Modeling the Impacts of Forest Carbon Sequestration on Biodiversity

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Organization

- Review of Matthews, O'Connor, and Plantinga (2002)
- Forest Fragmentation Research (in progress)

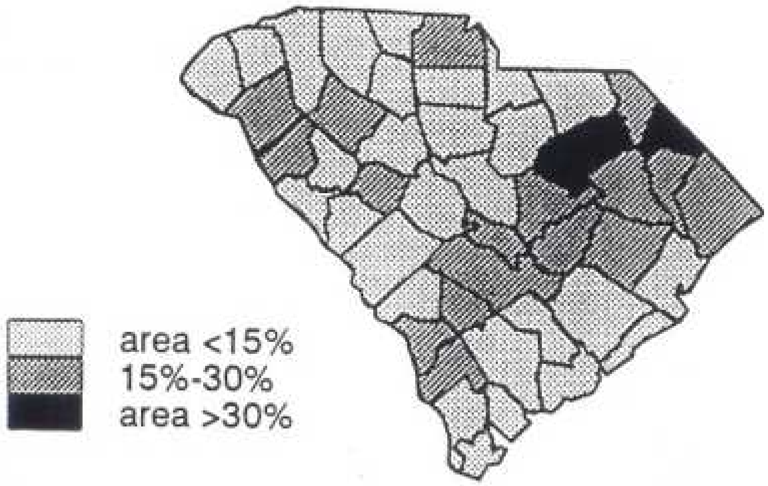
Overview of Methodology

- Estimate econometric models of land-use change
- Use econometric models to simulate incentives for forest carbon sequestration
- Analyze biodiversity effects of afforestation

Matthews, O'Connor, and Plantinga, in Ecological Economics (Jan. 2002)

- Econometric land-use models for Maine, South Carolina, and Wisconsin (Plantinga et al. 1999)
- Afforestation subsidies to achieve a 10% statewide reduction in agricultural land

Changes in Agricultural Land in South Carolina Under Afforestation Subsidy



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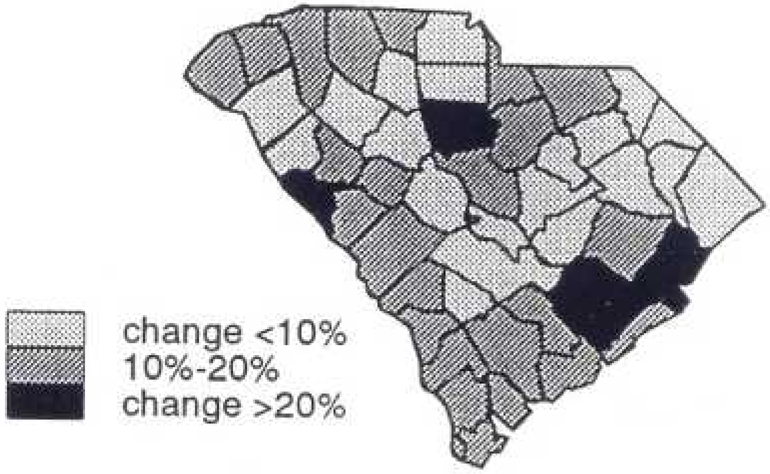

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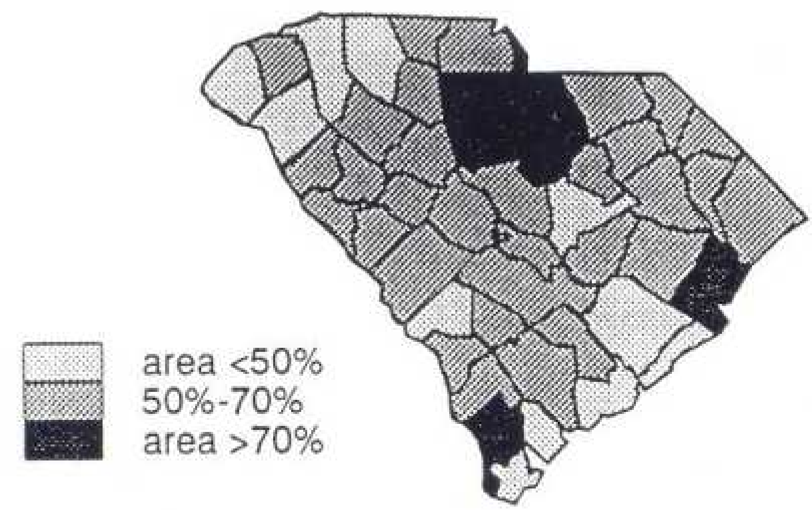
Changes in Forest Land in South Carolina Under Afforestation Subsidy



