# The FORE-SCE model: Land Use Modeling Parameterized with USGS Historical Data

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From Science to Solutions

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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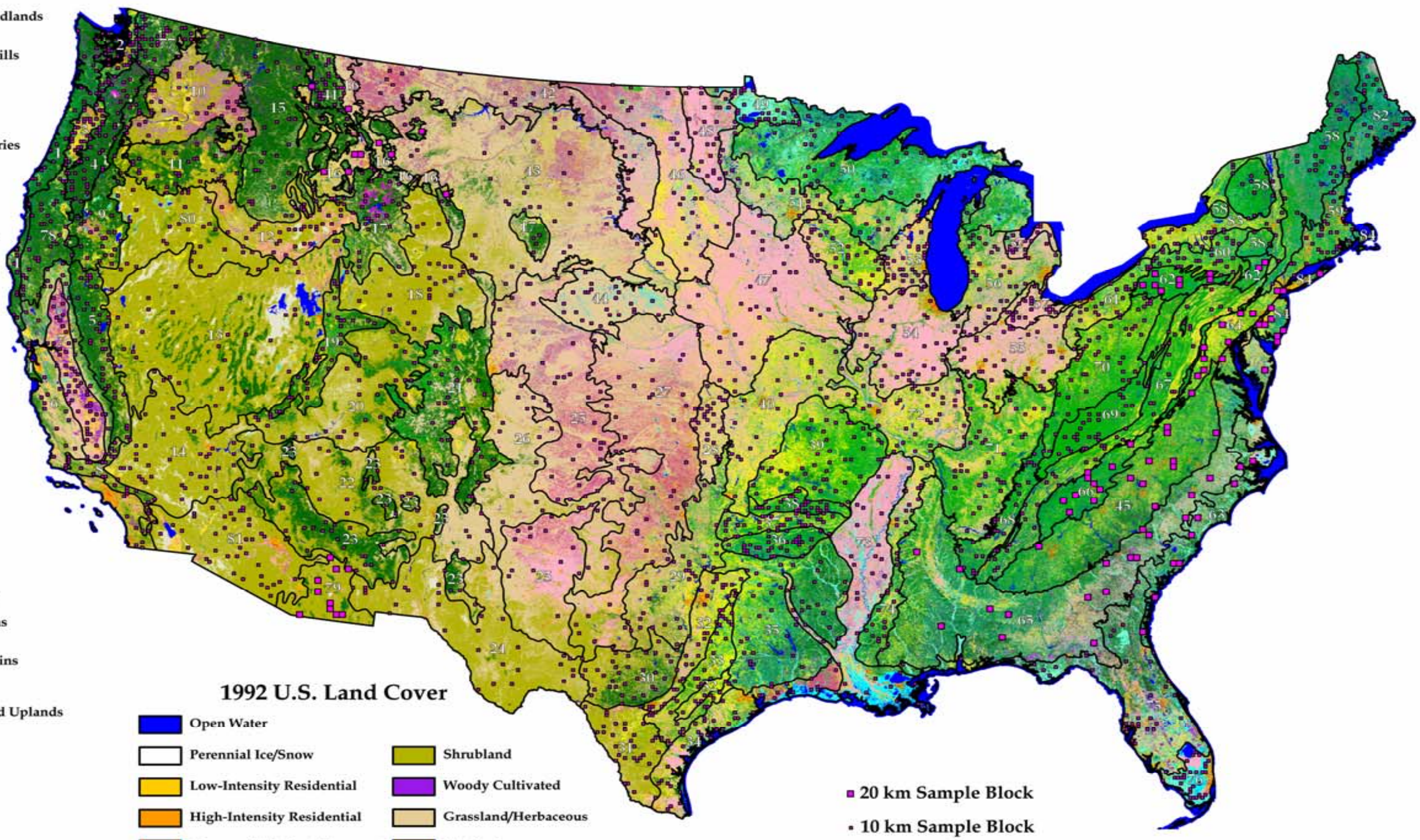
# United States Land Cover Trends

National Center for Earth Resources Observation and Science (EROS)

## Level III Ecoregions
March 1999 Edition

1. Coast Range
2. Puget Lowland
3. Willamette Valley
4. Cascades
5. Sierra Nevada
6. California Chaparral and Oak Woodlands
7. Central California Valley
8. Southern California Mountains
9. Eastern Cascades Slopes and Foothills
10. Columbia Plateau
11. Blue Mountains
12. Snake River Basin
13. Central Basin and Range
14. Mojave Basin and Range
15. Northern Rockies
16. Montana Valley and Foothill Prairies
17. Middle Rockies
18. Wyoming Basin
19. Wasatch and Uinta Mountains
20. Colorado Plateau
21. Southern Rockies
22. Arizona/New Mexico Plateau
23. Arizona/New Mexico Mountains
24. Chihuahuan Deserts
25. Western High Plains
26. Southwestern Tablelands
27. Central Great Plains
28. Flint Hills
29. Central Oklahoma/Texas Plains
30. Edwards Plateau
31. Southern Texas Plains
32. Texas Blackland Prairies
33. East Central Texas Plains
34. Western Gulf Coastal Plain
35. South Central Plains
36. Ouachita Mountains
37. Arkansas Valley
38. Boston Mountains
39. Ozark Highlands
40. Central Irregular Plains
41. Canadian Rockies
42. Northwestern Glaciated Plains
43. Northwestern Great Plains
44. Nebraska Sand Hills
45. Piedmont
46. Northern Glaciated Plains
47. Western Corn Belt Plains
48. Lake Agassiz Plain
49. Northern Minnesota Wetlands
50. Northern Lakes and Forests
51. North Central Hardwood Forests
52. Driftless Area
53. Southeastern Wisconsin Till Plains
54. Central Corn Belt Plains
55. Eastern Corn Belt Plains
56. S. Michigan / N. Indiana Drift Plains
57. Huron/Erie Lake Plains
58. Northeastern Highlands
59. Northeastern Coastal Zone
60. Northern Appalachian Plateau and Uplands
61. Erie Drift Plains
62. North Central Appalachians
63. Middle Atlantic Coastal Plain
64. Northern Piedmont
65. Southeastern Plains
66. Blue Ridge Mountains
67. Ridge and Valley
68. Southwestern Appalachians
69. Central Appalachians
70. Western Allegheny Plateau
71. Interior Plateau
72. Interior River Lowland
73. Mississippi Alluvial Plain
74. Mississippi Valley Loess Plains
75. Southern Coastal Plain
76. Southern Florida Coastal Plain
77. North Cascades
78. Klamath Mountains
79. Madrean Archipelago
80. Northern Basin and Range
81. Sonoran Basin and Range
82. Laurentian Plains and Hills
83. Eastern Great Lakes and Hudson Lowlands
84. Atlantic Coastal Pine Barrens



## 1992 U.S. Land Cover

- Open Water
- Perennial Ice/Snow
- Low-Intensity Residential
- High-Intensity Residential
- Commercial/Indust./Transport.
- Bare Rock/Sand/Clay
- Strip Mine/Quarry/Gravel Pit
- Transitional Barren
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrubland
- Woody Cultivated
- Grassland/Herbaceous
- Hay/Pasture
- Row Crops
- Small Grains
- Fallow/Bare Field
- Urban/Other Grasses
- Woody Wetland
- Herbaceous Wetland

▪ 20 km Sample Block

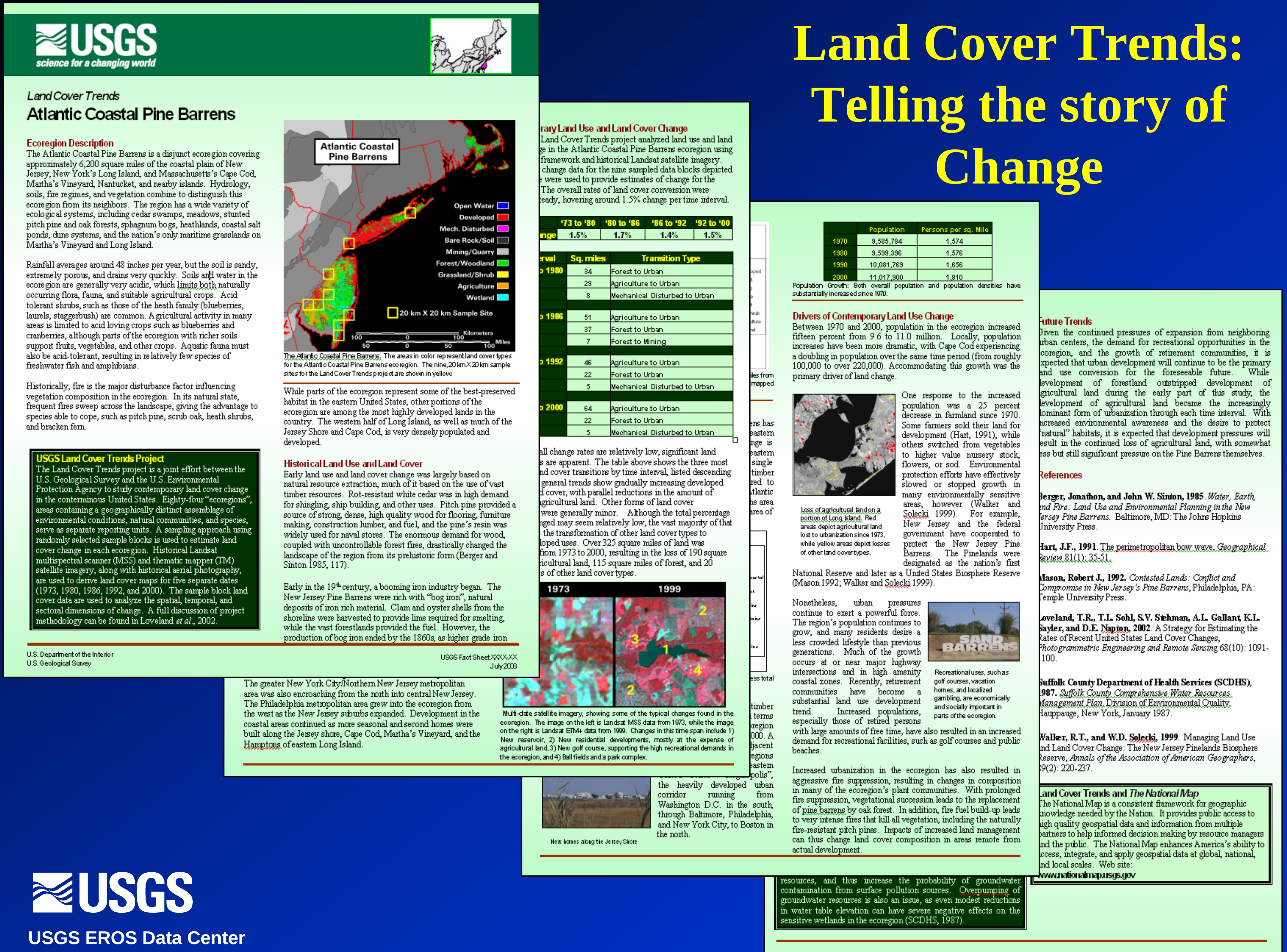
▪ 10 km Sample Block

Kilometers: 500 0 500 1000

Miles: 500 0 500

U.S. Department of the Interior
U.S. Geological Survey

# Land Cover Trends: Telling the story of Change

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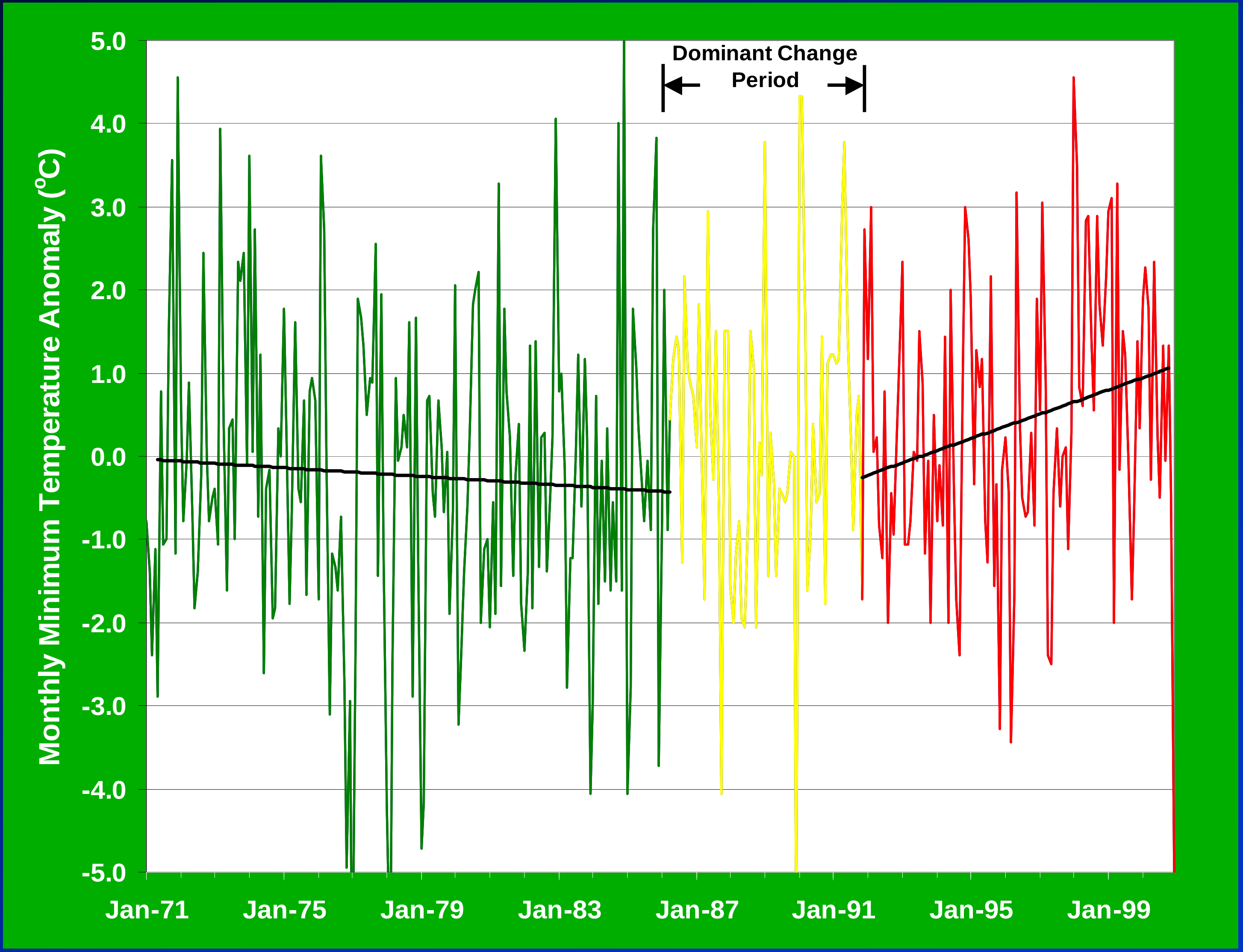
# Applications of Land Cover and Land Cover Change Data

