Modeling the Spatial Distribution of Land Uses with National Resources Inventory Data

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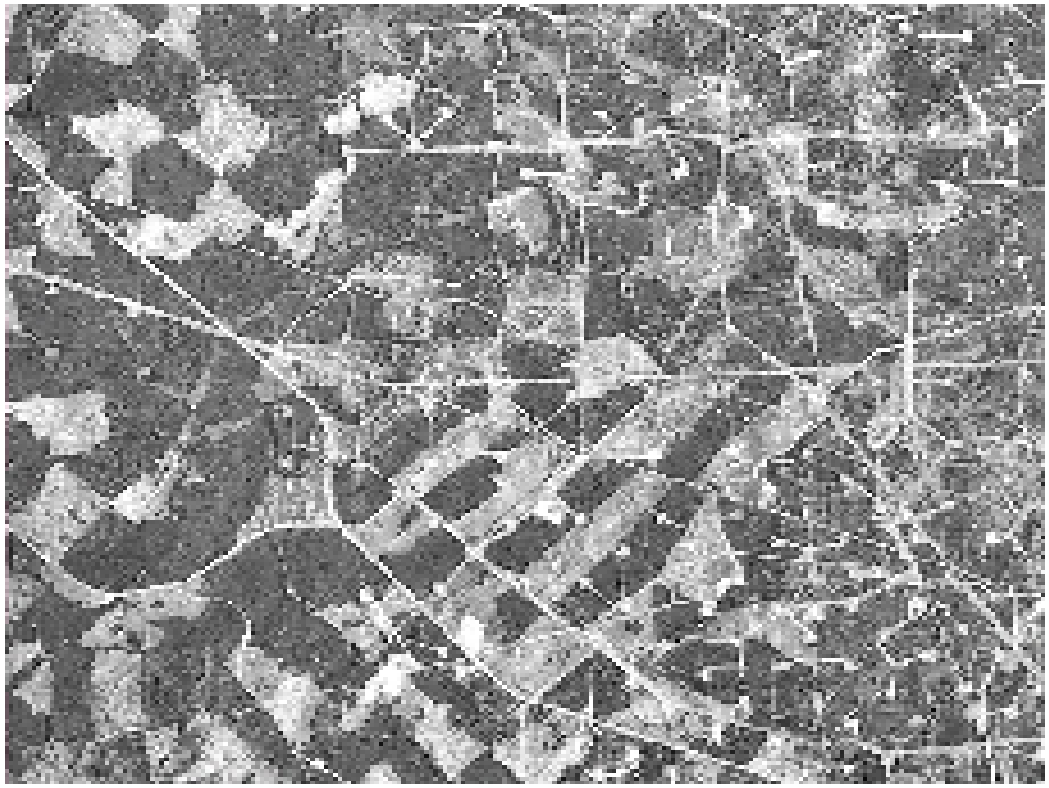
Spatial Pattern of Land Use



- Research with David Lewis (U. Wisconsin) and JunJie Wu (OSU)
- Supported by the U.S.D.A. Forest Service, Pacific Northwest Research Station
- At the end of my talk, I'll discuss other related research

