

Hierarchical Investigation of Socioeconomic Drivers of Decadal Scale Land-Cover changes in the Upper Midwest



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Rural Population Growth

DEMOGRAPHICS

Population of Rural America Is Swelling

By SCOTT KILMAN
And ROBERT L. ROSE

Staff Reporters of THE WALL STREET JOURNAL

Pat Murphy is moving his family to Algona, Iowa, from Stockton, Calif., to escape crime, expensive car insurance and slumping home values. But he's also in search of something he can't find in the city.

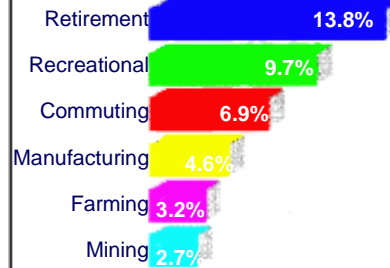
"In the doughnut shop, the customers are considerate enough to pour each other coffee," he says of life in northern Iowa. "You don't see that in California."

The 1990s, it turns out, are full of Pat Murphys trading in urban life for country living. At the same time, more people in rural areas are staying put. The result: Rural America is making a surprising comeback in population.

New research by two prominent rural demographers finds that most rural areas of the country are growing at their fastest rate in more than two decades. The demographers, Kenneth M. Johnson of Loyola University in Chicago and Calvin L. Beale of the U.S. Agriculture Department, found

Rural Population Grows

Growth by counties, grouped by dominant activity, 1990-95



Source: Kenneth M. Johnson and Calvin L. Beale

says Mr. Beale, who is credited with calling a previous rural population turnaround, when decades of migration out of rural areas were reversed in the 1970s.

Metropolitan areas, meanwhile, have had a 5.8% increase in population over the same period, still higher than the rural

South. But even places that are lagging, such as counties dependent on farming and mining, are faring far better than they did in the 1980s. And while the population turnaround in rural areas flies in the face of conventional wisdom, it doesn't surprise the people who are witnessing the comeback.

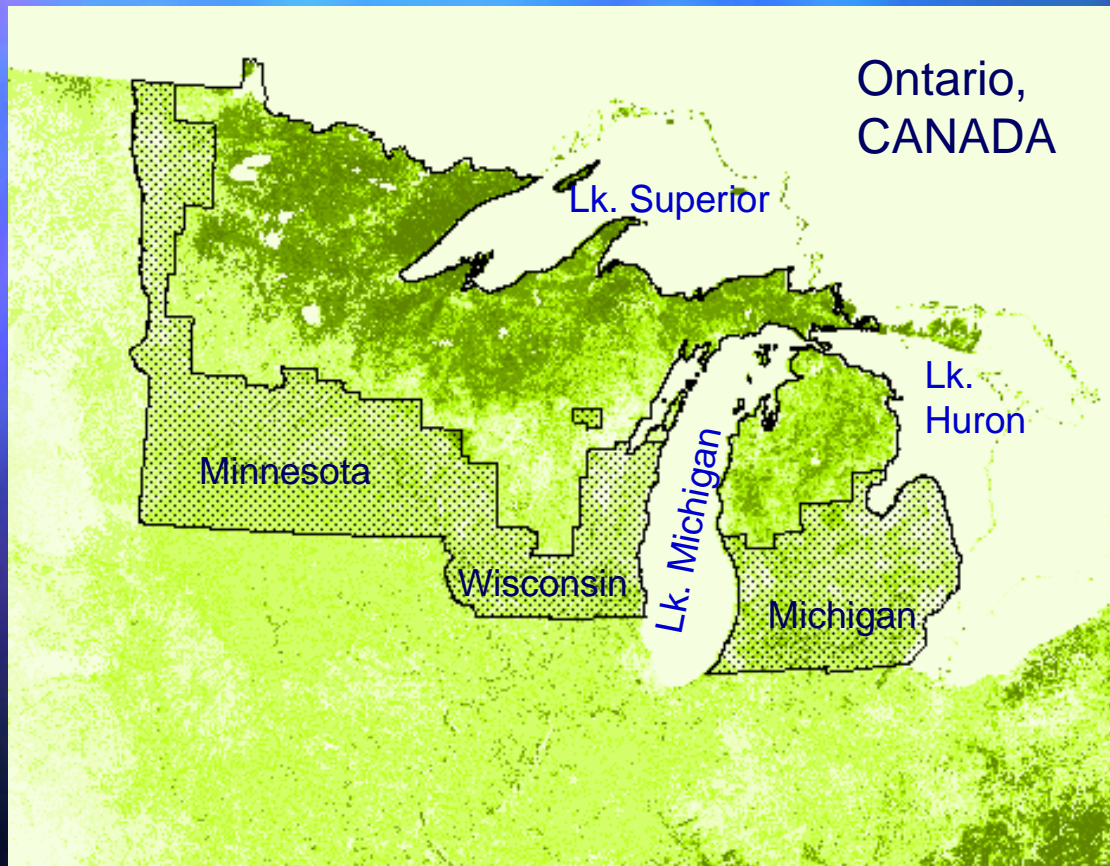
Mt. Pleasant, Iowa, grew 5.2% between 1990 and 1994 to 8,374 people. The southeastern Iowa town is in the middle of a boom in home-building. Main Street landlords are renovating second floors to accommodate the demand for retail space. "Life is a lot more peaceful here and homes are a lot cheaper," says Daniel Peterson, a local merchant and former pilot who once lived in Denver.

Others are finding they can enjoy rural life even while working for a big-city employer, either through telecommuting or long-distance commutes. The demographers found that 90% of the counties with a large portion of commuters are growing.

Jobs also appear to be drawing some city dwellers to the country. According to

Wall Street Journal

Study Area - Upper Midwest, USA



About 2/3 forested,
mostly rural

Forest cover has
been increasing
per inventories

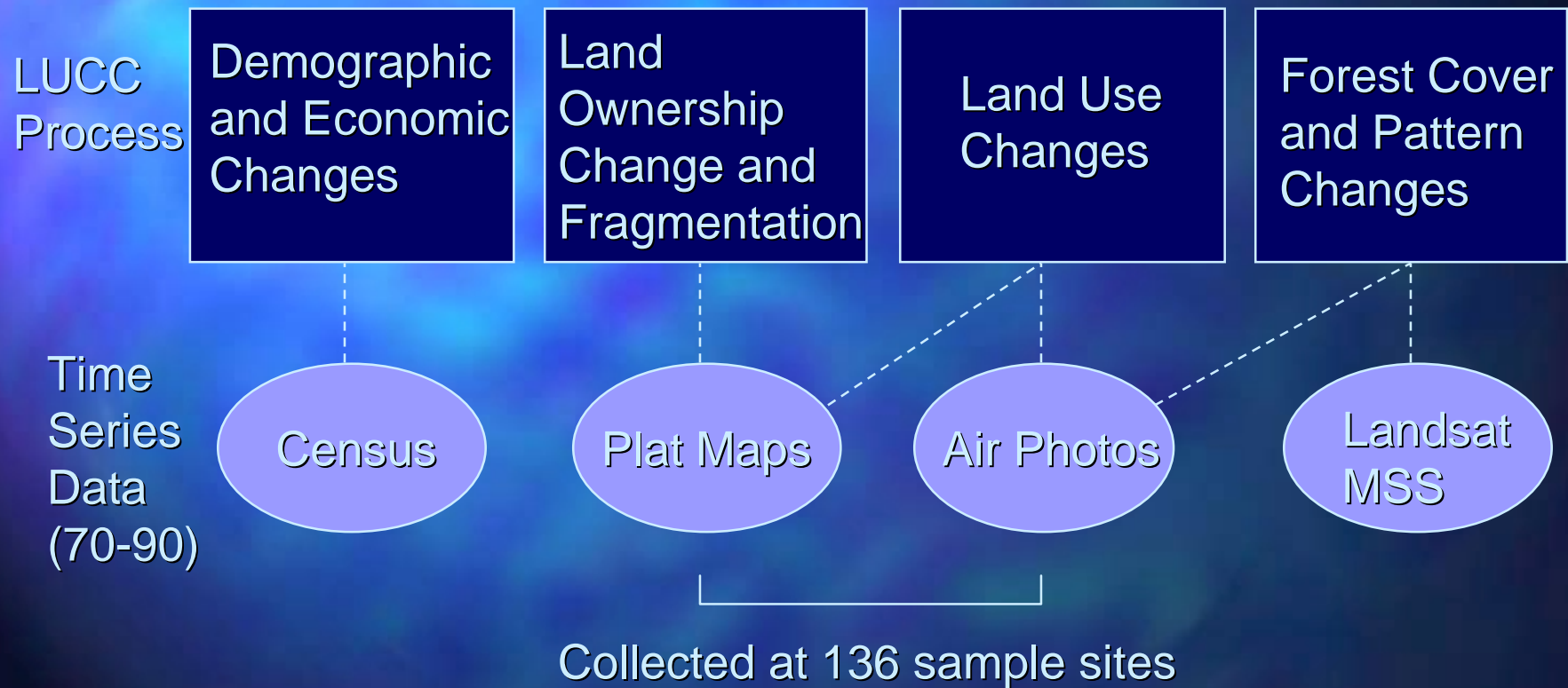
Nearly completely
deforested by
1910

Percent forest cover image
from AVHRR and USFS
FIA data by Zhu and Evans,
1994

Research Questions and Interim Progress

- 1 What were the types and rates of land cover change and fragmentation over two decades in the study region?
 - Pilot study in three county area of Michigan, methodological progress.
- 2 What is the sensitivity to the scale/resolution at which those changes are monitored (air photo versus MSS)?
 - Land use from air photos and forest cover from Landsat; thematic detail.
- 3 How are the changes and fragmentation related to changes in the fragmentation of land ownership?
 - In general, land ownership is fragmenting and forest cover is increasing, and often defragmenting, but the causal relationships require land use information.
- 4 What quantitative functions describe the effects of socioeconomic processes on observed rates of land cover composition and pattern change?
 - Economic, demographic, environmental, and institutional/policy factors.

Empirical Observation of LCLUC



Methods to Date

■ Forest cover and pattern mapping (NALC)

- Pre-processing, classification, and accuracy assessment
- Parcel fragmentation and forest cover change in three Michigan counties (S.A. Drzyzga, Master's Thesis)
- Error in change analysis based of pattern metrics

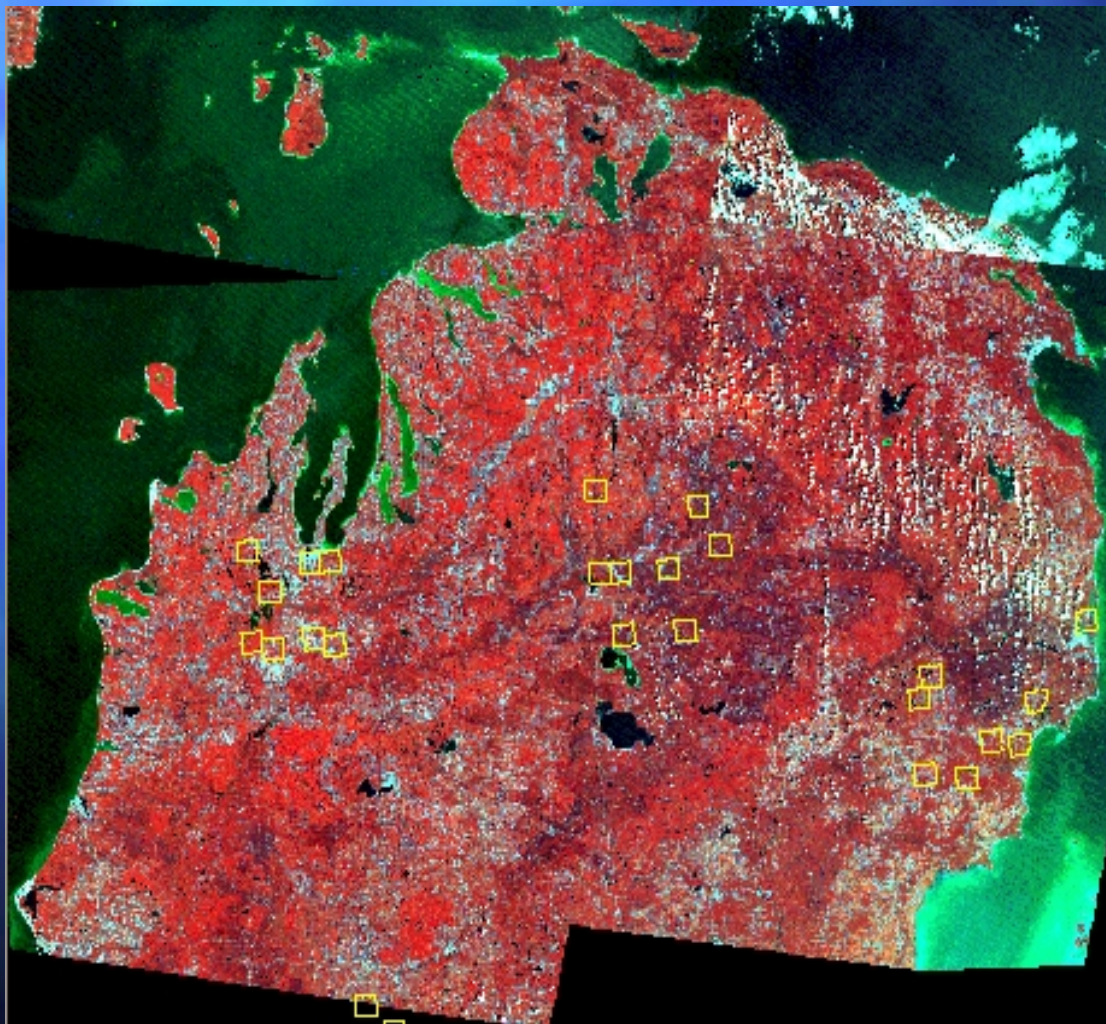
■ Land use mapping and change analysis

- Arc/Info based tools for: (1) mapping from air photos & parcels
(2) quality control (near complete)

■ Model development

- County-level land use estimates
- ArcView model & GUI with stochasticity and dynamics
- Link with SNNS for artificial neural network analysis
- Pilot-testing calibration and validation procedures

