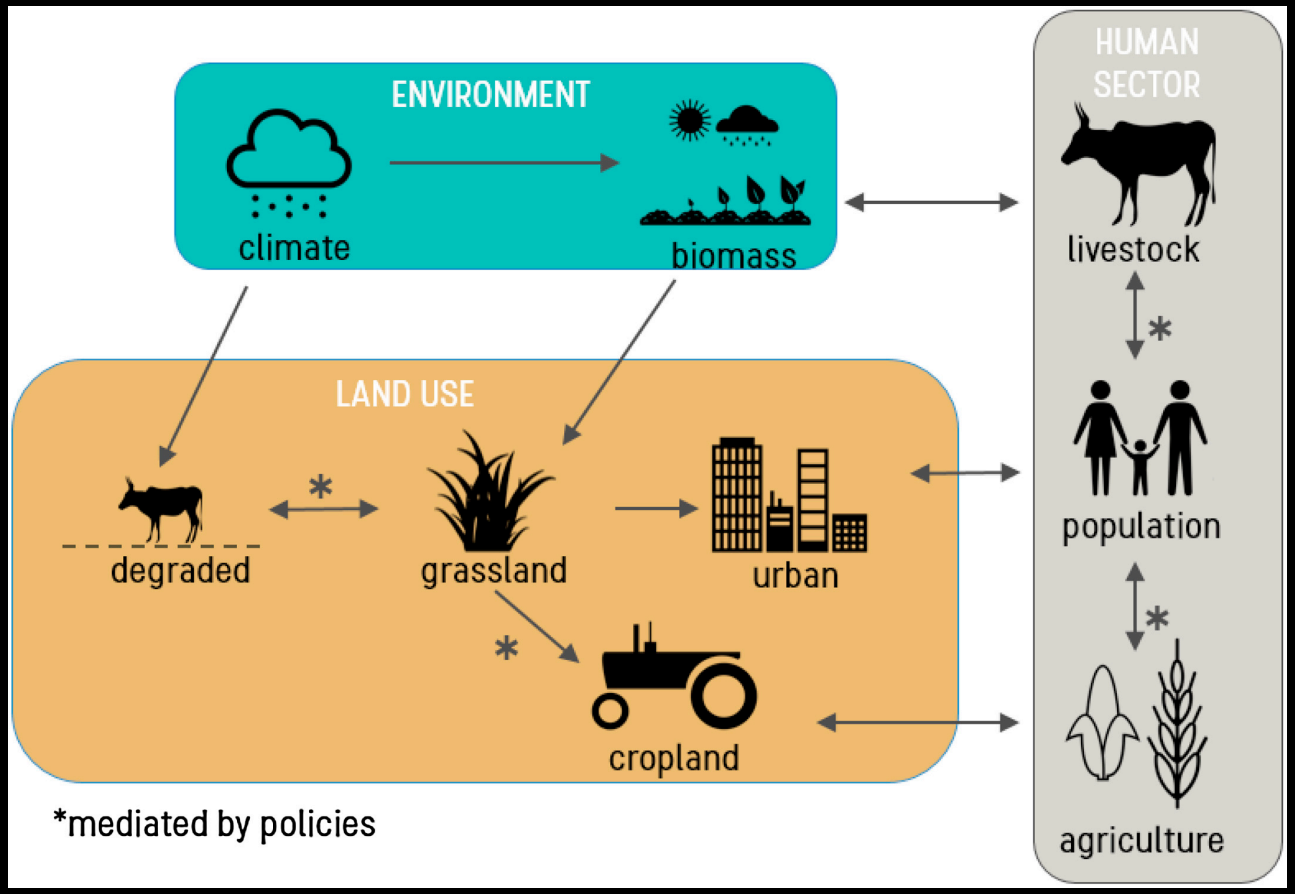
Scenario and Simulation

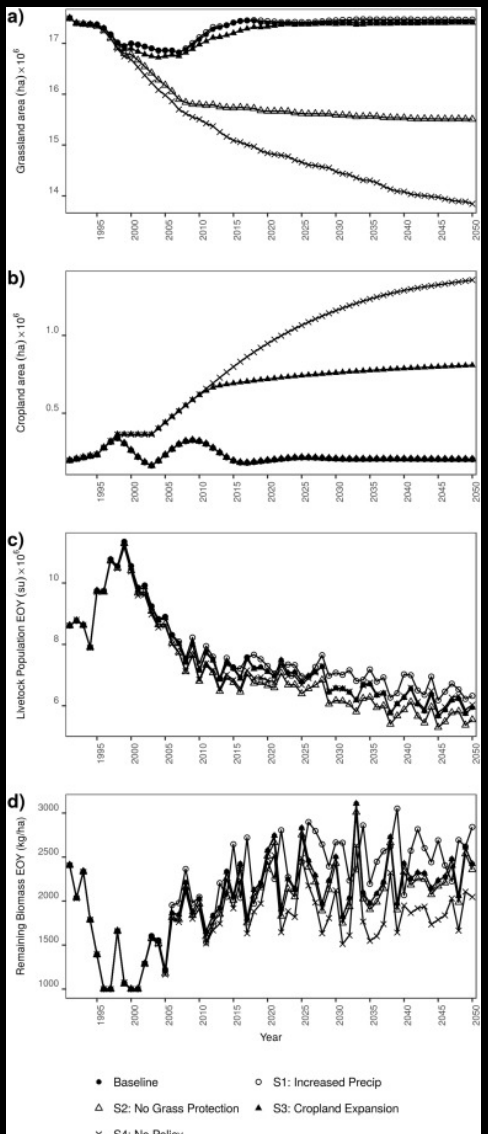


- Based on “Story and Simulation” approach (Alcamo 2008)
- Scenarios provide qualitative description of plausible futures.
- Models are used to simulate quantitative outcomes based on the qualitative scenarios.