- NOAA temperature trends analysis
  - Hale, R. C., K. P. Gallo, T. W. Owen, and T R. Loveland (2006), Land use/land cover change effects on temperature trends at U.S. Climate Normals stations. *Geophysical Research Letters* 33: L11703

# Monthly Minimum Temperature Anomaly - Memphis, TN




Pre-change trend: $-0.03 \pm 0.06$ °C/yr

Post-change trend: $0.15 \pm 0.12$ °C/yr

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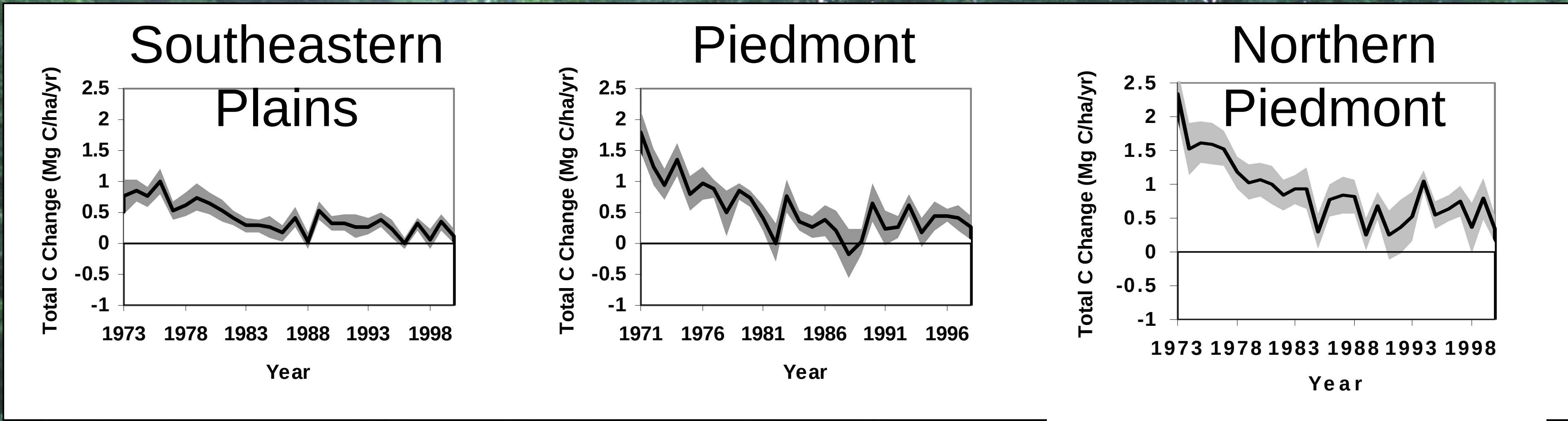
# Applications of Land Cover and Land Cover Change Data

- USGS/NASA United States regional carbon dynamics
  - Liu, J, S. Liu, and T.R. Loveland, 2006. Temporal evolution of carbon budgets of the Appalachian Forests in the U.S. from 1972 to 2000. *Forest Ecology and Management* (in press).
  - Liu, J., S. Liu, T.R. Loveland, and T.L. Tieszen, 2006. Estimating carbon sequestration in agricultural ecosystems in the Western Corn Belt Plains of the United States. *Global Change Biology* (currently going through USGS review).
  - Tan, Z., S. Liu, C. A. Johnston, T. R. Loveland, L. L. Tieszen, J. Liu, and R. Kurtz, 2005. Soil organic carbon dynamics as related to land use history in the northwestern Great Plains. *Global Biogeochemical Cycles* 19: GB3011.
  - Liu, S., T.R. Loveland, and R.M. Kurtz, 2004. Contemporary carbon dynamics on terrestrial ecosystems in the southeastern plains of the United States. *Environmental Management* 33: S442-S456.




# Ecoregion Carbon Dynamics

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

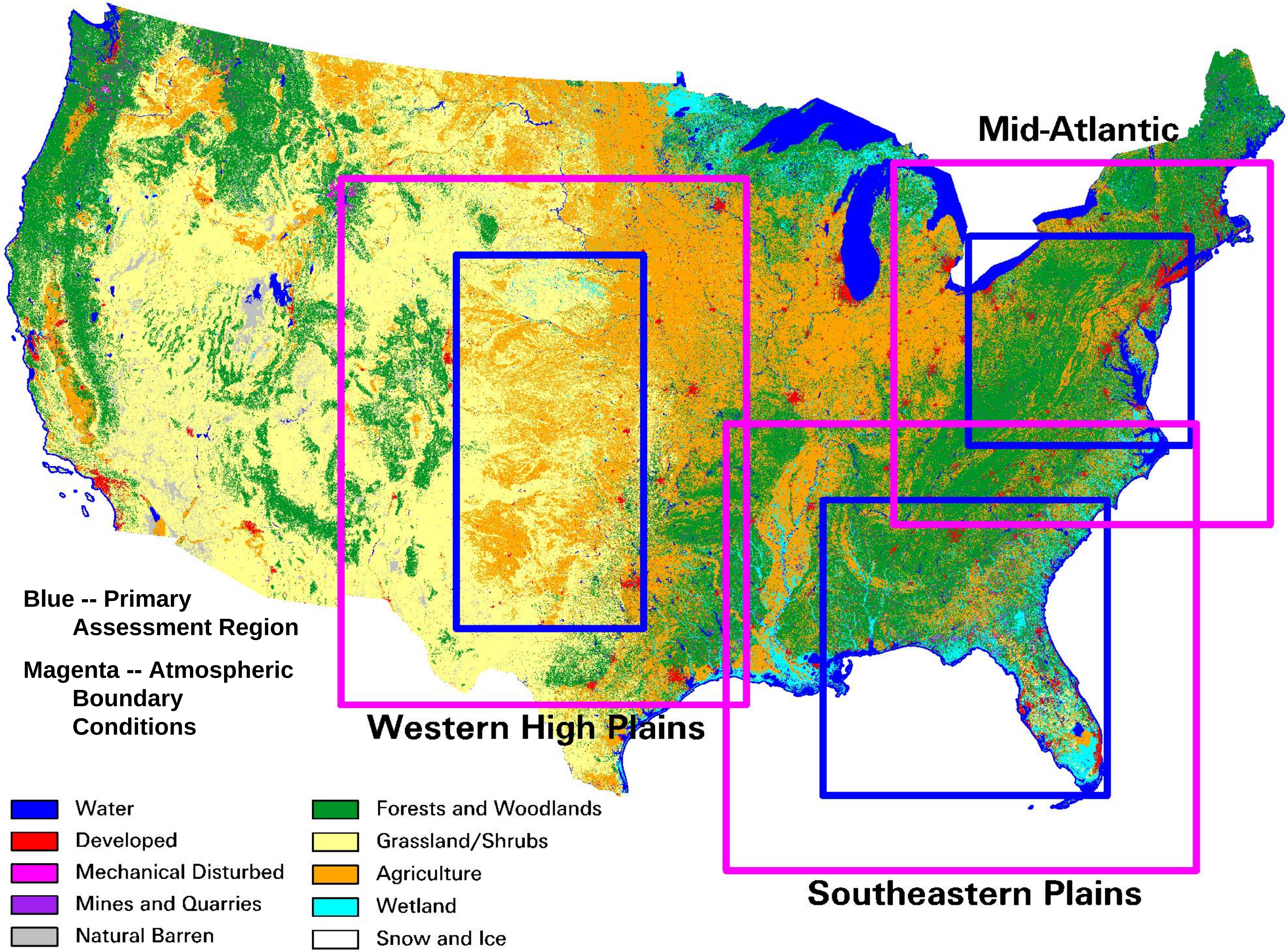
# Applications of Land Cover and Land Cover Change Data – Conservation Issues

- USGS ARMI regional amphibian habitat analysis
  - Price, S., M. Dorcas, A. Gallant, R. Klaver, and J. Wilson, 2006. Three decades of urbanization: estimating the impact of land-cover change on stream salamander populations. *Biological Conservation.*

- USGS/FWS National Wildlife Refuge ecological integrity assessment
  - Scott, J.M., Loveland, T.R., Gergley, K., Strittholt, J., and Staus, N., 2004. National Wildlife Refuge System: ecological context and integrity. *Natural Resources Journal* 44(4): 1041-1066.

# "The Influence of Historical and Projected Land Use and Land Cover Changes on Land Surface Hydrology and Regional Weather and Climate Variability"

- NASA ESE funded proposal
  - T. Loveland, R. Pielke Sr., T. Sohl, L. Steyaert
- Conduct a series of regional experiments that collectively address the extent to which changes in specific regional land use and land cover characteristics, including the types, biophysical properties, and spatial configurations, affect surface hydrology and regional weather and climate variability.
- Sister USGS Prospectus funding


Mid-Atlantic
Western High Plains
Southeastern Plains
Blue -- Primary Assessment Region
Magenta -- Atmospheric Boundary Conditions
Water
Developed
Mechanical Disturbed
Mines and Quarries
Natural Barren
Forests and Woodlands
Grassland/Shrubs
Agriculture
Wetland
Snow and Ice

# Technical Components

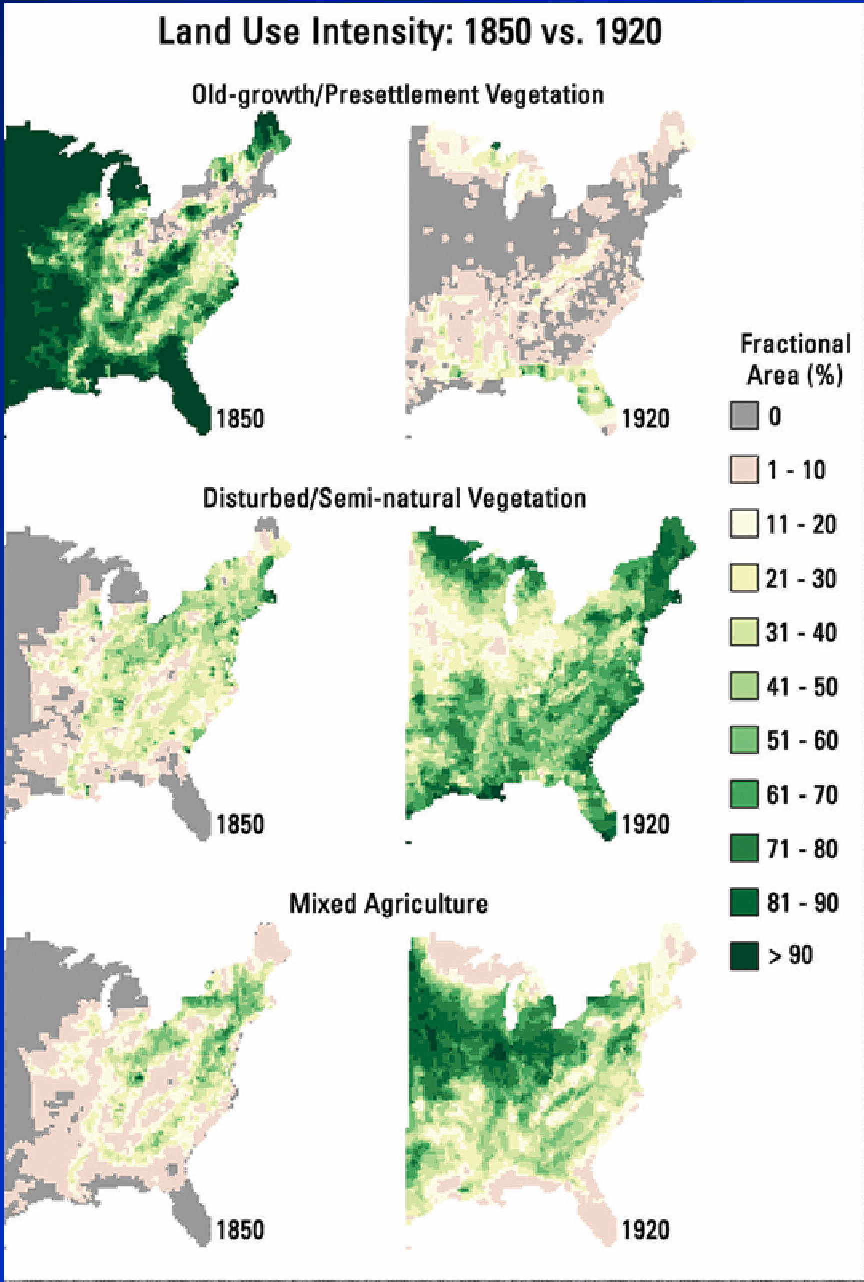
- Land cover database development (pre-settlement, 1920, 1992, and 2020)
- Biophysical parameter dataset development
- Sensitivity tests for summer months using RAMS/LEAF2/GEMTM
- Validation of model sensitivity
- Assessment of future regional climate vulnerability