Forest Cover Pattern and Change

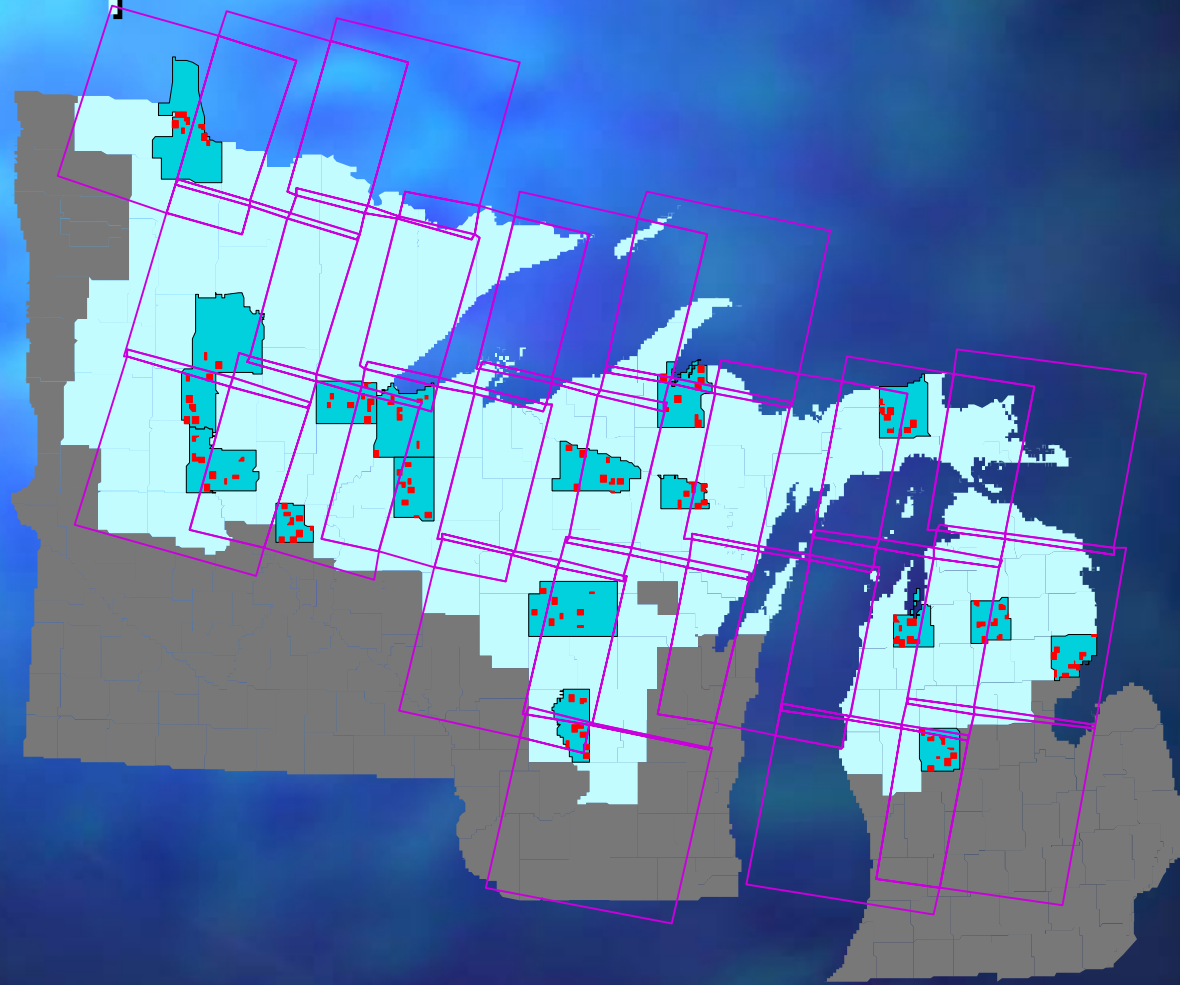


Based on North American Landscape Characterization (NALC) data.

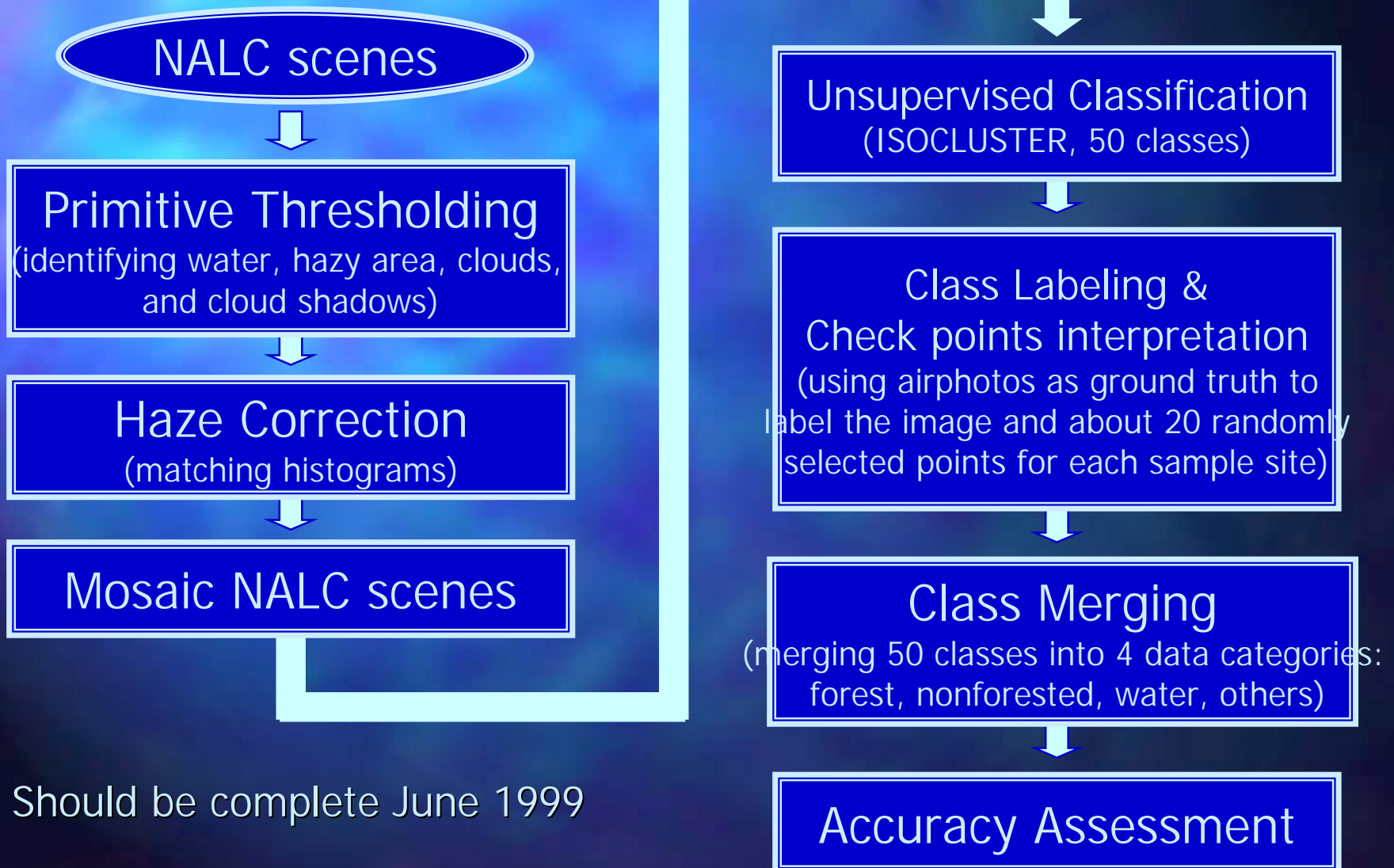
NALC Mosaic of the Northern Lower Peninsula of Michigan