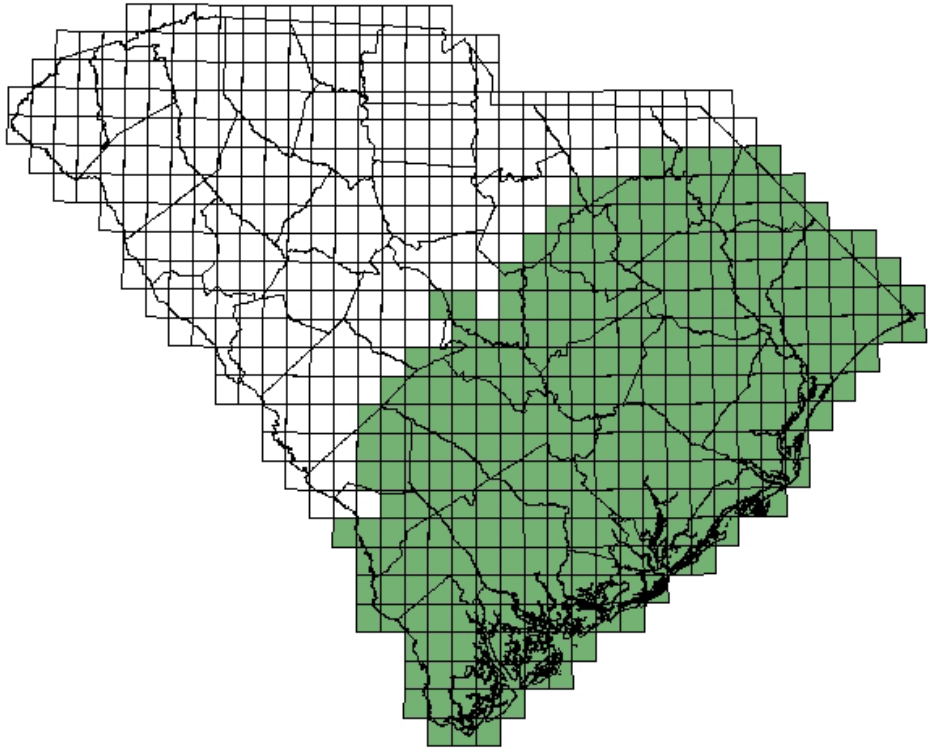
Forest Fragmentation

- Recent estimates indicate that one-fourth of U.S. bird species are declining in population.
- For many important species, habitat fragmentation is a central factor, particularly the loss of large contiguous blocks of forest.
- Many neo-tropical migratory songbirds are affected, especially ones that nest in the forests of the eastern U.S.

Research Question

- How can market-based policies, such as subsidies for afforestation, be used to influence the spatial configuration of forest?

Study Region: The Coastal Plain of South Carolina



Overview of Methods

1. Estimate an econometric model of private land-use decisions with NRI point data

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2. Transition probabilities expressed as functions of net returns to alternative uses, soil quality, etc.

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3. Link transition probabilities to GIS data on actual landscapes

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4. Simulate the effects of market-based policies on the spatial pattern of land use

1. Data for the Econometric Model of Land Use

- National Resources Inventory
  - Data from 1982, 1987, 1992, and 1997
  - Major land use (cropland, pasture, forest, urban)
  - Land Capability Class rating
  - Acreage weight
  - 29,714 points
    - North and South Carolina
    - Began one of three time periods in cropland, pasture, or forest
- County-level data
  - Net returns to agriculture (cropland and pasture), forest, and urban uses developed by Ruben Lubowski
- Data from the Economic Research Service
  - Urban influence for each NRI point, measuring proximity to urban population concentrations

1. Econometric Model

- Landowners are assumed to choose the use that maximizes their net benefits from the land
- Net benefits depend on:
  - The economic returns to land in different uses
    - The point-level return is a function of the county average return and the point-level LCC (agriculture, forest) or urban influence (urban)
    - The interaction between the county return and the LCC or urban influence variable “adjusts” the county return to the point level
  - Costs of converting from one use to another
  - A random component that captures factors unobservable by the researcher
- Certain distributional assumptions on the random components yield a conditional multinomial logit model of land-use transitions

1. Econometric Model

Net benefits from switching point i from use j to k in time t from are given by:

$$NB_{ijkt} = \beta'_{jk}\mathbf{X}_{ijkt} + \varepsilon_{ijkt}$$

$$i = 1,...,I; \quad j = 1,2;$$
$$k = 1,2,3; \quad t = 1,2,3$$

If the errors terms are IID Type I extreme value, then we obtain the land-use transition probabilities:

$$P_{ijkt} = \frac{\exp(\beta'_{jk}\mathbf{X}_{ijkt})}{\sum_{l=1}^{3}\exp(\beta'_{jl}\mathbf{X}_{ijlt})}$$

$$i = 1,...,I; \quad j = 1,2;$$
$$k = 1,2,3; \quad t = 1,2,3$$

1. Econometric Model

The betas are estimated with maximum likelihood where the likelihood function for starting use j is:

$$L_j = \prod_{i=1}^{I} \prod_{k=1}^{3} \prod_{t=1}^{3} W_{it} \left[P_{ijkt} \right]^{y_{ijkt}}$$

where y_{ijkt}=1 if point i switches from use j to k in time t and y_{ijkt}=0 otherwise and W_{it} is the NRI acreage weight

Pooling of time-series observations is appropriate if the unobserved components of net benefits are uncorrelated over time. Since this is unlikely to be the case, we employ a pooling strategy that maximizes the observations of land-use changes but does not require the restriction on the unobserved components.

