Exploiting Space in Agricultural Economics Models

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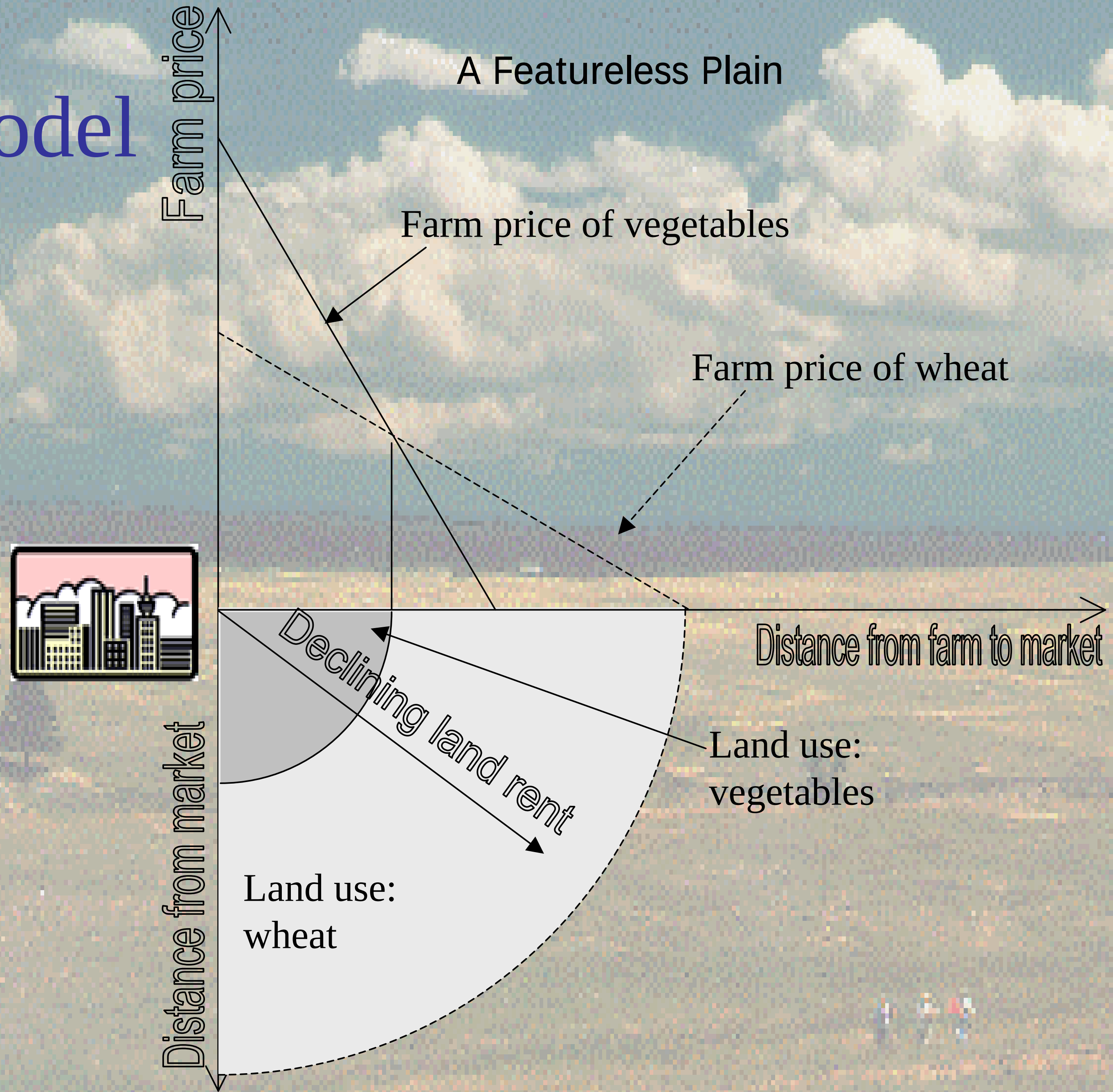
Outline of Presentation

- Economic theory and the role of location
- Spatial issues in
  - Precision agriculture
  - Rural-urban interface
  - Land use in LDCs

The von Thünen Model



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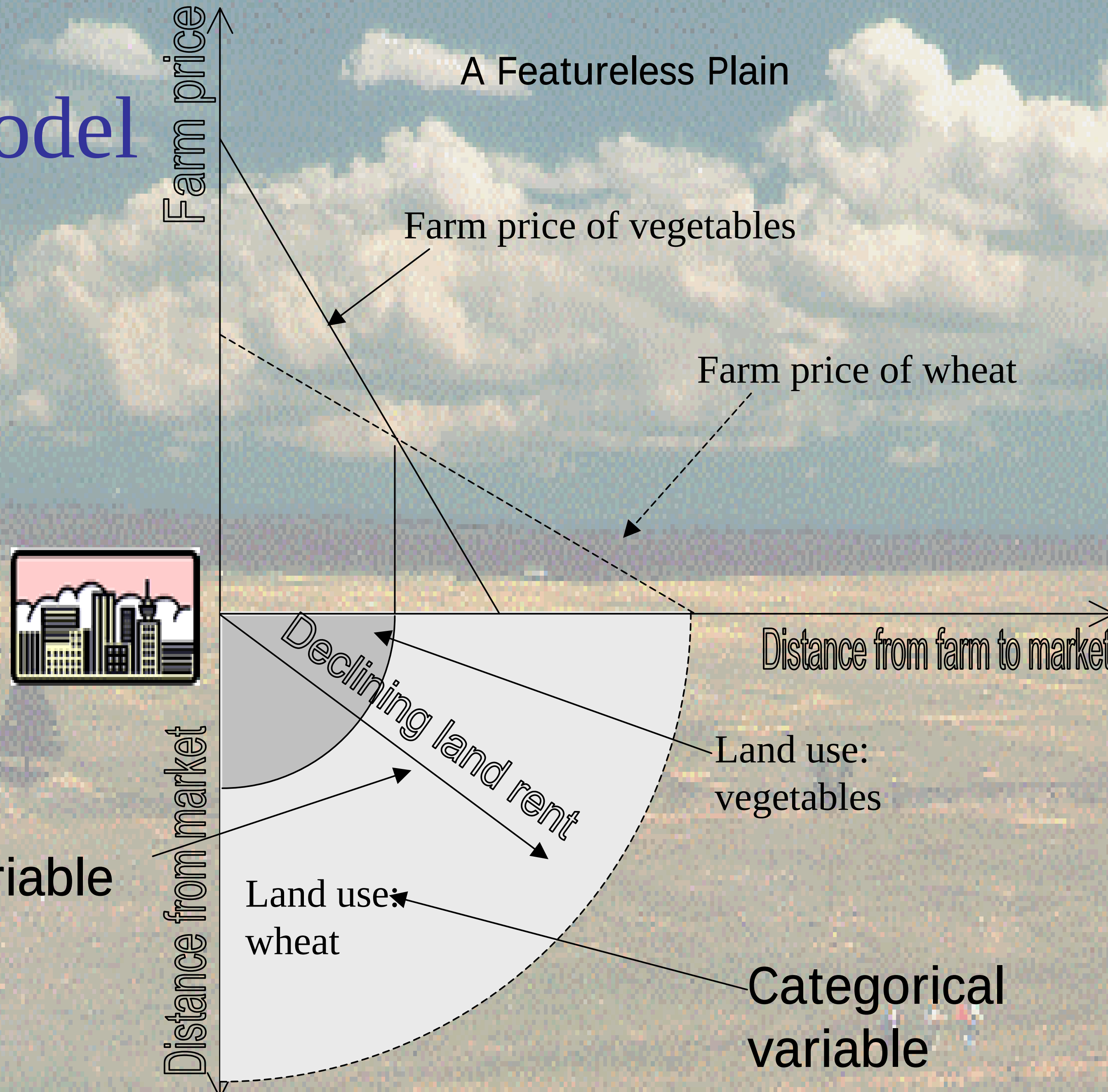


Economic Theory and Location

- Continuous variables
  - Production/profit/cost max/min
  - Hedonic analysis
- Categorical variables
  - Land use

- Examples
  - Does variable rate technology pay?
  - What is value of open space preservation?
  - When will housing development occur?
  - Do roads cause deforestation?