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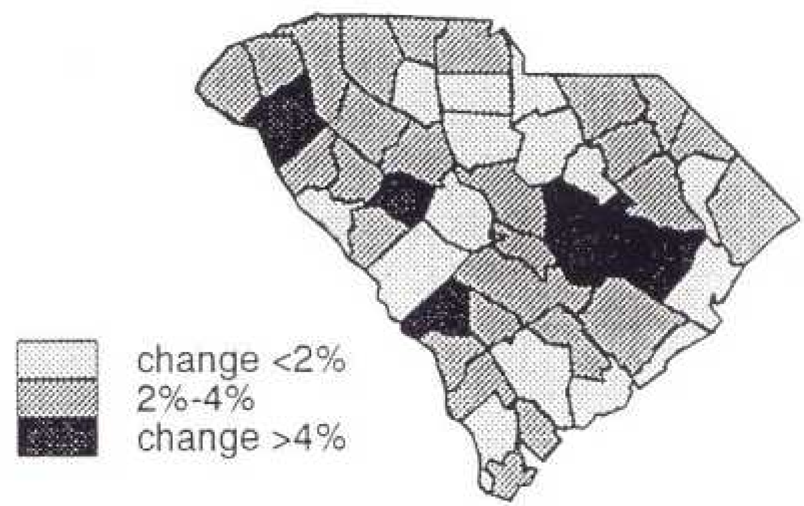

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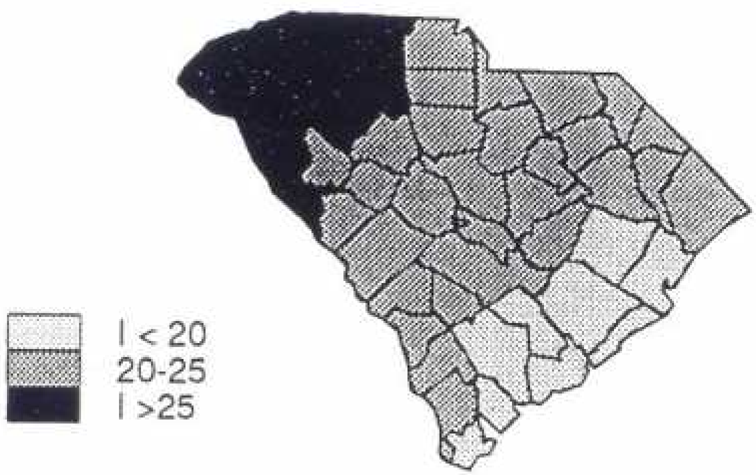
Mapping Land-Use Changes into Impacts on Biodiversity

- Focus on birds
- Breeding Bird Survey gives us incidence measure for each species
- Spatial interpolation used to construct incidence estimates for each county and 615 species
- Farmland and forest bird indices for each county
- Proportional reductions in bird abundance

Changes in Farmland Bird Abundance in South Carolina



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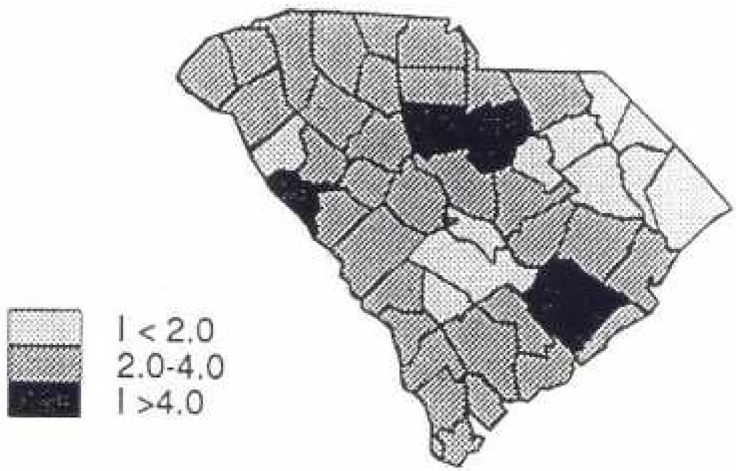