Because we do not observe the exact location of NRI points, we cannot adjust for spatial dependence in the unobserved components.

2. Transition Probabilities

The estimation yields functions for transition probabilities. The probability that point i will switch from use j to k is a function of estimated parameters, county average net returns, the LCC rating, and the urban influence measure:

$$P_{ijk} = f(\hat{\beta}_{jk}, \overline{\mathbf{NR}}_i, LCC_i, UI_i)$$

The estimation results are consistent with expectations:

Transition	AG returns	FOR returns	URB returns
AG-to-FOR	-	+	
AG-to-URB	-		+
FOR-to-AG	+	-	
FOR-to-URB		-	+

Also, agricultural returns have greater effects on higher quality lands. Forest returns have greater effects on lower quality lands. Points with higher urban influence more likely to convert to urban use.

2. Transition Probabilities and Market-Based Incentives

Market-based incentives can be introduced to modify the transition probabilities:

$$P_{ijk}(S) = f(\hat{\beta}_{jk}, \overline{\mathbf{NR}}_i, LCC_i, UI_i, S)$$

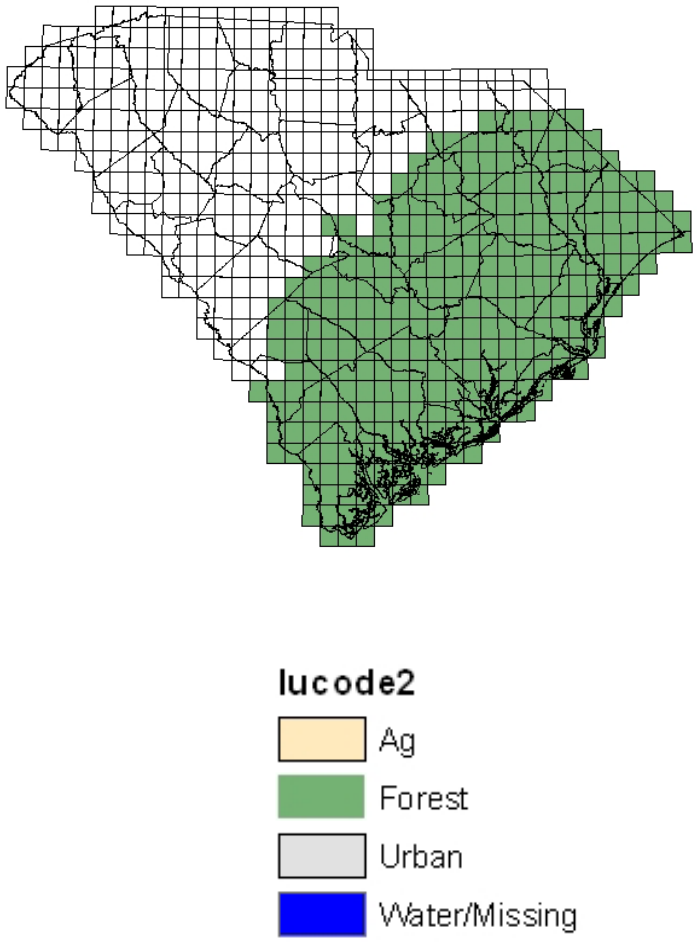
where S is the incentive.