Basic Spatial Economic Theory: A Location-specific Resource…

- Is operated by individual or group to maximize utility (sometimes profit)
- Has an exogenous set of geophysical and socioeconomic characteristics that influence resource use choices and productivity
- Choice may be influenced by ‘neighbors’ (Goodchild presentation)

Complications with Categorical Variables

- Decision variable(s) is (are) not observed (latent)
- Observed outcomes are discrete and constant over ranges of the latent variable
- Decision choices can be more complicated
  - E.g., choose among several different production technologies

References

- For this presentation
  - *Agricultural Economics* 27 (3),2002, Special issue on spatial issues for agricultural economists
- Others
  - L. Anselin, R. Florax, S. Rey (eds.) 2003. *Advances in Spatial Econometrics, Methodology, Tools and Applications*. Berlin: Springer.
  - *International Regional Science Review* 26 (2), 2003, Special Issue on Spatial Externalities
  - *International Regional Science Review*, 2004, Special Issue on Land Use

Continuous Data and Spatial Considerations

Variable Rate Technology

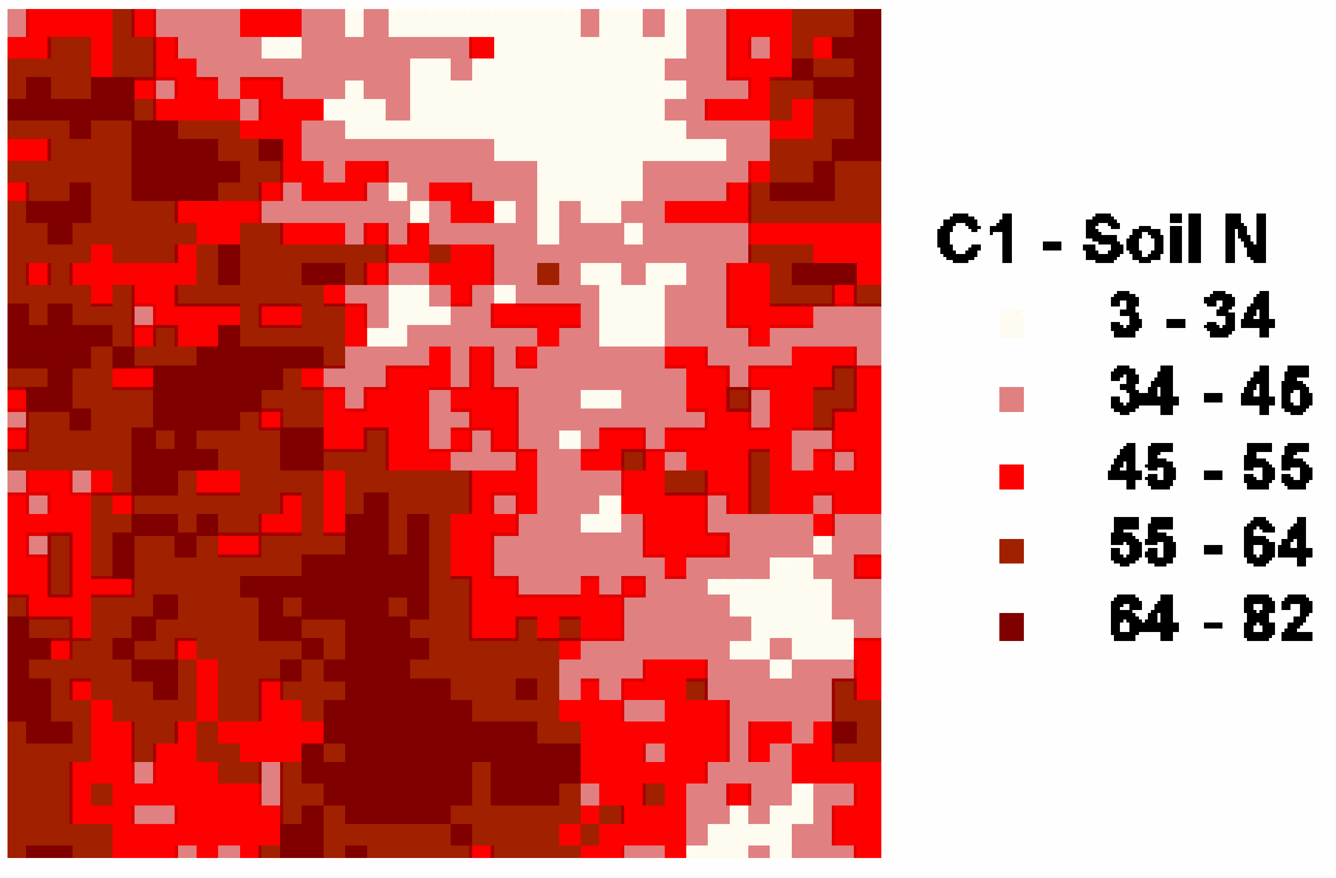
If it’s such a good idea, why doesn’t anyone use it?

The Problem

- Fields aren’t homogeneous
- Collecting information is expensive
  - Soil tests
  - Variable application of inputs
  - Harvest monitoring (yield monitors)

The Problem: Fields aren't Homogeneous

Simulated Soil Nitrogen



Bullock, Lowenberg-Deboer, Swinton

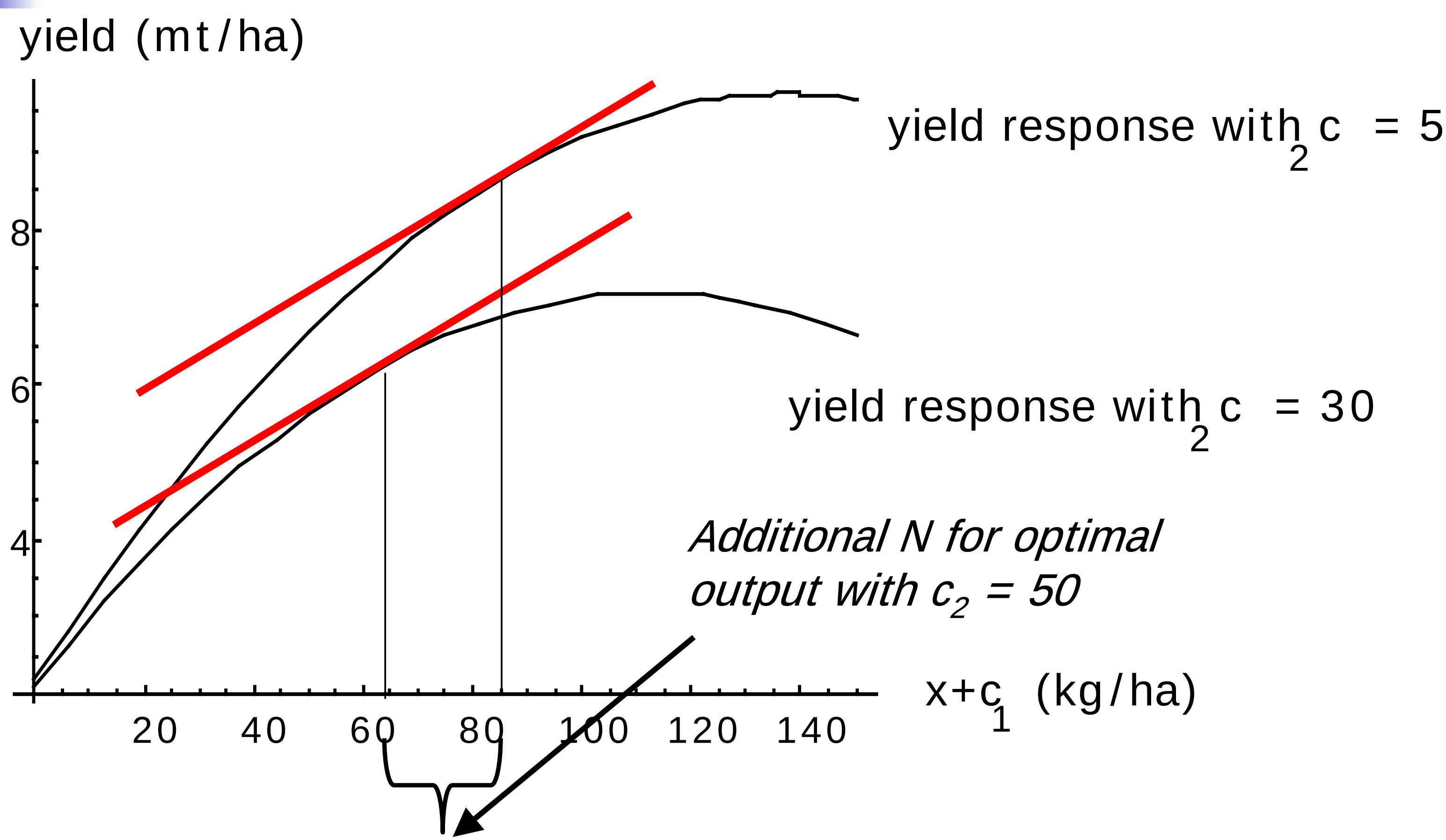
Basic Spatial Management Optimization Problem

