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Land Use Change and Agricultural Intensification:

Key Research Questions and Innovative Modeling Approaches

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Outline

- Approaches to modeling land use
- Environmental and ecological impacts
  - Water quality
- Integrate economic and biophysical models for policy analysis
  - Example I: Farming practices and nonpoint pollution
  - Example II: Land use pattern, carbon sequestration, and species conservation
- Important research questions and promising study areas
- Some challenges

Dimensions for arraying land use studies

Dimensions	Examples
Theoretical vs. empirical	Capozza and Helsley (1989) vs. Stavins and Jaffe (1990)
Structural vs. reduced form	Walsh (2007) vs. Chavas and Holt (1990)
Econometric vs. other approaches	Lubowski et al. (2006) vs. Parker et al. (2003)
Disaggregate vs. aggregate	Wu et al. (2004) vs. Chavas and Holt (1990)
Extensive- vs. intensive-margin studies	Wu (1999) vs. Babcock and Hennessy (1996)
Parcel-, farm-level vs. regional-, national-level vs. international studies	Lewis and Plantinga (2007) vs. Wu and Adams (2002) vs. Chavas and Holt (1990)
Drivers vs. consequences of land use change	Li et al. (2013) vs. Wu and Babcock (1998)
Policy vs. method-oriented studies	Just and Antle (1990) vs. Li et al. (forthcoming)

Modeling land use with micro-level data

- Household/farm surveys, satellite remote-sensing data
- Conceptual basis: a farmer makes land use decision to maximize the net returns to land subject to certain constraints
  - Land use decision: crop choice, tillage practice, technology adoption, the enrollment of a land conservation program, etc.
  - Continuous land use data: micro-parameter distribution model, e.g., Wu and Segerson 1995

When land use data are continuous

- Flexible functional form for the **restricted profit function**, then derive land use equations
  - Advantage: provide a theoretical link b/w profit function and land use equations
  - Disadvantage
    - Desirable local properties do not necessary hold globally
    - Does not ensure predicted shares lie in the 0–1 interval
- Flexible functional form for **land use equations** themselves
  - Advantage
    - Ensure predicted shares lie b/w 0–1
    - Has been shown to outperform other flexible functional forms
  - Disadvantage: reduced functional form

MODELING LAND USE WITH MICRO-LEVEL DATA (CONT.)