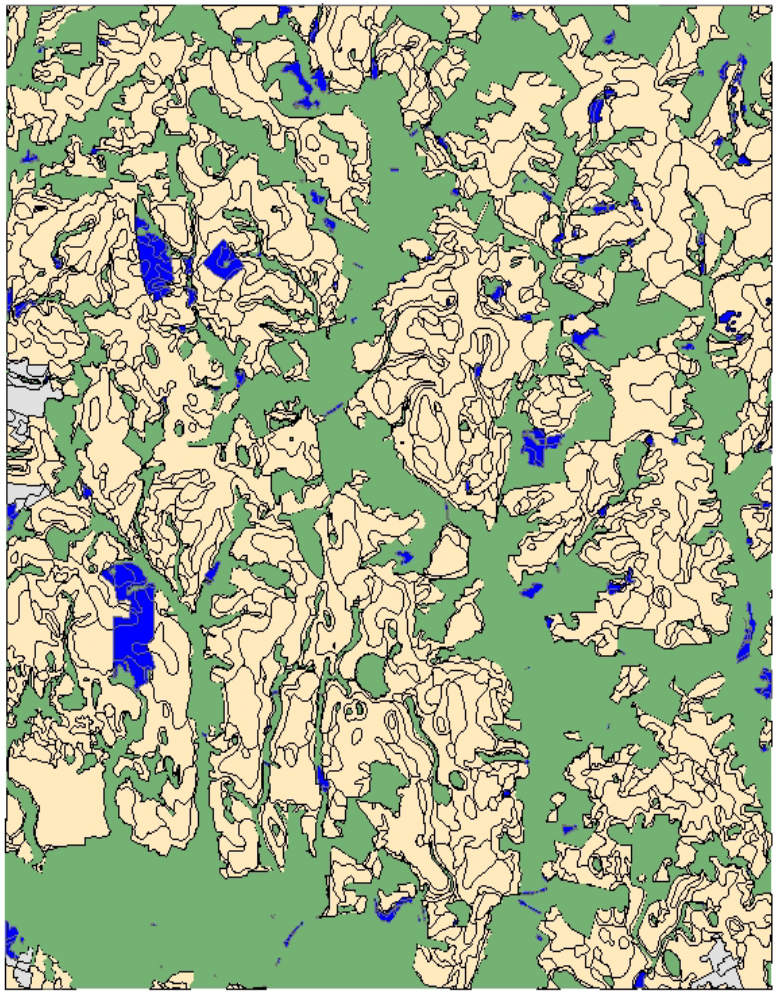
For example, if S is a subsidy for converting land to forest, it is added to the forest net return for land starting in agriculture.

3. Link Transition Probabilities to GIS Data

- Transition probabilities provide a set of rules that govern land-use change in a landscape simulation
- GIS data obtained for variables that differentiate the transition probabilities:
  - Starting land use (Land-use layer from SCDNR and U.S. F&W)
  - Net returns (County boundary layer from SCDNR)
  - Land Capability Class (NRCS)
  - Urban influence (ERS)
  - Ownership (SCDNR)