Mongolia Grassland Scenarios

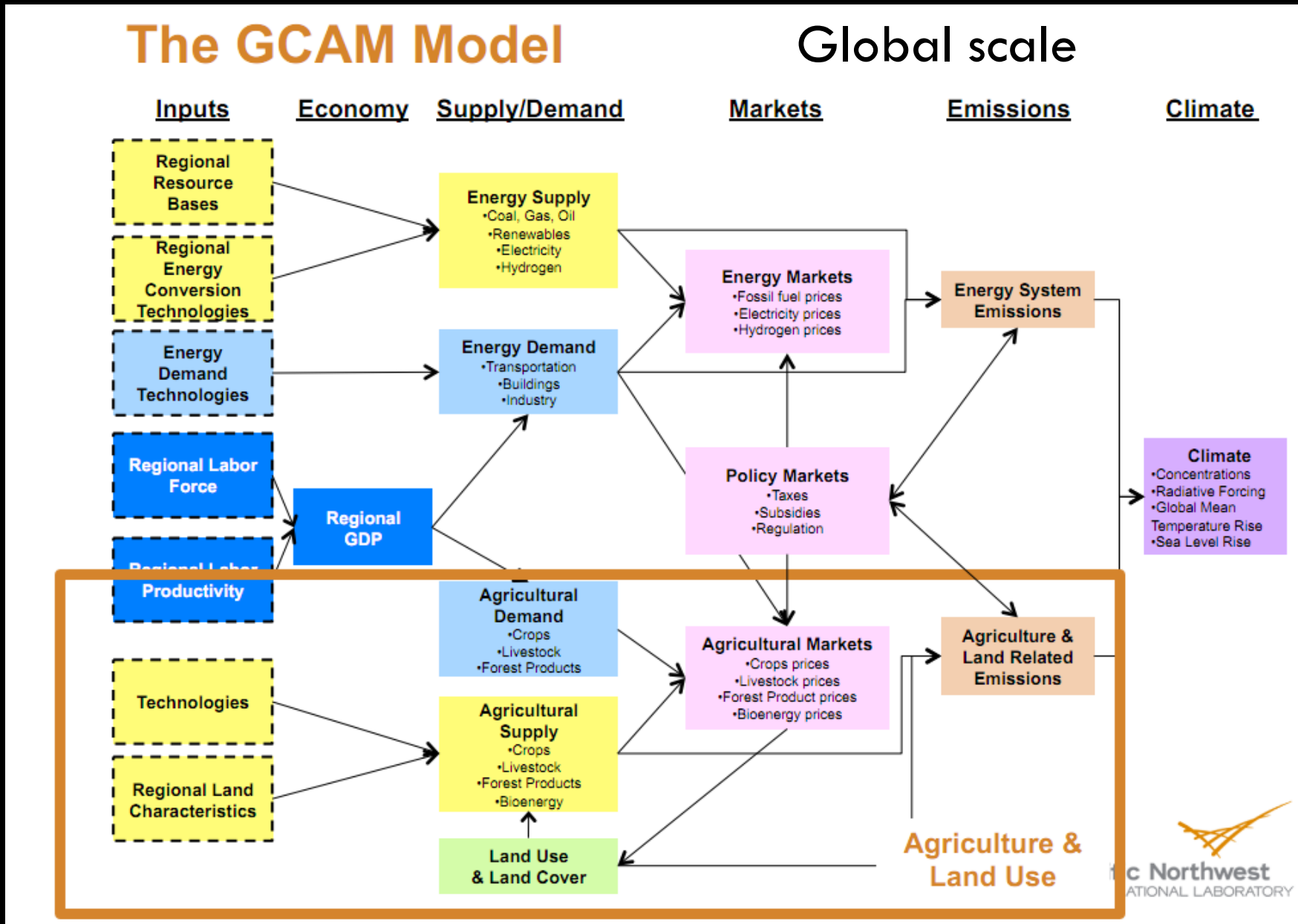
- System dynamics model links ecological and demographic processes to land change



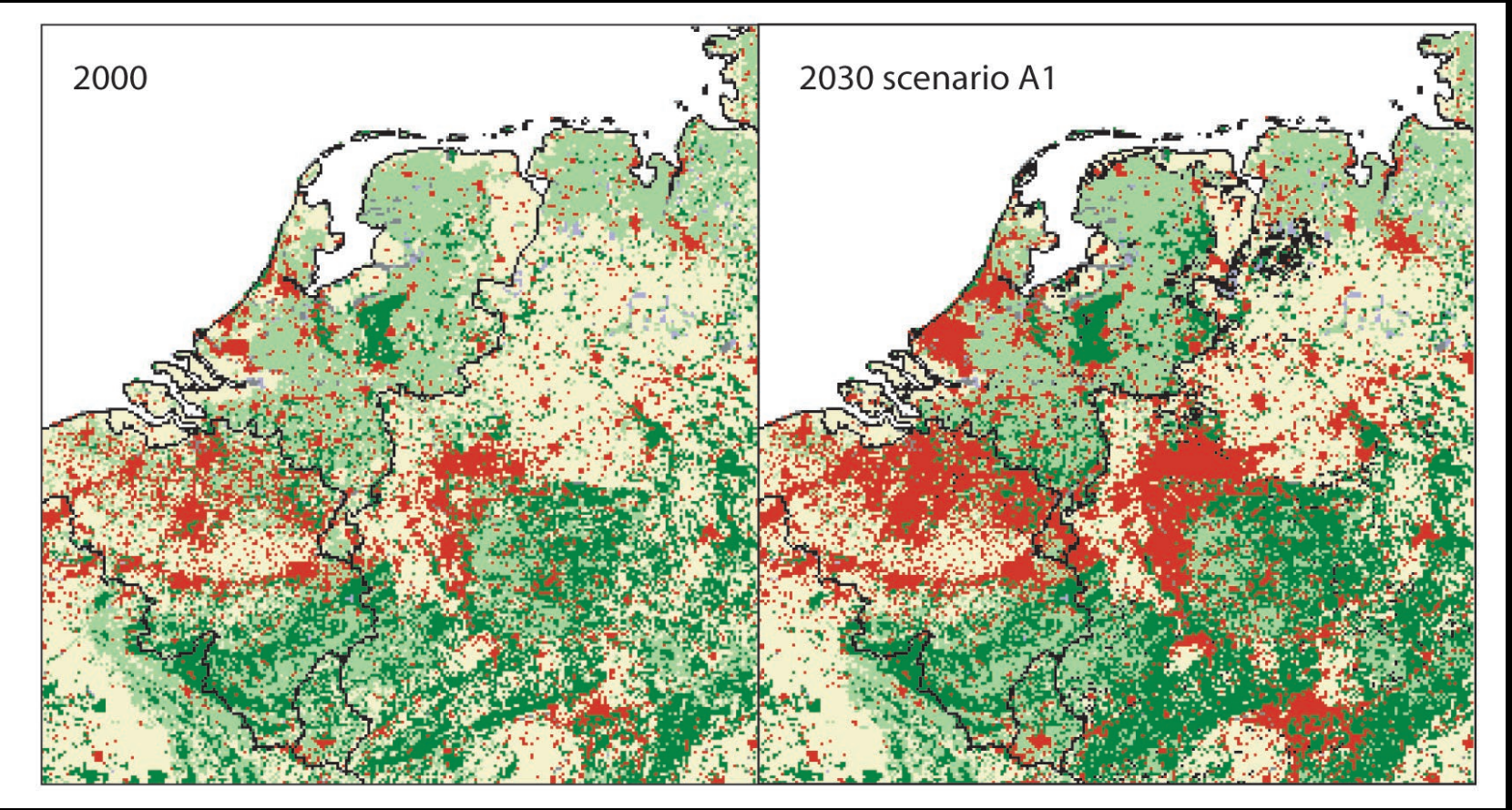


Allington et al. 2017. *Environmental Science and Policy*.