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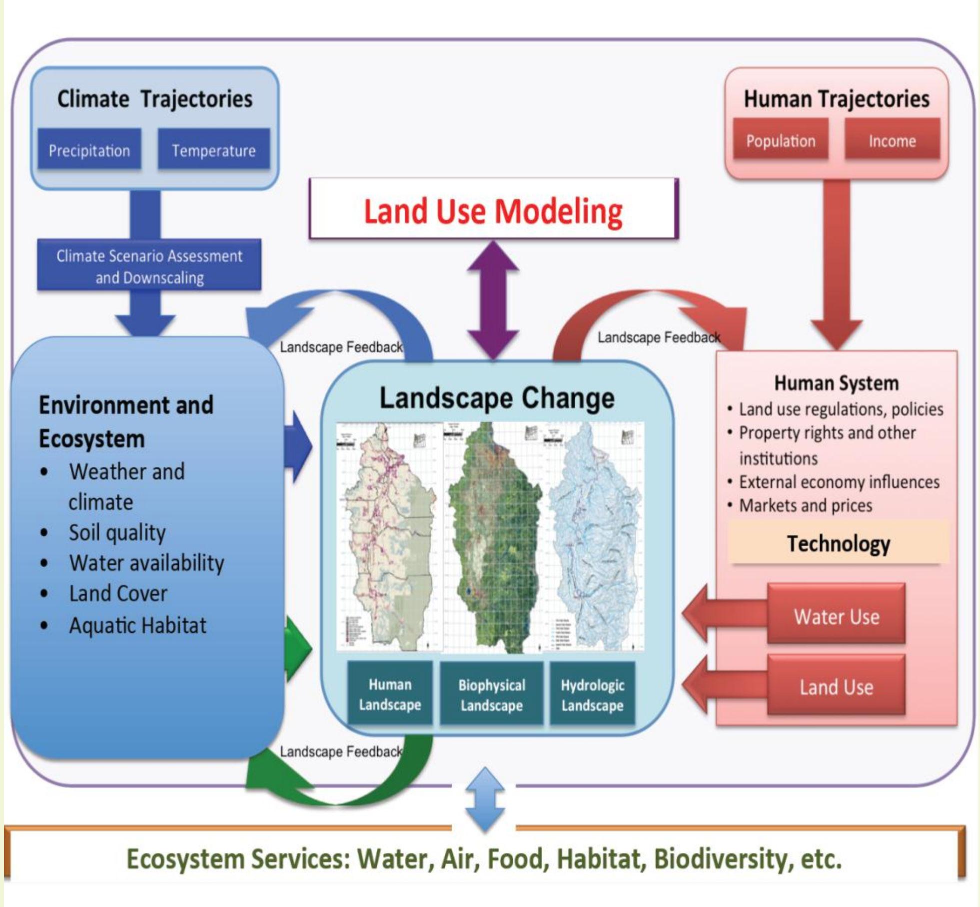
- Conceptual basis: a farmer makes land use decision to maximize the net returns to land subject to certain constraints
  - Land use decision: crop choice, tillage practice, technology adoption, the enrollment of a land conservation program, etc.
  - Continuous land use data: micro-parameter distribution model, e.g., Wu and Segerson 1995
  - Discrete land choice data: random utility model, e.g., Lubowski et al. 2006
    - Extreme value distribution
    - (Standard/multinomial/conditional/nested/mixed) Logit, probit, etc.

Environmental and ecological impacts of land use

- Important ecosystem services
  - Water purification
  - Flood control and soil retention
  - Nutrient cycling
  - Crop pollination
  - Pest control
  - Maintenance of species and genetic information
  - Generation and renewal of soil and soil productivity
  - Composition of atmosphere and climate stabilization



Source: Modified based on McDonnell et al. (2010)

Farming practices and water quality

	Model the effect of land use on water quality alone	Systematically model the process from land use decisions to water quality
Farm, field, watershed level	DeRoo (1980) Gilliam and Hoyt (1987) Hallberg (1989) Anderson et al. (1985)	Jacobs and Casler (1979) Braden et al. (1989) Johnson et al. (1991) Taylor (1992) Helfand and House (1995)
Regional, national level	Nielsen and Lee (1987) Kellogg et al. (1992) Wu et al. (1997)	Piper et al. (1989) Mapp et al. (1994) Wu and Segerson (1995) Wu et al. (2004)

Farming practices and water quality (cont.)

- Major challenges
  - Spatial heterogeneity complicates the design of models
  - Climate plays a role
- Necessary to identify the joint distribution of farming practices, land characteristics, and weather condition

Farming practices and water quality (cont.)

Study region	Main results	Reference
Two farms in Connecticut	• Over-fertilization on easily leachable soils led to high nitrate concentration in well water downstream from cropland	DeRoo (1980)
-	• The use of no-till practices instead of conventional tillage increases the possibility of leaching of soil N • Conservation tillage practices reduce N loss from surface run-off, making more N available to leach to groundwater	Gilliam and Hoyt (1987)
The US	• The enrollment of cropland in the CRP reduces one-half of the acreage of high risk areas of pesticide leaching from 1982–1992	Kellogg et al. (1992)
High Plains in the US	• Targeting particular soils or farming systems is an effective strategy to protect water quality • Adopting modern irrigation technologies in heavily irrigated areas is a key to reducing N water pollution	Wu et al. (1997)