$$\max_{x_{ij}} \pi = \sum_{i}^{n} \sum_{j}^{m} py_{ij} - wx_{ij} - g - v - F \; s.t. \; y_{ij} = f(x_{ij}, c_{ij}, z)$$

- Maximize quasi-rents
- p, w – field-level prices, output and inputs
- **y** is yield, **x** is a vector of managed inputs
- **c** - vector of site characteristics (e.g., soil nitrogen, depth)
- **z** - vector of uncontrollable characteristics (e.g. rainfall)
- g are quasi-fixed costs for data collection and management, v are quasi-fixed costs for VRA technology

Bullock, Lowenberg-Deboer, Swinton

Simulated Corn Yield Response to Total Nitrogen and Soil Depth



c_1 – soil nitrogen, x – applied nitrogen, c_2 – soil depth

Bullock, Lowenberg-Deboer, Swinton

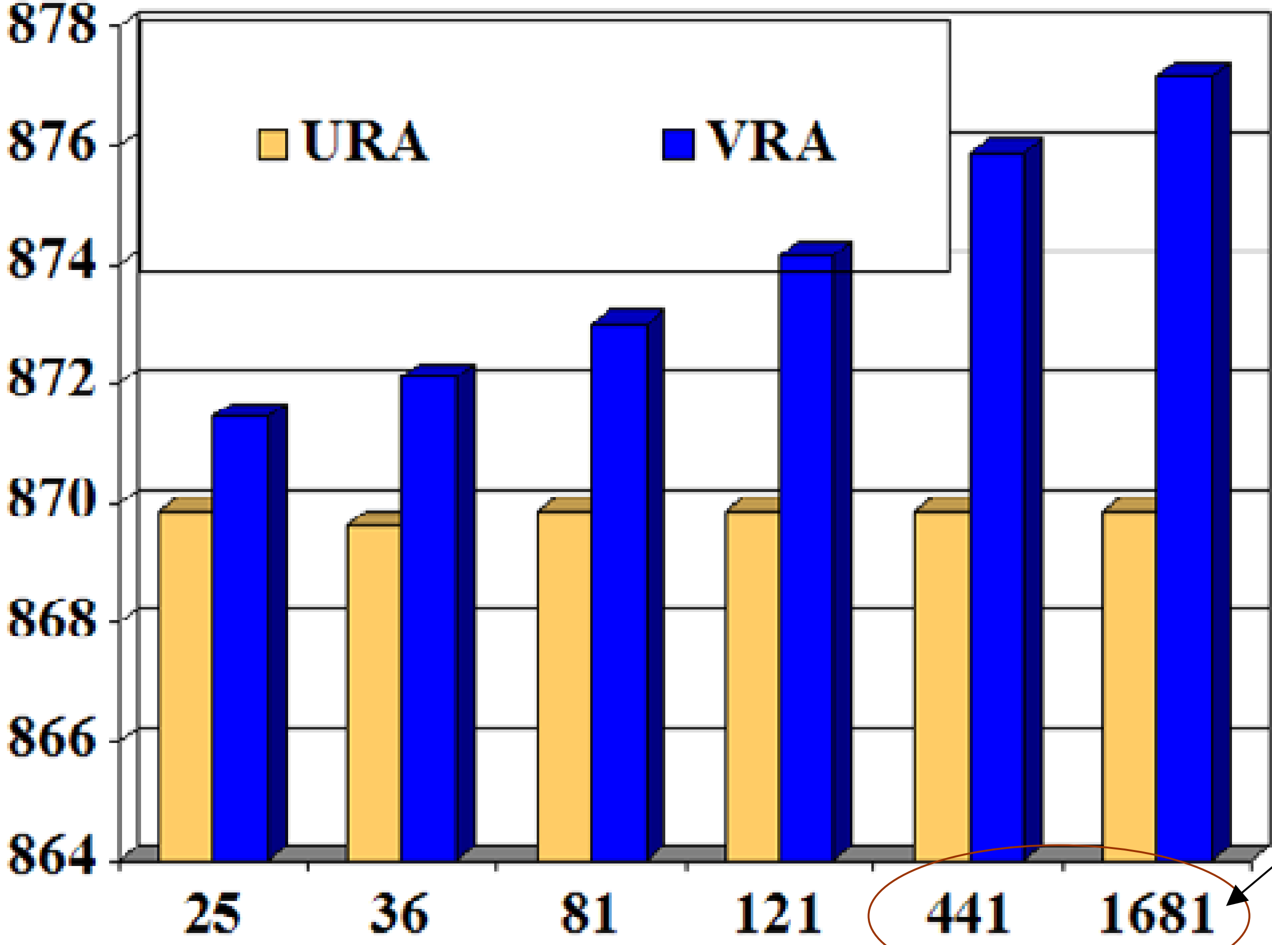
How Much Information to Collect?

- Do ‘agronomic’ experiments to collect response coefficients
- Sample nitrogen at various locations
- What is profit-maximizing information?