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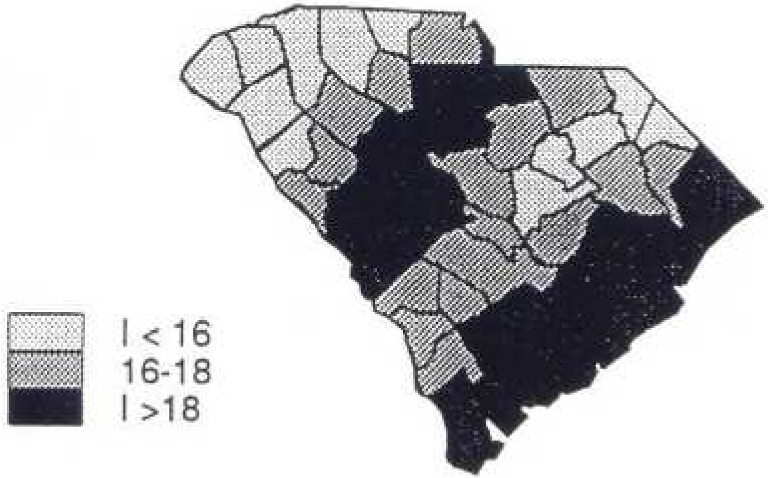
Changes in Forest Bird Abundance in South Carolina



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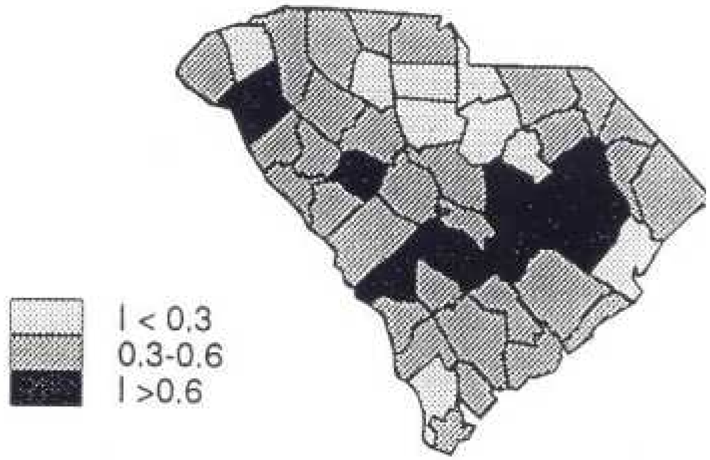

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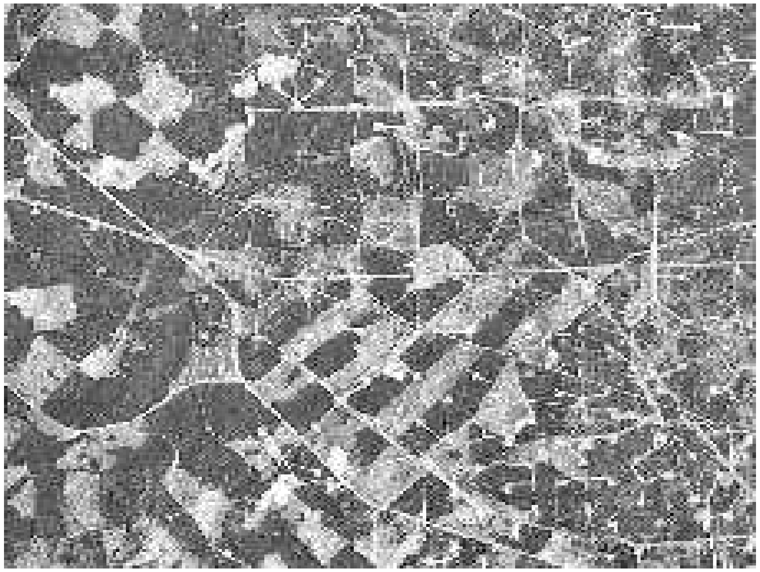
Summary of Bird Abundance Changes

Category	Maine	South Carolina	Wisconsin
		Percent Change	
Forest Birds	3.2	2.5	21.8
Farmland Birds	-10.8	-12.2	-11.7
Forest & Farmland Birds	-2.0	-2.3	-1.1

Landscape Fragmentation

- Fragmentation is a problem for many species, especially in the eastern U.S.
- A much finer spatial resolution than counties is needed to analyze fragmentation



Forest Fragmentation

- Forest fragmentation is one of the major causes of songbird decline in the eastern U.S.
- Bird densities are typically much lower in small patches of forest than in larger ones.