# LULC databases -- LEAF2 (modified) classification scheme (Western Plains Application)

- Oceans, Lakes
- Ice Caps, Glaciers
- Evergreen Needleleaf Forest
- Deciduous Needleleaf Forest
- Deciduous Broadleaf Forest
- Evergreen Broadleaf Forest
- Short Grass
- Tall Grass
- Desert
- Evergreen Shrub
- Deciduous Shrub
- Mixed Woodland
- Crops/Mixed Farming
- Row Crop (Dryland)
- Irrigated Crop
- Bog or Marsh
- Bare Ground
- Urban and Built-up

# Historical Land Cover Reconstruction

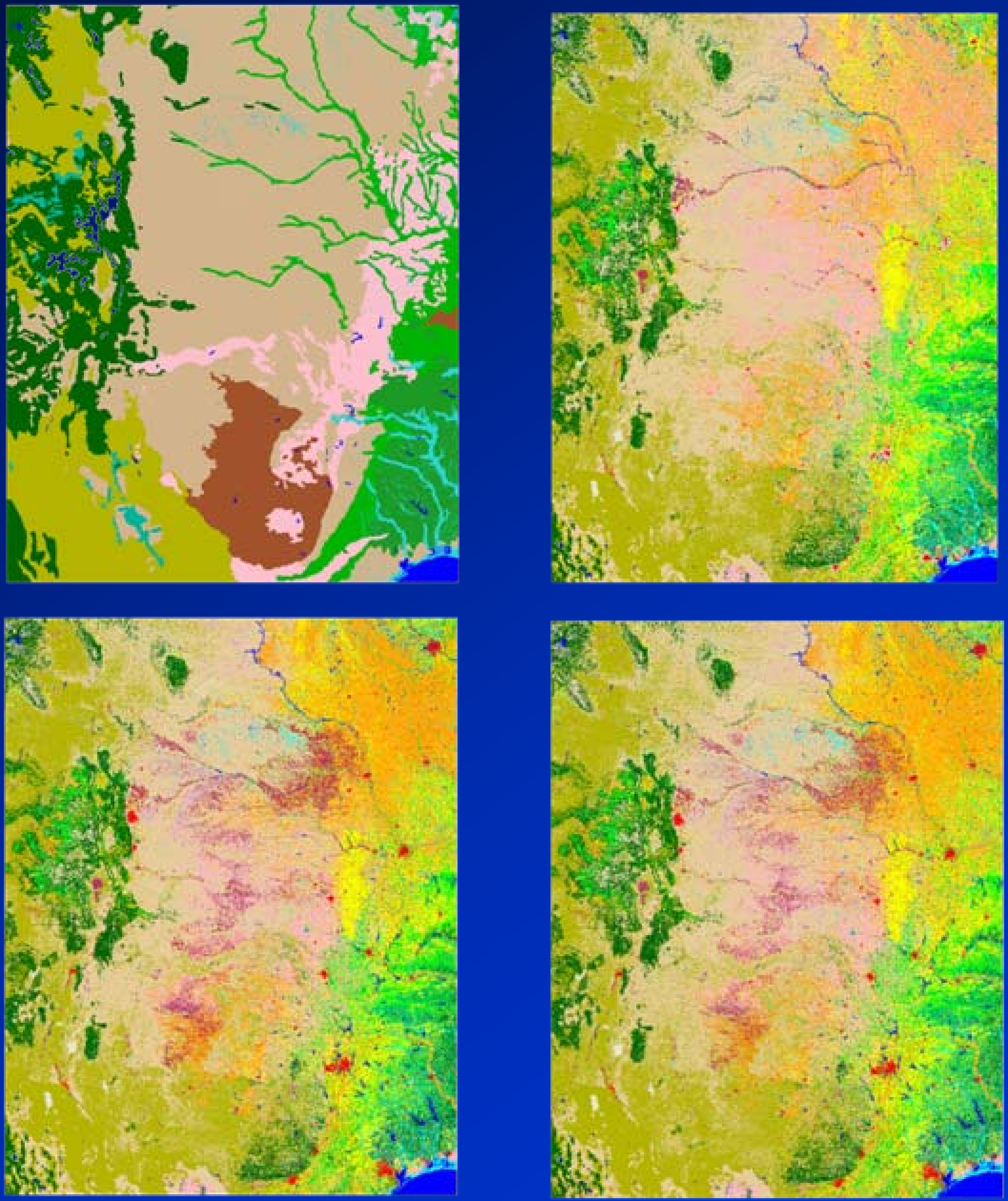
- A modified Kuchler's Potential Natural Vegetation (PNV) is used to represent pre-settlement (~1650)
- ~1920 chosen as it represents the period where agricultural activity reached a peak in much of the U.S., with eastern forests greatly reduced
- A cartographic modeling process used to reconstruct 1920s land cover, using:
  - PNV
  - County Ag stats
  - Census Data
  - Other historical data sources



# Historical, Contemporary, and Future Land cover in the High Plains:

## Assessing the Consequences of Land Cover Change on Regional Weather and Climate Variability

Pre-Settlement 1920



1992 2020

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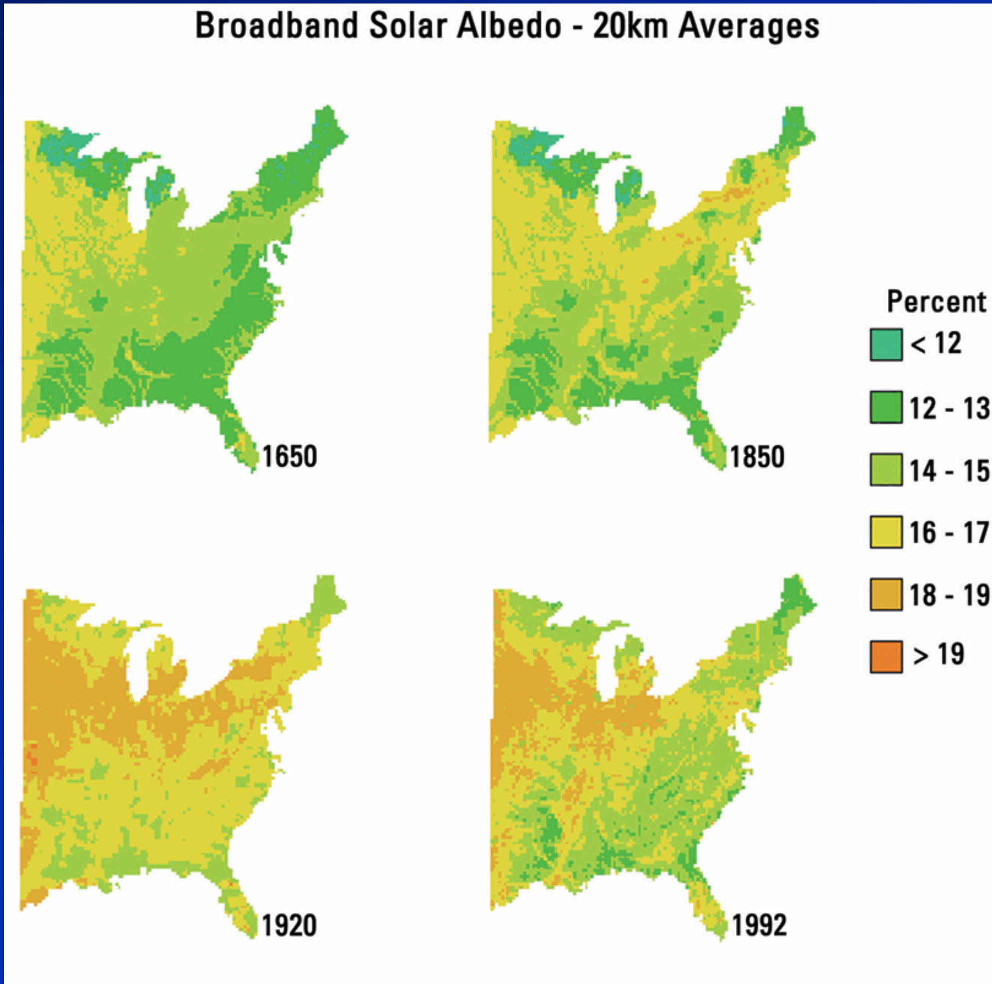
# Biophysical Parameter Construction

- Biophysical parameter datasets for coupled land-atmosphere modeling are based on mapped land cover classes.
- Aggregated time series of MODIS products (albedo, leaf area, veg. indices) used to improve the basis for prescribing these parameters for each land cover type.
- These data are combined with field and other data to construct final biophysical parameter data layers
- These serve as input to RAMS/GEMTM modeling system

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# Projecting Land Cover Change: The FORE-SCE model

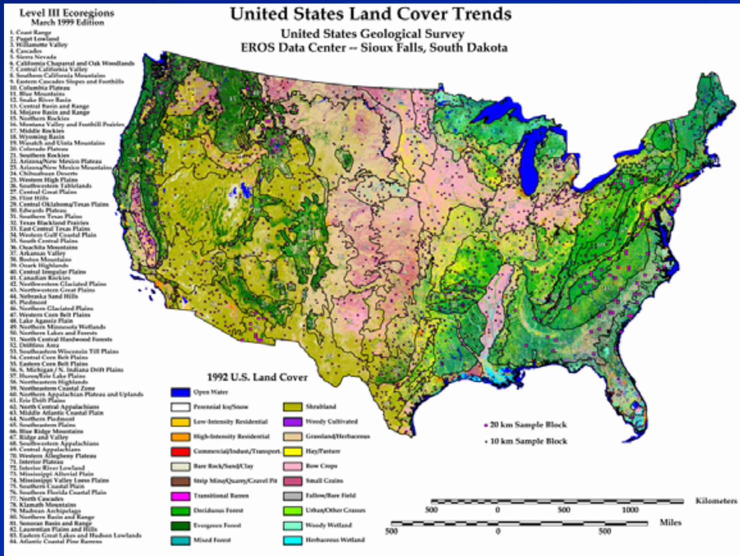
- FORE-SCE – FOREcasting SCEnarios of land use change
- Our goal is to:
  - Provide scenario-based projections of change (3 scenarios per region)
  - Project the proportions of each land cover in a region
  - Site the cover on the lands with the highest potential for supporting that land use and cover
  - Generate the clusters of cover and patterns of fragmentation so that the projected landscape represents a specific composition and configuration for each region.

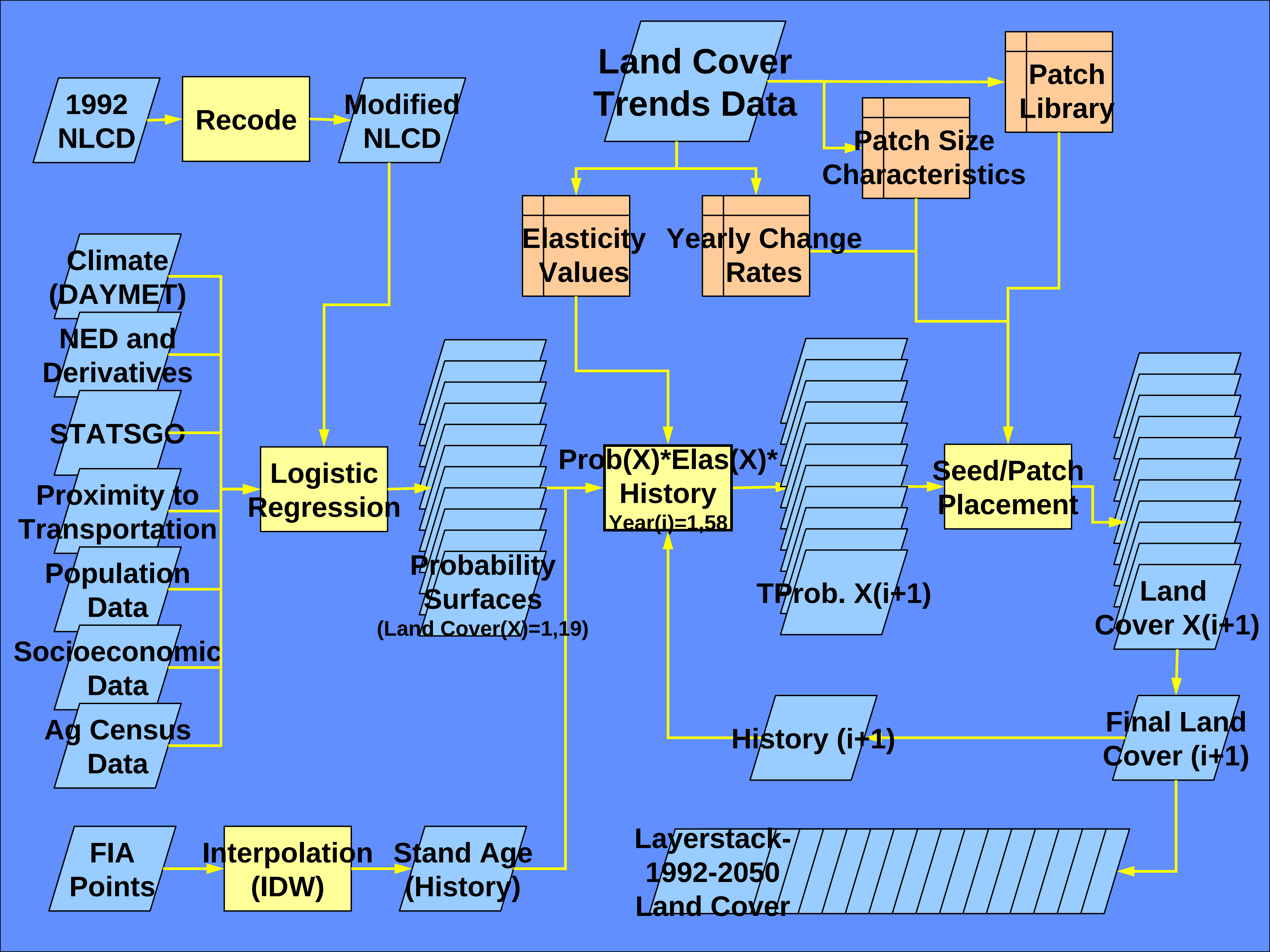
# FORE-SCE: Model structure

- **Issues of Scale -- Demand vs. Spatial Allocation module**
  - **Demand Module**
    - Driven by macro-level socioeconomic drivers
    - Drivers often not spatially explicit, not able to be mapped quantitatively
    - Non-spatial...calculates area change for all land use types at the aggregate level
  - **Spatial Allocation Module**
    - Driven by lower-level socioeconomic and biophysical drivers
    - Requires the establishment of quantitative relationships between LULC distribution and drivers
      - Drivers MUST be mappable at the scale of analysis
    - Output from Demand Module translated into spatially explicit allocation of land use change, based on a combination of empirical information, spatial analysis, and dynamic modeling.