1991

Locations of Landsat Scenes, Sample Counties and Sites

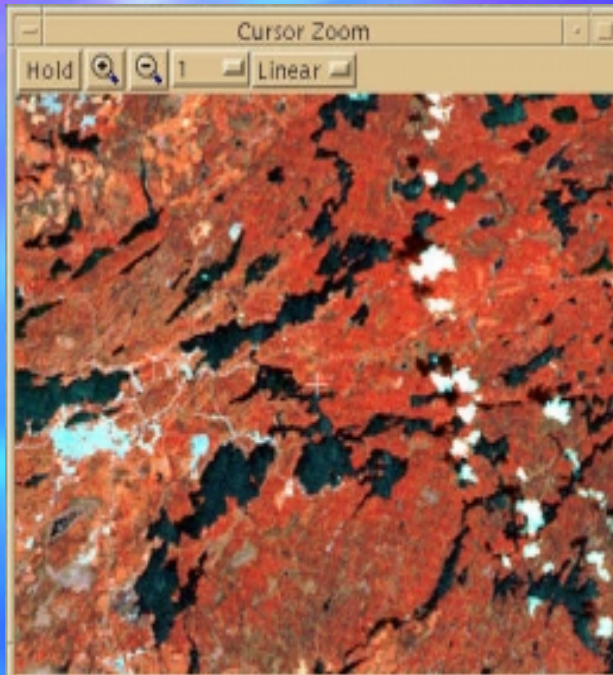


NALC Processing Procedures

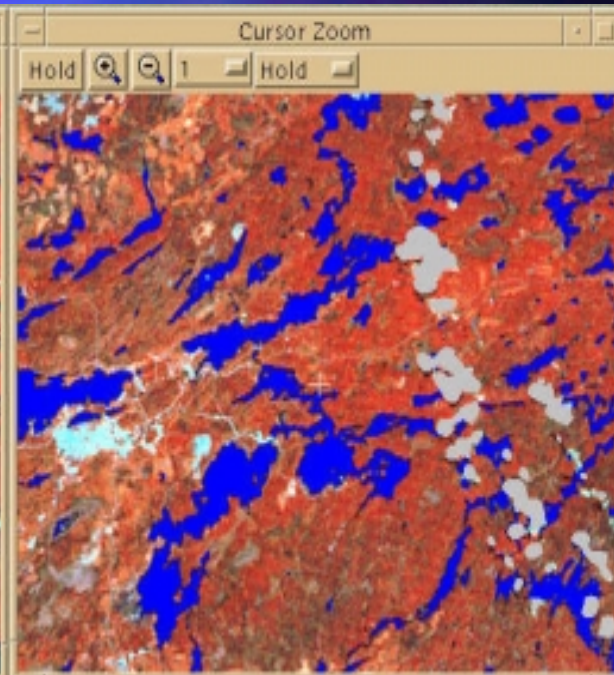


Should be complete June 1999

NALC scene



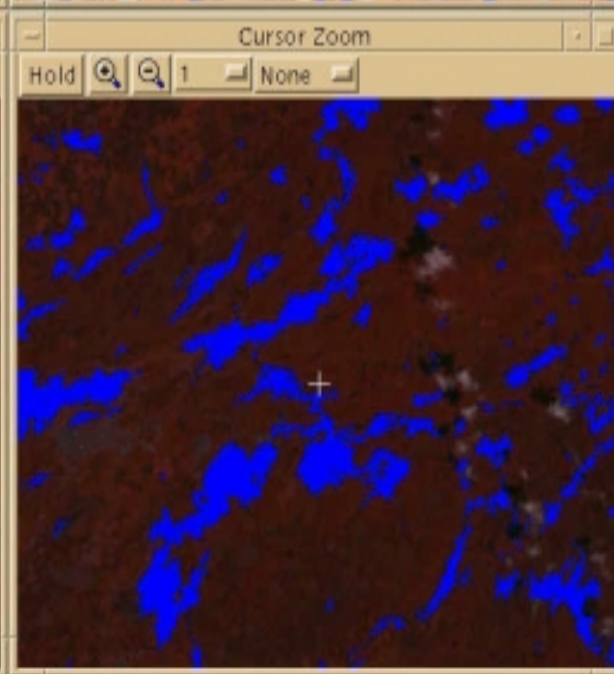
NALC scene with masks



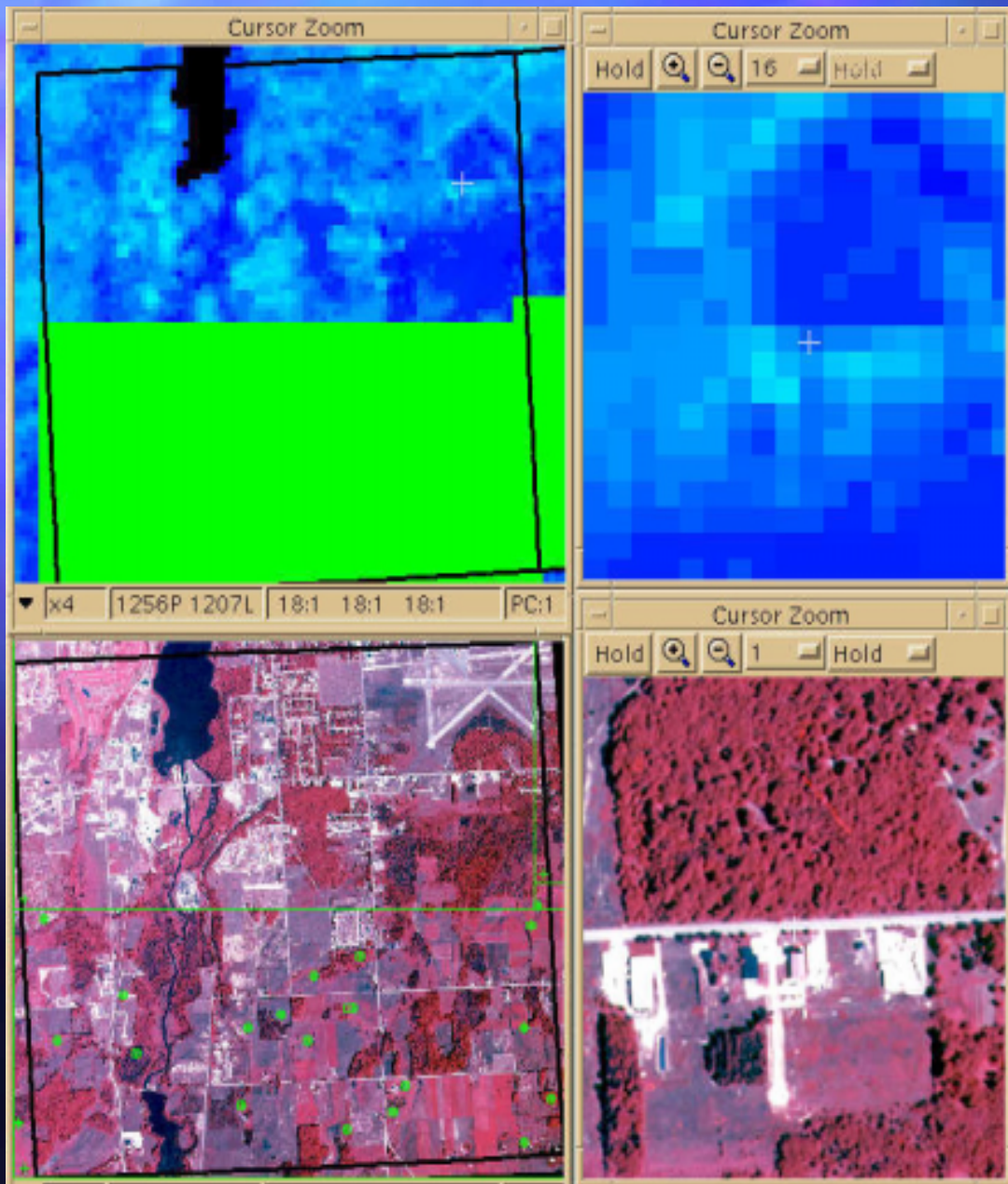
Clouds & shadows mask



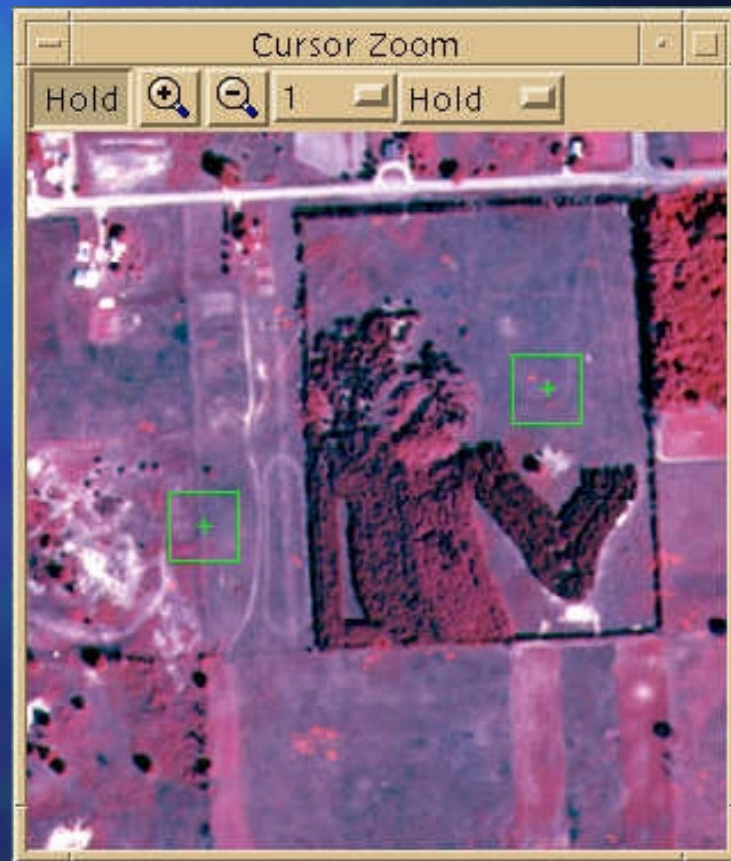
Water mask



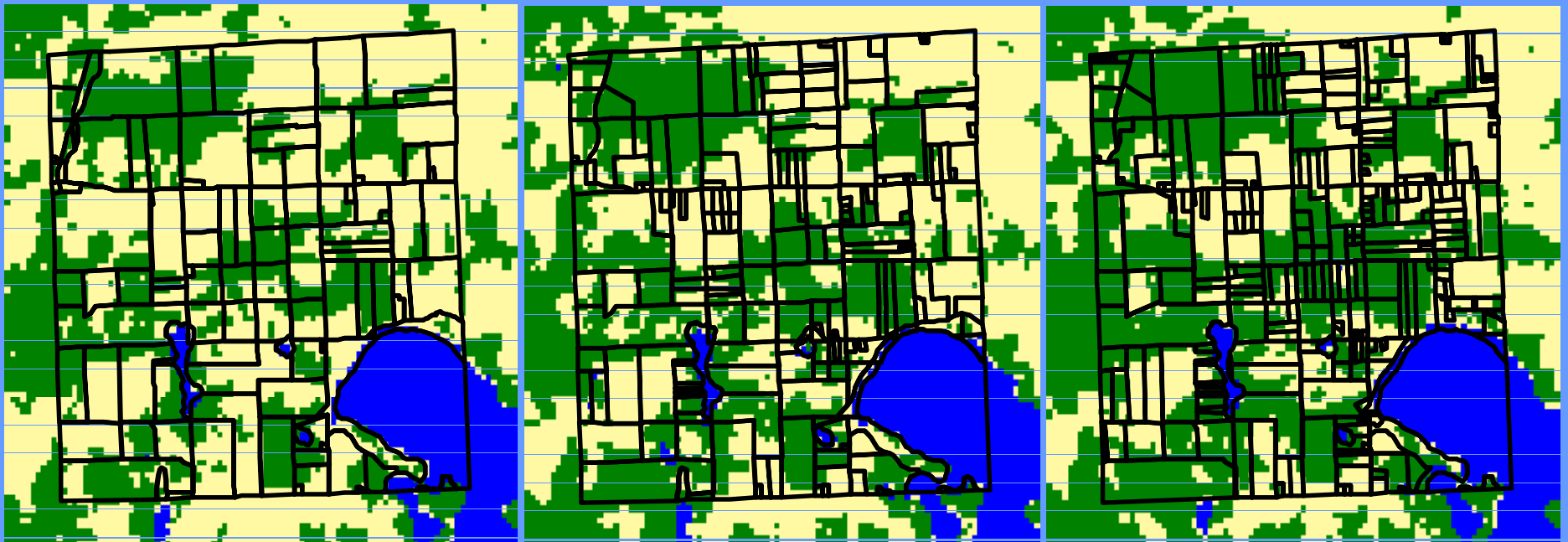
Labeling classes by using airphoto as ground truth



Sample points for accuracy assessment (green lines depict the actual pixel size on NALC)



Forest Cover Change



1973

1985

1991

 Forest

 Nonforested

 Water

Forest Fragmentation Pilot Studies

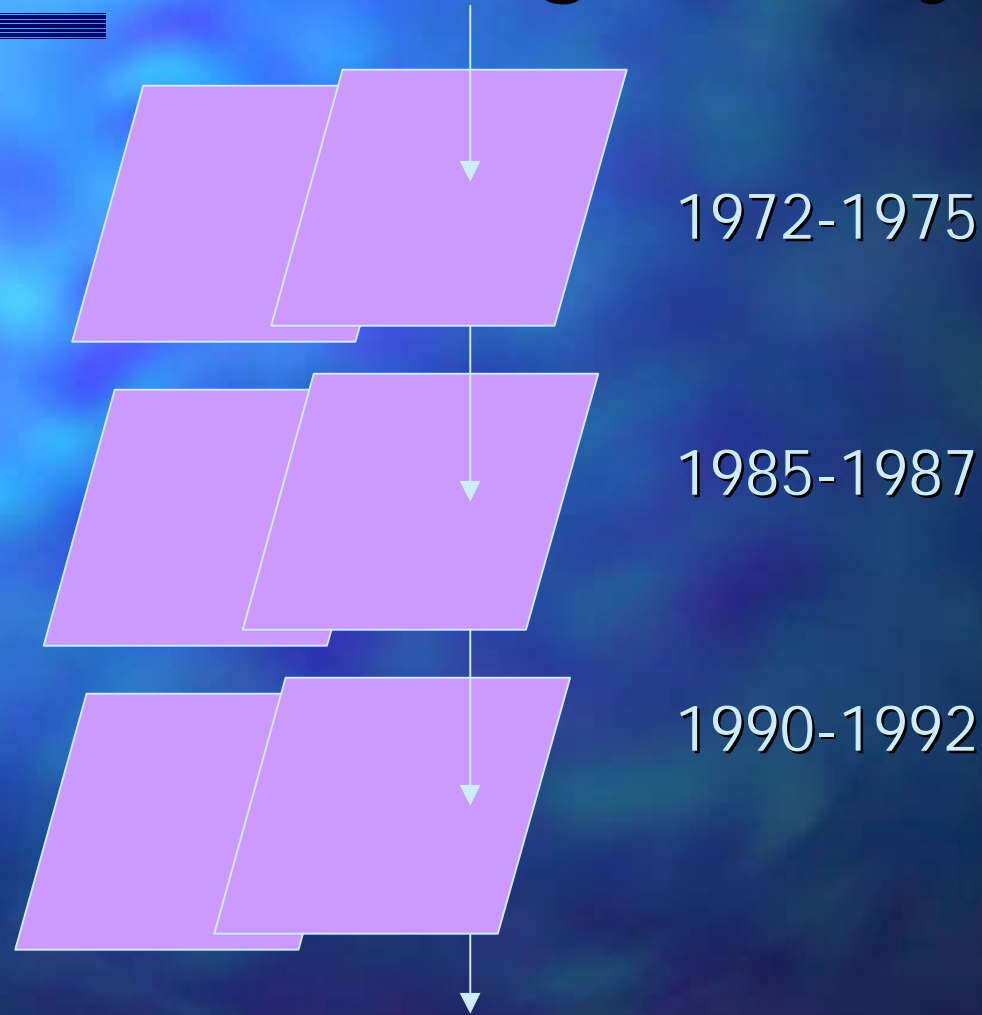
- Sample area study to quantify errors in measuring forest fragmentation dynamics.
- Small area study to test for meaningful relationships between parcel changes and forest cover change and fragmentation.