Fragmentation Research

- How can carbon sequestration policies address fragmentation?
- Integrate econometric land-use models, spatially-explicit simulation methods, and wildlife statistics.
- Analyze land-use policies and associated environmental and economic tradeoffs.

Econometrically Estimated Transition Probabilities

- Lubowski (2002) uses NRI data to estimate land-use transition probabilities for six land-use categories
- Policy simulations to determine how transition probabilities change under incentives for carbon sequestration

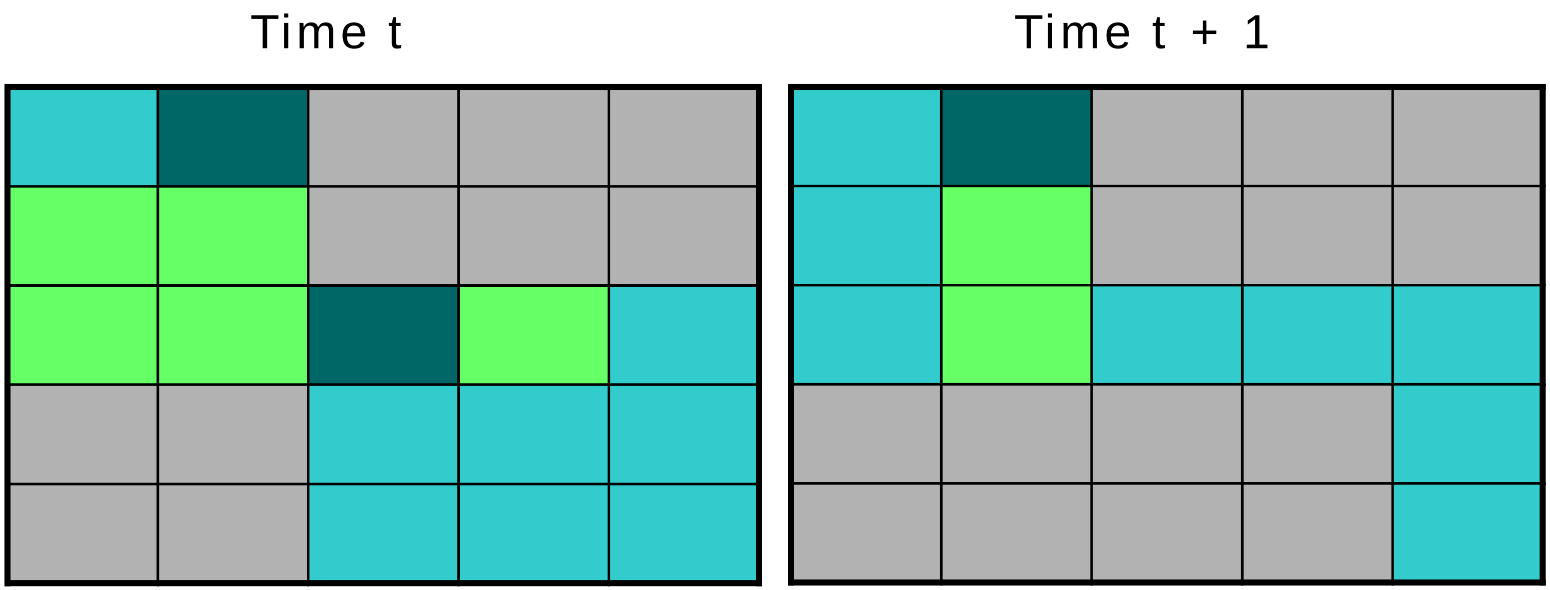
Spatially-Explicit Simulation Methods

- Transition probabilities (dependent on carbon sequestration incentives)
- Existing land cover at fine spatial resolution
- Landscape simulation is performed to determine spatial distribution of land-use changes.