Integrate economic and biophysical models for policy analysis

Category	Economic model	Biophysical model	Policy impacts	Examples
Disaggregate model	Micro-unit decisions	Site-specific	Regional and/or national policy impacts **cannot** be easily derived from these studies	Braden et al. (1989); Johnson et al. (1991); Taylor (1992); Wu et al. (1994); Helfand and House (1995)
Aggregate model	Regional or national linear programming model	Aggregate level	Aggregate impacts	Piper et al. (1989); Mapp et al. (1994); Wu at al. (1995)
	Micro-level behavioral responses	Incorporate site-specific characteristics, e.g. meta-modeling approach	Site-specific impacts are **aggregated** to polygon or regional level	Wu and Segerson (1995); Wu at al. (1996); Wu et al. (2004)

Example I: The choice of crops and tillage and the resulting N runoffs (Wu et al. 2004)

- Study region: more than 42,000 NRI sites in the upper-Mississippi river basin
- Objective: evaluate alternative conservation policies for controlling the hypoxia problem in the Gulf of Mexico
- Integrated model
  - **Economic model**—farmer chooses the combination of crops and tillage practices that yields the highest expected utility at an NRI site
  - **Meta-modeling N runoff and leaching**—use GIS and statistical techniques to integrate an environmental process simulation model with a geo-referenced database that contains crop management practices and site characteristics
  - **Policy simulation**—incentive payment on the adoption of crop rotation and conservation tillage

Example I: Changes in potential nonpoint source pollution under a payment of $50/acre for conservation tillage

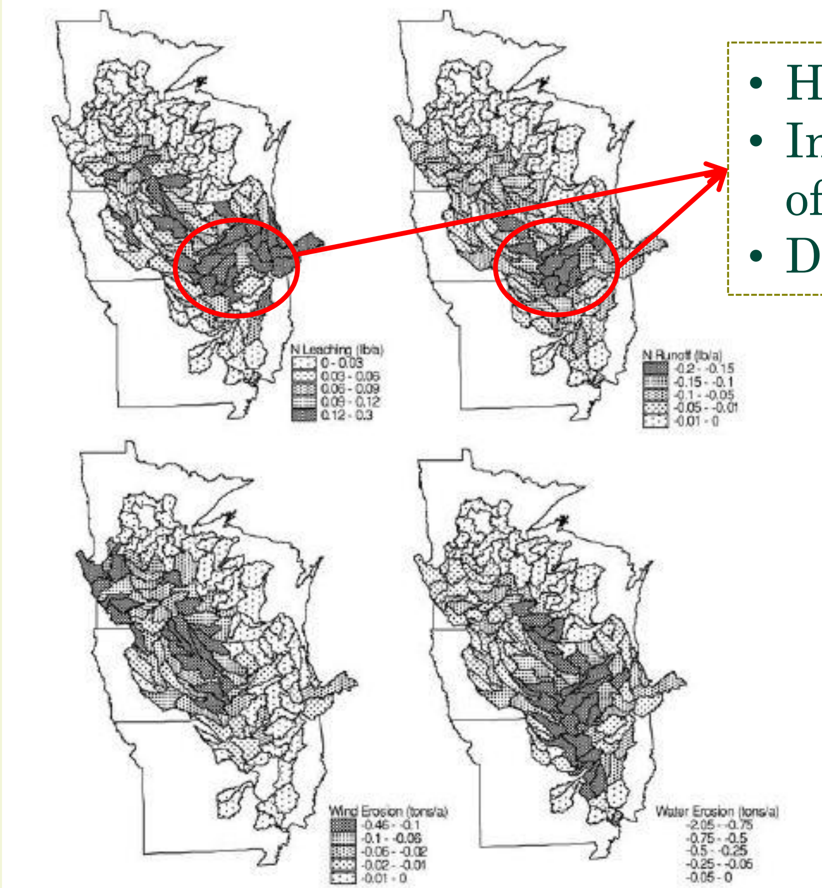


Figure 2. Estimated changes in nonpoint pollution under green payments for conservation tillage ($50/acre)