NALC Data for Change Analysis

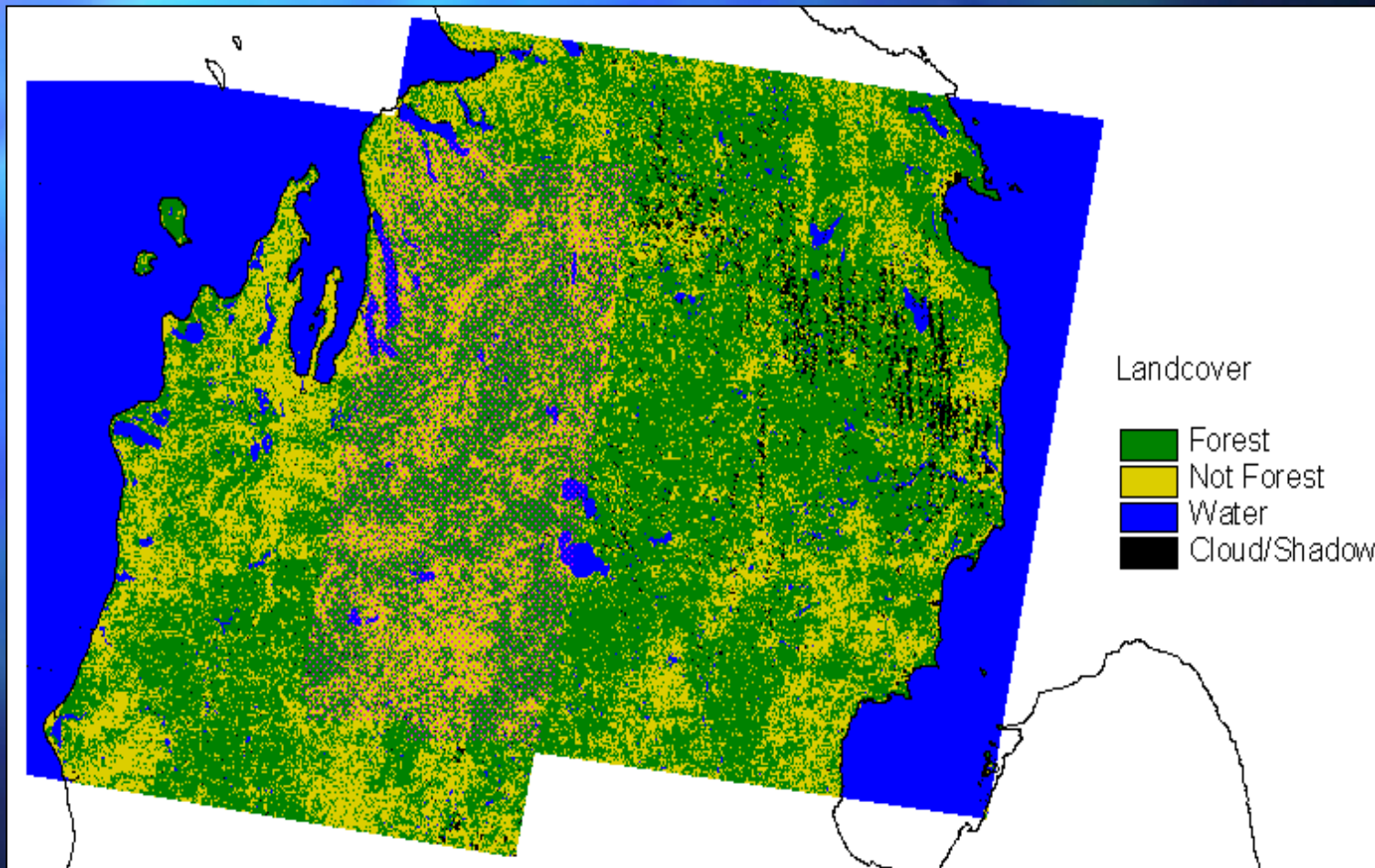
Pre-registered
Landsat MSS
Scenes

60 m resolution

About 25 %
overlap between
adjacent scenes

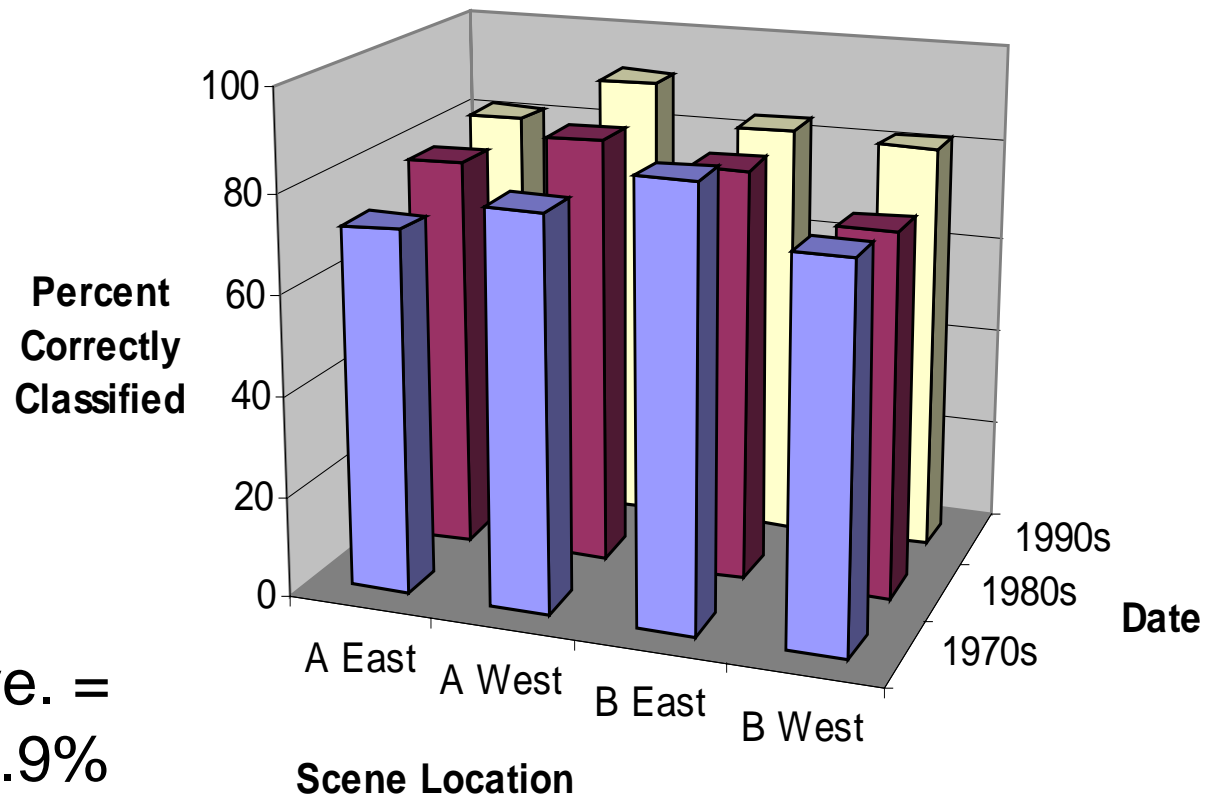


Classified Land Cover: Site A 1990s

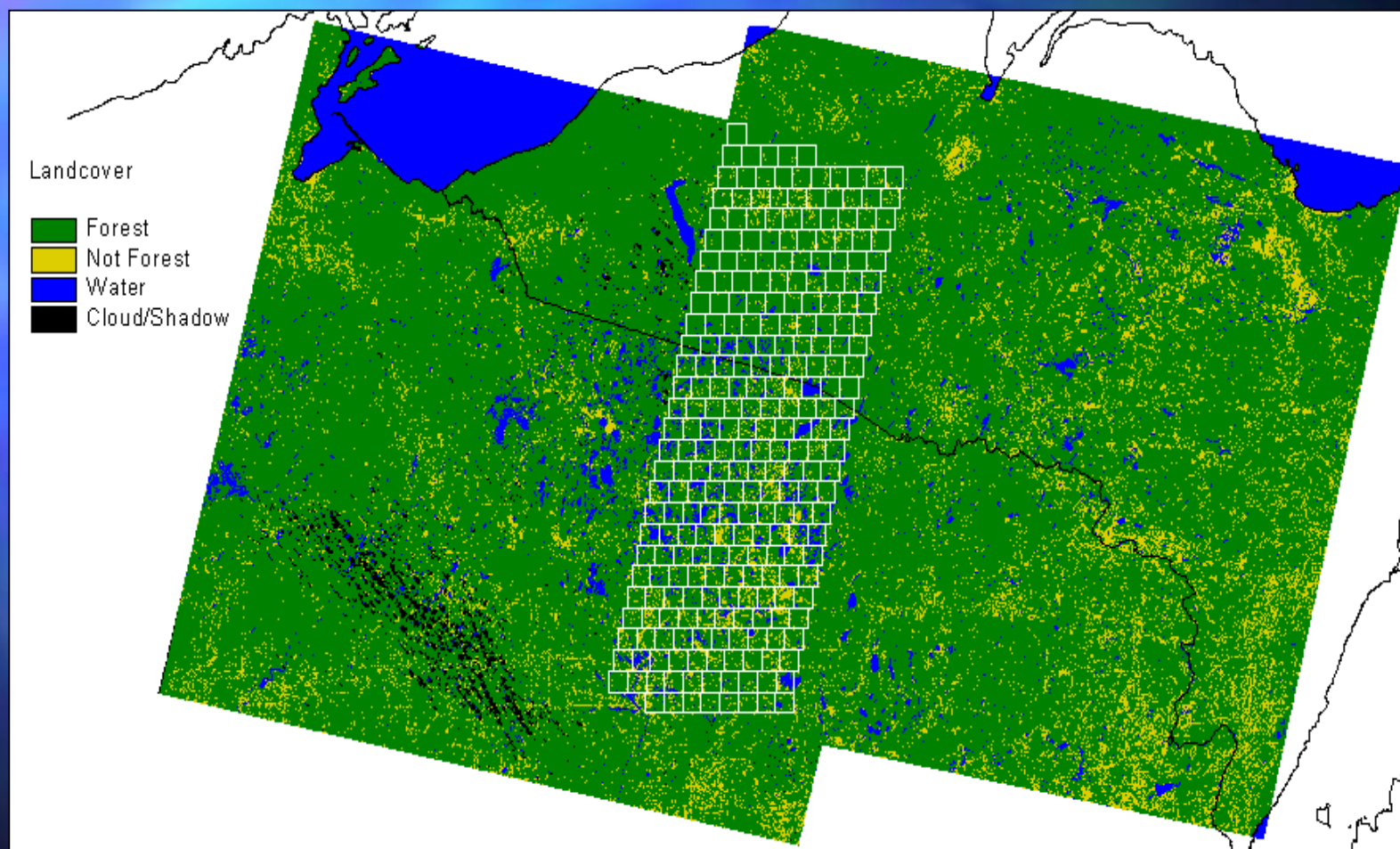


Shading indicates overlap
area

Classification Accuracies



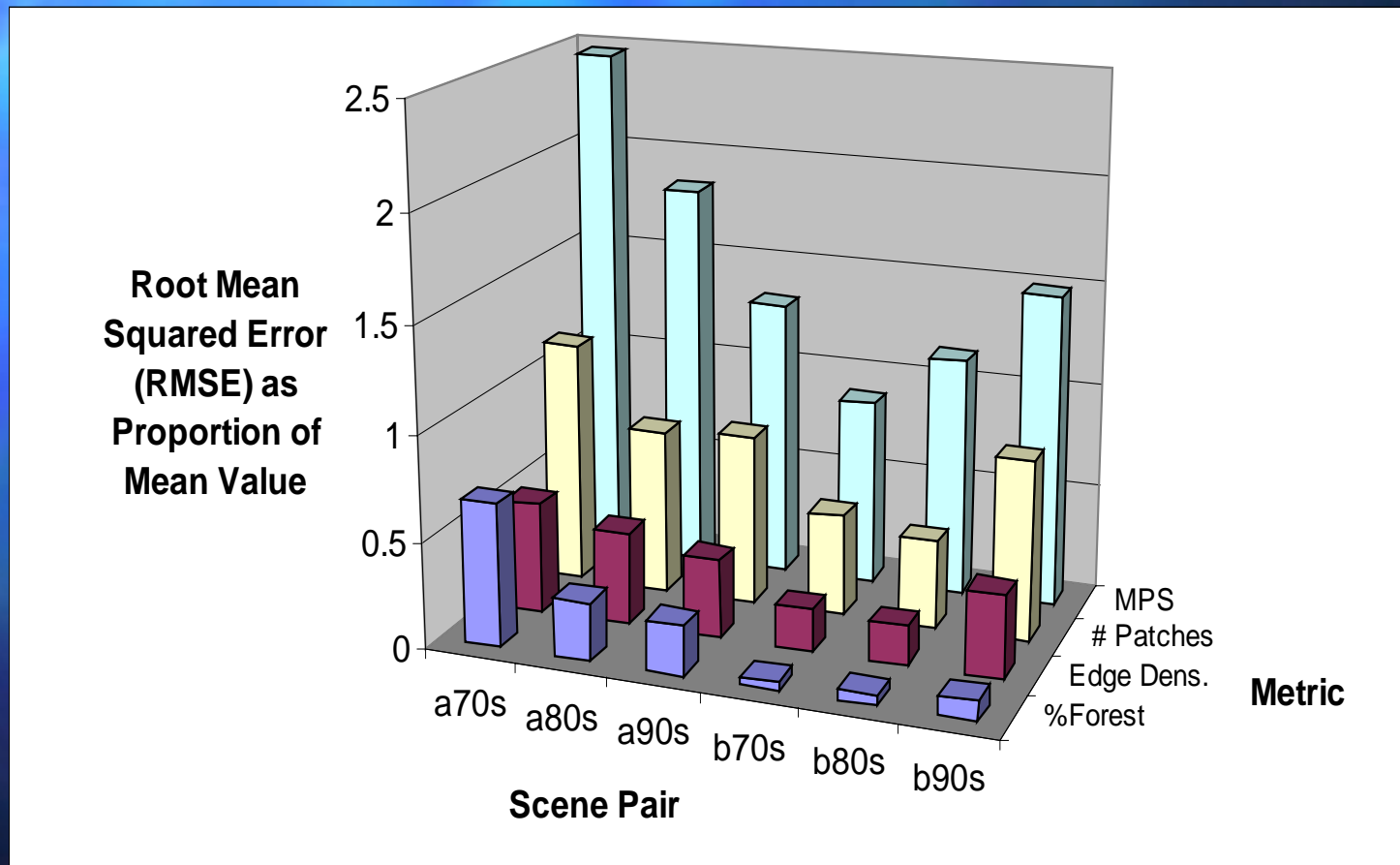
Classified Land Cover: Site B 1990s



Landscape Metrics Assessed

Metric	Abbr.	Definition
percent forest	PF	proportion of the landscape covered by forest
number of patches	NP	number of forest patches
mean patch size	MPS	average size of forest patches
edge density	ED	length of forest/non-forest edge \div landscape area

Summary of Errors in Image Pairs



Model of Error in Metric Differences

Hypotheses

Errors are larger where:

- forest is near parity with non-forest
- haze is more prevalent
- image pair is taken under divergent phenological conditions

Variables

- 2nd-order polynomial of ave. percent forest
- % of site with haze
- diff. in image avg. NDVI or difference in Julian date

Predicting Error in Percent Forest

Error in Percent Forest =

$-7.93 + 0.45 (PF) - 0.005 (PF^2) + 0.12 (\text{haze}) + 1.99 (\text{diff NDVI})$

■ F-test = 423.84 ($p > 0.99$); Adj. $R^2 = \underline{0.50}$

With difference in Julian Date instead of diff
NDVI

$-4.87 + 0.37 (PF) - 0.004 (PF^2) + 0.06 (\text{haze}) + 0.31 (\text{diff Days})$

■ F-test = 284.02 ($p > 0.99$); Adj. $R^2 = \underline{0.40}$

all variables are significant at $p > 0.99$

Predicting Error in # of Patches

Error in Number of Patches =

$-27.00 + 2.03 (PF) - 0.02 (PF^2) + 0.42 (\text{haze}) + 7.56 (\text{diff NDVI})$

■ F-test = 453.23 ($p > 0.99$); Adj. $R^2 = \underline{0.51}$

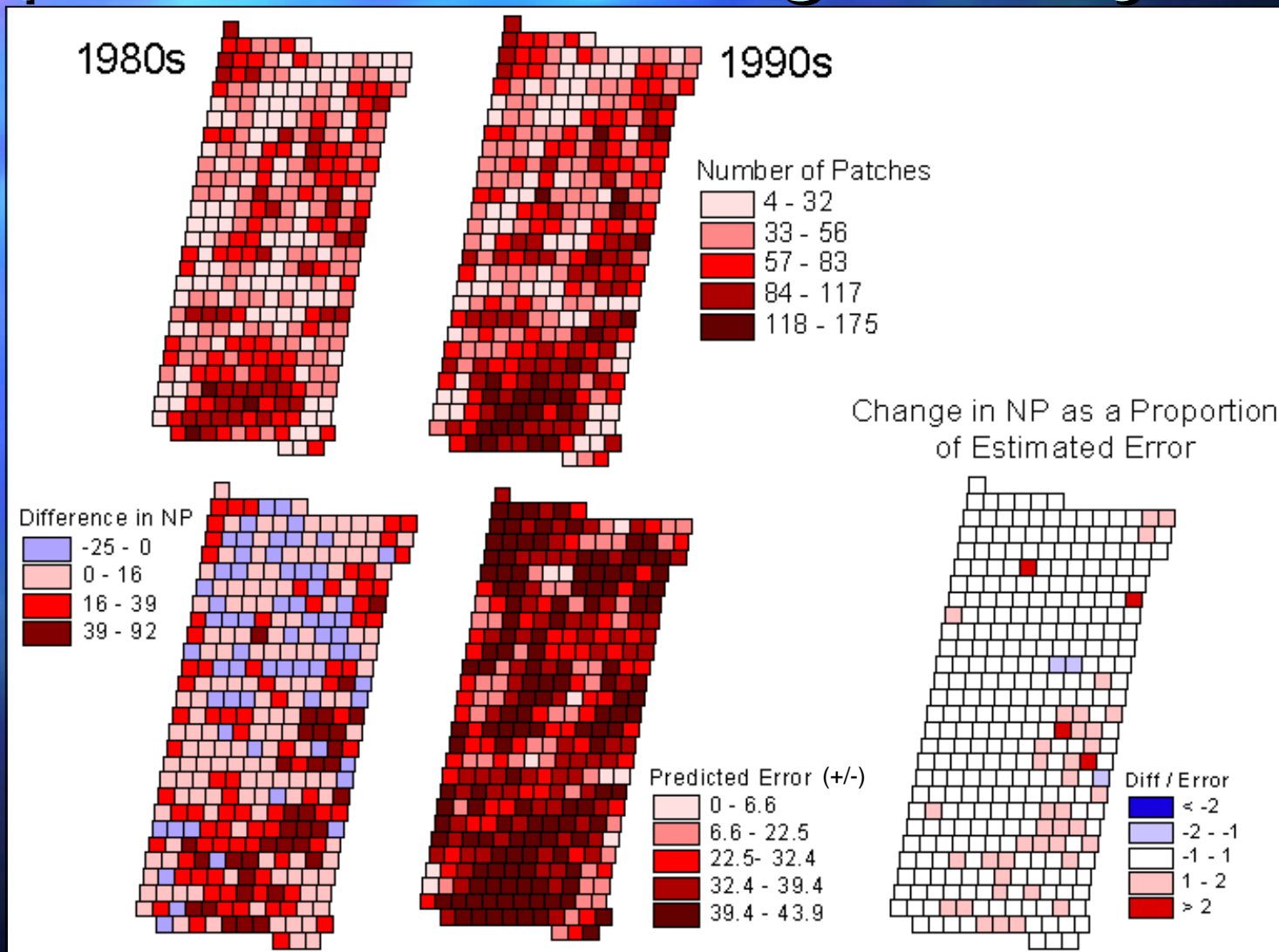
With difference in Julian Date instead of diff
NDVI

$-9.85 + 1.71 (PF) - 0.02 (PF^2) + 2.00 (\text{haze}) + 1.01 (\text{diff Days})$

■ F-test = 307.81 ($p > 0.99$); Adj. $R^2 = \underline{0.42}$

all variables are significant at $p > 0.99$

Application to Change Analysis



Conclusions from Pilot Study I

- Landscape metrics calculated from satellite images are subject to measurement error.
- Increasing size of landscape partitions decreases error, but map generalization through sieving or filtering has inconsistent effect on error.
- Error at a location for some metrics can be estimated using percent forest, haze, and difference in phenological condition.