# Land Cover Trends Data -- Our Ace-in-the-hole

- Use of Land Cover Trends project data
  - We have empirical data on contemporary land cover change in the three study areas (change rates, patch characteristics, habitat fragmentation, drivers of change)
  - Incorporation of Trends information -- Gives us an advantage that many modelers of LULC change don't have.
  - Existence of Trends data, 1992 NLCD, and 2000 NLCD offers the possibility for calibrating model results

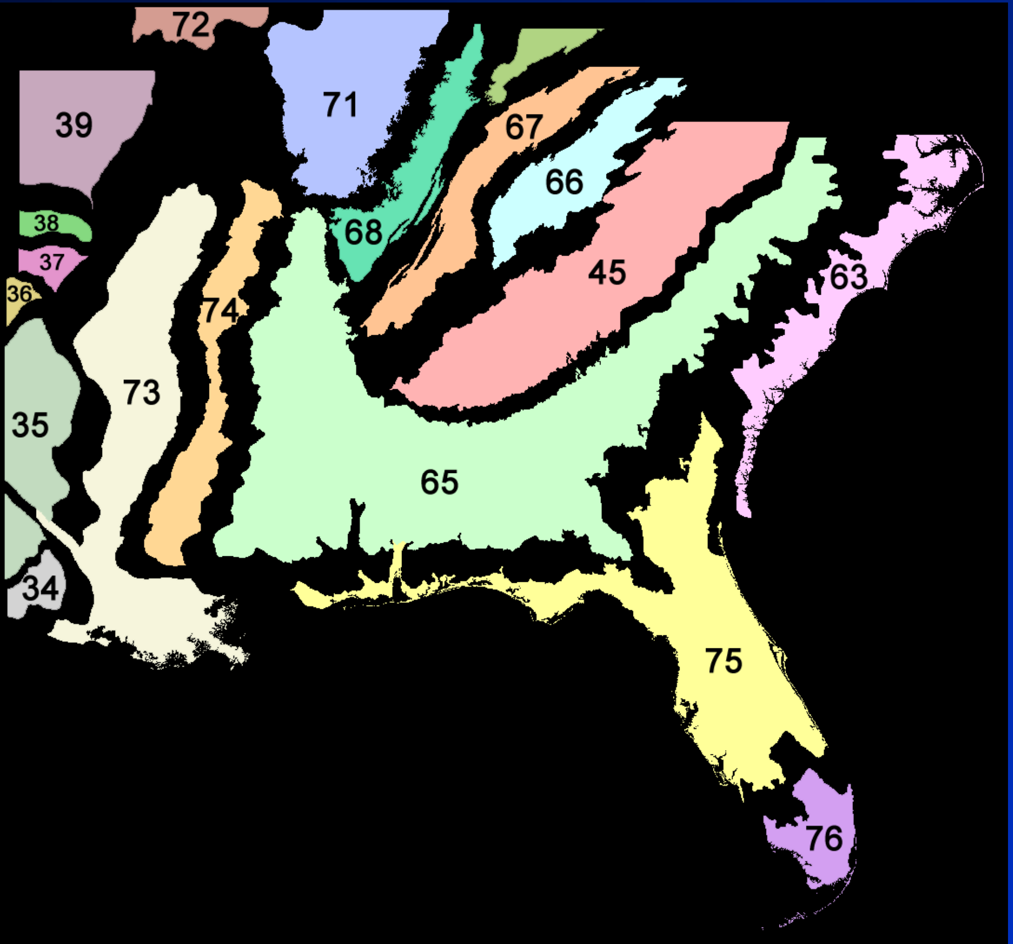




1992 NLCD
Recode
Modified NLCD
Land Cover Trends Data
Patch Library
Patch Size Characteristics
Elasticity Values
Yearly Change Rates
Climate (DAYMET)
NED and Derivatives
STATSGO
Proximity to Transportation
Population Data
Socioeconomic Data
Ag Census Data
Logistic Regression
Probability Surfaces
(Land Cover(X)=1,19)
Prob(X)*Elas(X)*
History
Year(i)=1,58
TProb. X(i+1)
Seed/Patch Placement
Land Cover X(i+1)
Final Land Cover (i+1)
History (i+1)
FIA Points
Interpolation (IDW)
Stand Age (History)
Layerstack-
1992-2050
Land Cover

# FORE-SCE Model: Trends data and model parameterization

- Ecoregion-by-ecoregion model parameterization using Trends data
- Ecoregion specific parameters including change rates, change patch characteristics, “Elasticity” values, “Clumpiness” values




**Clear-cutting**

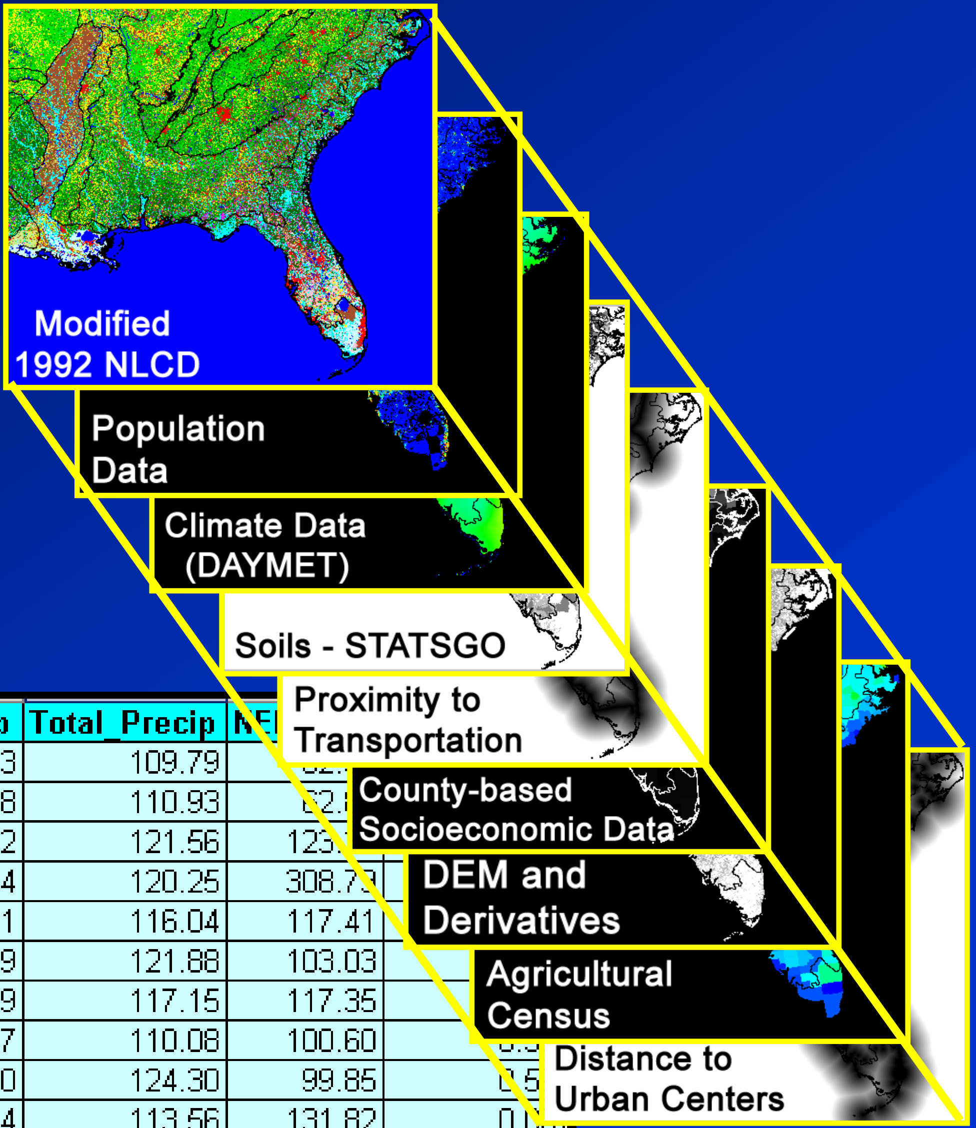
| | Annual Area (km2) | Mean Patch Size (ha) | Std. Deviation (ha) |
|---|---|---|---|
| Eco. 45 | 292.0 | 18.6 | 32.1 |
| Eco. 63 | 231.2 | 26.7 | 57.9 |
| Eco. 65 | 1470.7 | 22.9 | 37.6 |
| Eco. 66 | 8.0 | 11.6 | 13.1 |
| Eco. 67 | 47.5 | 8.8 | 18.2 |
| Eco. 68 | 56.8 | 9.3 | 24.4 |
| Eco. 69 | 3.9 | 10.6 | 15.9 |
| Eco. 70 | 0.6 | 4.6 | 6.8 |
| Eco. 71 | 19.7 | 6.5 | 19.4 |
| Eco. 74 | 70.0 | 21.1 | 34.7 |
| Eco. 75 | 448.0 | 22.5 | 60.7 |
| Eco. 76 | 0.5 | 12.4 | 27.7 |

**ELASTICITY** FROM CLASS

| | ECO 75 | Mining | Trans. | Decid. | Mixed | Evergr. | Natural Grass | Hay / Pasture | Row Crops | Small Grains | Woody Wet | Herby Wet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water | 0 | 5 | 7 | 7 | 7 | 8 | 10 | 8 | 8 | 0 | 10 |
| T | Urban | 6 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 6 | 6 |
| O | Mining | 0 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 5 | 5 |
| | Transitional | 0 | 0 | 5 | 8 | 10 | 0 | 0 | 0 | 0 | 2 | 0 |
| C | Deciduous | 0 | 0 | 0 | 0 | 0 | 5 | 10 | 8 | 8 | 0 | 0 |
| L | MixedFor | 0 | 0 | 0 | 0 | 0 | 5 | 10 | 8 | 8 | 0 | 0 |
| A | Evergreen | 0 | 0 | 0 | 0 | 0 | 5 | 10 | 8 | 8 | 0 | 0 |
| S | Natural Grass | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S | Hay/Past | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Row Crop | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Small Grains | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Woody Wet. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Herby Wet. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

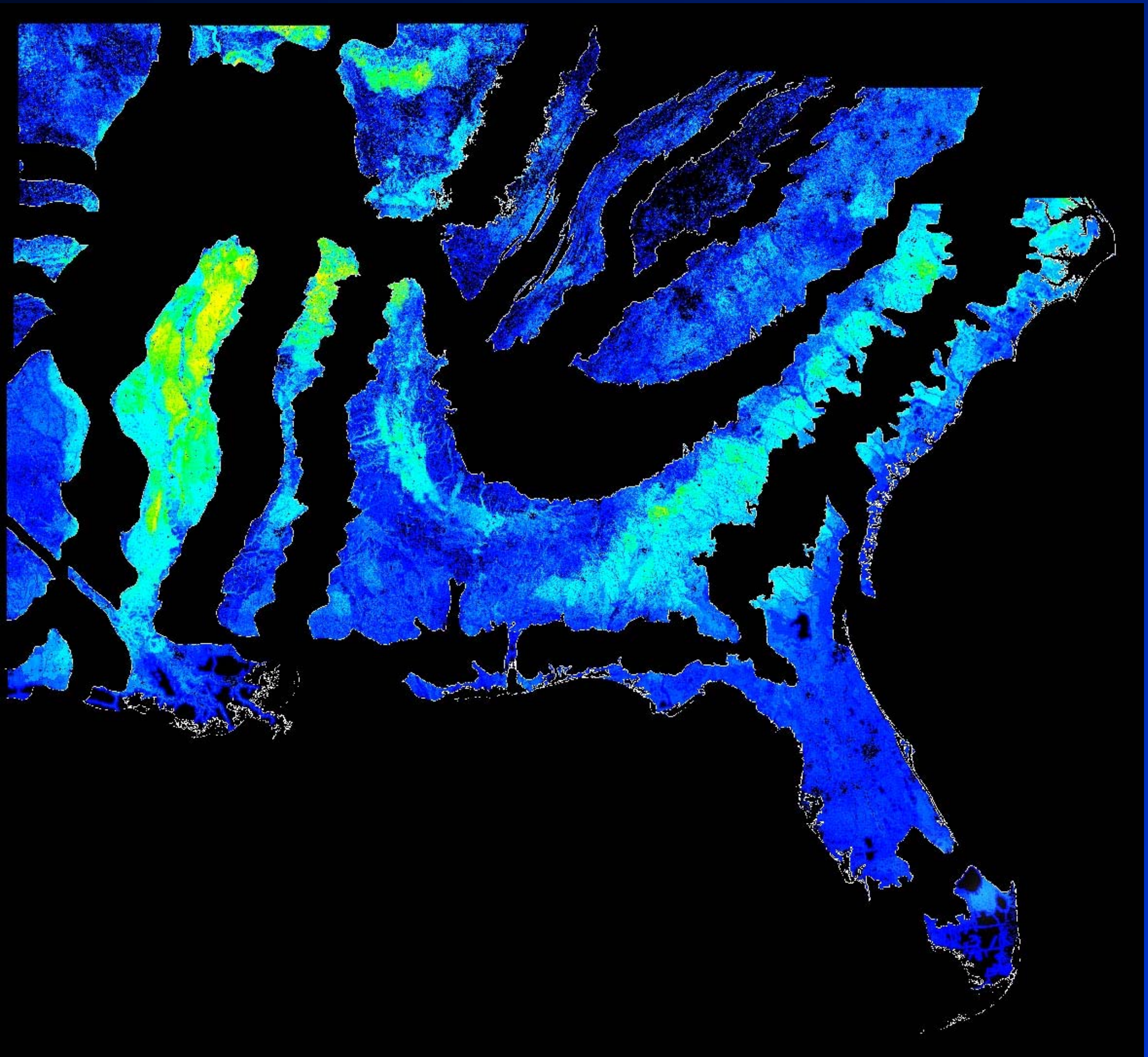
# Ancillary Data – Used in Logistic Regression