Cellular Automata Modeling

- Features of cellular automata (CA):
  - Cells arranged in a d-dimensional grid.
  - Each cell is in a state selected from a finite set of states.
  - Cells change their states according to characteristics of the current state of the cell as well as neighboring cells.
  - In each discrete time period, cells are updated simultaneously.

Cellular Automata Modeling

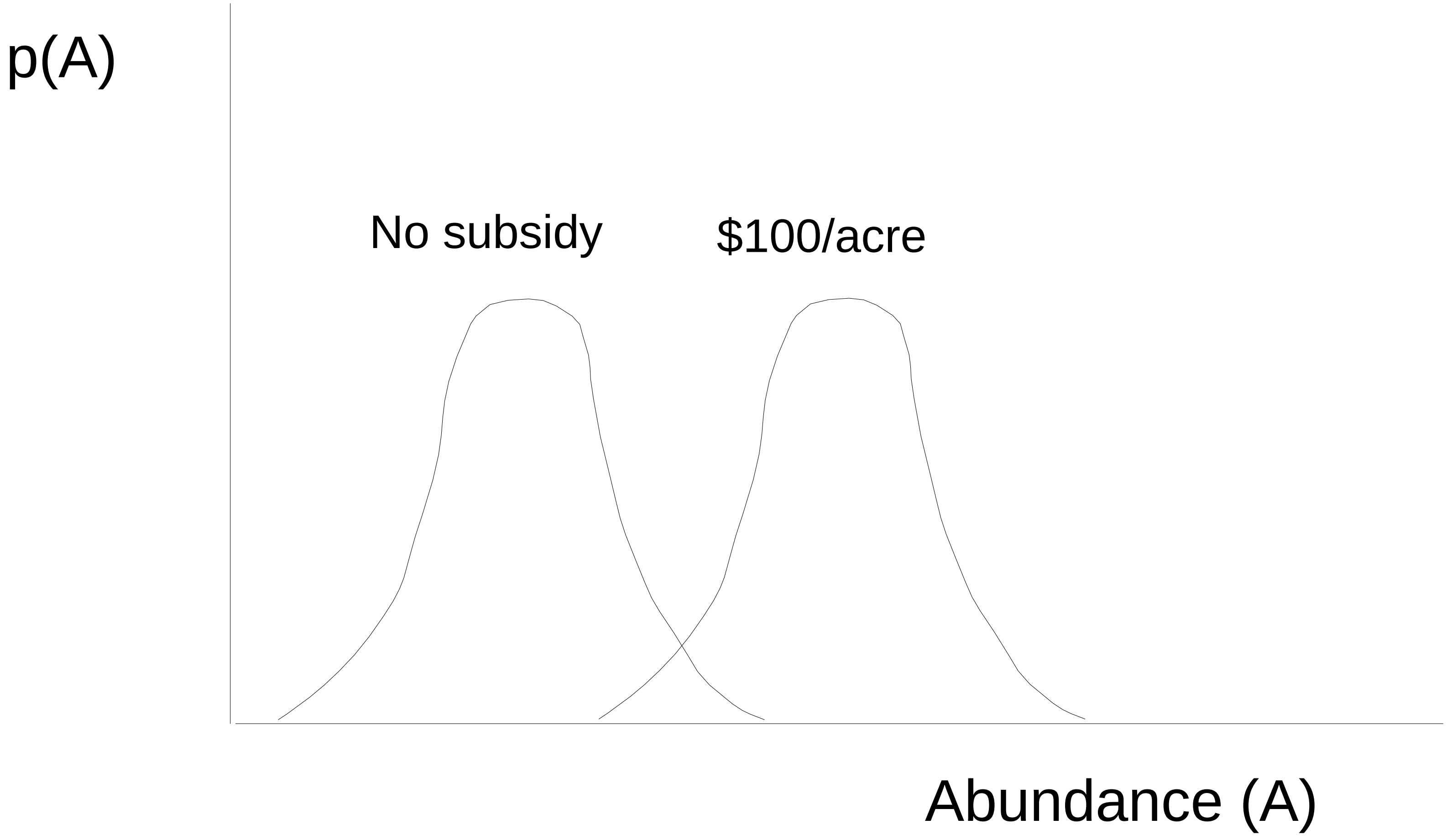


In our application, transition probabilities provide rules that govern changes in states