3. GIS Land-Use Data





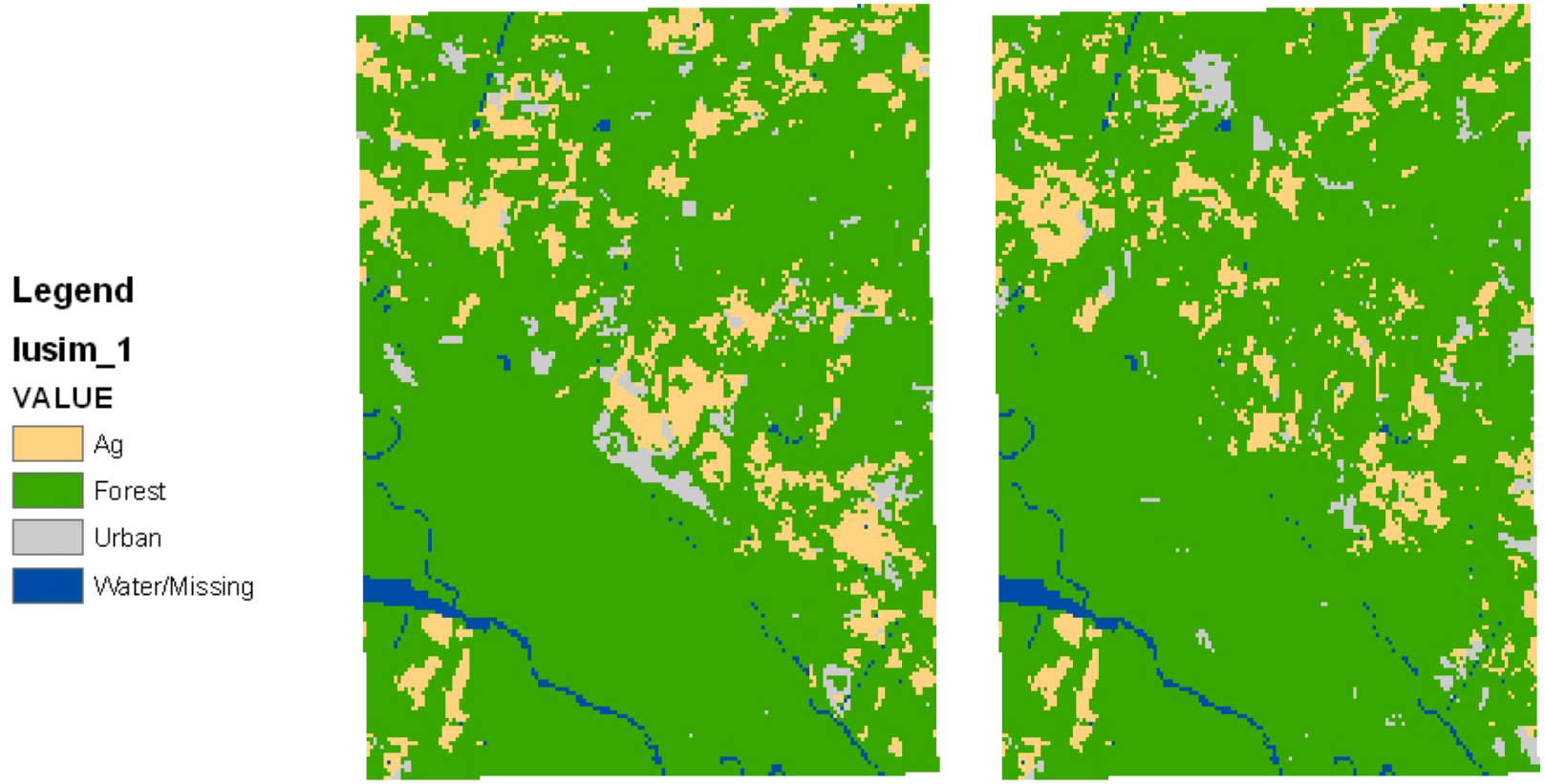
3. Overlay Data Layers

- For each quad, we overlay the data layers for land use, LCC, etc., to identify distinct parcels
  - 295 quads in the study region
  - Approximately 7,500 parcels per quad
  - Parcels have an average size of 5 acres
- Based on its characteristics, each parcel is assigned a set of transition rules
  - For example, for each agricultural parcel we compute the probability that it remains in agriculture, the probability that it changes to forest, and the probability that it changes to urban

4. Landscape Simulations

- For a given agricultural parcel, suppose prob(ag)=0.8, prob(for)=0.1, and prob(urb)=0.1
  - If the landowner were faced with the same choice occasion many times, agriculture would be chosen 80% of the time, forest 10% of the time, and urban 10% of the time.
  - A random number generator is used to simulate the choice occasion for every parcel on the landscape
- Each round of the simulation produces a landscape that is consistent with the transition rules
- Hundreds of landscapes are generated to capture the range of potential spatial configurations