Key Spatial Data

- Geophysical – within field
  - Soil fertility
  - Depth
- Socioeconomic – field level
  - VRA costs
  - Geophysical data gathering costs
  - Input and output prices

Gross Margins over Applied Nitrogen Costs, Uniform versus Variable N Application



Number of field sample points

Note: Not linear

Bullock, Lowenberg-Deboer, Swinton

Land Use Change at the Rural-Urban Interface

Where the Suburbs End

Bell and Irwin

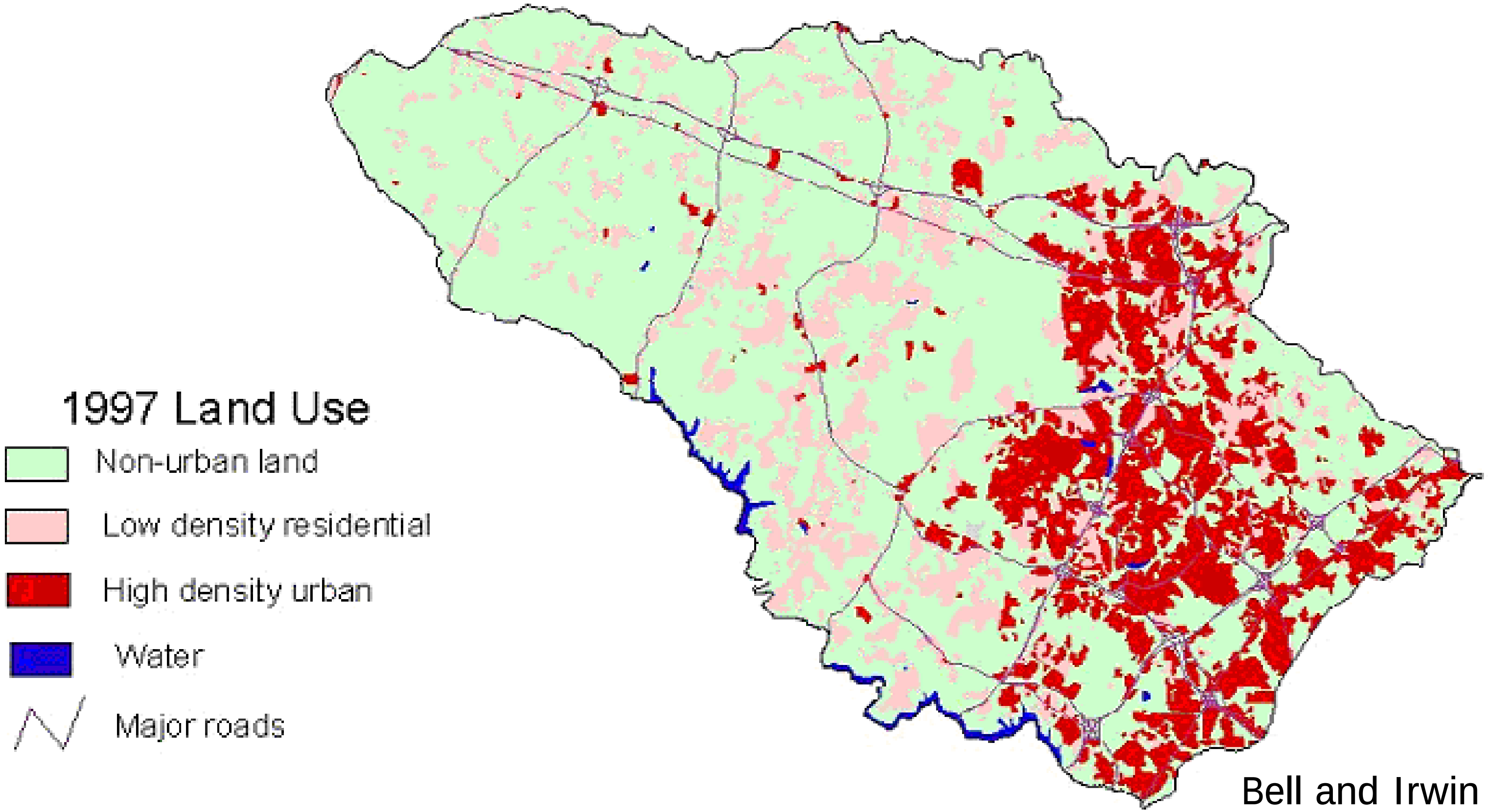
Characteristics of the Interface

- Cost of providing local public services influenced by
  - Pattern of development
  - Rate of land conversion to development
- Environmental effects
  - Reduced water quality due to increased urban runoff
  - Loss and fragmentation of wildlife habitat

Characteristics of the Interface

- Changes in land use patterns
  - Alter the aesthetics, dynamics, and sense of place
  - Are often externalities
- Rich in spatial data
  - Spatial data for tax assessment, emergency services, environmental resource management

Land Use 1997: Howard County, Maryland



Bell and Irwin

Key Drivers of **Overall** Change

- Improved accessibility of exurban areas
- Changing economic environment in urban areas (e.g., taxes, housing prices, quality of life)
- Changes in the population structure (e.g., more retirees)
- Changes in technology (e.g., telecommuting)

Drivers of **Spatial Distribution** of Change

- Proximity to employment
- Proximity to other activities (e.g., shopping, recreation, entertainment
- Spatial distribution of
  - public services (e.g., sewer and water)
  - natural features (e.g., rivers, mountains, slope)
- Surrounding land uses of an area
- Zoning policies and other growth management policies

Basic Models

- Convert from land use *u* *(undeveloped)* to *r* if
  - Today (static)

$$R_{krt|u} \geq R_{kjt|u}\,; \forall\ j = 1, \ldots, J$$

  - In time period t (dynamic)

$$R_{krT|u} - \sum_{t=0}^{\infty} R_{kuT+t}\,\delta^{T=t} > 0$$

$$R_{krT|u} - R_{kuT} > \delta(R_{krT+1|u})$$

Bell and Irwin

Empirical Modeling

- Survival (Hazard) Analysis
  - When does conversion occur
  - Hazard function - conditional probability conversion occurs between *t* and *Δt*,

$$h(t) = \lim_{\Delta t \to 0} \frac{G(t+\Delta t) - G(t)}{\Delta S(t)} = \frac{g(t)}{S(t)}$$

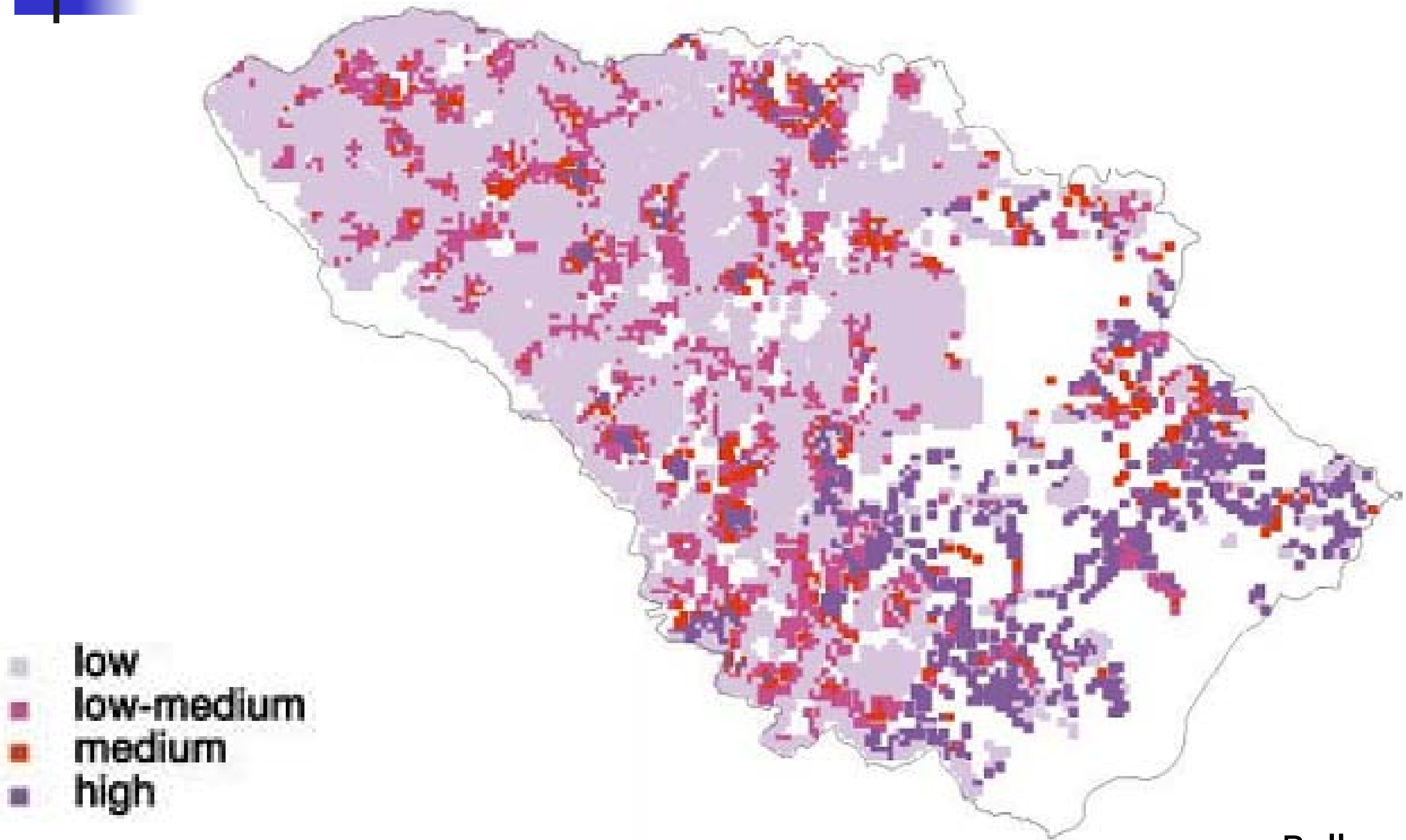
S(t) = 1 – G(t), where G*(t) = Pr(T ≤ t)*
T – duration length