- Modified 1992 NLCD and all ancillary data compiled into one data stack
- 50,000 points, minimum 1,000 per land cover class
- Point land cover and corresponding ancillary data values imported into SAS




| Land Cover | Road_Dist | Istate_Dist | Citybuff_Dist | Dly_Ave_temp | Total_Precip | NE[illegible] | [illegible] |
|---|---|---|---|---|---|---|---|
| 1 | 1492.00 | 65.89 | 275.25 | 14.53 | 109.79 | [illegible] | [illegible] |
| 14 | 396.44 | 87.33 | 267.33 | 14.48 | 110.93 | [illegible] | [illegible] |
| 14 | 1011.56 | 25.78 | 52.33 | 13.32 | 121.56 | [illegible] | [illegible] |
| 3 | 510.67 | 453.00 | 192.83 | 13.24 | 120.25 | [illegible] | [illegible] |
| 1 | 135.11 | 675.67 | 237.33 | 14.11 | 116.04 | 117.41 | [illegible] |
| 7 | 1185.78 | 194.58 | 208.89 | 13.49 | 121.88 | 103.03 | [illegible] |
| 9 | 62.22 | 686.44 | 248.44 | 14.09 | 117.15 | 117.35 | [illegible] |
| 15 | 805.33 | 217.33 | 243.56 | 14.47 | 110.08 | 100.60 | [illegible] |
| 3 | 597.33 | 372.00 | 375.67 | 14.00 | 124.30 | 99.85 | [illegible] |
| 8 | 352.00 | 287.44 | 120.33 | 14.34 | 113.56 | 131.82 | [illegible] |

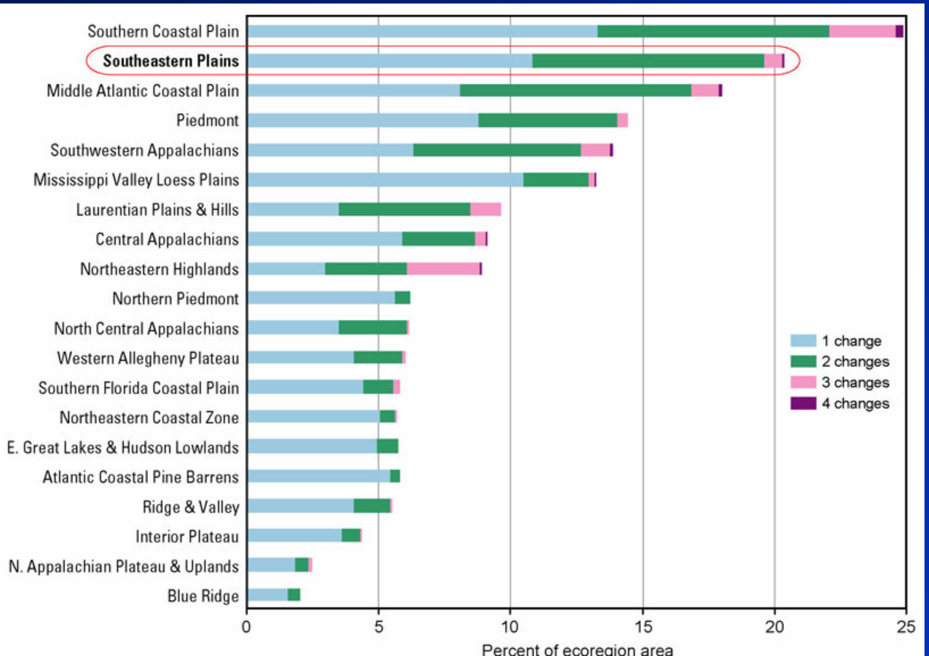
# Regression-based Probability Surfaces

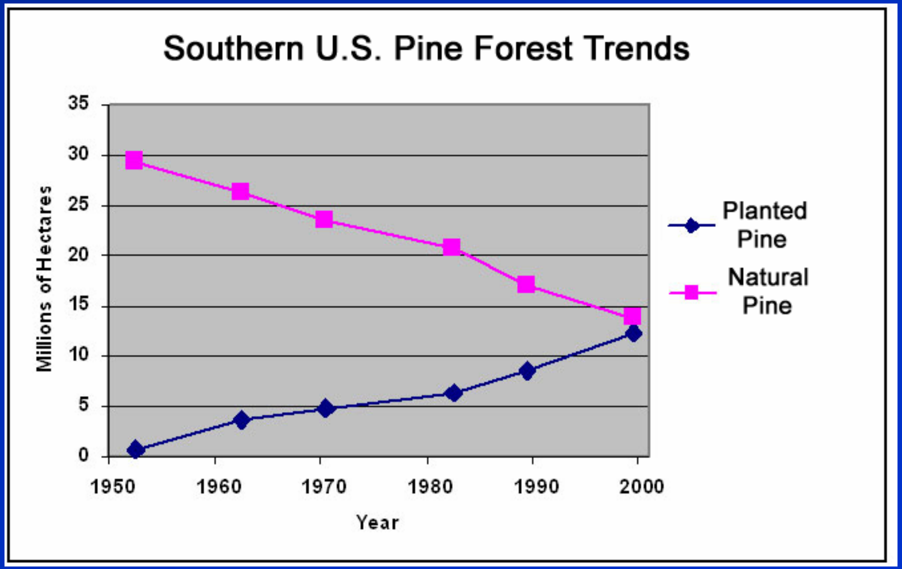


- Logistic regression used to analyze relationships between each land cover type and ancillary data sets
- Probability surfaces constructed for each land cover type

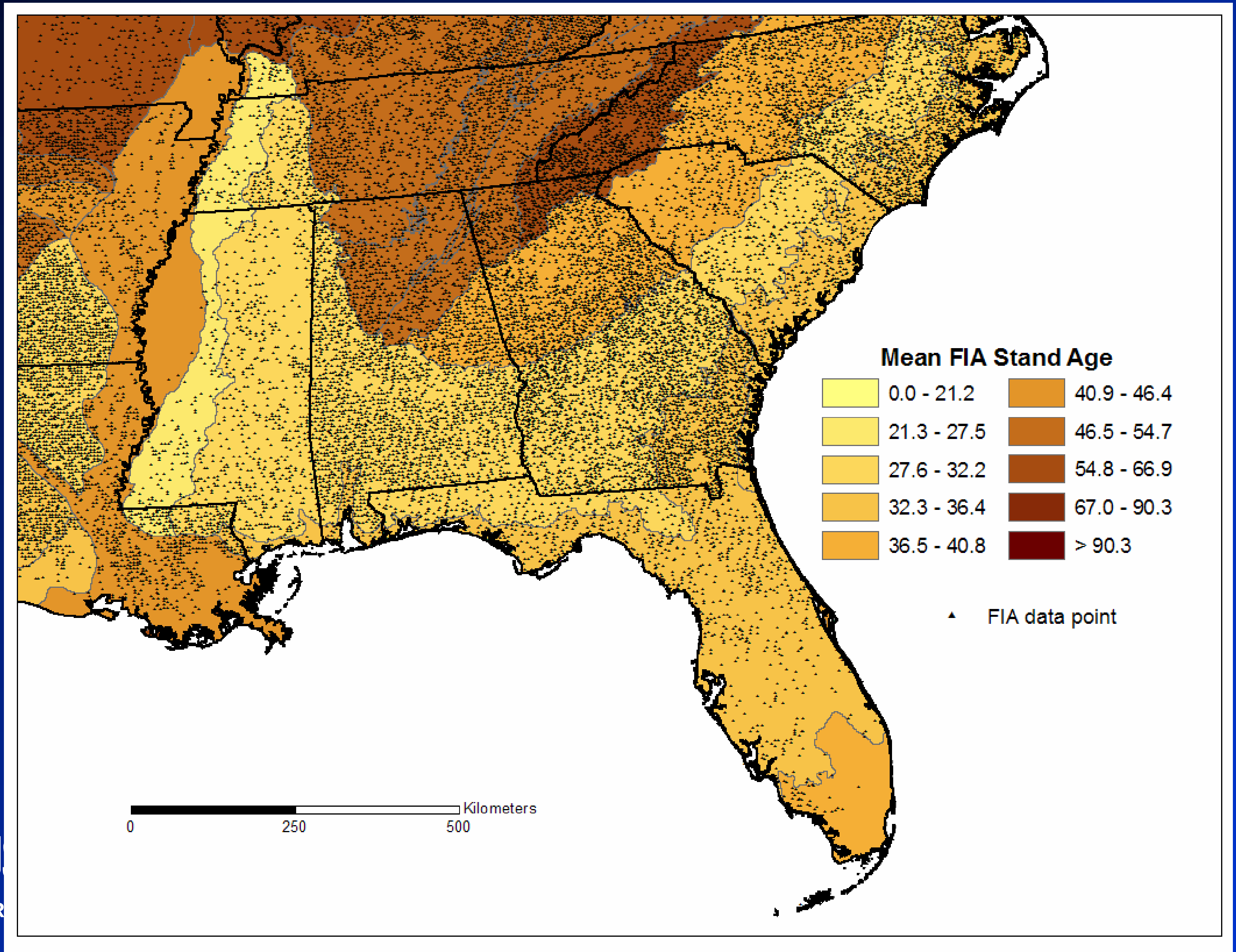
# Tracking Change through Time – HISTORY Variable

- Forestry activity in the Southeast results in an extremely dynamic landscape
  - Over 20% of the Southeastern Plains ecoregion changed land cover type at least once between 1973 and 2000
  - ~75% of change in the Southeastern Plains is directly related to forest cutting
- Forest cutting cycles on loblolly pine plantations in the Southeast average 20-25 years
- Introduction of HISTORY variable that tracks “age” of every pixel in the SE study area
  - Allows for much more realistic modeling of forest cutting cycle



# Establishing Stand Age – Forest Inventory and Analysis (FIA) Data

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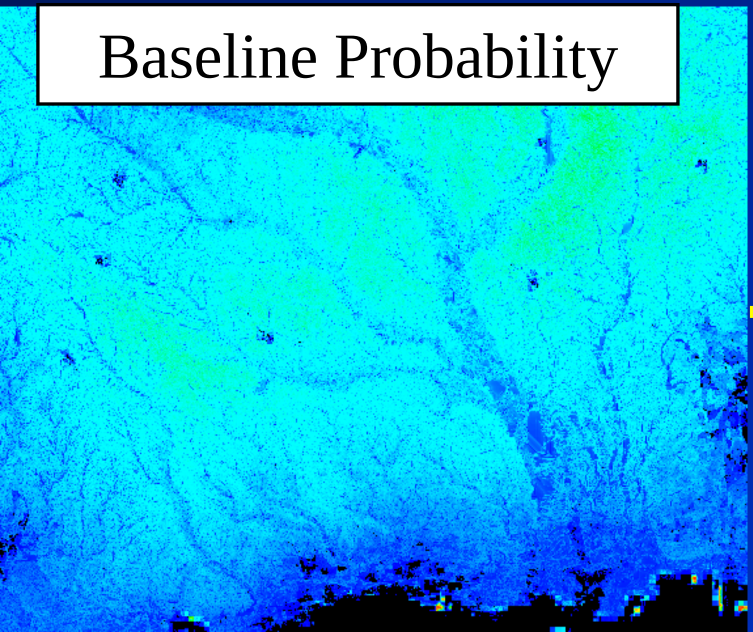
# Controlling Transition Probabilities

- "Elasticity" is an ecoregion-specific modifier to base probability values. It's simply a number from 0 to 10 that gives the likelihood of a specific transition type occurring in that ecoregion.
- Elasticity for every possible land cover transition determined from Land Cover Trends data
- Powerful tool for control of scenario development. Depending upon the scenario, we can tightly or loosely restrict the types of land cover transitions that are allowed to occur.

| | | FROM CLASS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ECO 65** | Water | Low-Int Res. | Mining | Transitional | Deciduous | Mixed | Evergreen | Natural Grass | Hay/Pasture | Row Crops | Small Grains | Woody Wet | Herby Wet |
| | Water | 0 | 0 | 0 | 5 | 7 | 7 | 7 | 8 | 10 | 8 | 8 | 0 | 10 |
| T | Urban | 0 | 0 | 6 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 |
| O | Mining | 0 | 0 | 0 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 5 | 5 |
| | Transitional | 0 | 0 | 0 | 0 | 7 | 8 | 10 | 0 | 0 | 0 | 0 | 8 | 0 |
| C | Deciduous | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 8 | 8 | 0 | 0 |
| L | MixedFor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 8 | 8 | 0 | 0 |
| A | Evergreen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 8 | 8 | 0 | 0 |
| S | Natural Grass | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S | Hay/Past | 0 | 0 | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Row Crop | 0 | 0 | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Small Grains | 0 | 0 | 0 | 6 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 5 |
| | Woody Wet. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Herby Wet. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Calculating Total Probability (TPROB)

- Total Probability (TPROB) constructed prior to generation of change polygons
  - TPROB = Baseline Probability * ELASTICITY * Function(HISTORY) * PAD
- ELASTICITY used both to modify probabilities based on likelihood of change, and to “zero out” probabilities for transitions we don’t want to occur
  - Value 0-10, rescale to 0.0 to 1.0 for TPROB multiplier
- HISTORY used to zero out probability of new transitional (clear-cut) patches until forest stand age reaches minimum of 20 years
- PAD – Protected Areas Database