4. Two Simulated Landscapes



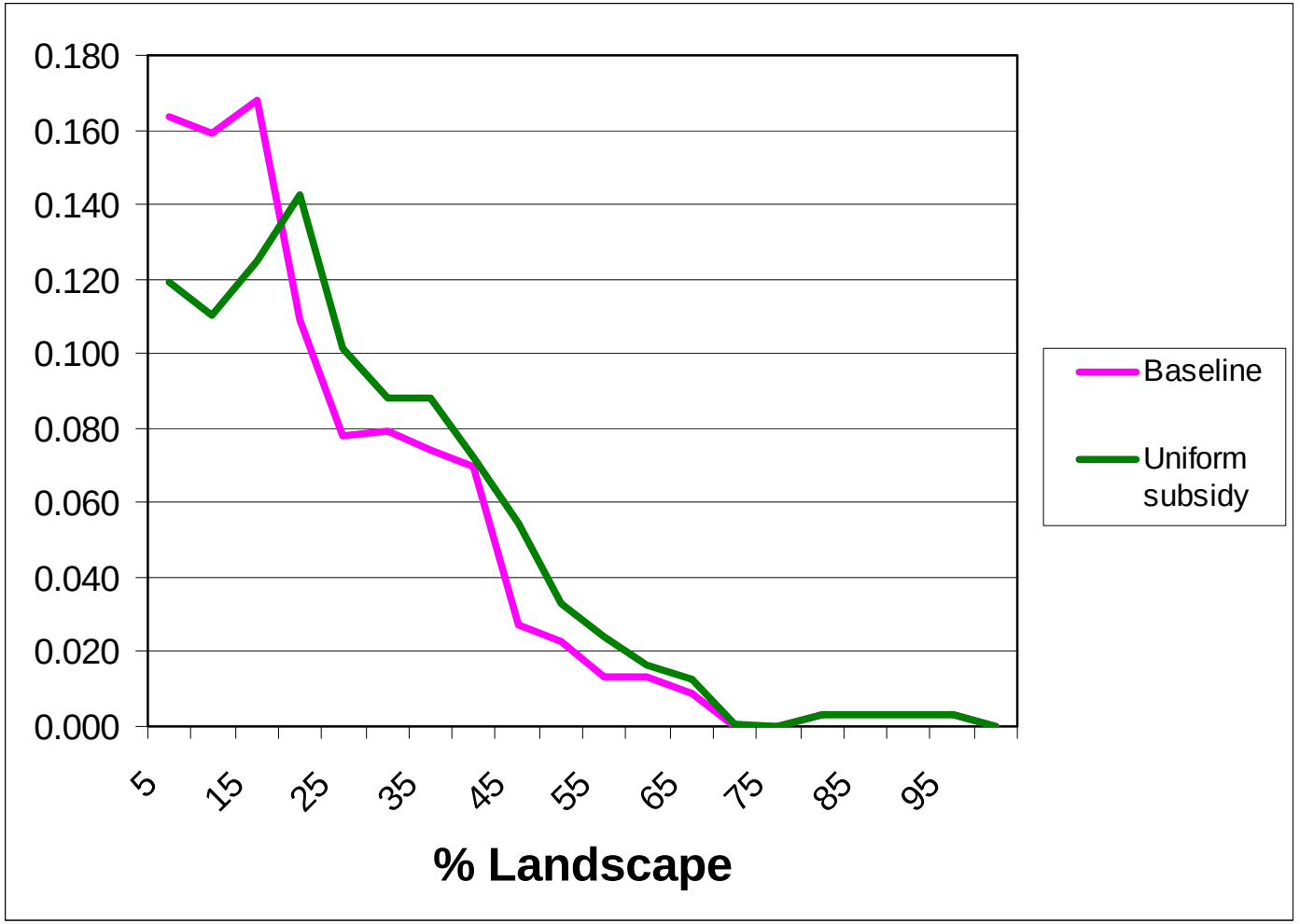
4. Summarizing Spatial Pattern

- We summarize the spatial configuration of forest with fragmentation indices computed with Fragstat software.
- Two indices of relevance to interior-forest birds:
  - Proportion of the landscape in core forest
    - A parcel is core if it is >200m from nearest non-forest edge.
  - Average forest patch size
    - The total forest area on a landscape divided by the number of spatially distinct forest patches.