Bell and Irwin

Empirical Modeling

- Hedonic property value models
  - Land value *y* in use *h* depends on
    - Structure attributes
    - Location attributes
  - $y^h = X\beta + \varepsilon;$
  - *h – location use, X – attributes,*
  - β *- marginal willingness to pay for property characteristic*

Land Conversion Probability: Howard County, Maryland



Bell and Irwin

Categorical Data

Categorical Data and Economic Theory

$$R^{*}_{hlT} = \int_{t=0}^{\infty} \left(P_{hlT+t}\, Q_{hlT+t} - \mathbf{C}_{hlT+t} \mathbf{X}_{hlT+t} \right) e^{-i_l t} dt$$

Net Present Value (NPV)	equals	Value of Output	minus	Cost of Inputs	Discount effect

One optimization for each possible land use h

Then choose land use with highest rent

R^{*}_{hlT} **not observable (latent variable)**

Nelson and Geoghegan

Estimated Model

- Prob(h=i) = f(G,S,A)
- What is the probability that land use *i* (with highest NPV) is chosen in location *h*?
- This probability is determined by
  - G – geophysical variables at location
  - S – socioeconomic variables at location
  - A – effects from surrounding locations (spatial effects)

Geophysical Variables Determine Possible Choices

- Soil productivity
- Temperature
- Rainfall
- Elevation
- Slope
- Gross and net solar radiation

Socioeconomic Variables Determine Most Profitable Choice

- Location-specific prices (affected by cost of access)
  - Outputs from land use
  - Intermediate inputs
  - Factors of production
  - Cost of access often the only available price information
- Effective security of tenure

Theory Issues

- Production/land use choices may have differing temporal dimensions
  - E.g., trees versus annual agriculture
- Future prices not known; decision-making under uncertainty

More Issues

- Not all choices are possible at all locations
  - (E.g., can’t have wetlands on steeply sloping parcel)
- Conversion from one land use to another
  - Is costly (cost may be infinite)
  - Is not necessarily symmetric
- Not all potential choices may be present
- Static versus dynamic analysis
  - Deforestation is response to change in incentives (disequilibrium)

Some Problems with Existing Research

- Doesn't account for transition costs or asymmetries
- Doesn't deal well with spatial effects
  - Besag sampling/Kelejian-Pruja statistic
  - Meaningful versus statistical significance
- Data/problem mismatch. What is the
  - Correct unit of analysis?
  - Correct area of analysis?

Interesting Questions

- How do roads affect land use (static analysis)?
- How do roads affect deforestation (dynamic analysis)?
- How will new infrastructure investments affect land use?
- How do changes in property rights regimes affect land use?
- Are location-specific critical resources threatened by ag or macro price changes?

Data Environment

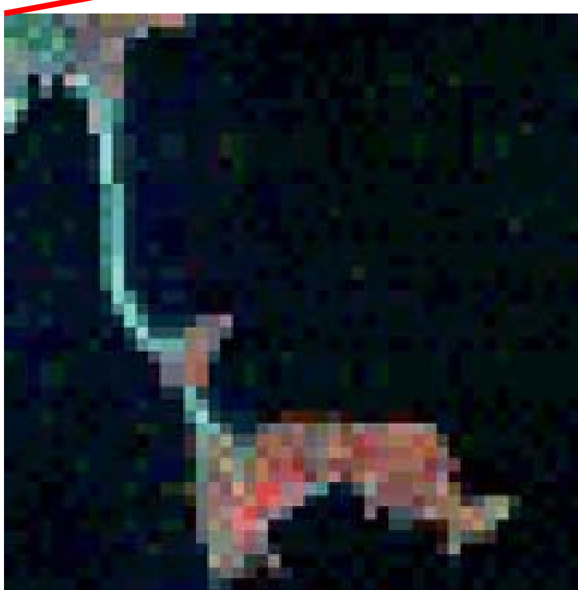
- Statistical agencies don’t collect
- Primary data collection (surveys) expensive or impossible
- Satellite images provide alternative

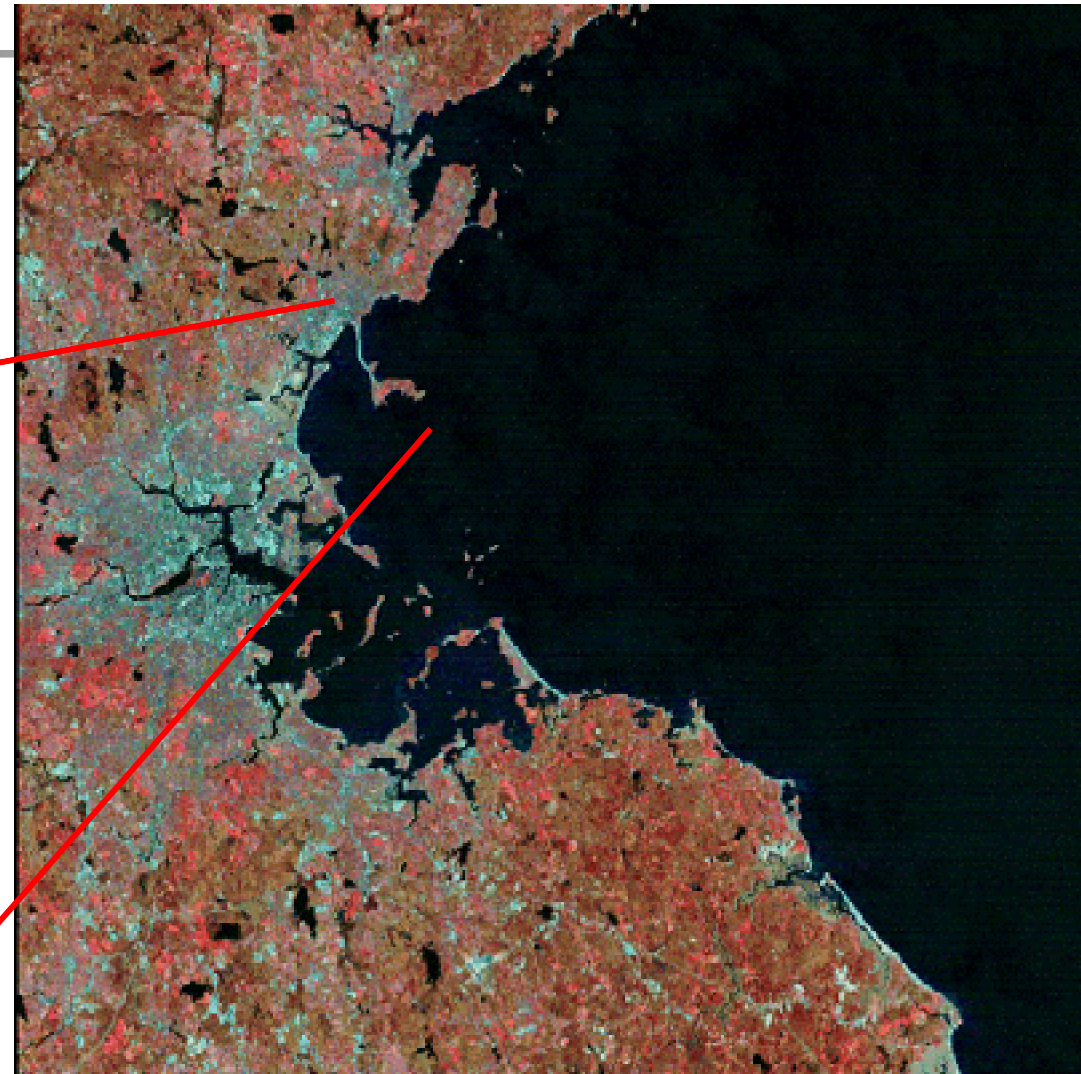
What are 100 m pixels? Boston Harbor
False Color Composite