Example Sector-based Model



Ex-ante Policy Evaluation



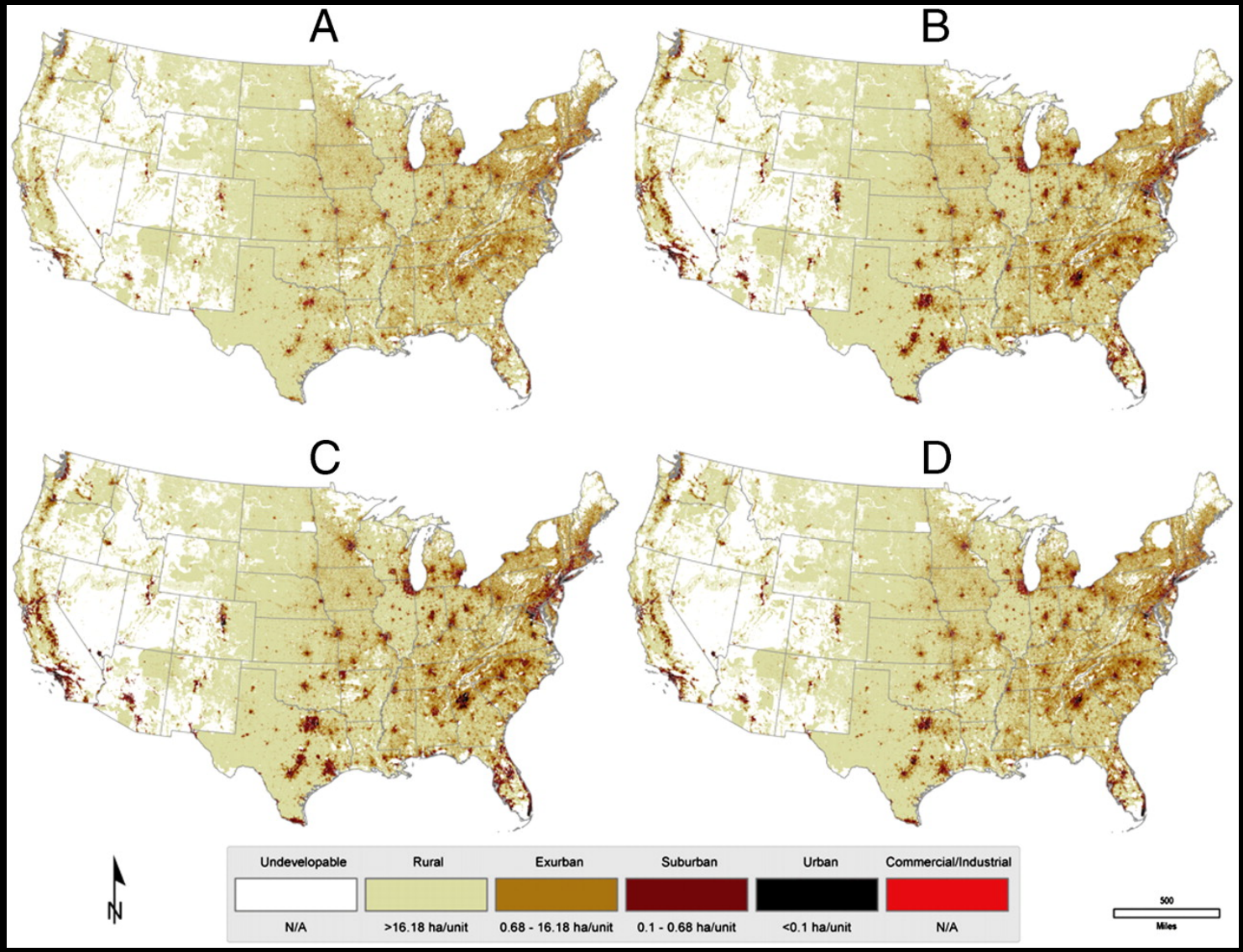
CLUE models combines with sector-based models to support discussion of policy alternatives. (Verburg et al. 2008)

Remote Sensing for Spatial Patterns

Bierwagen et al. 2011 *PNAS*

- Projected county-level percentages in housing-unit densities to 2100 based on population forecasts under four SRES scenarios.
- Forecasts of demographic components from US Census.
- Downscaled to 100 m (1 ha) cells using distance and NLCD-based weightings.
- Percent impervious surface area estimated using regression tree models.

Housing density for the conterminous United States shown as (A) actual housing density in 2000; (B) modeled housing density in 2100 for base case; (C) for scenario A2; and (D) for scenario B1.