Land Parcel Changes

Ownership Characteristics

Mecosta County, MI



Site Locator County Locator

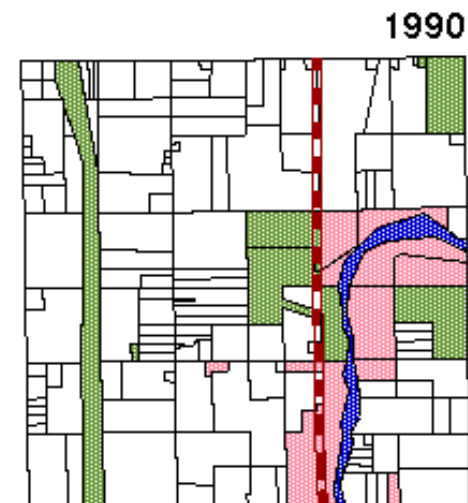
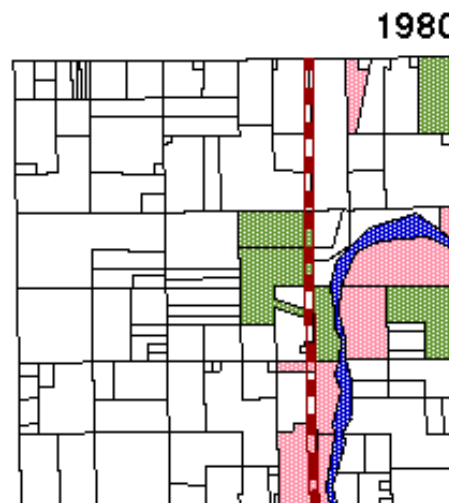
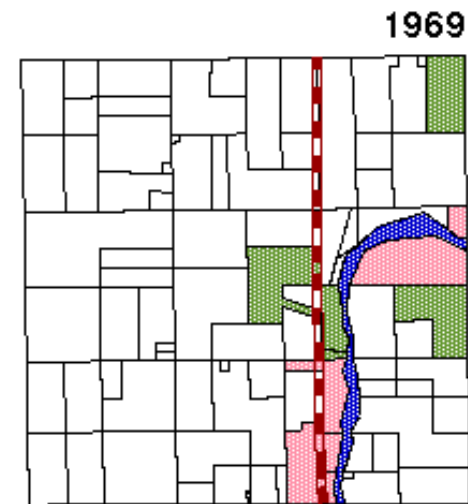
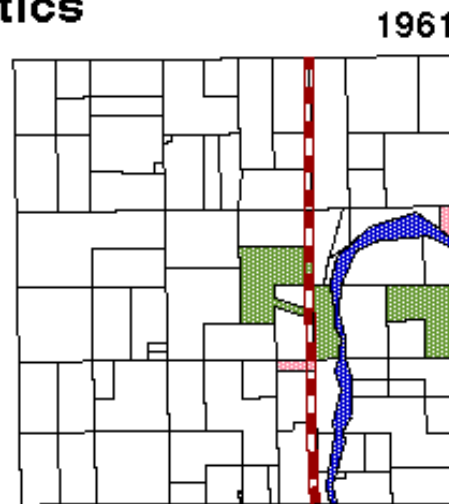
Legend

- Water Features
- Public Lands
- Small Parcels
- Parcel Boundaries
- Major Highway

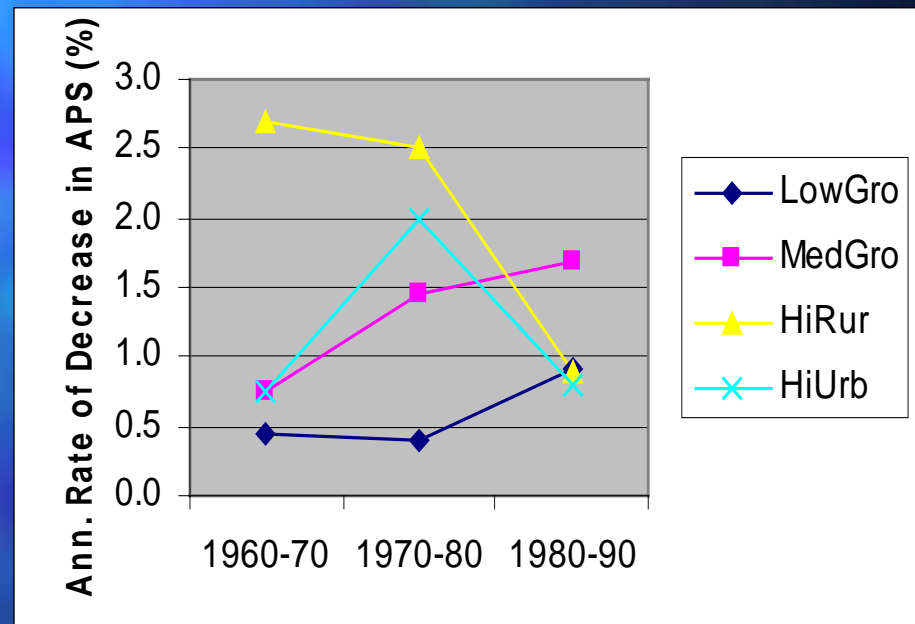
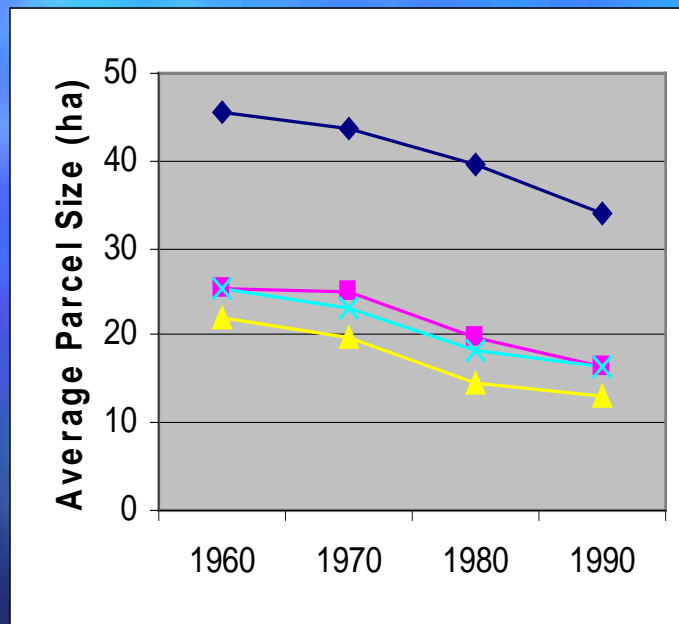
Land Ownership:
Rockford Maps Publishing

Natural Features:
USGS 1:100000 Topographic Maps

Compilation: Scott A. Drzyzga



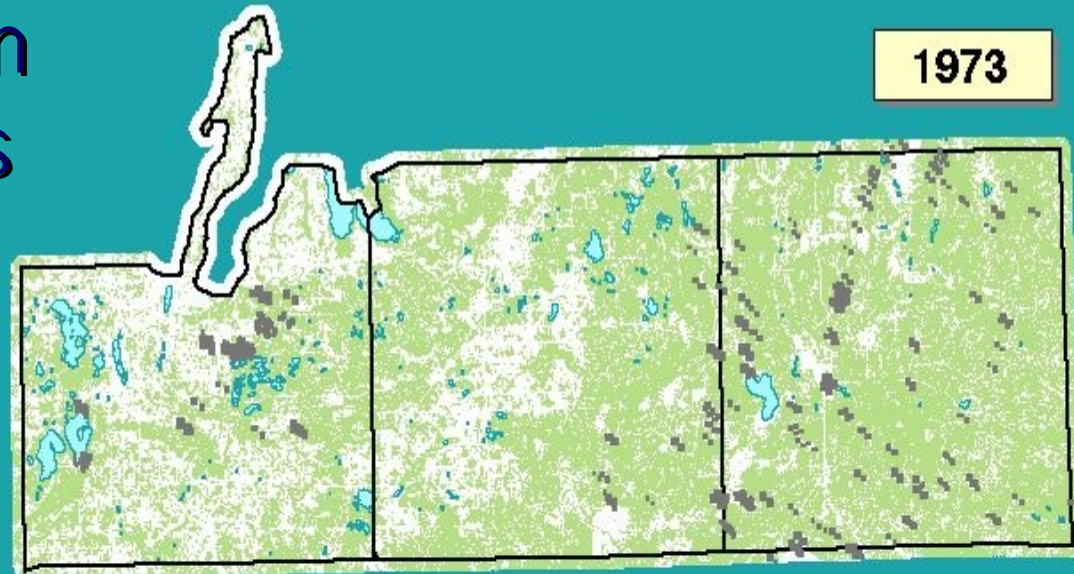
Parcel Size Average and Change by County Type



Forest Cover from NALC Composites

Pilot study area used for a student thesis. Forest fragmentation was compared with ownership parcelization at county, township (MCDs), and survey section scales.

1973

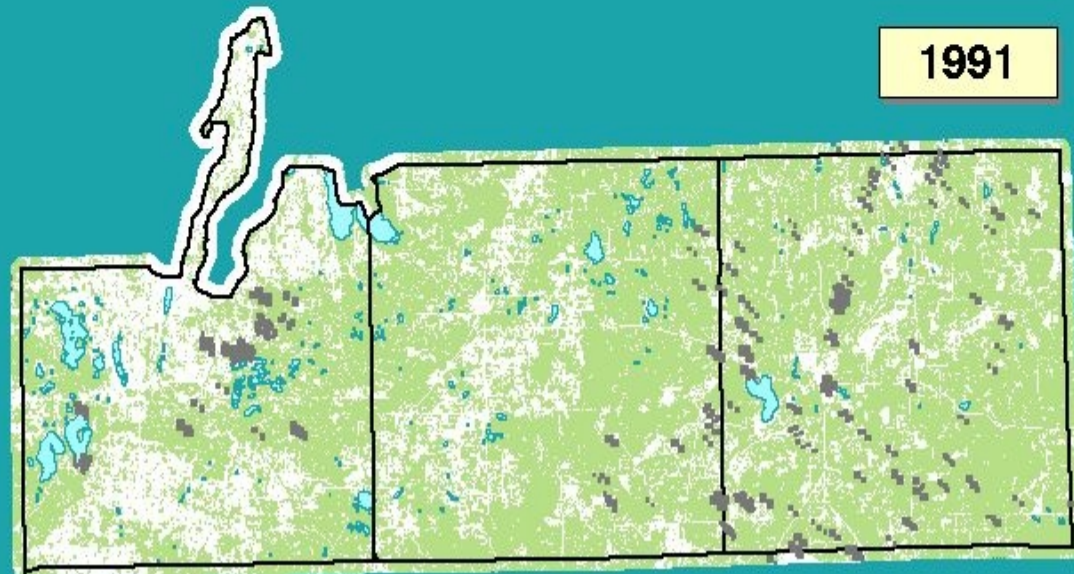


Grand Traverse

Kalkaska

Crawford

1991



Legend

- Forested
- Non-forested
- Water
- Clouds & Shadows



Conclusions from Pilot Study II

- Forest cover increased from 1973-91 and became less fragmented.
- Kaskaskia County, with high population growth rate (156% over period) but low initial population (5272), experienced greatest forest regrowth (22.4%) and defragmentation (24%).
- Spatial patterns tend to be at scale of MCDs.
- Although consumption theory of land rent explains a good deal of variation in parcel sizes, relationship with forest cover is inconclusive.

Hypothesized Land Use Drivers

- Development of agricultural lands
 - Ag to developed, with some forest recovery
- Development of undeveloped lands
 - undeveloped (including forest) to developed
- Agricultural abandonment
 - Ag to undeveloped, usually with regrowth
- Recreation and tourism based development
 - any conversion to recreation-based use (includes seasonal homes)