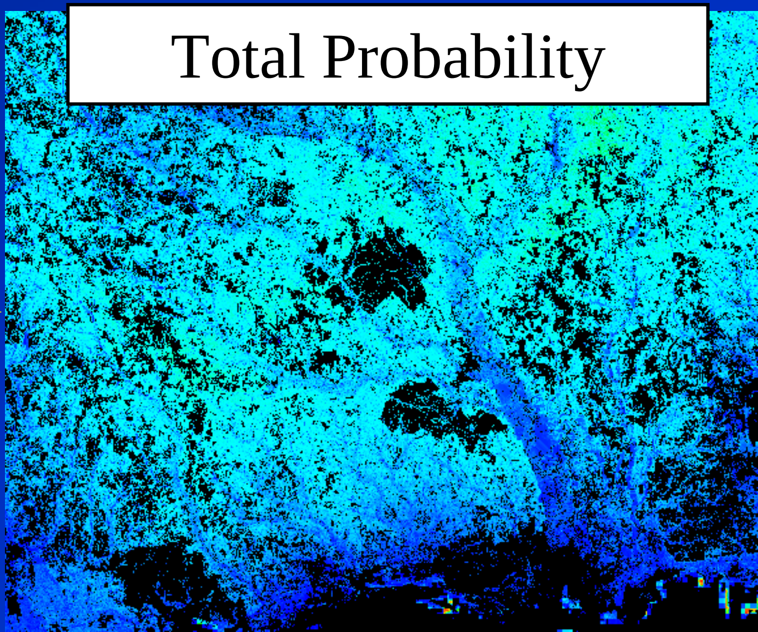



***Existing Cover***

***Elasticity***

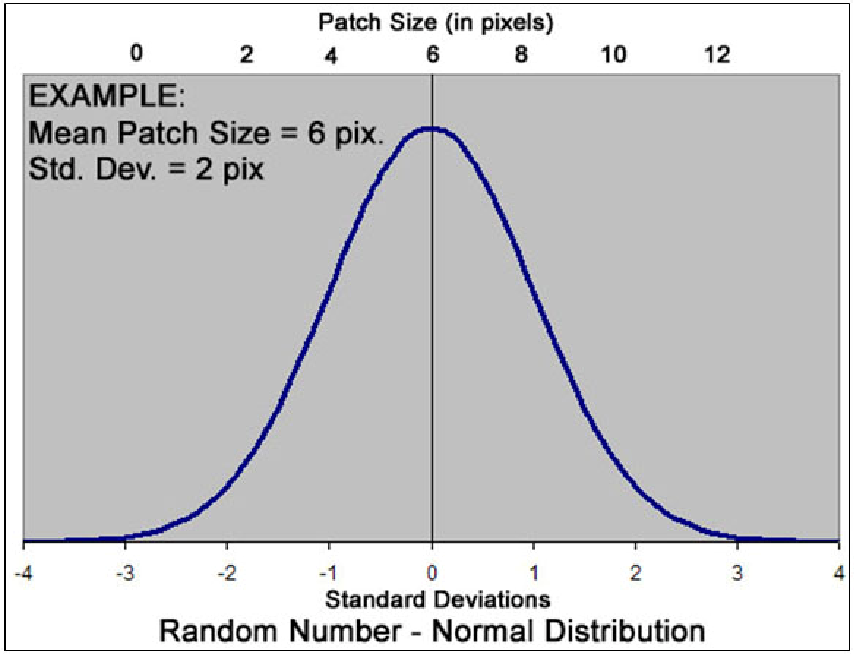
***History***

***PAD***



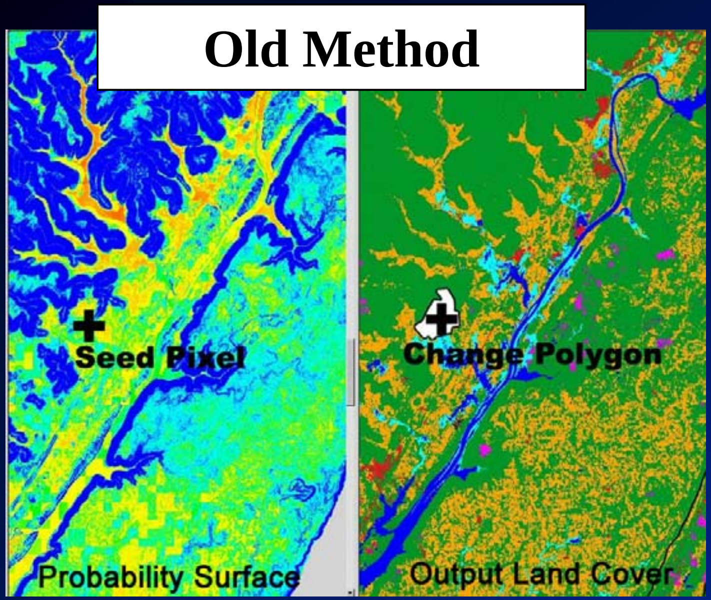
# Generating Change Polygons

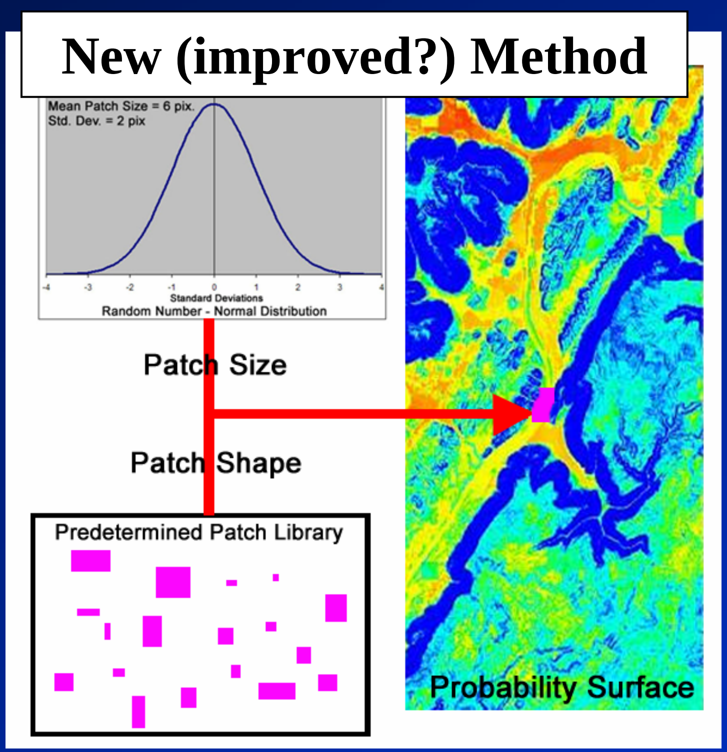
| TRANSITION TYPE | Mean Patch Size | Standard Deviation |
|---|---|---|
| Grass/shrub to Urban | 7.10 | 5.84 |
| Grass/shrub to Mining | 1.37 | 2.40 |
| Grass/shrub to Agriculture | 57.14 | 114.22 |
| Grass/shrub to Wetland | 2.88 | 1.08 |
| Agriculture to Urban | 3.75 | 3.54 |
| Agriculture to Mining | 6.84 | 8.41 |
| Agriculture to Grass/shrub | 58.43 | 103.17 |
| Agriculture to Wetland | 3.00 | 0.74 |
| Wetland to Agriculture | 4.36 | 6.44 |
| Wetland to Wetland | 3.76 | 8.85 |




- Probability surfaces used in conjunction with Trends information to create change polygons
- Use of "Seeds" planted on probability surfaces
- Change patches assigned a realistic size range for that transition type
    - Uses lookup table of mean and standard deviation of patch size for each LC type, for each ecoregion (from Trends project)
    - Normal distribution of patch size modeled based on those parameters (simplification)
    - Random number (normal distribution) used to select patch size for each seed
- DEMAND drives # of "seed" pixels
    - With normal distribution:

$$\# \text{ Seeds} = \text{TotalArea}(lc_x) / \text{Mean}$$

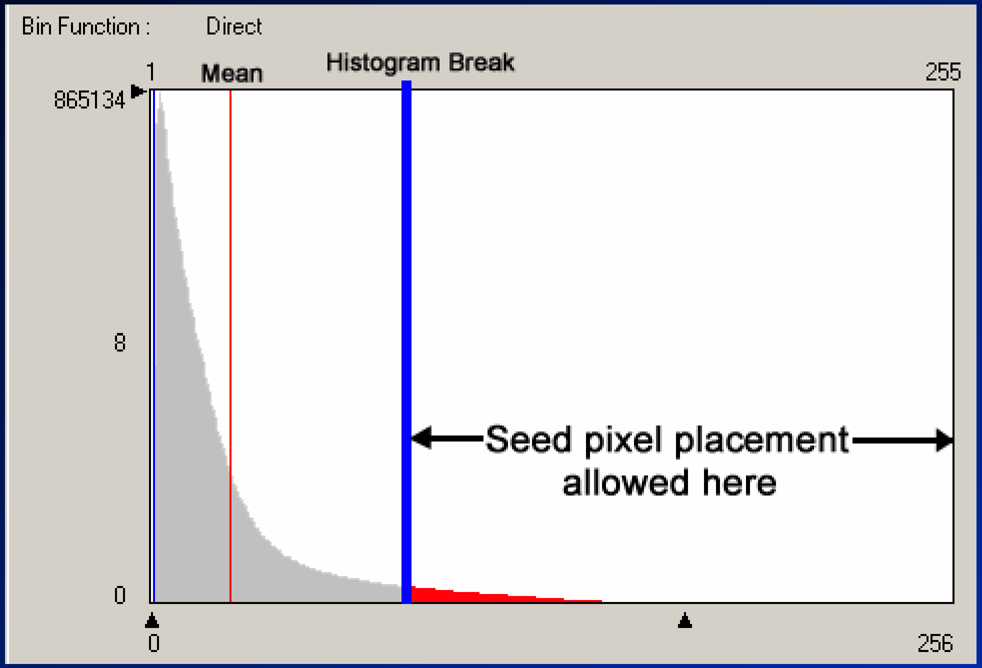



# Generating Change Polygons and FORE-SCE run time

- Once seed size is determined, a change patch centered on that seed is placed
- <u>**Old method**</u> – Region grow function into adjacent pixels of similar (or higher) probability
  - Patches more “organic”, dependent upon probability surface characteristics
  - Problem – Model Run times were 2-3 real days per yearly model iteration
- <u>**New method**</u> – Pre-established patch “library” of a limited number of patch configurations
  - Assigned patch size for a seed determines pool of potential patch configurations
  - Underlying probability surface still controls individual pixel placement
  - “Canned” patches with less variability, but:
  - 1992 to 2050 model run (58 iterations) now takes just over 24 hours

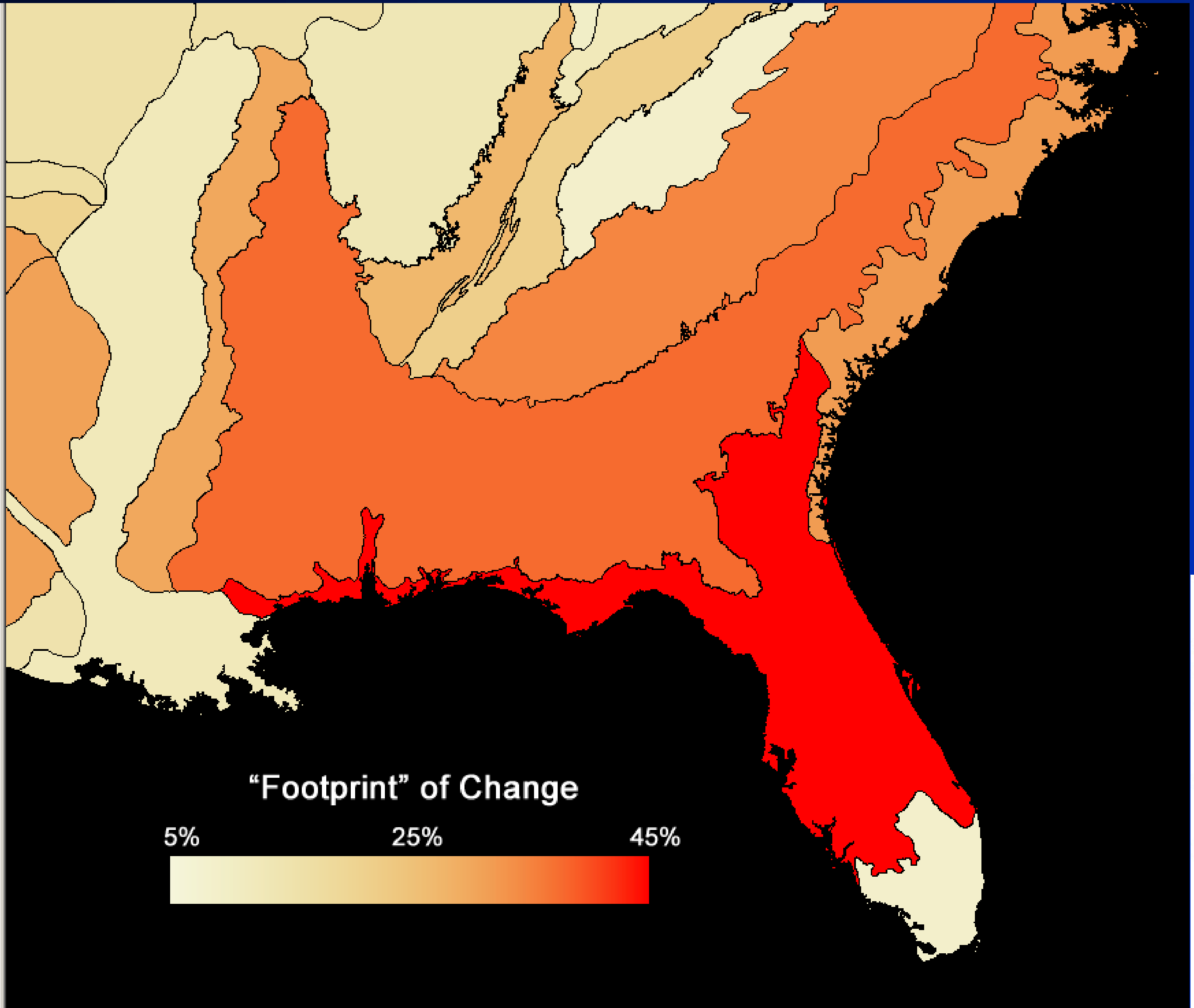
# Controlling "Clumpiness" of LULC change