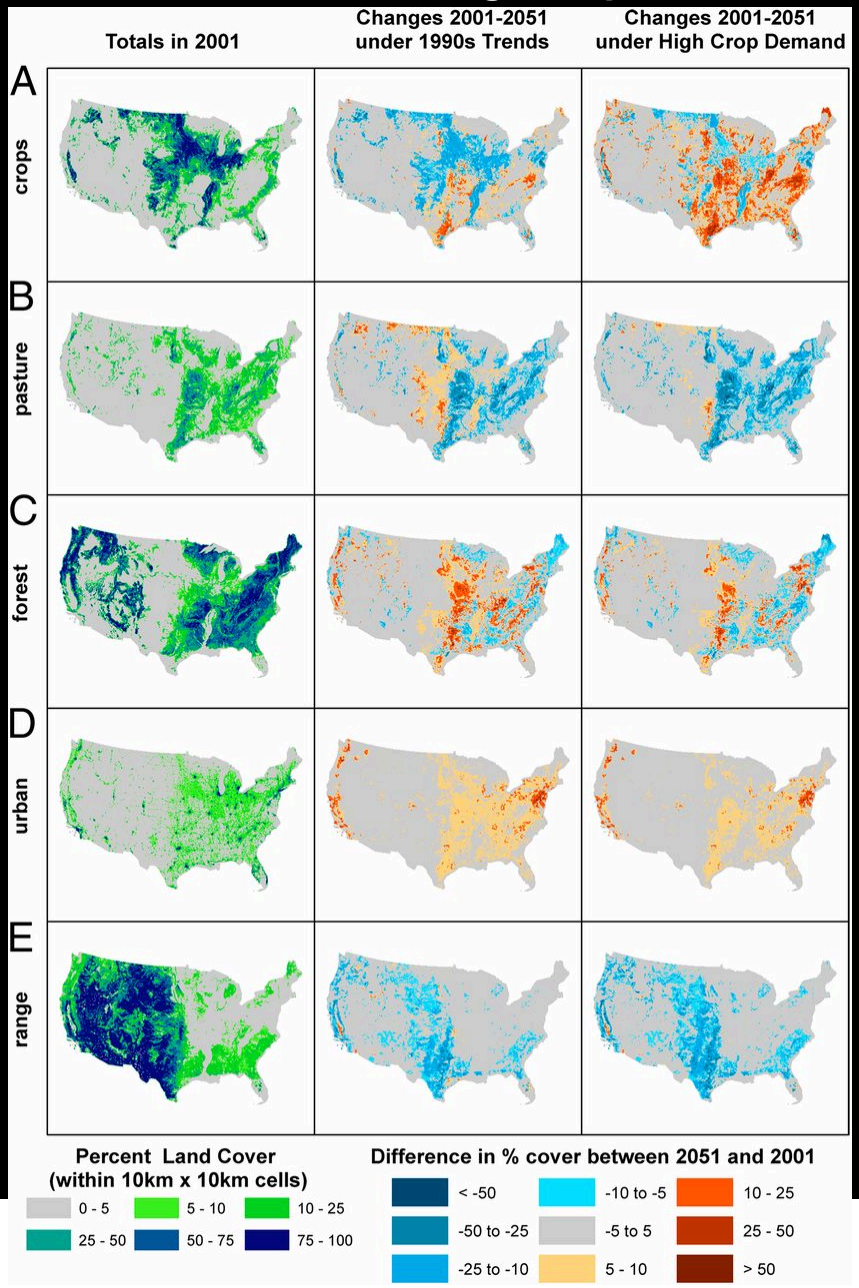


Bierwagen B G et al. PNAS 2010;107:20887-20892

Remote Sensing Provides t0

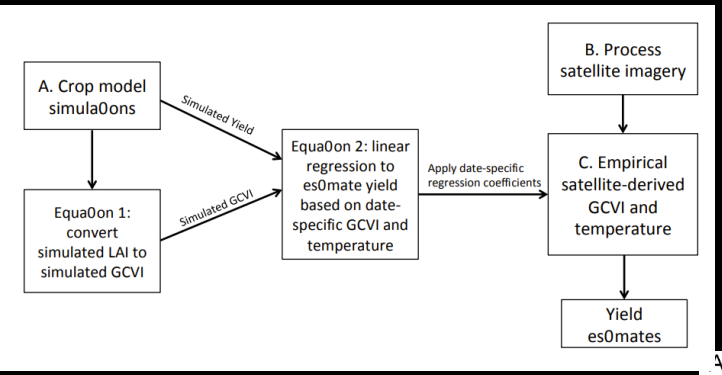
- Lawler et al. 2014, *PNAS*
  - Use econometric model based on net returns to land use at the county level and NRI land use information, 1992-1997 (Lubowski)
  - Estimate land uses for 100 m cells, modified for 2051 based on starting patterns in NLCD 2001.
  - Evaluated impacts of 2 trend and 3 alternative policy scenarios on carbon storage, species habitat, timber production, and food production.

2001 land cover and change between 2001 and 2051 under two scenarios 1990s trends and high crop demand



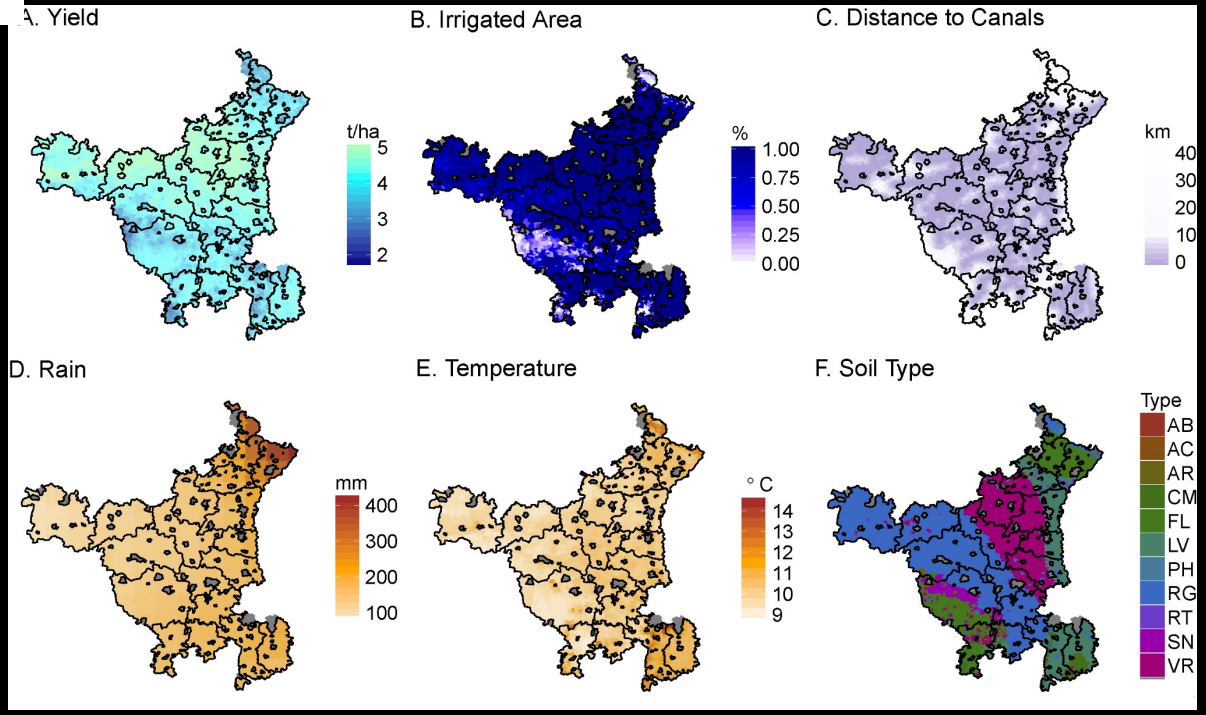
Lawler et al. 2014. *PNAS*

Remote Sensing for Key Process Parameters



- RS-based crop-yield estimation to identify yield gaps from variations in management.