Black – water

Red – vegetation

Grey/blue – urban areas, sand





Probability to Prediction

- Logit or probit generates probability estimates for each location
- Predicted land use derived by
  - Land use with highest probability – all locations assigned
  - Land use with probability greater than x % (e.g., 50%) – some locations unassigned

Prediction to Simulation

- Change values of right-hand-side variables (simulate new policy/investment)
- Calculate new probabilities
- Do new land use predictions
- Compare to old predictions

Pave the Pan American Highway in Darién, Panama ?

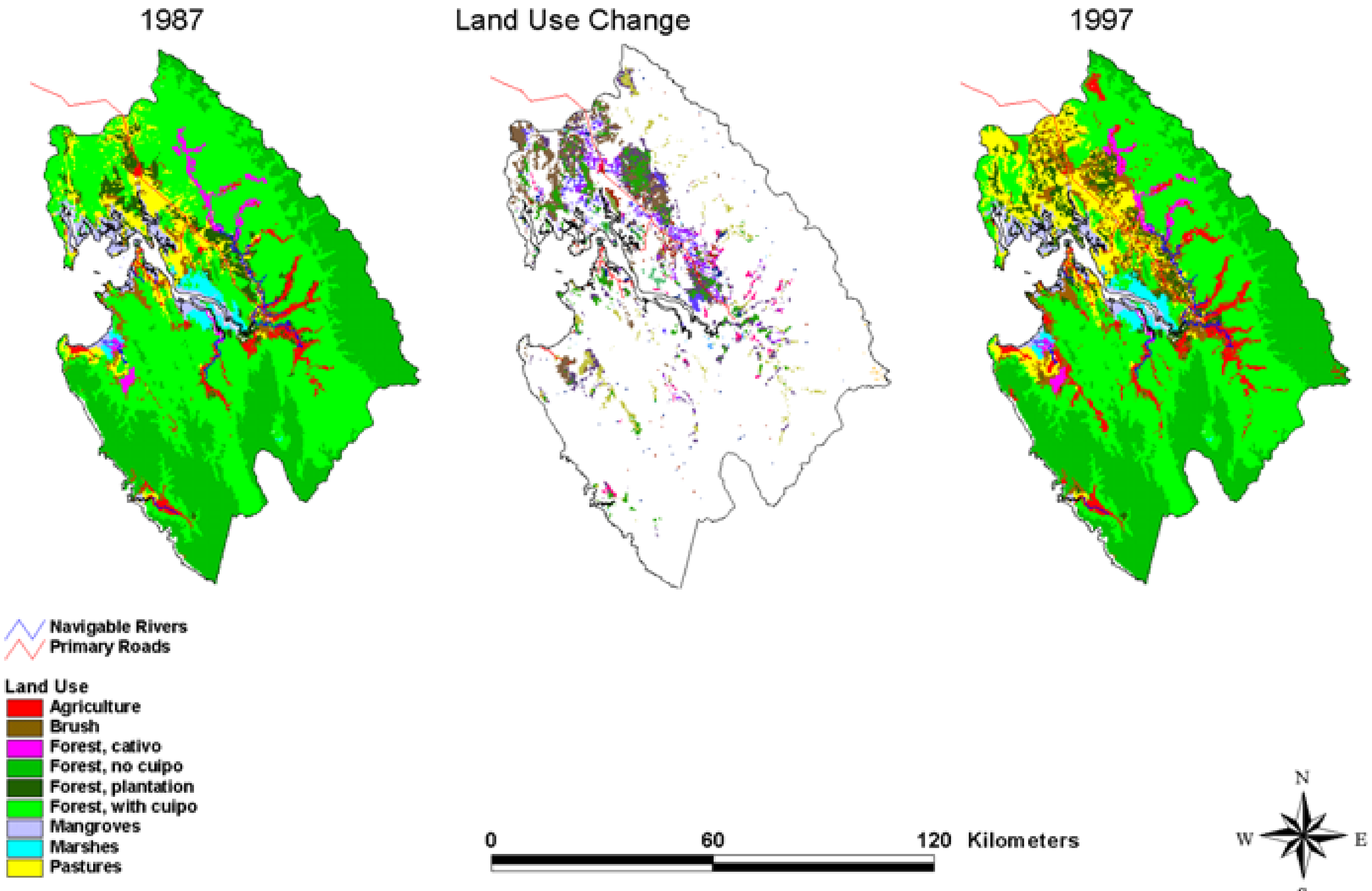
Darién, Panama Environmental Resources

- Land bridge between N and S America
- Darién National Park
  - UNESCO World Heritage Site, 1981
  - Biosphere Reserve, 1983
- Indigenous population relatively undisturbed

Legal Property Rights

- National park
  - Southern border (with Colombia)
- Cemaco reserve
  - Middle of province, near Pan American highway
- Sambú reserve
  - Southwestern part of province, not near roads


Pan American Highway
Comarca Emberá No. 1
(Cemaco District)
San Blas
Meteti
Boca de Mamagantí
La Palma
Chepigana
Yavisa
Pinogana
Garachiné
Pirre
El Real
Camogantí
Boca de Cupe
Alto Limón
Boca de Sabalo
Boca de Pavarandi
Darién Park
Comarca Emberá No. 2
(Sambu District)
La Piña
Puerto Piña
Colombia
Cocalita
Province Border
Towns
Primary Roads
Comarca Sambu
Navigable Rivers
Comarca Cemaco
0
20
40
Kilometers
N
W
E
S


1987
Land Use Change
1997
Navigable Rivers
Primary Roads
Land Use
Agriculture
Brush
Forest, cativo
Forest, no cuipo
Forest, plantation
Forest, with cuipo
Mangroves
Marshes
Pastures
0
60
120 Kilometers
N
W
E
S