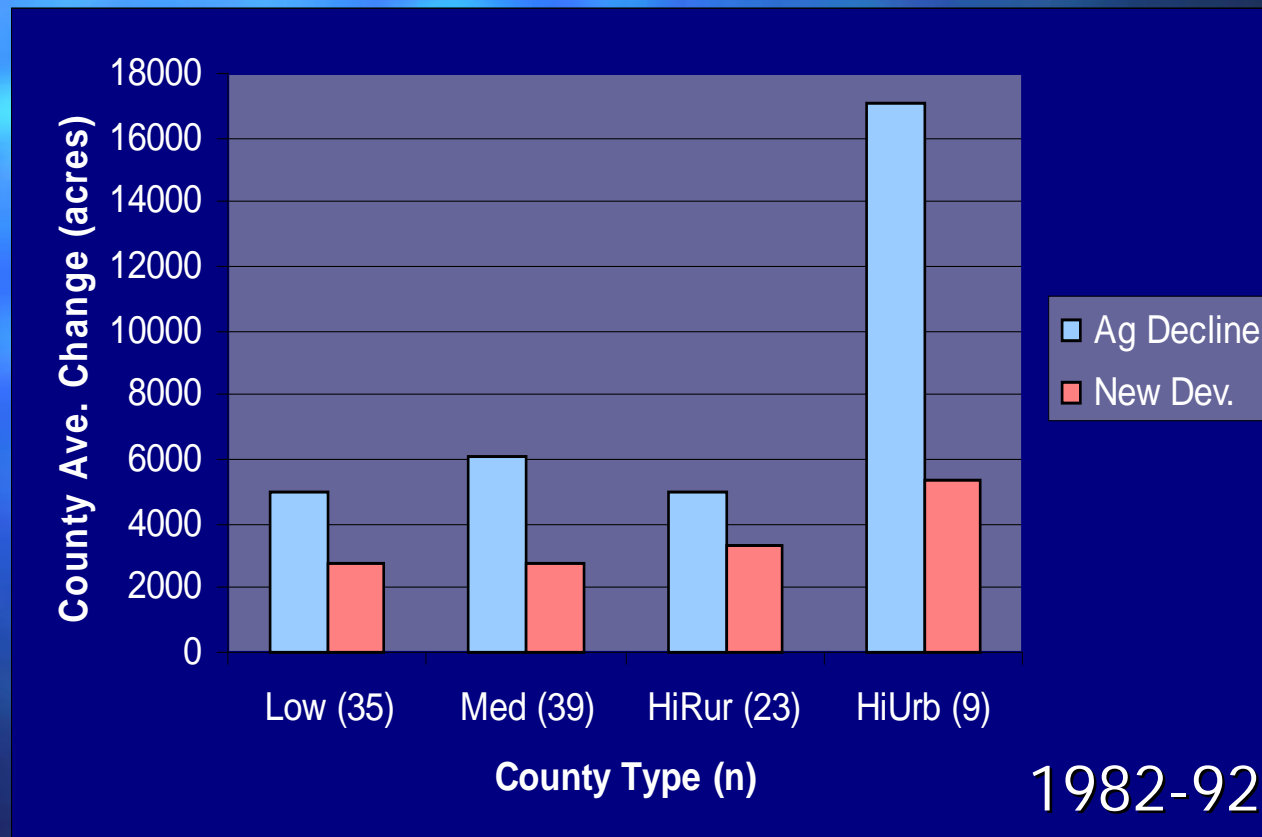






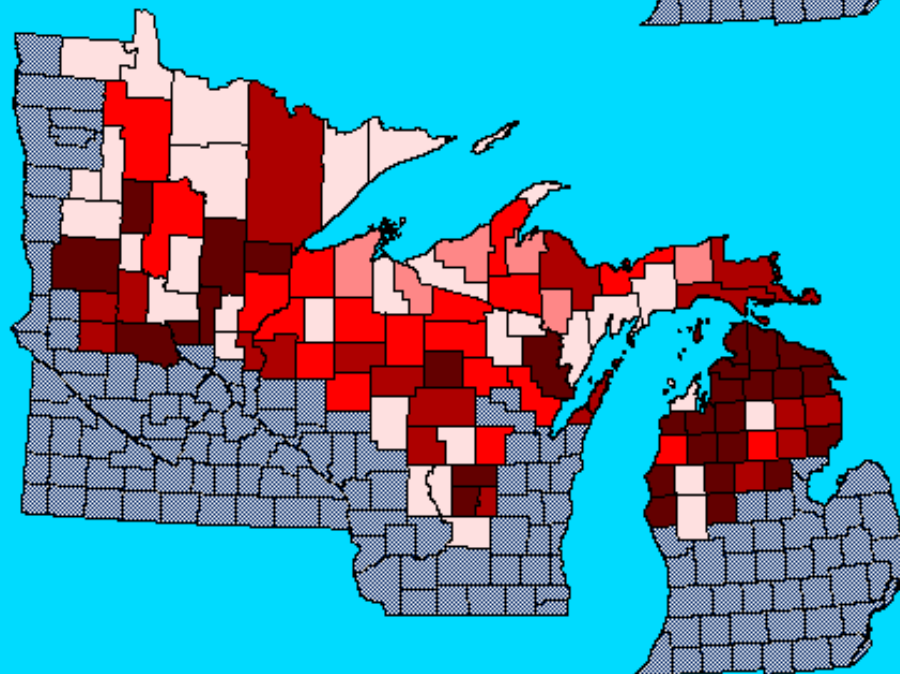
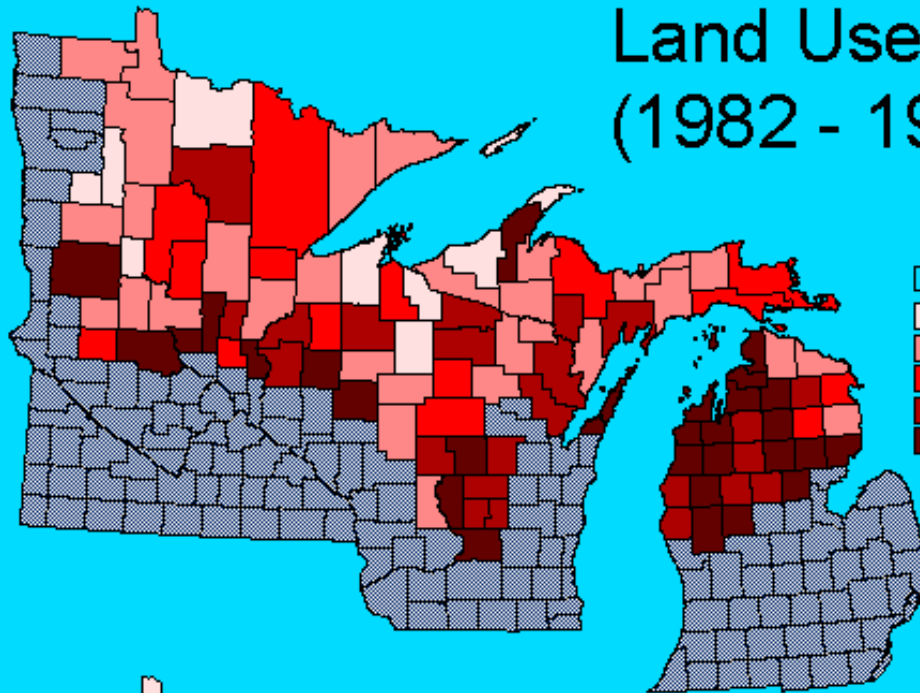


Land Use Drivers in the Region



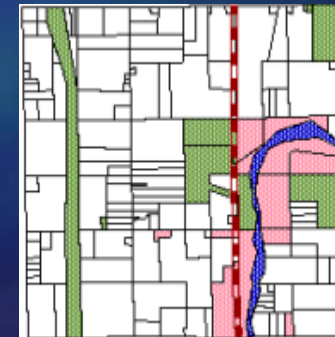
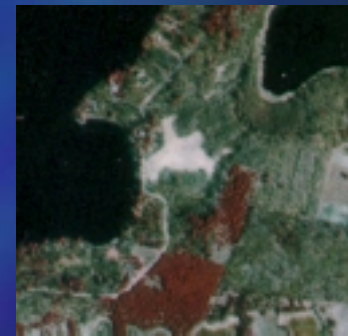
Source: Natural Resources Inventory (NRI),
NRCS

Land Use Change (1982 - 1992; NRI)



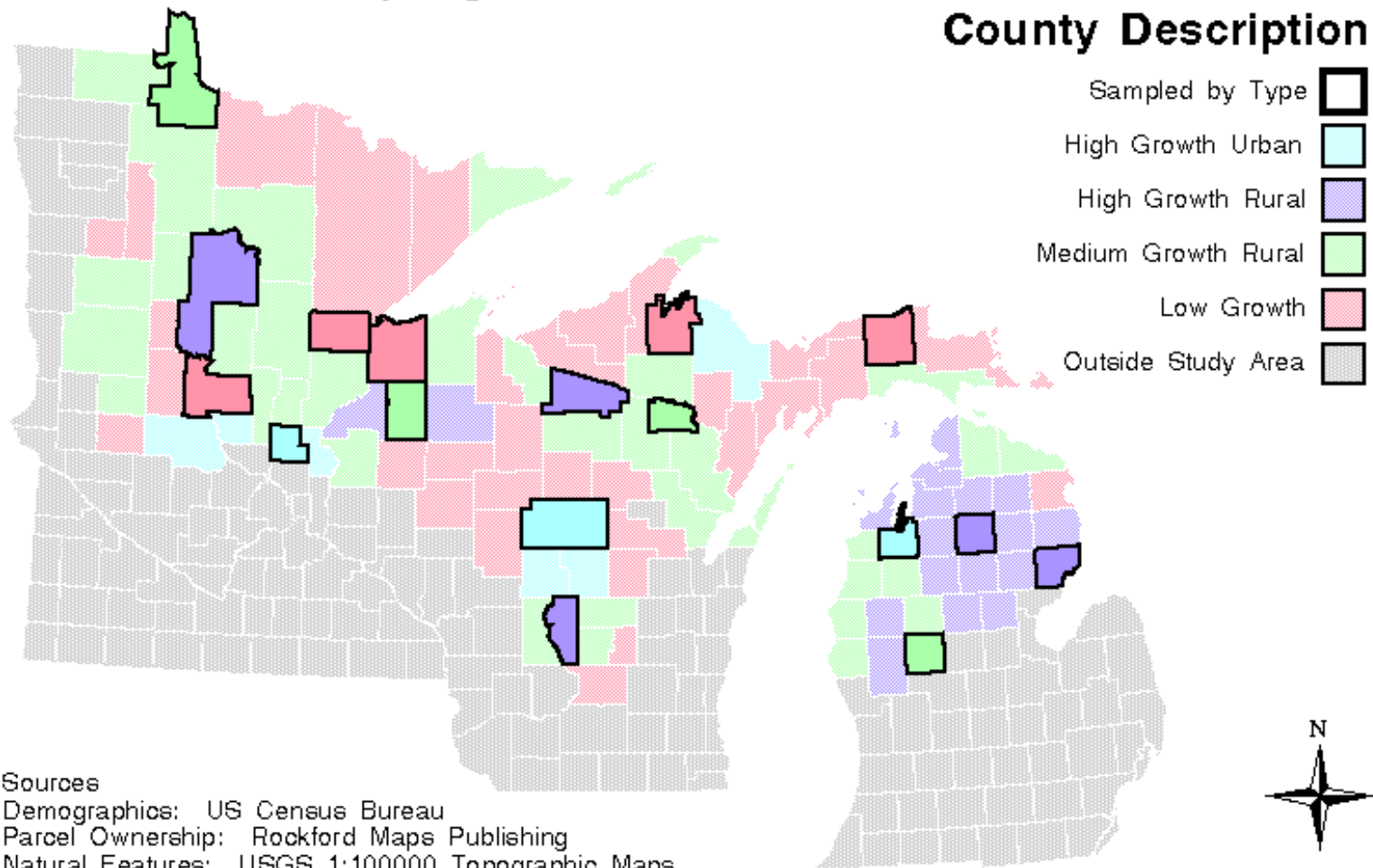
Air Photo Archive & Parcel Data

- 136 sample sites (~2500 ha) three epochs each (early 1970s, early 1980s, early 1990s)
- >1,200 archival photos scanned, rectified, mosaiced (2 m resolution)
- >10,000 polygons per epoch georeferenced & digitized from plat books.



Demographic / Economic County Types

Area Frame Sampling











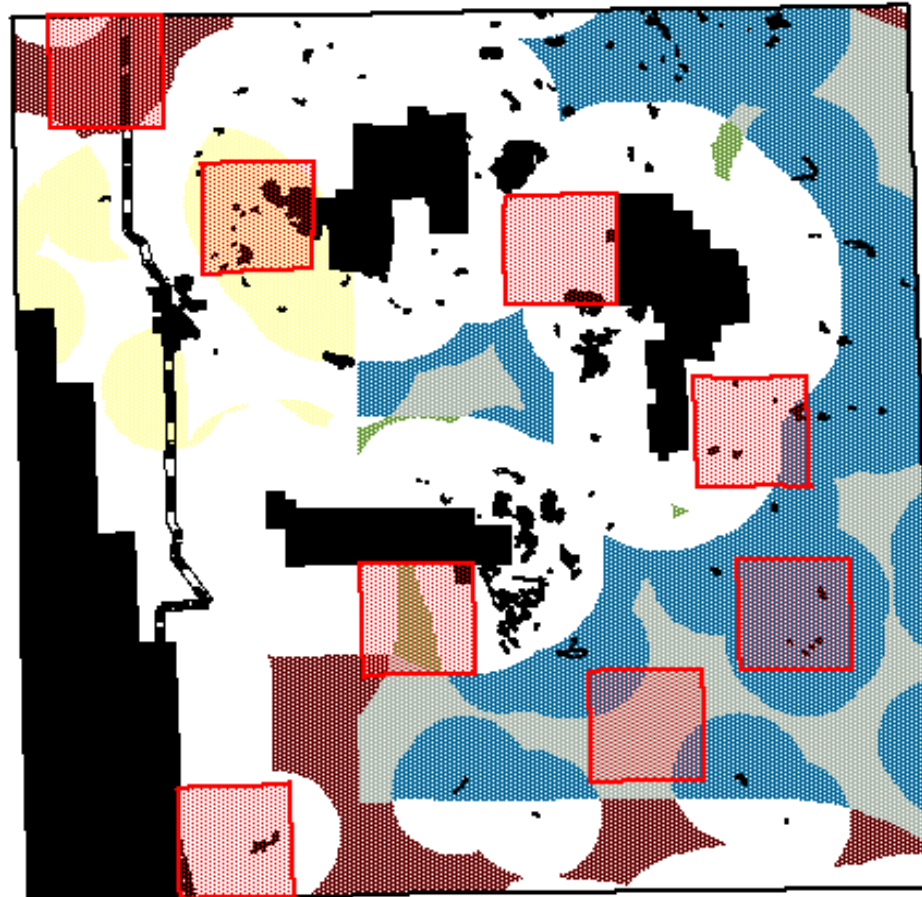
Stratified Sample Site Selection

Mecosta County Buffered Features



Legend

-  Sample sites
-  Buffered Features
-  Under all influence
-  Road-only influence
-  Public land-only influence
-  Hydro-only influence
-  Under no influence
-  Under multiple influence



Source: USGS 1:100000 Topographic Quad Maps

Compilation: Scott A Drzyzga 11/10/96

Code	Land Use Type
100	Developed
110	Residential
111	High density Residential
112	Low density Residential
120	Retail/Office
130	Industrial/Warehouse
140	Infrastructure/Transportation
141	Airport
142	Transport Corridor or Terminal
143	Utility corridor or station
144	Institutional
150	Site-based outdoor recreation
151	Campground
152	Golf course
153	Ski area
154	Marina
155	Park and outdoor assembly
160	Mining/extractive
170	Other developed

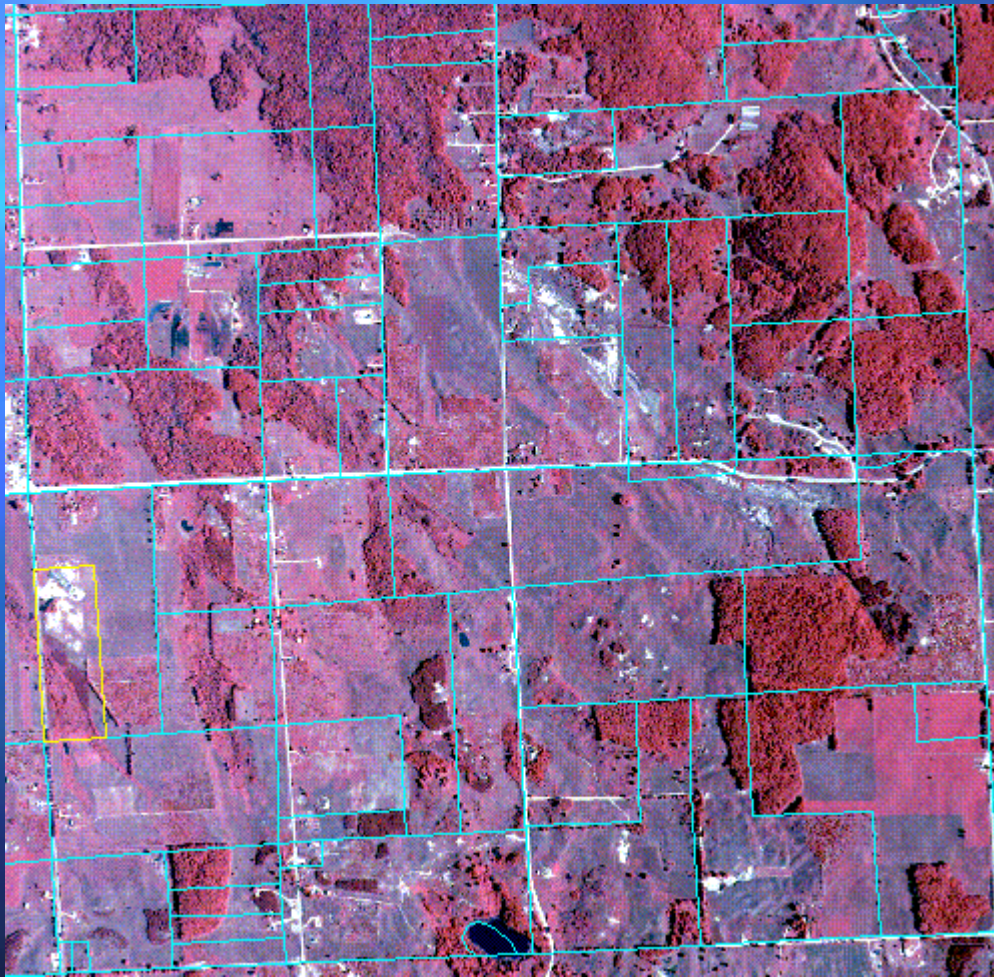
Land Use Classification

Students trained to identify classes using rules based on

- photo interpretation
- parcel size

200	Agriculture
210	Row crop
220	Non-row crop
230	Pasture/grazing
240	Other agriculture
300	Undeveloped
310	Open/grass
320	Old field/young forest
330	Mature Forest
340	Tree Plantation
350	Open Water
360	Wetland
370	Riparian Zone / Forested Wetland
380	Other Undeveloped