- High N application
- Intensive cropping of maize
- Deep soils

Source: Wu et al. *AJAE* 2004, From microlevel decisions to landscape changes: An assessment of agricultural conservation policies

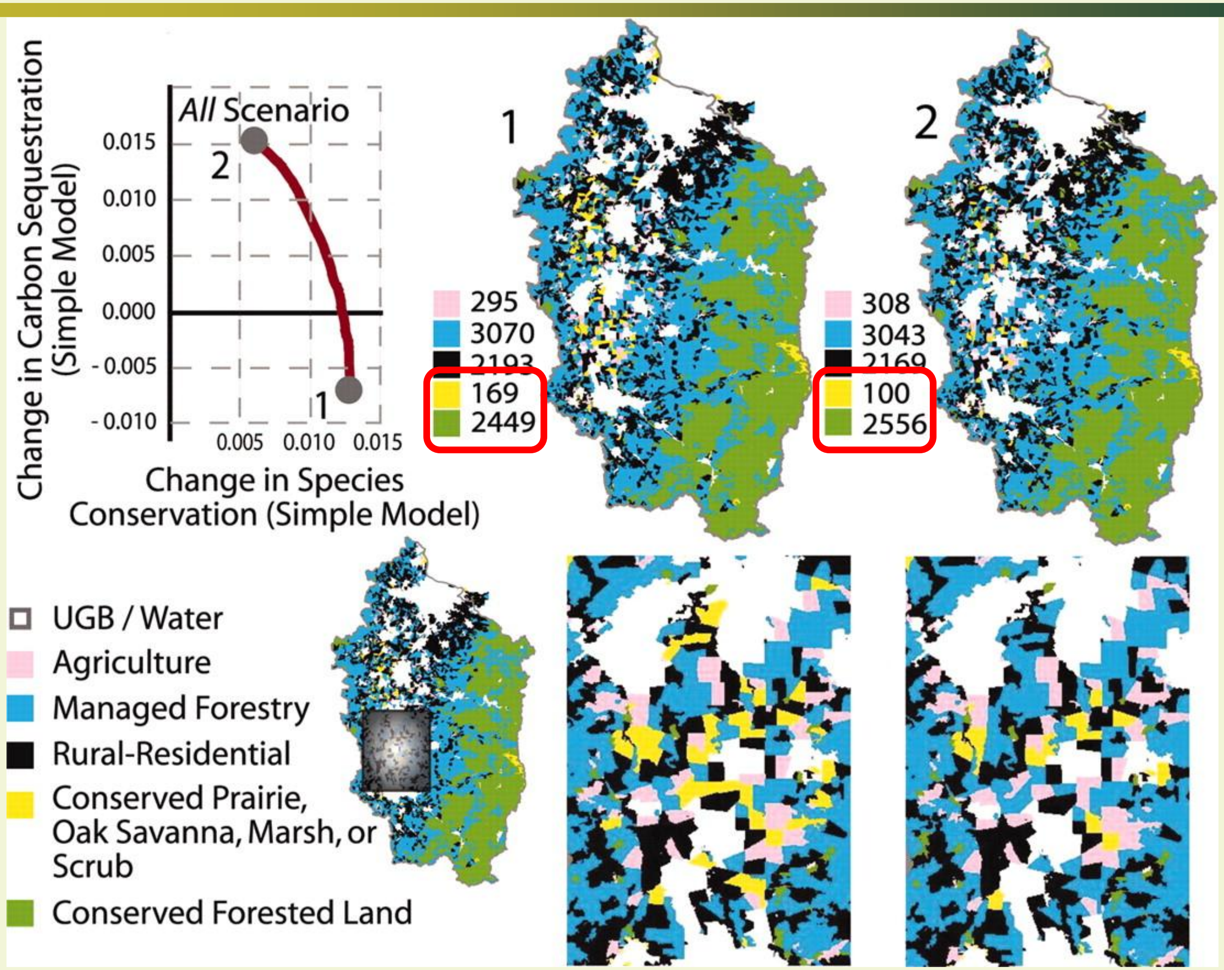
Example II: Incentives to jointly increase carbon sequestration and species conservation (Nelson et al. 2008)