Jain et al. 2017. *Environmental Research Letters.*



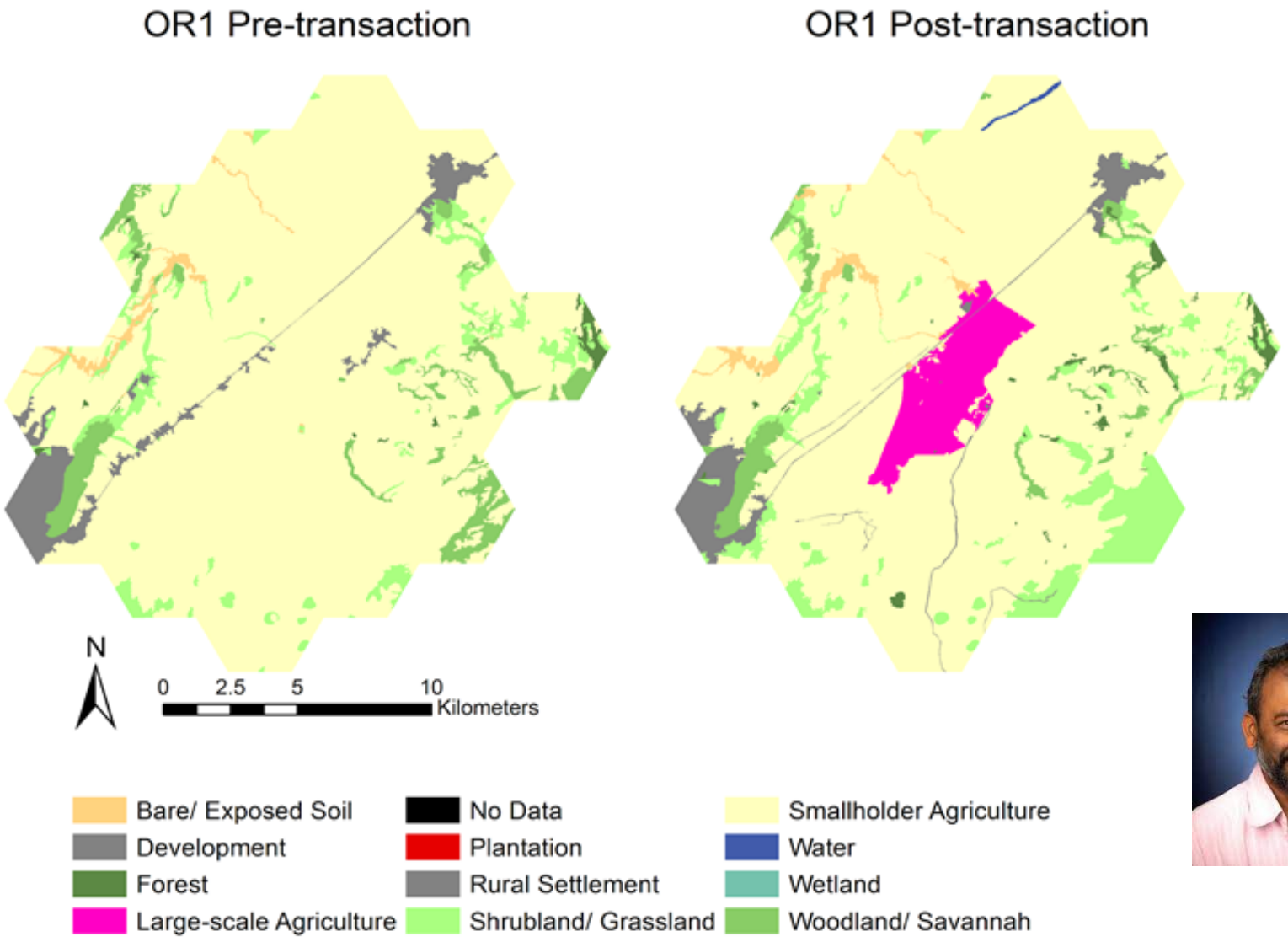
RS for Parameterizing ABMs

RS and spatial data useful for identifying relationships between spatial factors and agent decisions. Such questions can include:

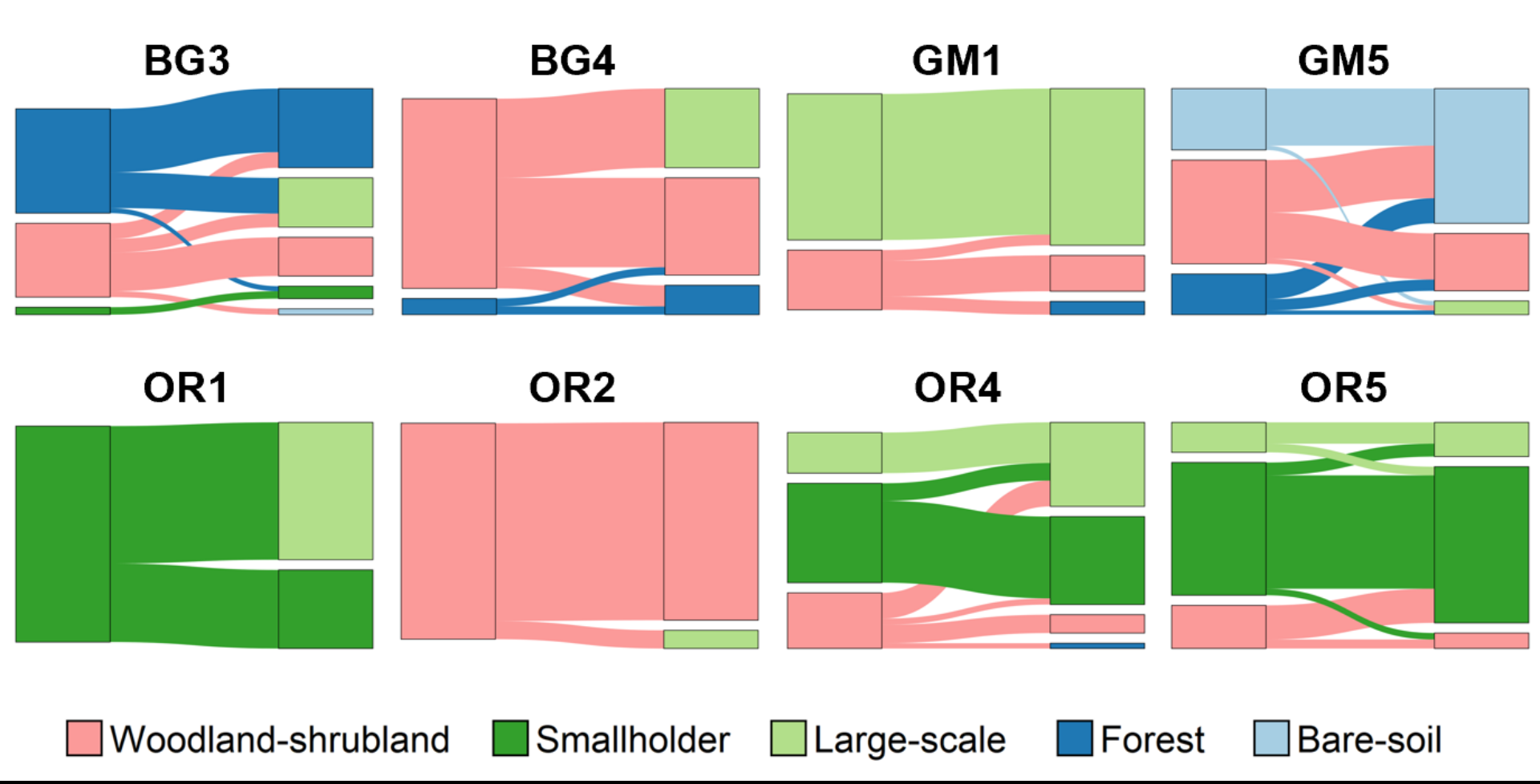
- What is the relative influence of biophysical factors, such as soil fertility, on the probability that an agent will convert from one land use to another?
- How do biophysical factors interact to affect particular decisions?
- How do neighborhood characteristics affect decision-making?
- How do spatial relationships vary over time and space?”