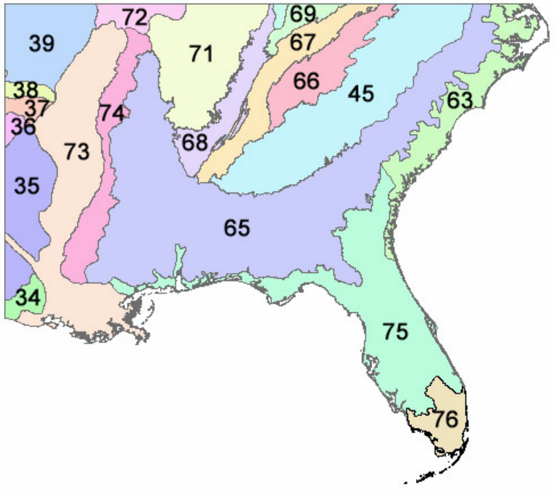

| Histogram Breakpoints - Portion of histogram allowed for seed placement | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water | Developed | Mining | Transitional | Deciduous | Mixed | Evergreen | Grass | Hay/Pasture | Row Crops | Small Grains |
| Eco. 34 | 99 | 97 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 35 | 95 | 97 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 36 | 95 | 95 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 37 | 95 | 95 | 85 | 85 | 90 | 90 | 90 | 0 | 85 | 85 | 85 |
| Eco. 38 | 95 | 95 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 39 | 95 | 98 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 45 | 92 | 96 | 85 | 80 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 63 | 95 | 96 | 85 | 80 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 65 | 95 | 98 | 85 | 80 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 66 | 95 | 98 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 67 | 95 | 97 | 85 | 80 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 68 | 95 | 98 | 85 | 80 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 69 | 95 | 95 | 90 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 70 | 95 | 95 | 90 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 71 | 95 | 98 | 90 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 72 | 95 | 98 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 73 | 99 | 97 | 85 | 85 | 90 | 90 | 90 | 0 | 85 | 85 | 85 |
| Eco. 74 | 95 | 97 | 85 | 80 | 85 | 85 | 90 | 0 | 85 | 85 | 85 |
| Eco. 75 | 95 | 96 | 85 | 70 | 85 | 85 | 85 | 0 | 85 | 85 | 85 |
| Eco. 76 | 95 | 96 | 85 | 85 | 85 | 85 | 85 | 0 | 85 | 95 | 85 |

- Probability surface guides placement of seed pixels for change
- Some land cover transitions are spread evenly across the landscape, some are more clumped
- Histogram breakpoints used to control "clumpiness"
- Ecoregion-by-ecoregion parameterization
- Highly dependent upon characteristics of individual probability surface
- Quantitatively determined from Trends data….???

# “Footprint” of Change – 1992 to 2050

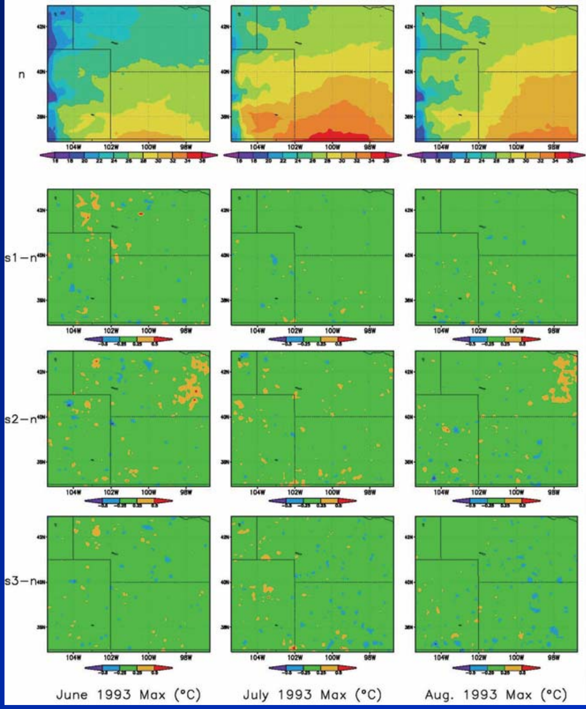


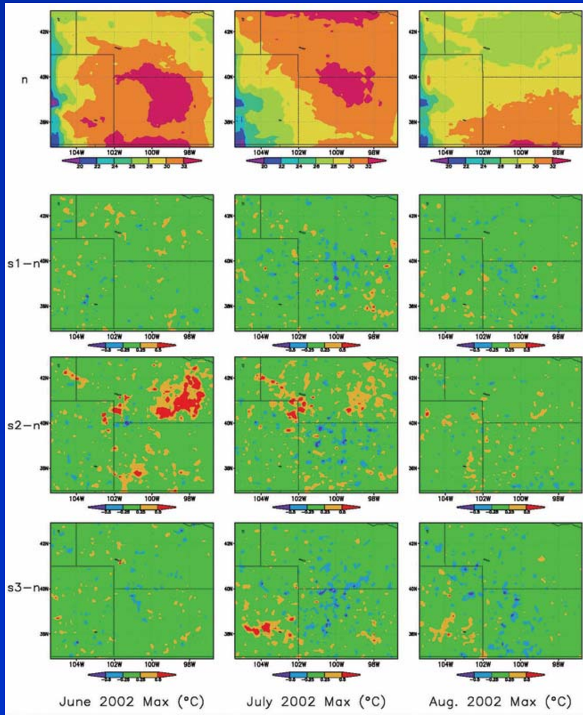

| Ecoregion | Footprint |
|---|---|
| Ecoregion 34 | 11.8% |
| Ecoregion 35 | 28.9% |
| Ecoregion 36 | 28.9% |
| Ecoregion 37 | 17.6% |
| Ecoregion 38 | 13.6% |
| Ecoregion 39 | 12.5% |
| Ecoregion 45 | 32.6% |
| Ecoregion 63 | 29.9% |
| Ecoregion 65 | 35.8% |
| Ecoregion 66 | 4.6% |
| Ecoregion 67 | 18.7% |
| Ecoregion 68 | 24.9% |
| Ecoregion 69 | 9.1% |
| Ecoregion 70 | 5.9% |
| Ecoregion 71 | 9.7% |
| Ecoregion 72 | 12.6% |
| Ecoregion 73 | 8.6% |
| Ecoregion 74 | 27.3% |
| Ecoregion 75 | 43.6% |
| Ecoregion 76 | 4.6% |



# RAMS/LEAF2/GEMTM Modeling

- RAMS/LEAF2 coupled modeling system is used to quantify the potential effects of LULC change on surface hydrology, weather, and climate variability
- Summer season (60-90 day duration) conducted, using each land cover data set, but with identical meteorological forcing data
- “Wet” year (1993, top right) and “Dry” year (2002, bottom right) averaged maximum monthly air temperature shown
- Top row – 1992 NLCD baseline run
- 2nd – 4th row – Differences from baseline
  - S1 – Trends extrapolation
  - S2 – Agricultural decline scenario
  - S3 – Agricultural expansion scenario

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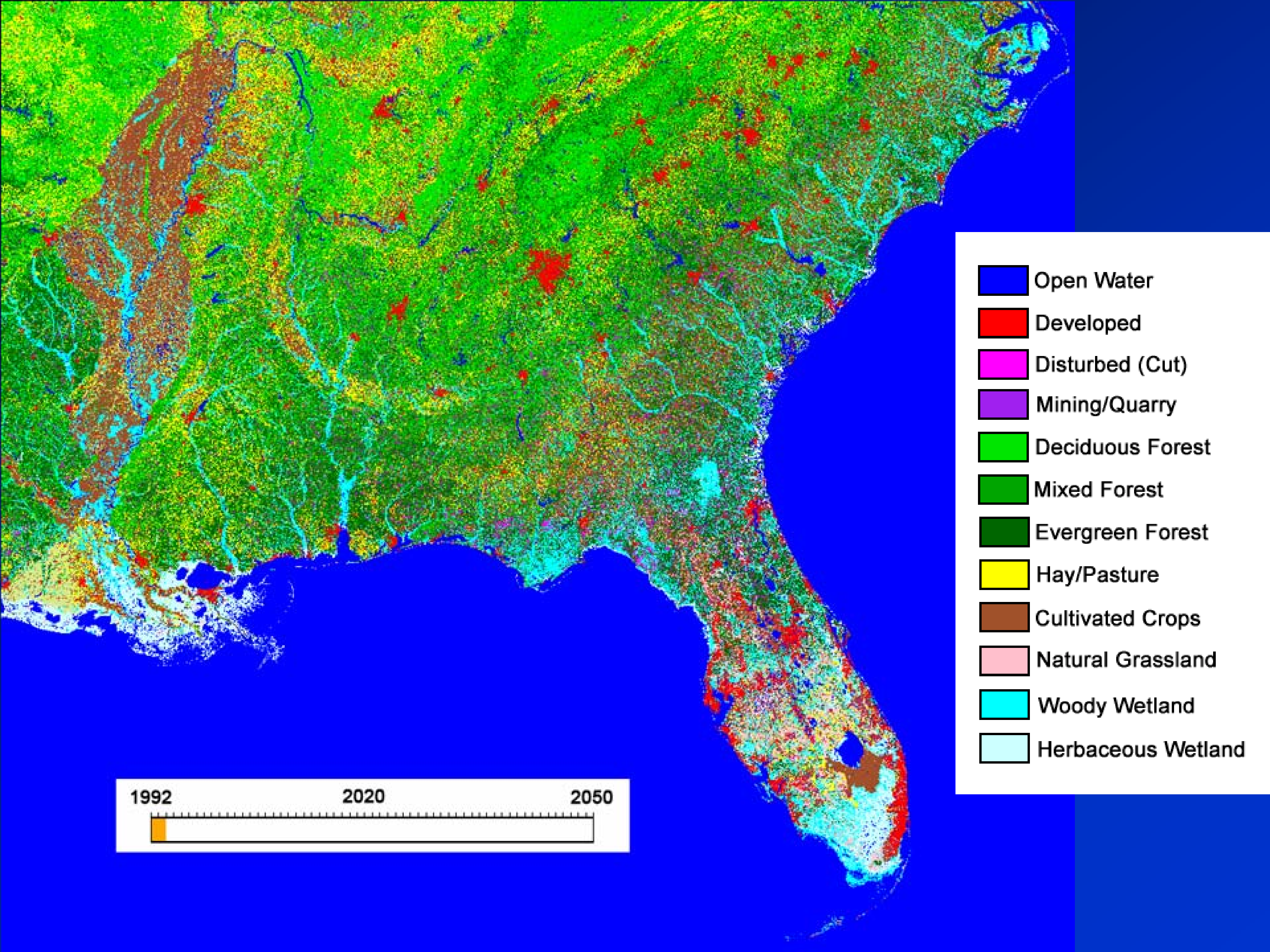
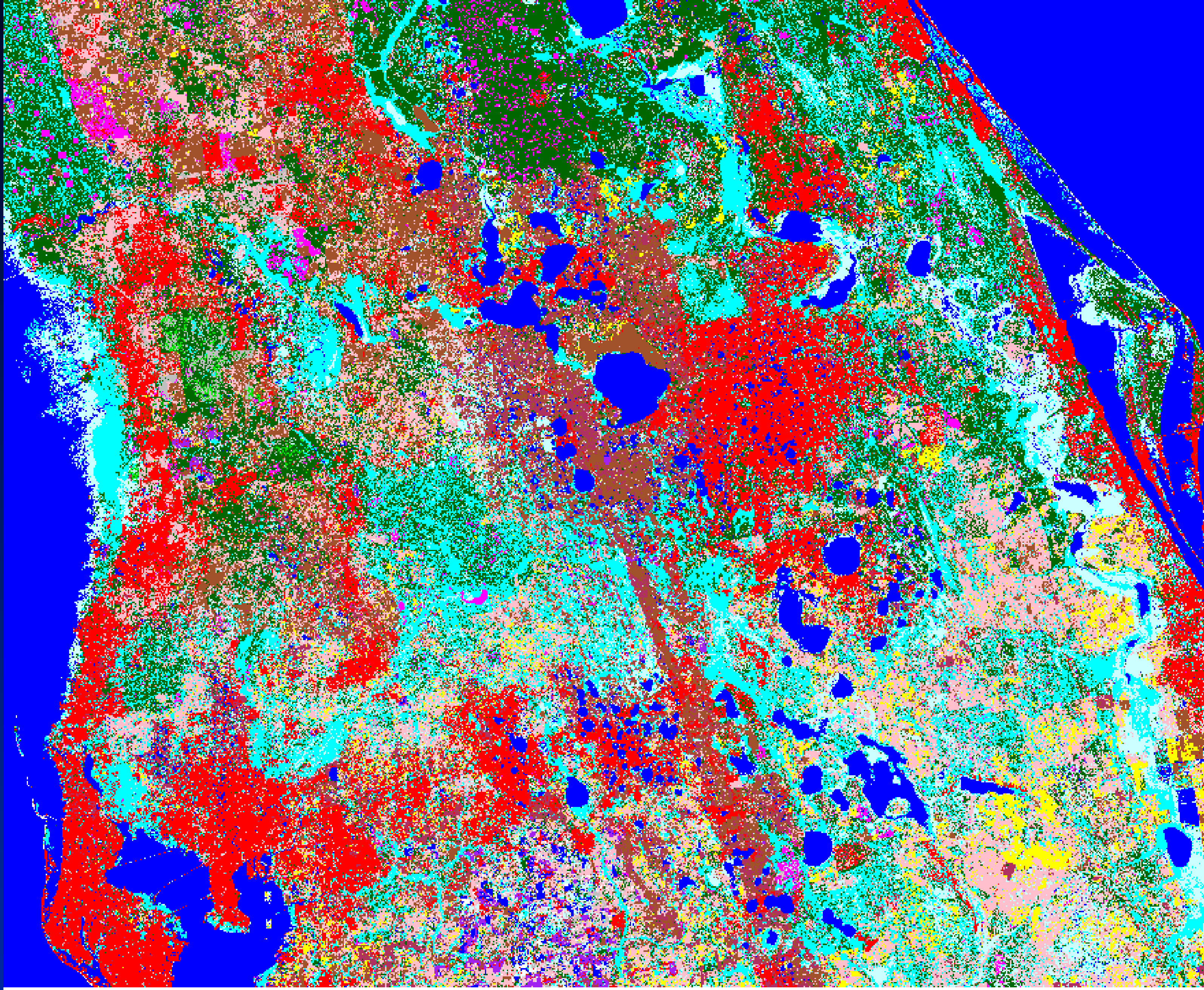