Land-use Change, Fragmentation, and Bird Populations

- Given initial states (land uses) and rules (transition probabilities), simulate large number of landscapes
- Index to characterize degree of fragmentation for each landscape
- Map fragmentation indices into bird populations

Effects of Afforestation Policies on Abundance Distribution

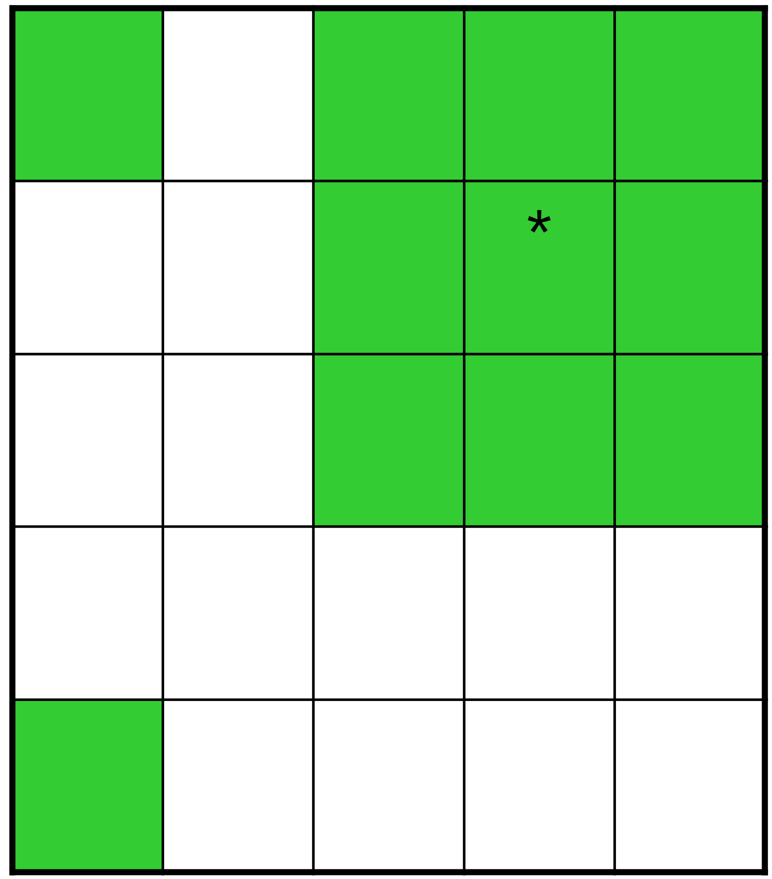


A Simple Cellular Automata Model for Two Different Afforestation Policies

- Least-Cost Policy:
  - Fixed budget; maximize the total amount of new forested parcels.
  - Converts parcels of low-quality land first.
  - Often the criteria used in carbon sequestration cost studies.
- Interior-Targeted Policy:
  - Fixed budget; maximize the total amount of new interior forest parcels.
  - Target parcels that create new interior forest patches.

Interior Forest Parcels

- A parcel is an interior parcel if it is completely surrounded by forested parcels.
- Interior parcel will have higher bird densities (based on Temple and Cary 1988).



Modeling Steps

- Step one: Generate random landscape where each cell has probability p of being forested.
  - 1-4: Low soil quality
  - 5-8: High soil quality

1	5	2	2	4
7	8	4	3	2
5	5	7	1	3
8	7	8	5	6
4	5	7	4	6

Agriculture

Forest

Modeling Steps

- Step two: Simulate land conversion policies.
  - In a least-cost approach, we target those parcels of lowest soil quality to convert (labeled #).
  - In an interior-targeted approach, we target those parcels that create an interior parcel (labeled *).