Land Use Patterns and Change



Digitized parcel
map and aerial
photography

Interactive Land Use Classification System

CLASSIFICATION

COVERAGE PRIMARY SECONDARY CONFIDENCE PUBLIC QUIT

LPCI v1.0 USERNAME db
COUNTY GTRAVERSE
DECADE 70
AIRPHOTO DATE 8/3/73
AIRPHOTO TYPE CIR


View

Areal Photographs

SELECTED PARCEL ATTRIBUTES		PERCENT
PARCEL TYPE	Private	
PRIMARY LANDUSE	Unclassified	0
SECONDARY LANDUSE		0
PUBLIC DESIGNATION		
CONFIDENCE		
EDGE PARCEL COMPLETENESS	Complete	

PARCELVISION

Pan/Zoom




CONSOLE

Please wait. Connection closed by Arcserve host.

ARCEDIT

Pan/Zoom x,y: 394443,67186,243641,65802
dx,dy: 2805,43379,-649,29262 dist: 2879,59019



cmdto

```

on.Landuse9 : 0 of 1089
on.Landuse7 : 651 of 651
on.Landuse7 : 1 of 651 s
al expressions. Type END
ACY MIN-PRIMARY
112.000000
on.Landuse7 : 0 of 651 s
on.Landuse8 : 913 of 913
on.Landuse8 : 1 of 913 s
al expressions. Type END
ACY MIN-PRIMARY
230.000000
on.Landuse8 : 0 of 913 s
on.Landuse9 : 1089 of 10
on.Landuse9 : 1 of 1089
al expressions. Type END
ACY MIN-PRIMARY
210.000000
on.Landuse9 : 0 of 1089
on.change : 1340 of 1340
on.change : 1 of 1340 se
al expressions. Type END
ACY MIN-MATRIX
119.000000
on.change : 0 of 1340 se
on.change : 1340 of 1340
on.change : 760 of 1340
on.change : 0 of 1340 se
on.Landuse9 : 1089 of 10
on.Landuse9 : 0 of 1089

```

CLASSIFICATION

COVERAGE	PUBLIC	CONFIDENCE	SECONDARY	PRIMARY
COUNTY	mecosta			
EDIT COV	1990			
	1970	1980	1990	
Area (ha)	24	15	14	
Area (ac)	60	36	35	
Primary	LD Residential	Pasture	Row Crop	
Percent PRI	40	70	40	
Ownership	Private	Private	Private	
Confidence	Above Avg	High	High	
Secondary	Retail/Office	LD Residential	LD Residential	
Percent SEC	10	10	10	
Public				
Editphoto DATE	6/10/72	May-81	Jun-92	
Editphoto TYPE	B&W	BCIR	COLOR	

REFRESH SCREEN SAVE CHANGES Edit PARCELS 1970 1980 1990

1970 Landuse LD Residential Site 1 2 3 4 5 6 7 8 CO

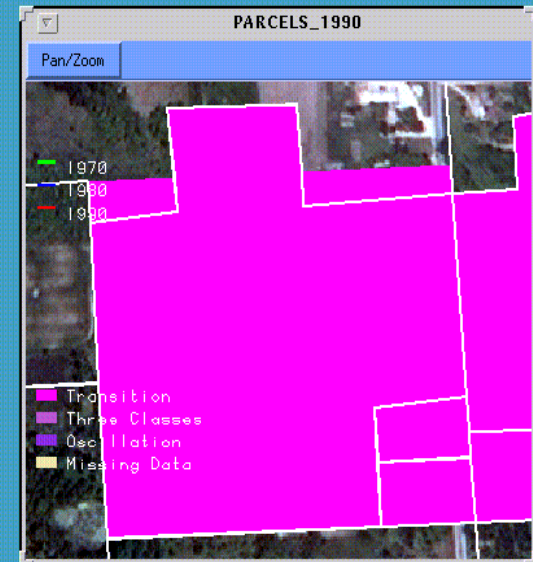
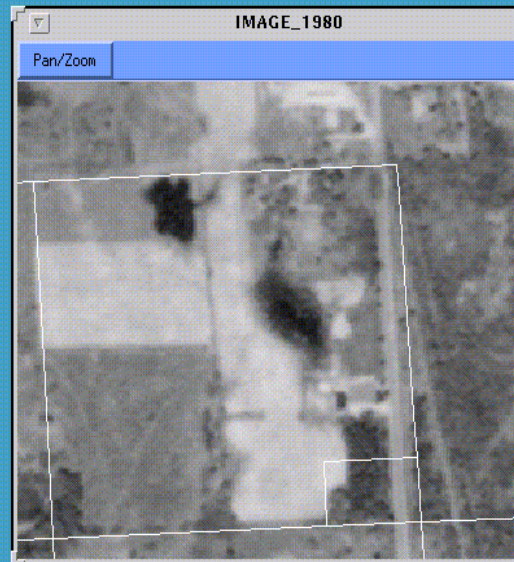
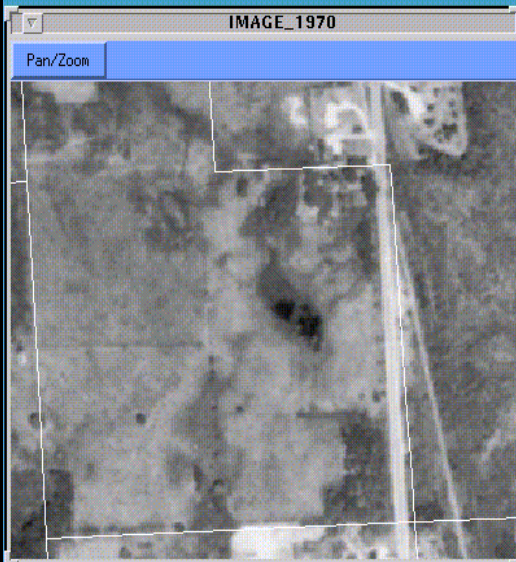
1980 Landuse Pasture

1990 Landuse Row Crop Show SHOW FLAGS SHOW PARCELS

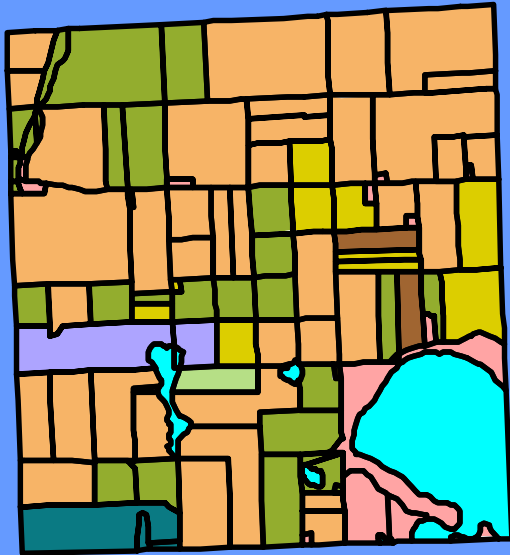
Error Type Transition

Select Parcel * SELECT PARCEL *

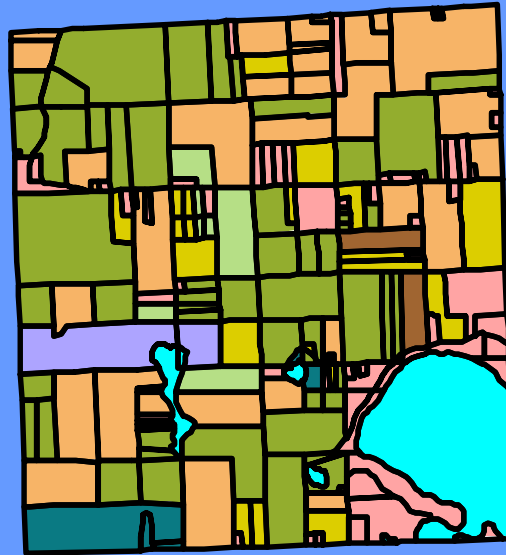
LPOC - Quality Control



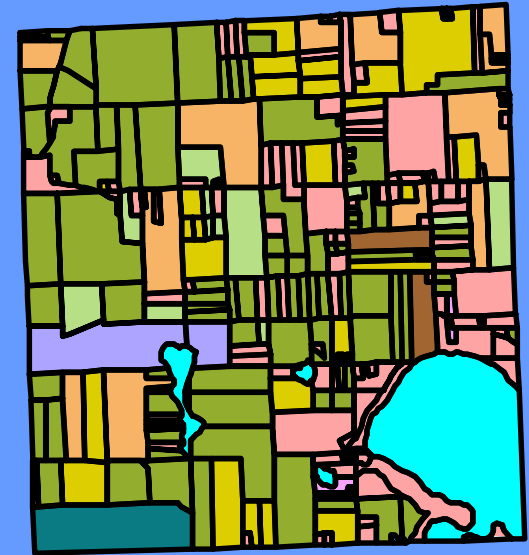
Interpreted Land Use



1973



1985



1991

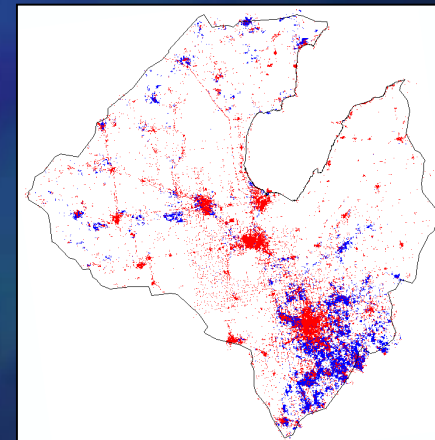
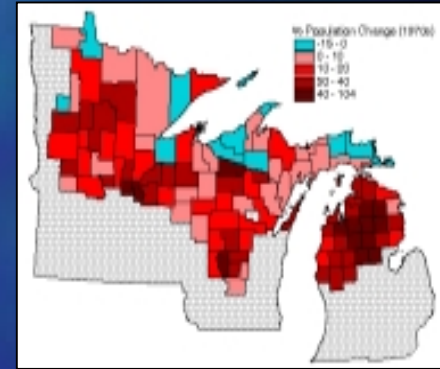
Unclassified
 Residential
 Commercial
 Trans/Utility
 Recreational

Mining/Extract
 Other/Cemetery
 Agriculture
 Open/Grass
 Old Field/Yng Forest

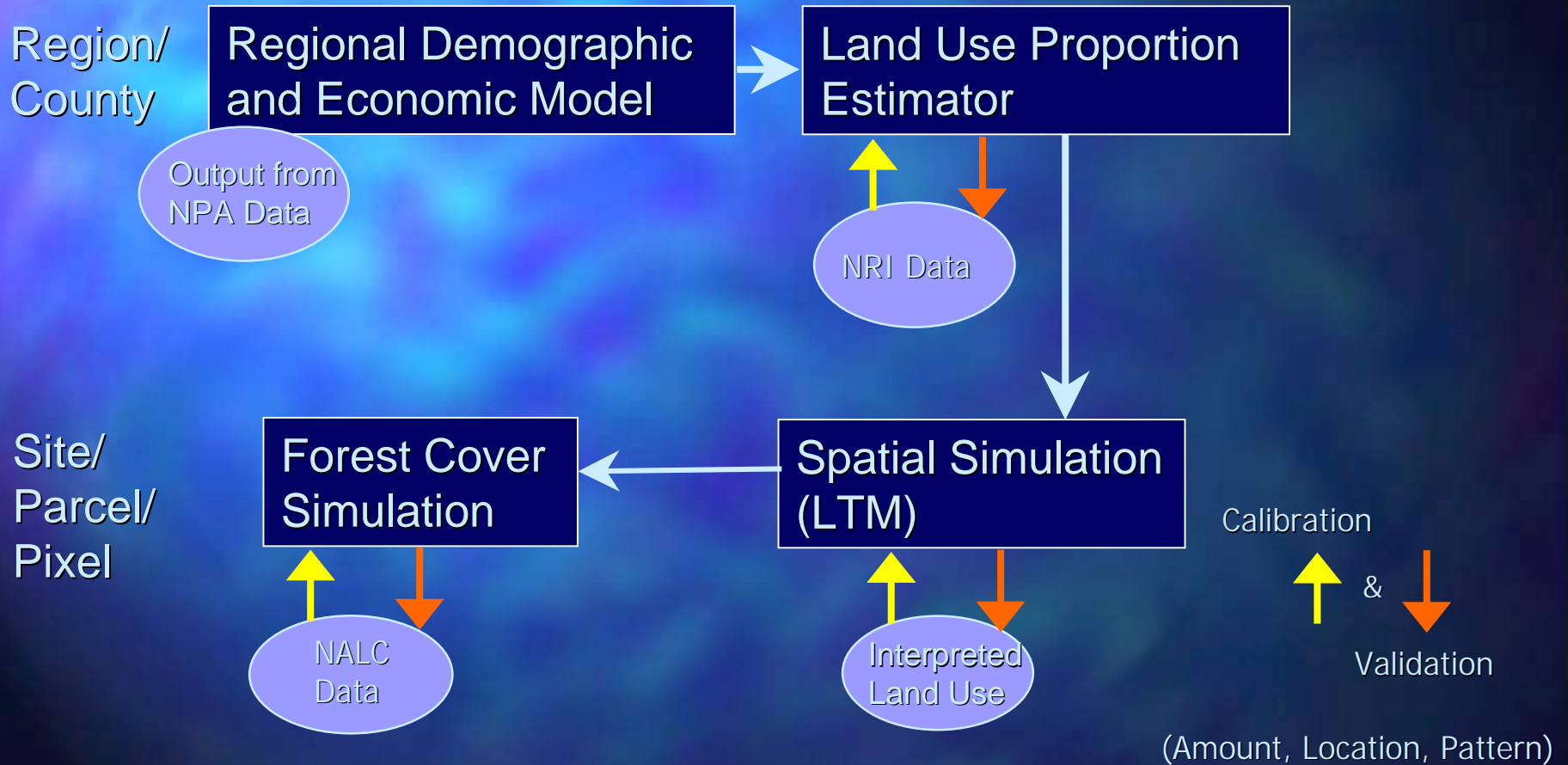
Forest
 Open Water
 Wetland
 Other Undev

Approach to LCLUC Modeling

- Regional economic & demographic model produces county-level estimates.
 - statistically calibrated to project change in land use proportions using NRI data.
- GIS-based Land Transformation Model (LTM) used to spatially disaggregate and map LU changes.
- Probabilistic link between LU and forest cover change.