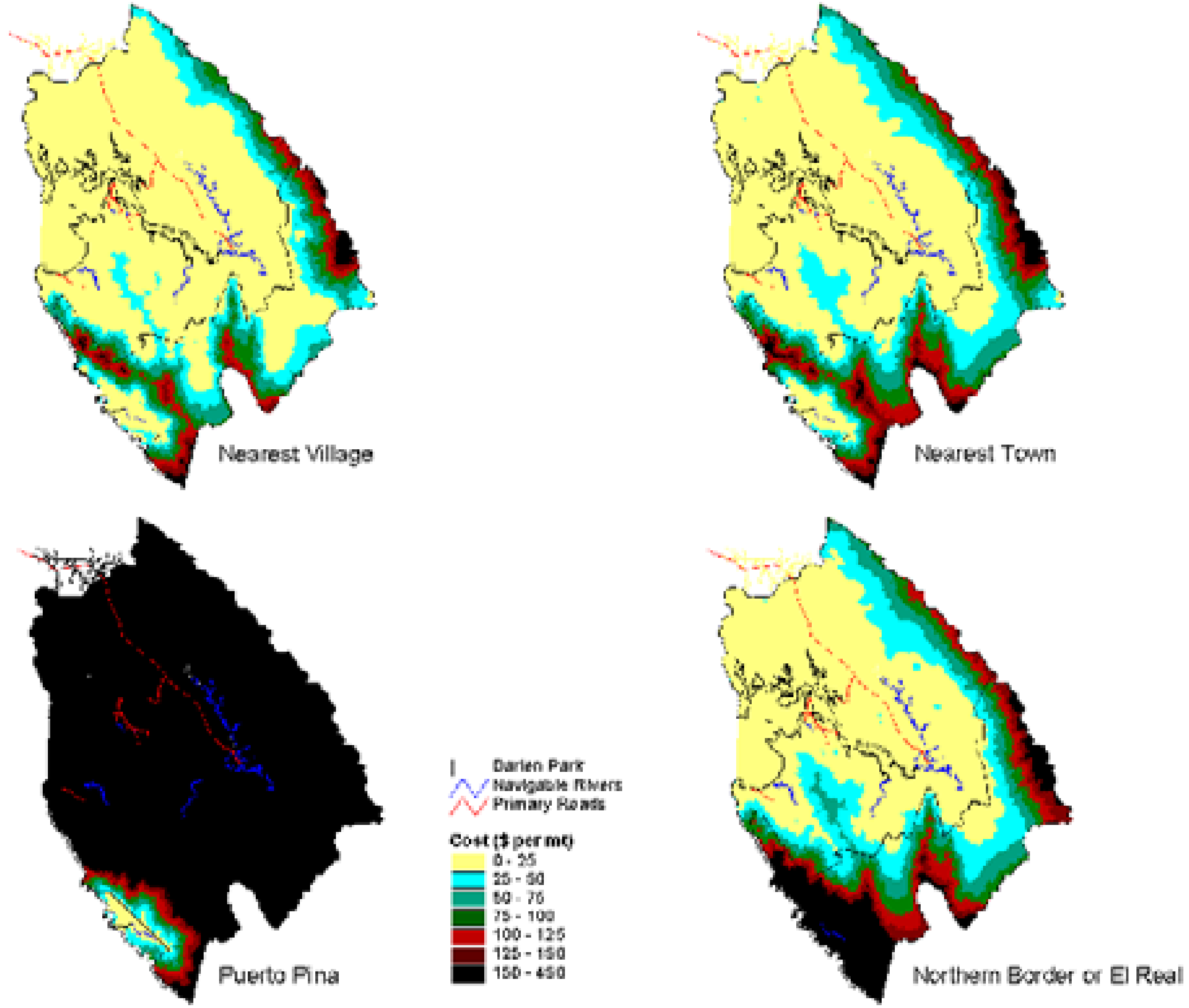
Multinomial Logit Estimation

- Y – 5 land use choices
- Geophysical variables
  - Elevation, slope, temperature, soil type
- Socioeconomic variables
  - Cost of access to
    - Nearest 'export' outlet
    - Nearest village
    - Nearest town
    - Pacific port
  - Property rights dummies
- Spatial lag

Data Sources and Manipulation

- 15 land use categories -> 5
  - 3 kinds of forest, “human intervention”, marshes
- Elevation, temperature, rainfall
- Location of roads, rivers
- Transport costs along highways
- Some prices
- Calculate cost surfaces, others

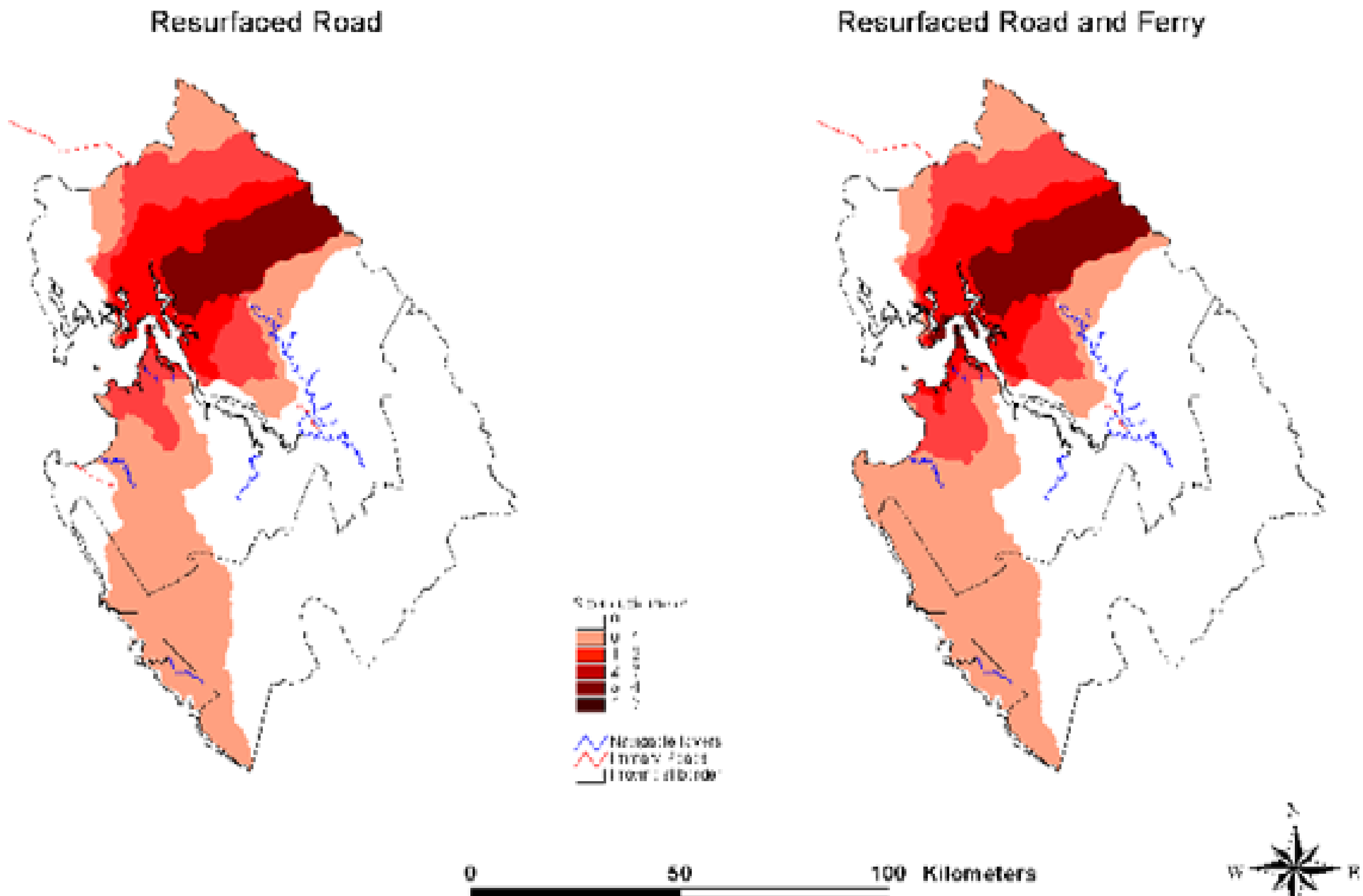
Transport Cost to ...



Two Simulations: Effect on Land Use of

- Reduce road transport cost by 50 percent (change cost surfaces)
- Create new property rights (change dummy value from 1 to 0)

Change in Transport Cost



Note: The northwest corner is served by a secondary road; the southeast is served by navigable rivers.