1	5 #	2	2	4
7	8	4	3	2
5 #	5 #	7 *	1	3
8	7	8	5 #	6
4	5 #	7	4	6

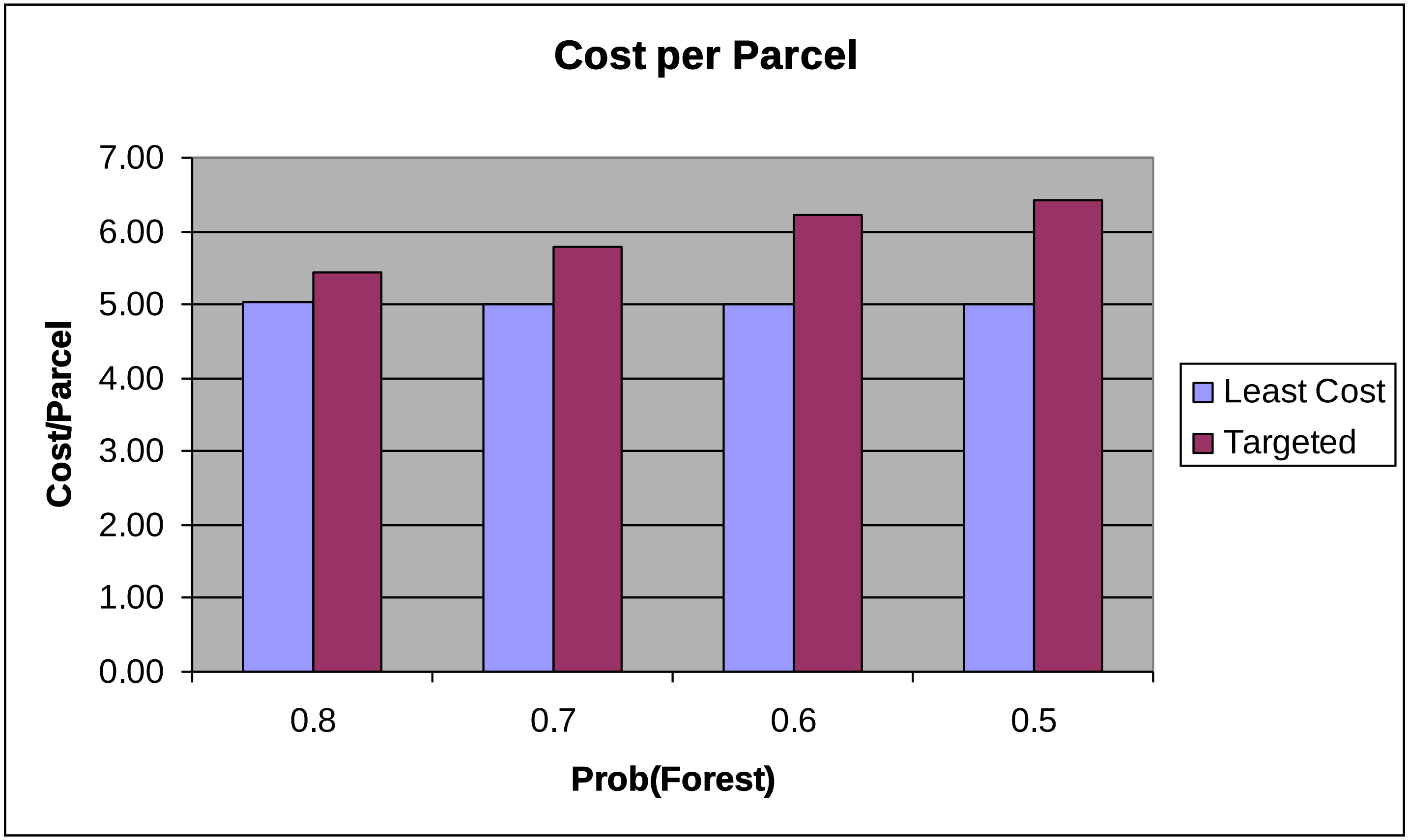
Example

- Simulate two policies for landscapes with p = 0.5, 0.6, 0.7, 0.8.
- Assume cost of conversion equals soil quality.
- Objective is to target 5% of land for new forest parcels.
- Grid is 100x100 plots

Results (500 converted parcels)