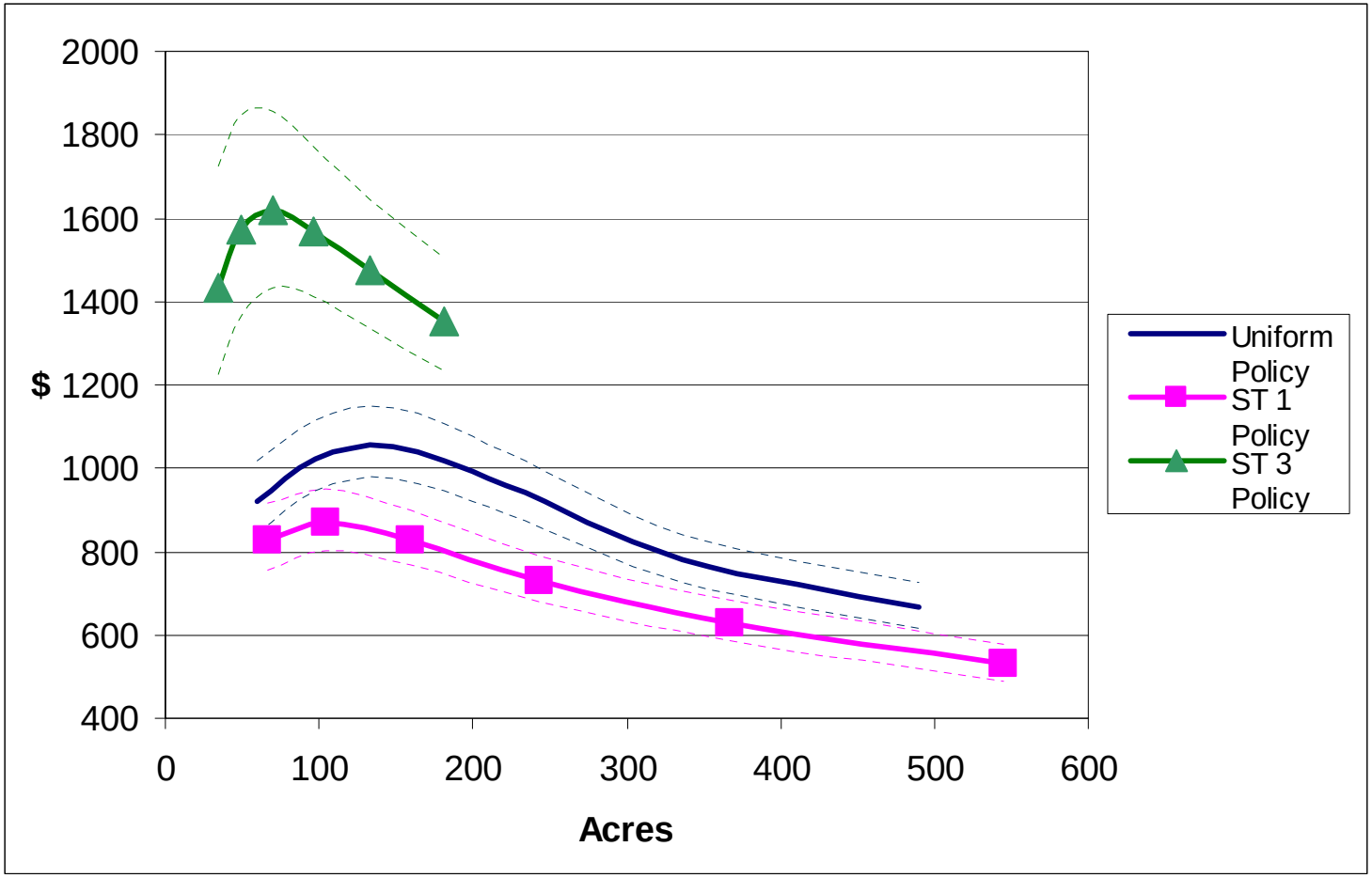
4. Policy Scenarios

- Baseline with no incentive
- Subsidies
  - Payment per acre for converting agricultural land to forest
  - Uniform subsidy: the same payment given to all landowners
  - Targeted subsidies: a parcel must be located next to either one or three forested parcels to be eligible for the subsidy

The Effect of a $25/acre Afforestation Subsidy on the Core Forest Distribution



Marginal Costs of Increasing Average Patch Size (50% Initial Forest)



For Further Information

- Work presented today
  - Lewis, D.J., and A.J. Plantinga. 2007. Policies for Habitat Fragmentation: Combining Econometrics with GIS-Based Landscape Simulations. *Land Economics* 83(2):109-127.

- Theoretical and empirical analysis of optimal targeting approach
  - Lewis, D.J., Plantinga, A.J., and J. Wu. 2007. Targeting Incentives to Reduce Habitat Fragmentation. Working Paper, Department of Agricultural and Resource Economics, Oregon State University.

Related Research

- Comparison of market-based incentives to optimal solution; populations of species and carbon sequestration are modeled.
  - Nelson, E., Polasky, S., Lewis, D.J., Plantinga, A.J., Lonsdorf, E., White, D., Bael, D, and J. Lawler. 2007. Efficiency of incentives to provide ecosystem services. Working Paper, Department of Applied Economics, University of Minnesota.
- National land-use model developed by Ruben Lubowski and used to project land use for the Resources Planning Act assessments
  - Plantinga, A.J., Alig, R.J., Eichman, H., and D.J. Lewis. 2007. Linking Land-Use Projections and Forest Fragmentation Analysis. Res. Pap. PNW-RP-570. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Station. 41 p.

QUESTIONS?