Modeling of LCLUC



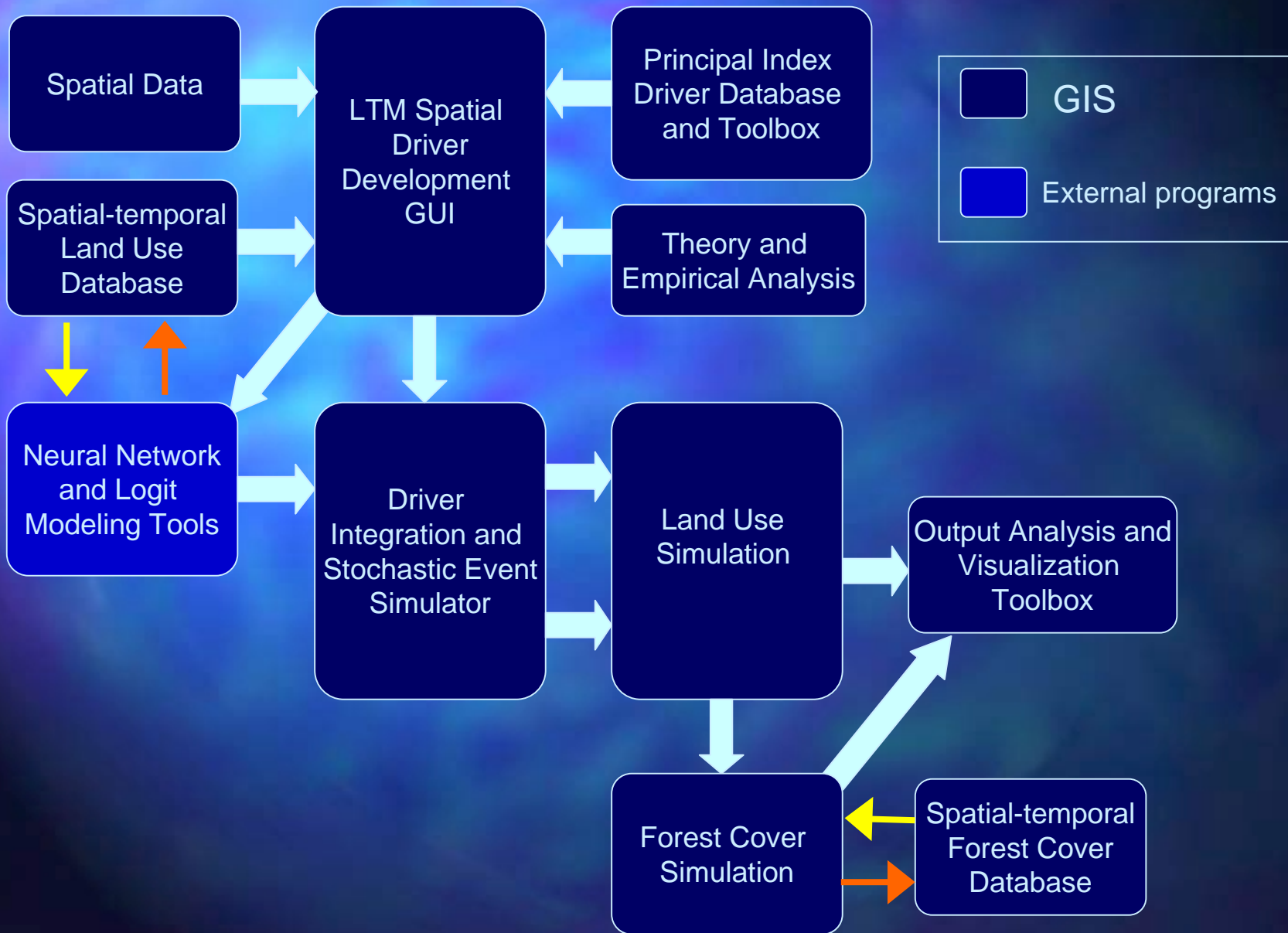
Land Use Proportion Estimates

Change in land use proportion = f(

- change in population and number of households
- initial populations and numbers of households
- initial land use proportions
- change in employment and income by 1-digit SIC code
- average climate and soils
- change in population age structure
- state-level policy differences)

To be estimated using NRI data (1982, 1987, 1992) and socioeconomic data from NPA Data Associates (1967-2030).

LTM Modeling Toolbox





Land Transformation Model



The Land Transformation Modeling Project

Integrating Policy, Socioeconomics & Environmental Factors

LTM Overview



Initialize



Time Steps



Driving Variables



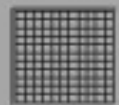
Stochastic



Weights



Exclusionary



Integration



PID

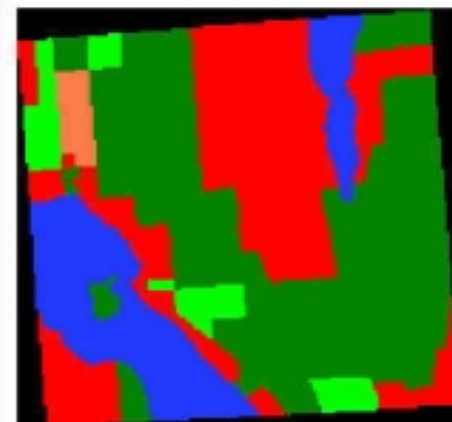


Croberos

Scale 1: 526,715.73
351,735.54

aStartinodata

- t0
 - Developed
 - Old field / young forest
 - Mature forest / close
 - Water
 - Riparian Zone
 - No Data



aWineuts

- Roads.shp
- Rec
 - Campground
 - Golf Course
 - Park
 - No Data
- Water
 - Water
 - No Data
- Urb
 - High density
 - Low density
 - Airport
 - Campground
 - Golf Course
 - Park
 - Mining / Ex
 - No Data



Spatial Variables

- soils
- terrain
- waterfronts (lakes and rivers) and views
- surrounding land use and existing urban
- roads
- parcel sizes
- public land ownership (constraint)



LTM

Select a theme : Ag80

Spatial Interactions

- Neighborhood
- Patch size
- Site specific
- Distance

Spatial Scaling

- Equal Area
- Equal Interval

Patch Parameters

Resolution : 30.0000

Define threshold parameter

Relation

- Direct Transition
- Inverse Transition

Threshold definition

Field:

Value:

Navigation buttons: <<, <, >, >>, and, or, not

Query:

Add View Cancel

Principle Index Driver Construction

Definition of the principle index driver may be accomplished in two ways :

- Define by coverages (excel)
- Define by area-wide values

Definition by area-wide values

Population increase :

Time interval (years) :

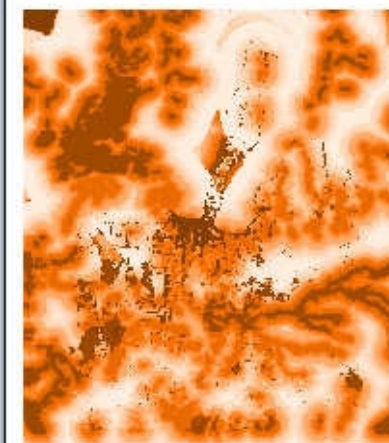
per capita area requirement (acres/person) : 1.1

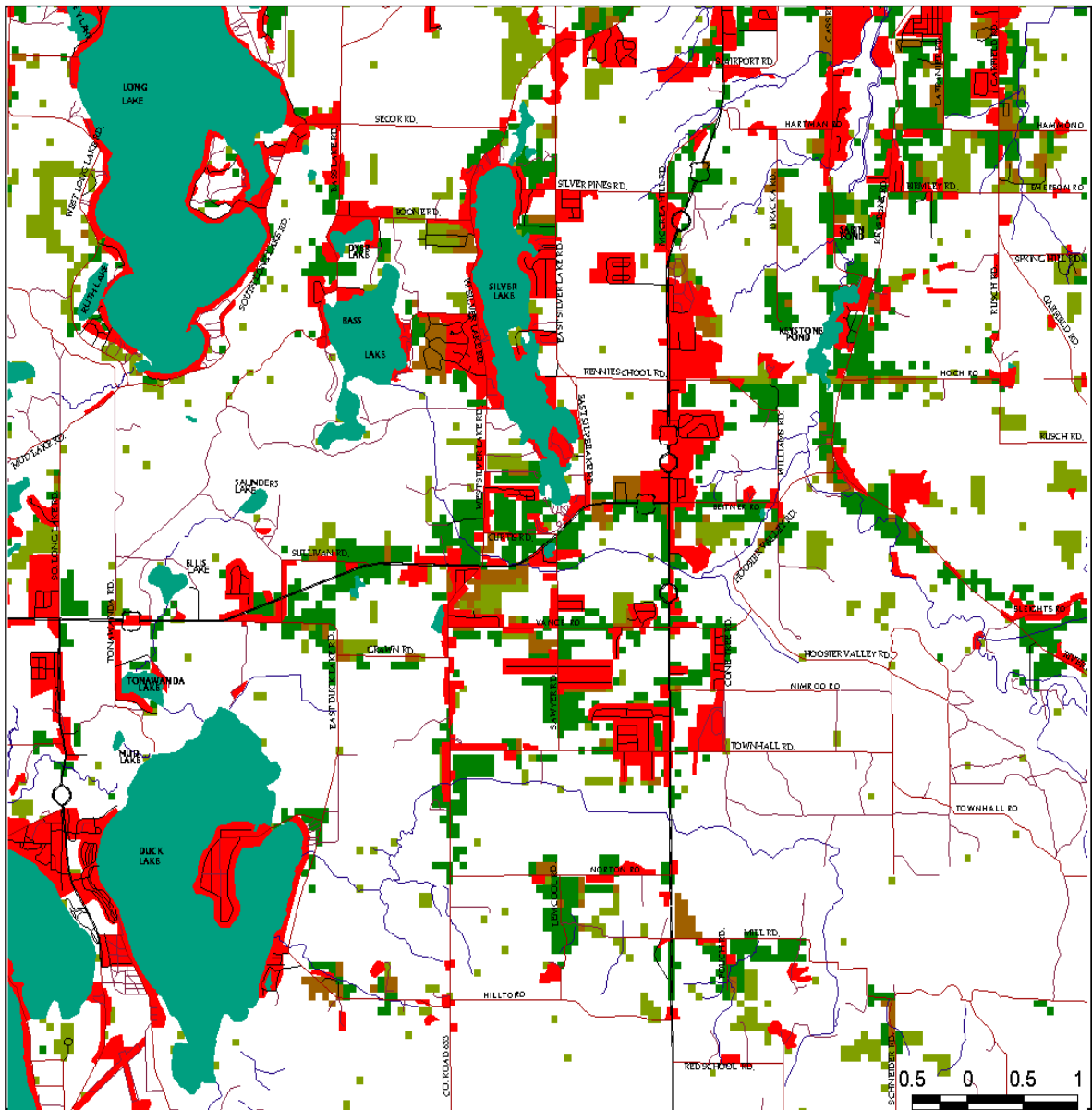
Cancel OK

aIntegraoutputs

probability map

- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- No Data

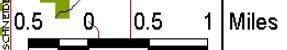
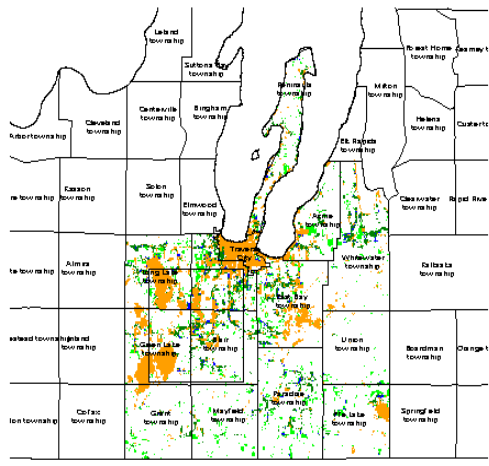
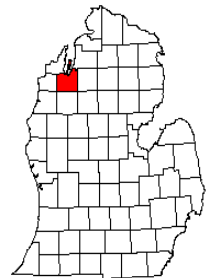




Predicted and Not Predicted

- County Roads
- Highways
- Streets
- Rivers
- Lakes
- urban Land Use 1980
- non-urban

- ### Changemap
- not transitioned and not predicted
 - transitioned, not predicted
 - not transitioned but predicted
 - transitioned and predicted
 - No Data



Methodological Contributions to Date

- Procedures and tool development for land use change mapping.
- Error estimation in quantifying forest cover change and fragmentation.
- Incorporation of neural network estimation, stochastic events, and dynamics into a nested version of GIS-based Land Transformation Model.

Possible Policy Implications

- Current patterns and trends in forest cover and pattern change tend to be positive (says nothing of forest characteristics).
- Development has not yet had a significant negative influence on forest cover, but ag. abandonment has had a positive influence.
- Ownership fragmentation increases complexity of management and likelihood of land use conflict.
- Agriculture is interrelated with forest regrowth and carbon sequestration. We need a good model of agricultural abandonment.

Outreach

- USGCRP National Assessment
 - Land use/cover change is often not included in assessments of system response to climate change (e.g., VEMAP I). Data and models will help.
- Upper Great Lakes RESAC
 - Output from project supports delivery of land use/cover change tools and data to agency-based stakeholders (DNRs, USFS, USGS, NRCS).

Project Timeline

Tasks	1997	1998	1999	2000
Air Photo Interpretation	█	█		
NALC Pre-Processing		█		
NALC Classification		█	█	
Accuracy Assessment and Mosaicking			█	█
Empirical Analyses			█	█
LTM Modification and Testing		█	█	█
Reports and Papers		█	█	█