- Study region: the Willamette Basin, Oregon
- Objective: evaluate policy performance compared with the maximum feasible combinations of carbon sequestration and species conservation under various annual budgets
- Five conservation policies
  - **All**—any parcel is eligible for a conservation contract
  - **Rare Habitat**—only parcels that could convert particular types of rare natural habitat are eligible
  - **Carbon**—only parcels that could convert to conserved forest are eligible
  - **Riparian**—only parcels with significant stream density are eligible
  - **Species Conservation**—only parcels identified as important for vertebrate species conservation in the Basin

EXAMPLE II: MODELING FRAMEWORK

- Integrated model
  - **Econometric land use model**—landowner chooses land use to maximizes the net returns to a parcel of land
  - **Carbon sequestration model**—detailed information about the dist. of tree species, tree ages, canopy densities, soil type, etc.
  - **Species conservation model**—predict species persistence as a function of the amount and spatial pattern of breeding and feeding habitat, as well as area requirements and dispersal abilities
  - **Policy simulation**—predict landowner decisions as a function of existing market conditions and incentive-based conservation payments ($1 million, $5 million, $10 million per year)
  - **Efficiency frontiers**—find land use pattern that maximizes species conservation subject to the land use pattern meeting a specified carbon sequestration value and a given policy budget

EXAMPLE II: LAND USE PATTERNS UNDER *ALL* SCENARIO ON $10 MILLION EFFICIENCY FRONTIER



Source: Nelson et al. *PNAS* 2008, Efficiency of incentives to jointly increase carbon sequestration and species conservation on a land scape

KEY RESEARCH QUESTIONS AND PROMISING STUDY AREAS

Technology adoption and agricultural intensification (AI):

1. What are the implications of labor-saving and biological technologies on AI?

   Suggested study areas: Bt. cotton in India, Pakistan; genetically modified maize in Brazil

Interactions b/w AI, economic growth, and the environment:

2. How does AI affect farm income, rural economies, and rural socioeconomic structure?
3. How does economic development (e.g., from an agrarian economy to a mid-income country) and accompanying structural changes and urbanization in turn affect AI?
4. How does AI affect the environment and ecosystems?
5. How do changes in environmental quality in turn affect AI?

   Suggested study areas: Bangladesh, Vietnam, Uganda, Malawi, Tanzania

KEY RESEARCH QUESTIONS AND PROMISING STUDY AREAS (CONT.)

Poverty, income inequality, and AI:

6. How do AI and its interaction with economic development affect poverty rates and income inequality?

   Suggested study areas: China, India, Vietnam

The roles of AI:

7. Can AI serve as a "smart strategy" to deal with global economic and environmental challenges (e.g., to feed the growing population, to protect the environment)?

   Suggested study areas: All areas suggested above

Selection criteria

- Research questions must be highly relevant and important to the suggested study areas
  - Biological technologies: Bt cotton in India and Pakistan; genetically modified maize in Brazil and Argentina
  - Economic development, structural changes, poverty rates, income inequality: China, India, Brazil, or Vietnam
- Data availability
  - Integrated household surveys: SSA, SA, SEA
  - Limitations
    - Agricultural intensification is not explicitly measured
    - Important indicators of environmental quality (e.g., water pollution) cannot be found from these surveys

Challenges

- The lack of data and counterfactuals poses significant challenges to answering some research questions
- Self-selection complicates the evaluation of a program's impacts
- Endogeneity arises when investigating the interactions b/w AI, economic growth, and the environment
  - Finding approximate IV is difficult but important

Thank you for your attention!