Robinson et al 2007. *Journal of Land Use Science*

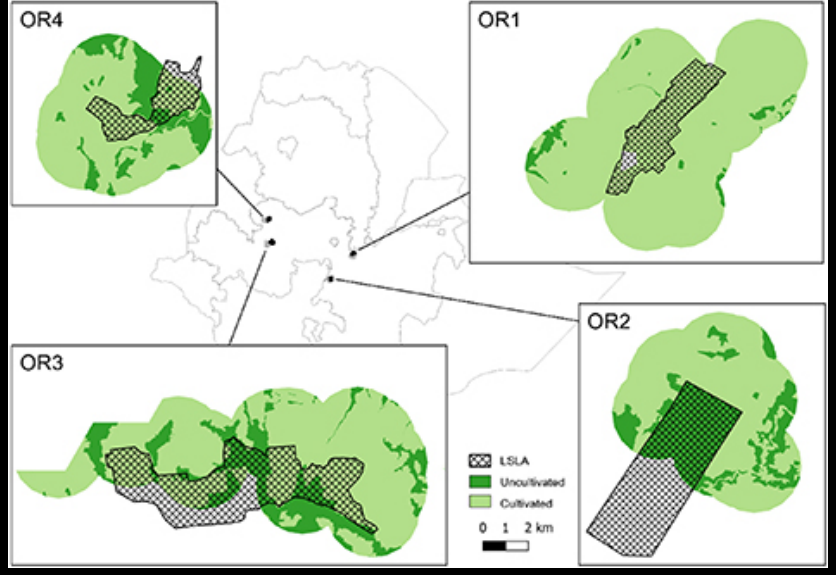
Impacts of Land Transactions in Africa



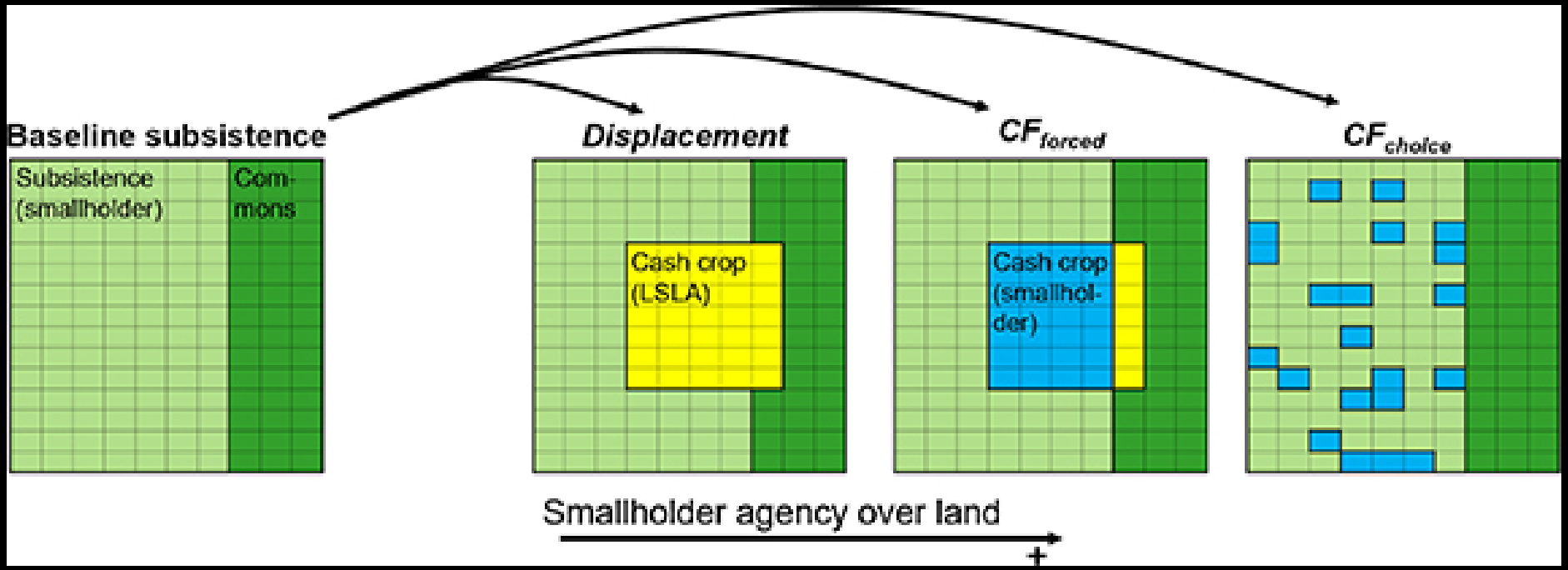
Land Change in Ethiopian Sites



Williams et al. 2021. *Ecology and Society*.