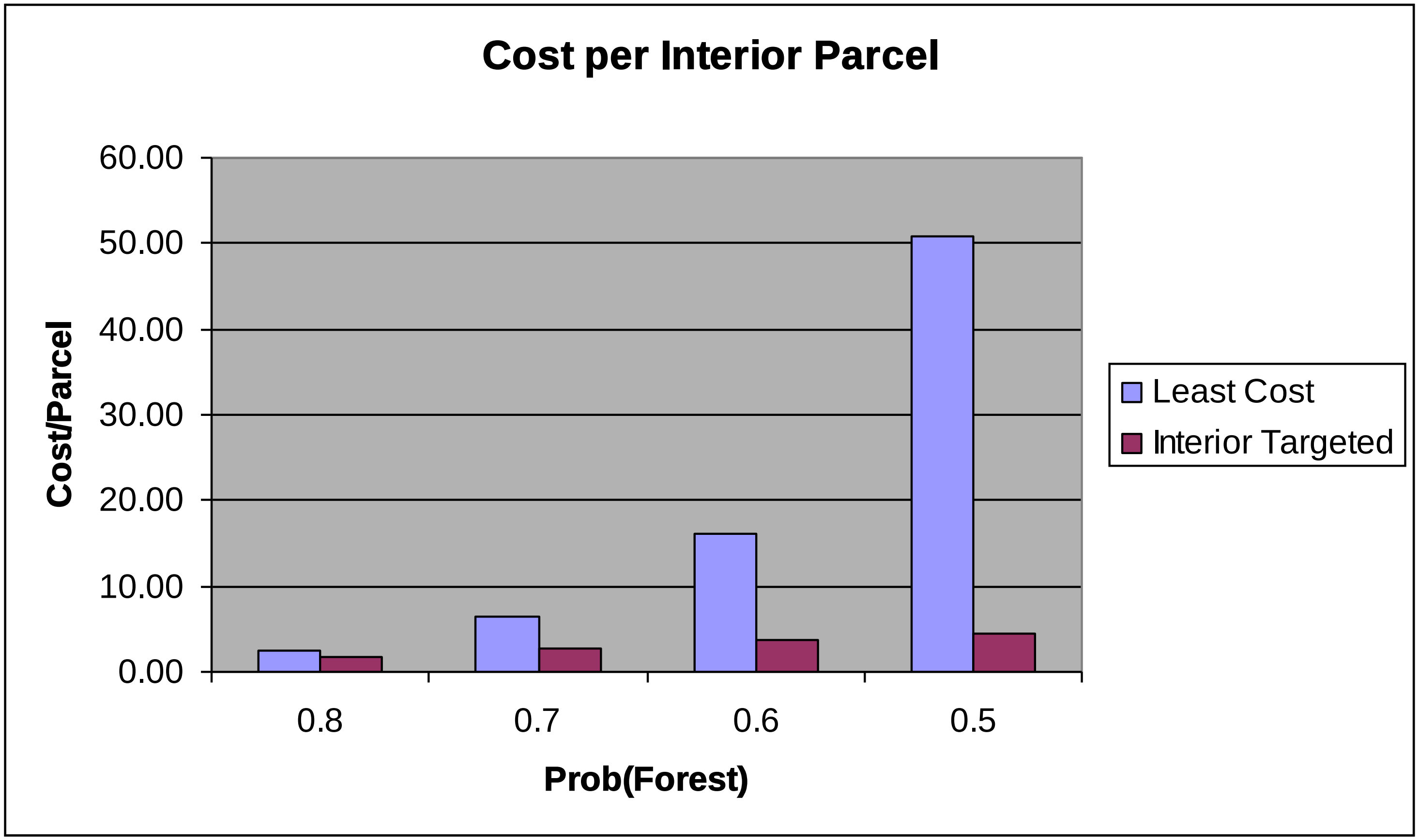
	Least-Cost			Interior-Targeted		
Prob of Forest	Cost/ Inter	Cost/ Tot	Inter Parcels	Cost/ Inter	Cost/ Tot	Inter Parcels
0.8	2.59	5.05	2276	1.75	5.44	2856
0.7	6.57	5.00	775	2.69	5.79	1470
0.6	16.08	5.00	242	3.70	6.21	924
0.5	50.71	5.00	68	4.57	6.42	721

Results



Cost per Parcel
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Cost/Parcel
0.8
0.7
0.6
0.5
Prob(Forest)
Least Cost
Targeted

Results



Cost per Interior Parcel
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Cost/Parcel
0.8
0.7
0.6
0.5
Prob(Forest)
Least Cost
Interior Targeted

Concluding Remarks

- Policy design: What are tradeoffs between policies in terms of costs, carbon, and co-effects?
- Due to computational burden, tradeoff between spatial resolution and size of region
- Expand applications to consider other species of conservation interest