Prediction Matrix

Actual	0	1	2	3	4	Total	Ratio, correct to total
Forest without cuipo (0)	**16,805**	1,499	0	51	14	18,369	**0.915**
Forest with cuipo (1)	1,000	**22,604**	11	2,546	187	26,348	**0.858**
Forest with cativo (2)	0	483	**62**	272	93	910	**0.068**
Human inter-vention (3)	130	748	35	**14,631**	195	15,739	**0.930**
Marsh (4)	0	228	0	632	**1,668**	2,528	**0.660**
Total	17,935	25,562	108	18,132	2,157	63,894	

Spatial Measures of Predictive Power

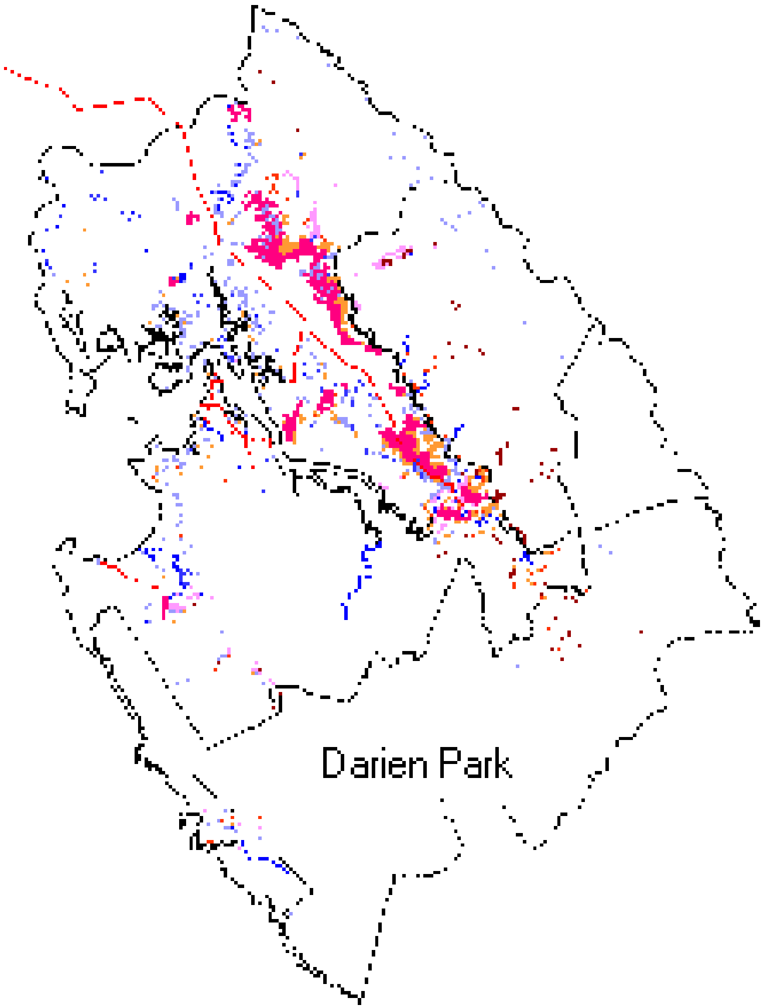
PDif
Max prob - Next Highest

PMax
Max probability value

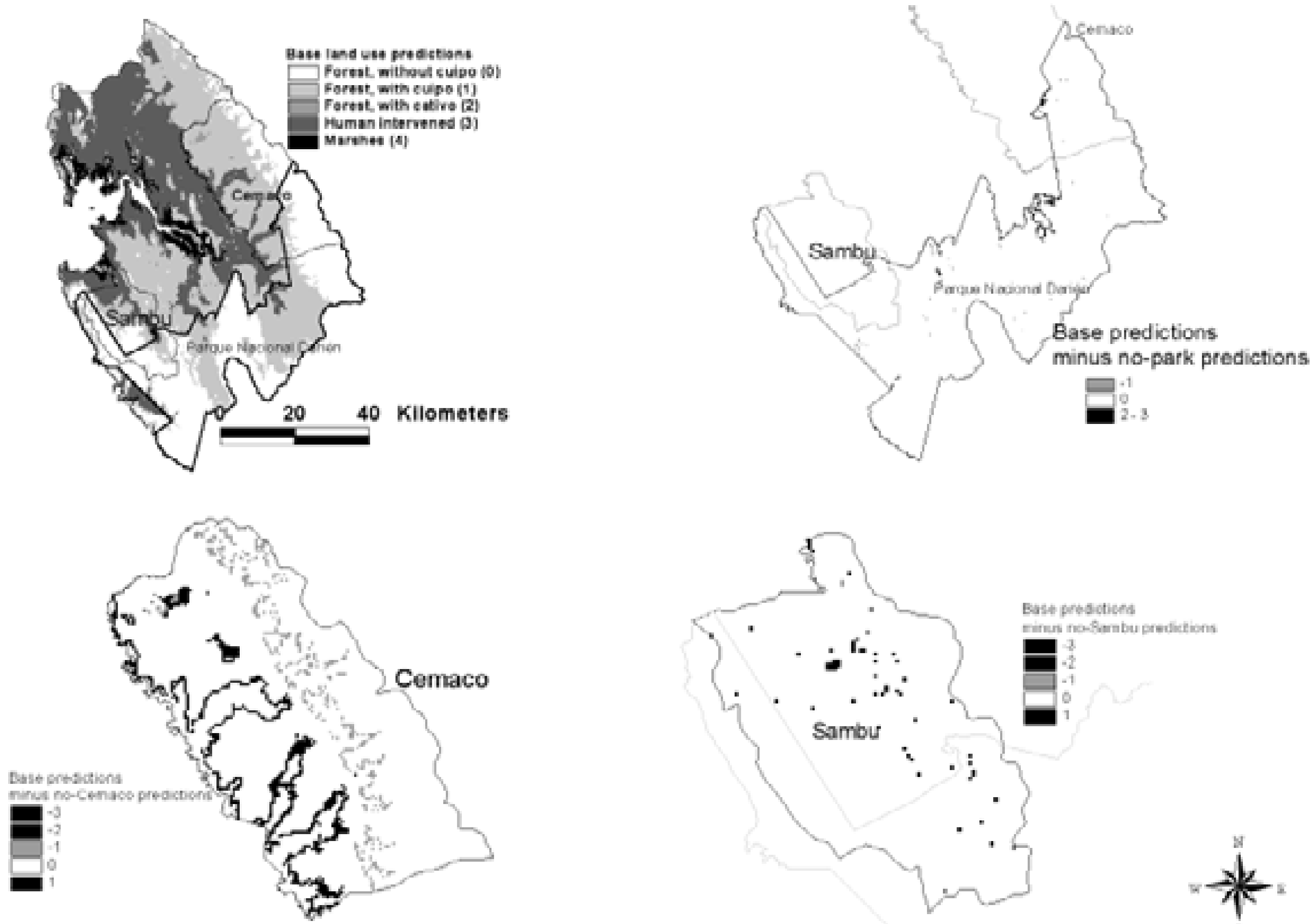
Identifying the Simulation Effect: The Transition Matrix

Simulated Land Use Categories	Base Land Use Categories									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Forest without cuipo 0										4,465
Forest with cuipo 1	15		28				25		40	7,238
Forest with cativo 2										31
Disturbed/second-ary/ plantation forest 3		32					103		7	199
Mangrove areas 4		2				4	13			471
Fresh water marshes 5		4								187
Scrub 6		3	4						20	362
Pasture 7		18	5	28	23	0	360		25	2,624
Agriculture 8			2							419
Total	4,481	7,188	70	84	475	187	835	2,166	510	15,995

Land Use Change with Road Resurfacing



Effect of Property Right Removal



The End

- This presentation will be available (soon) at
- http://web.aces.uiuc.edu/wf