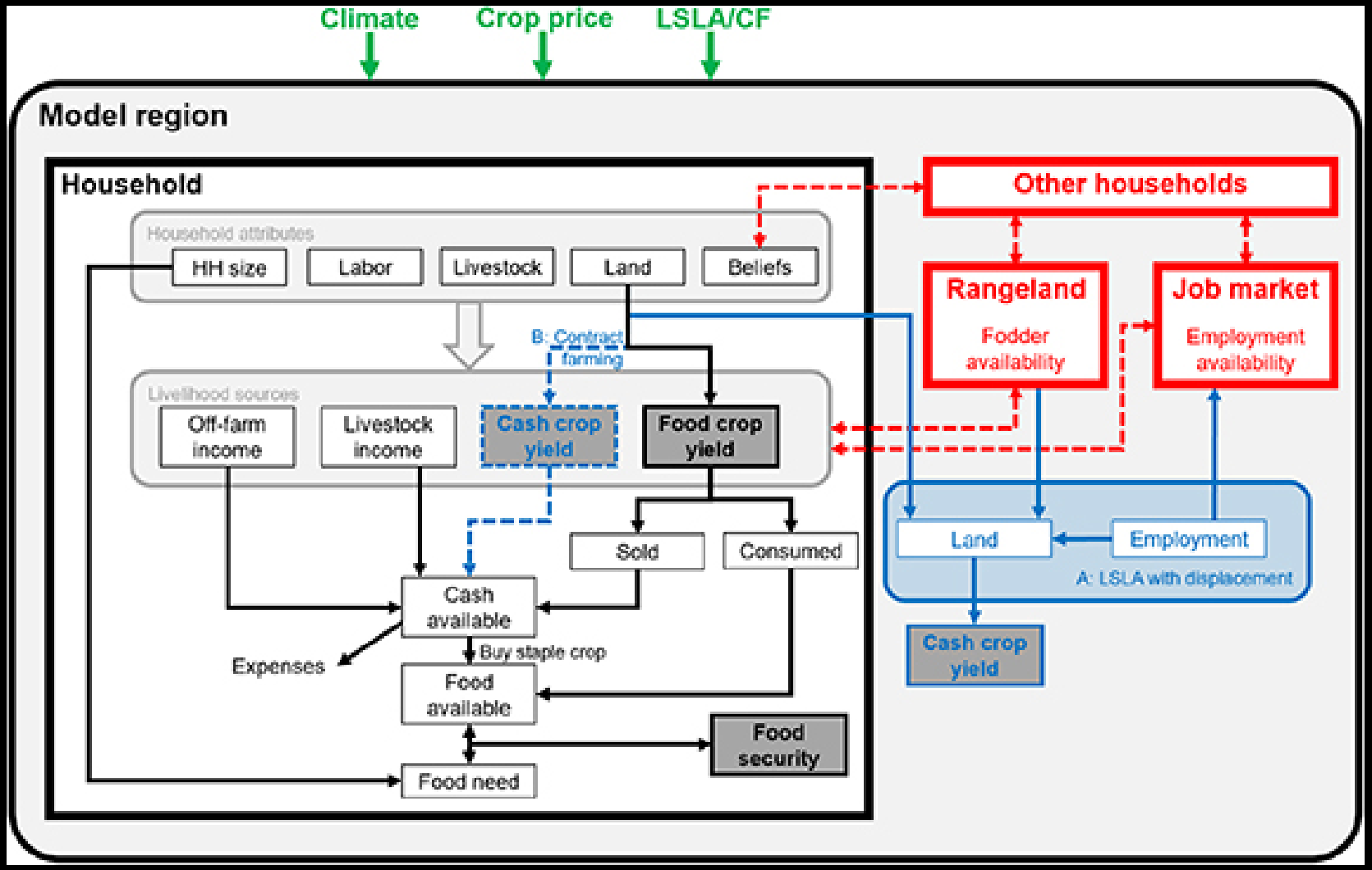


Modeling LSLA Impacts



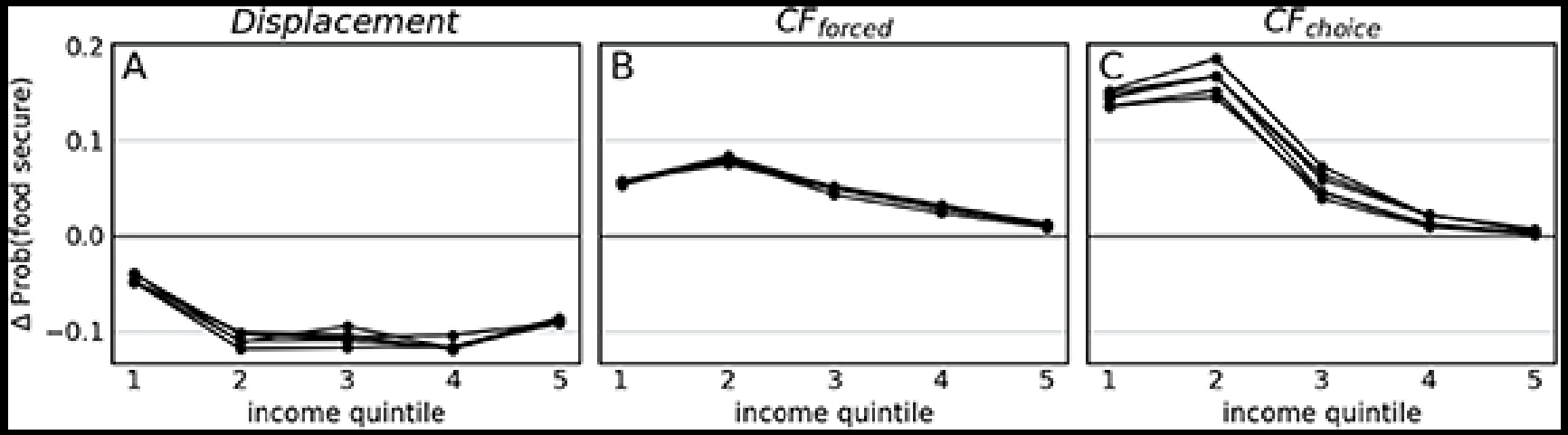
Williams et al. 2021. *Environmental Research Letters*.

Household ABM Structure



Headline Conclusions

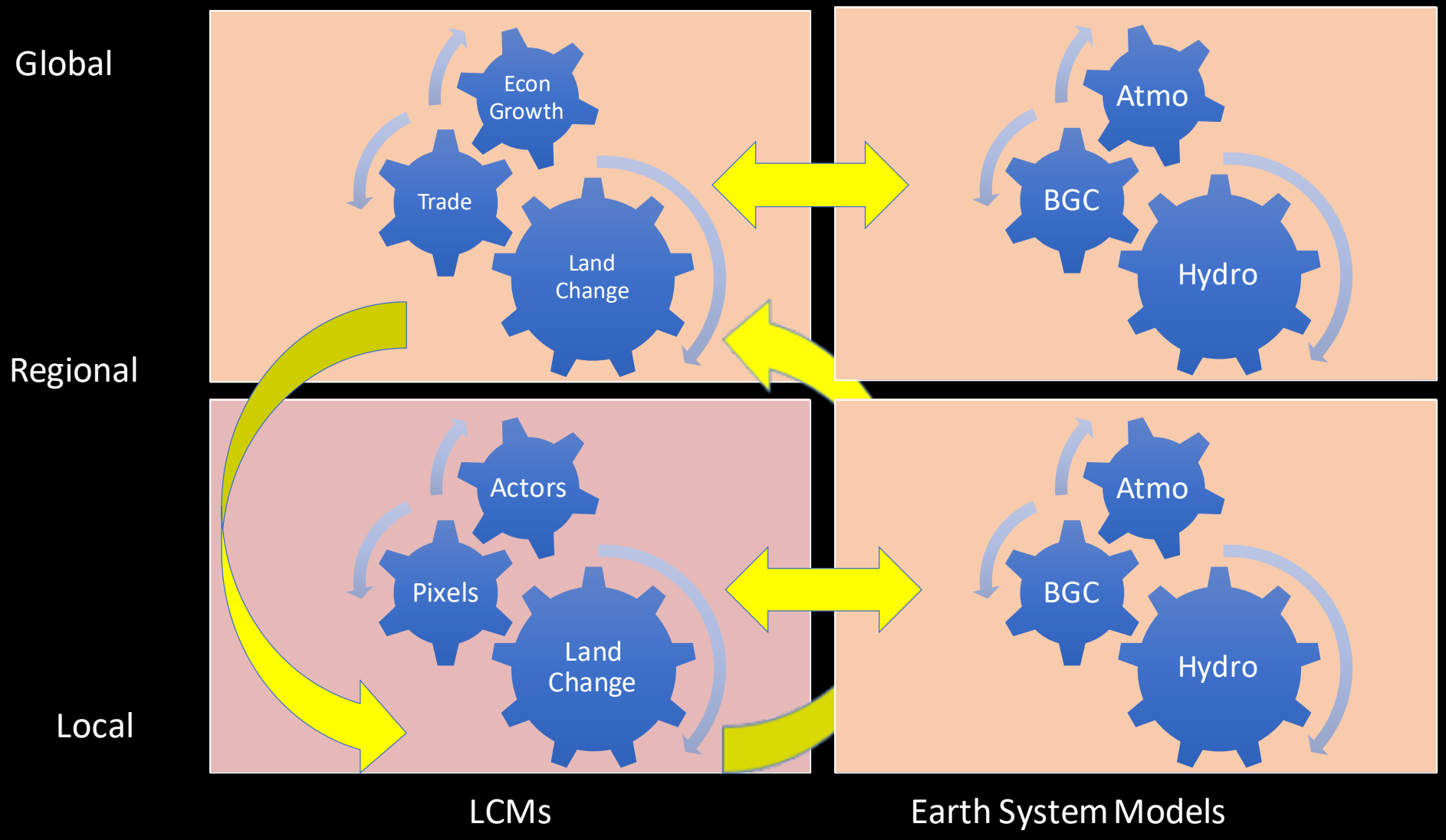
- Displacement negatively impacts food security.
- Contract farming can improve food security, especially for lowest income households and when households have a choice in participating.
- ABM facilitates assessment of distributional effects



Opportunities in LCM Research

- Advancement of process-based, structural approaches
  - Required for policy analyses, e.g. PES schemes.
  - Expanding models to include teleconnections and social networks
- Cross-scale integration of models
  - Bridging knowledge from aggregate and disaggregate approaches.
- Cross-scale integration of LCMs and Earth System models
  - Need models that address biophysical, like impervious to link with hydro models, albedo to link with climate models.

Opportunities to Integrate Process Models



Opportunities to Bridge Scales

> Sector-based models represent teleconnections in land-use changes and top-down causation in land-use systems.
  - Limited by aggregate nature of models

> Agent-based models (ABMs) represent interactions among heterogeneous agents driving bottom-up causation in land-use systems.
  - Limited by lack of generalizable models and computational and data challenges in scaling.

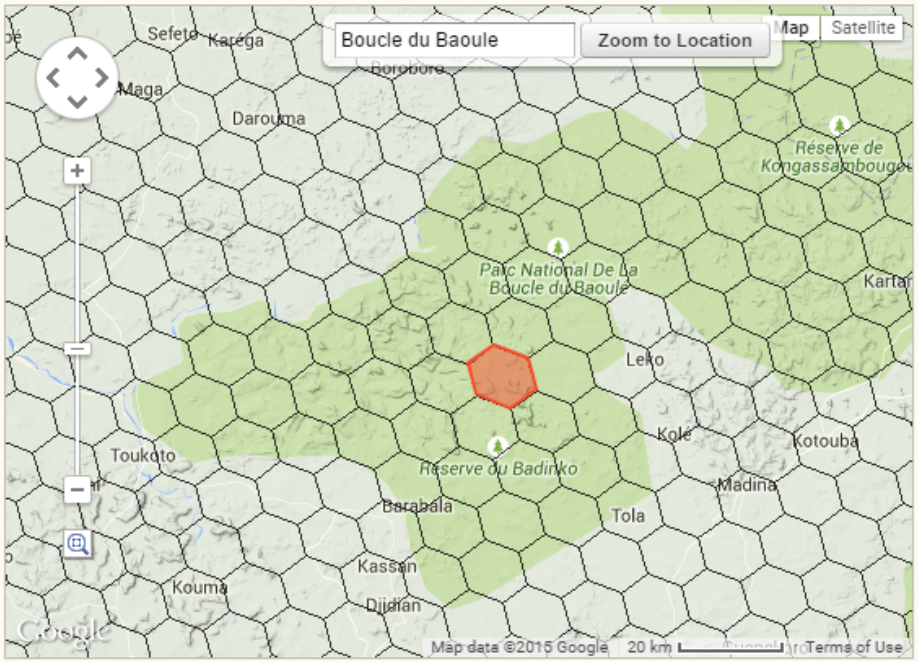
Rounsevell et al. 2014. *Earth System Dynamics*

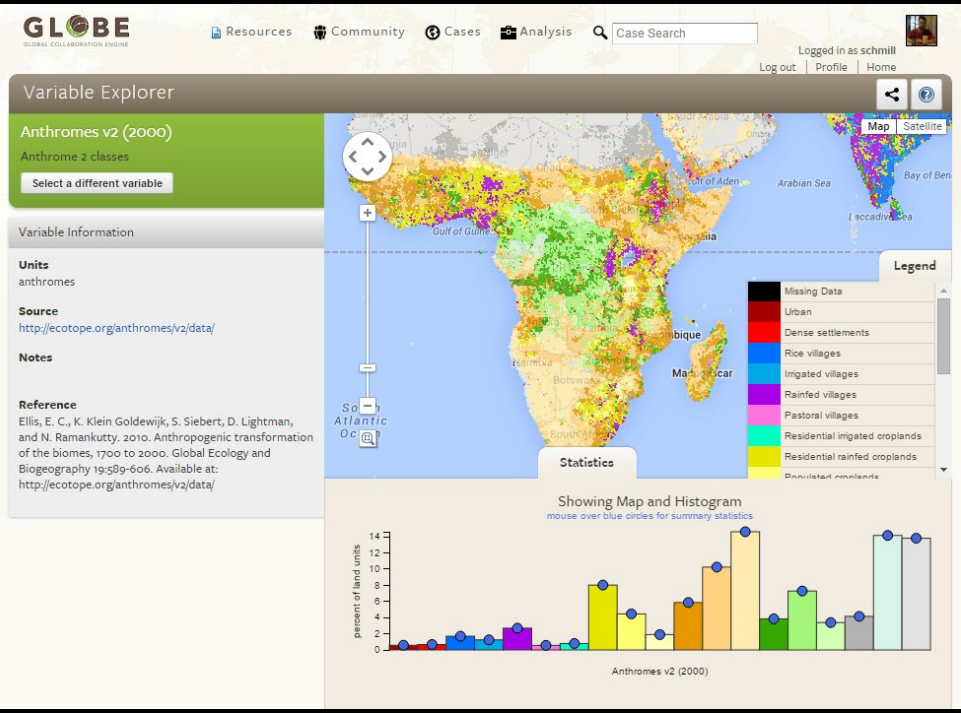
GLOBE: Links case studies to global context

globe.umbc.edu

Discrete Global Grid

Collection or Global Variables





BeModelS: Behavioural Models of Land Systems

- International working group of GLP and AIMES
- Promotes alternatives to econometric, equilibrium-based and 'top-down' models by incorporating insights from the behavioural sciences.
- Aims to catalyse the coupling of behavioural land-use models with other model types, such as dynamic global vegetation models, biodiversity models and/or climate emulators to evaluate the consequences for ecosystem services.

Global LAND Programme

Questions?