Open Water
Developed
Disturbed (Cut)
Mining/Quarry
Deciduous Forest
Mixed Forest
Evergreen Forest
Hay/Pasture
Cultivated Crops
Natural Grassland
Woody Wetland
Herbaceous Wetland
1992
2020
2050

# 1992 to 2050 Projected Change: Florida





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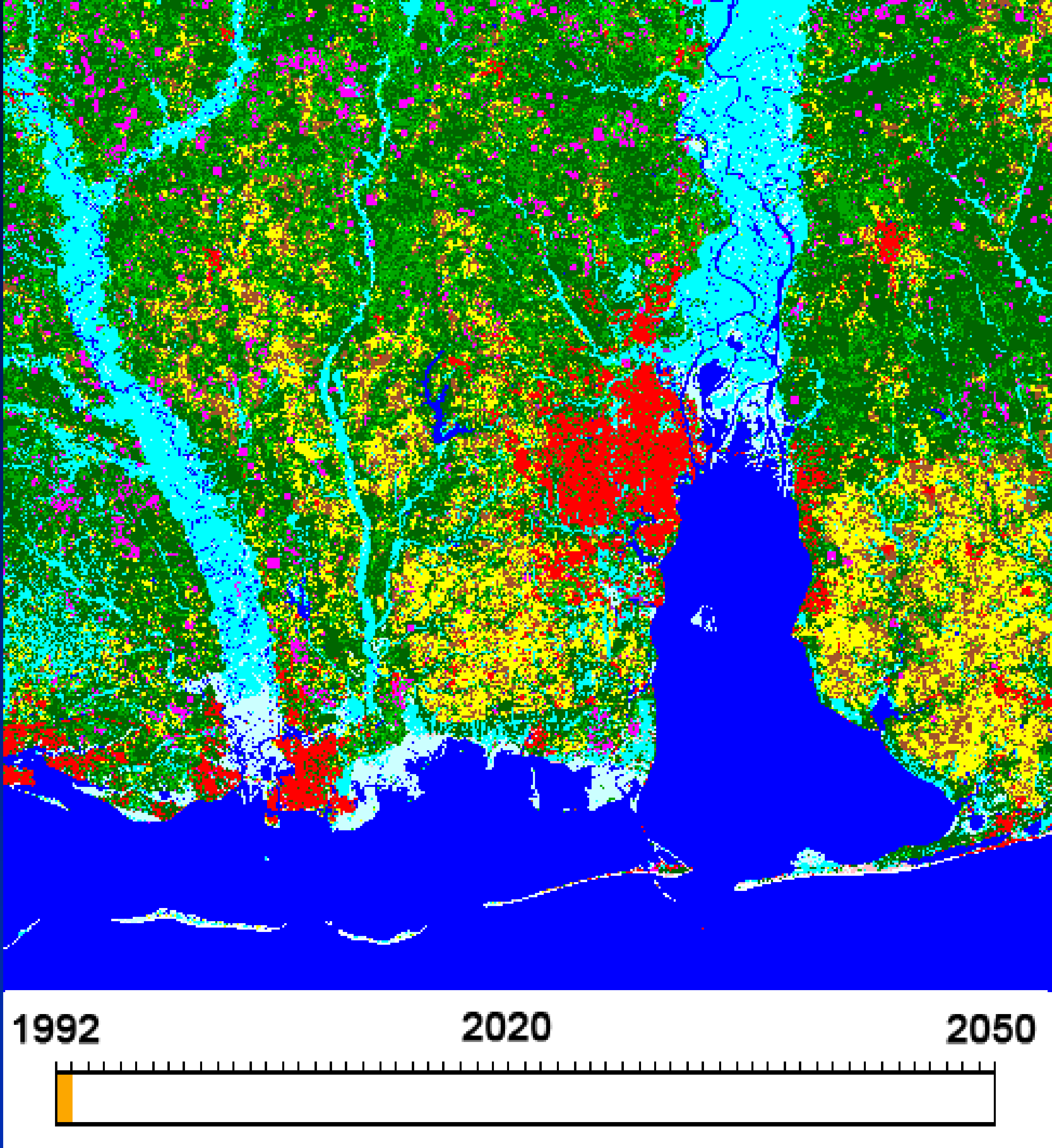
# 1992 to 2050 Projected LULC Change: Mobile, Alabama

- Open Water
- Developed
- Disturbed (Cut)
- Mining/Quarry
- Deciduous Forest
- Mixed Forest
- Evergreen Forest
- Hay/Pasture
- Cultivated Crops
- Natural Grassland
- Woody Wetland
- Herbaceous Wetland

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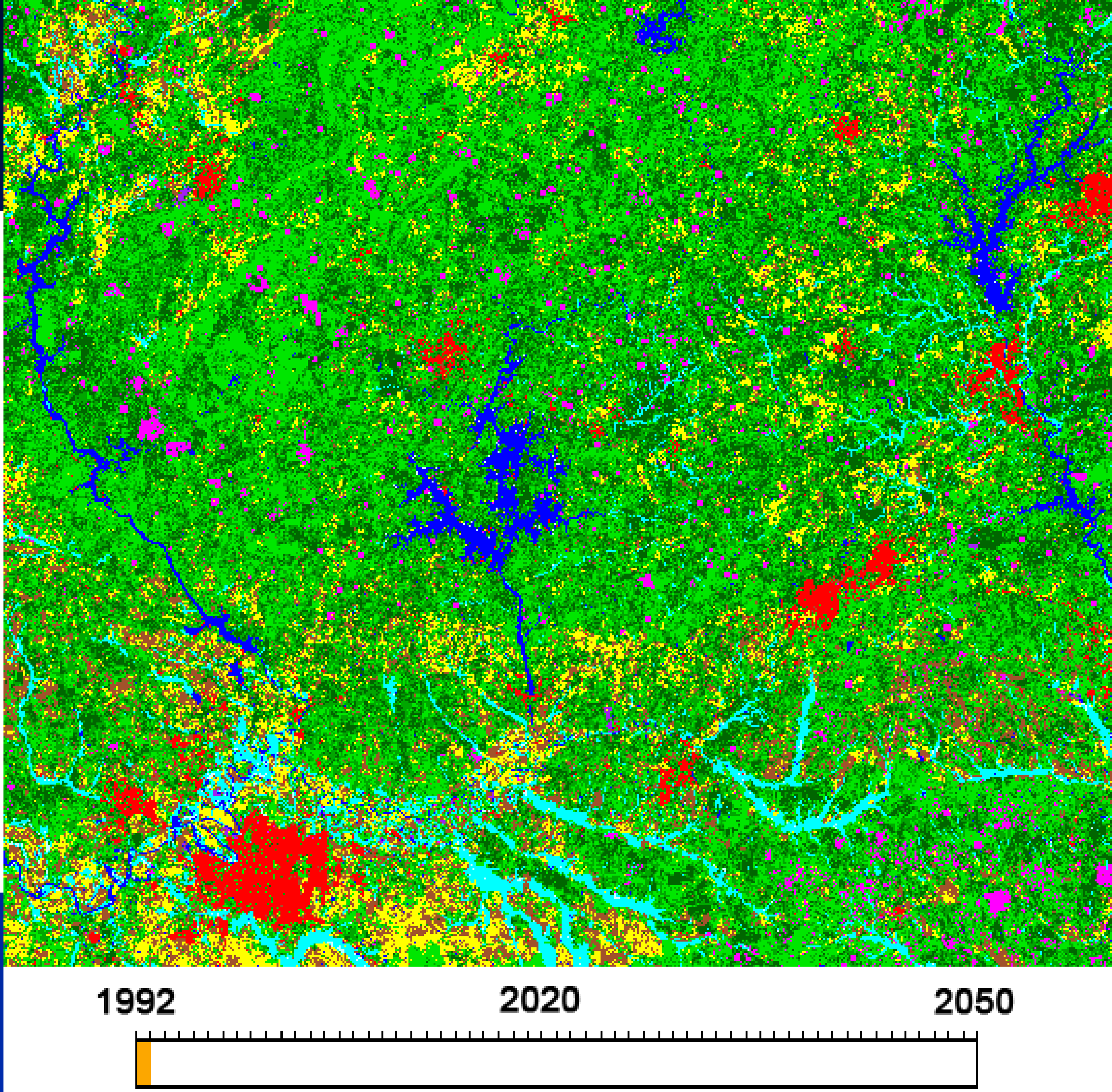
# 1992 to 2050 Projected LULC Change: Montgomery, AL area

- Open Water
- Developed
- Disturbed (Cut)
- Mining/Quarry
- Deciduous Forest
- Mixed Forest
- Evergreen Forest
- Hay/Pasture
- Cultivated Crops
- Natural Grassland
- Woody Wetland
- Herbaceous Wetland

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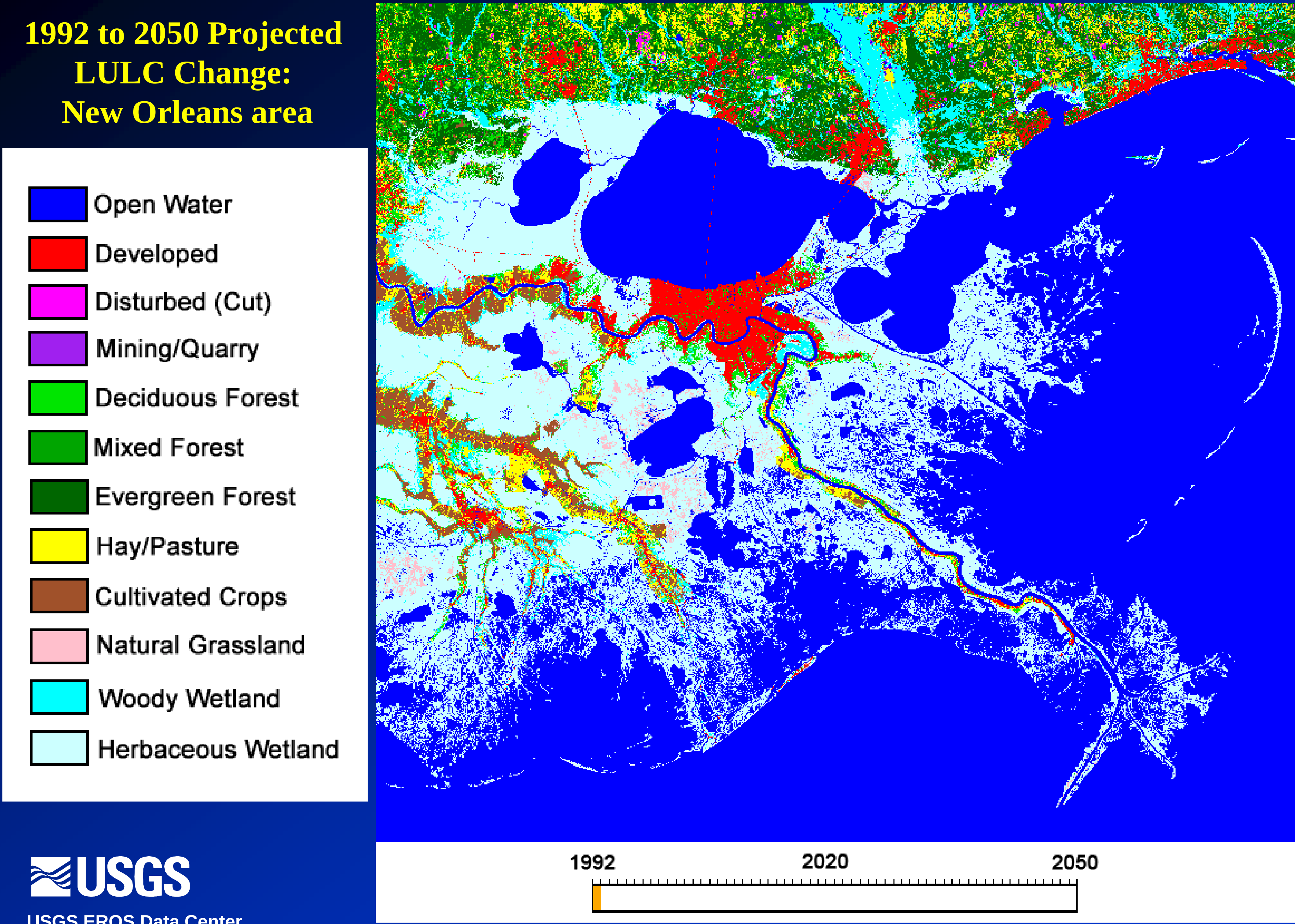
# 1992 to 2050 Projected LULC Change: New Orleans area

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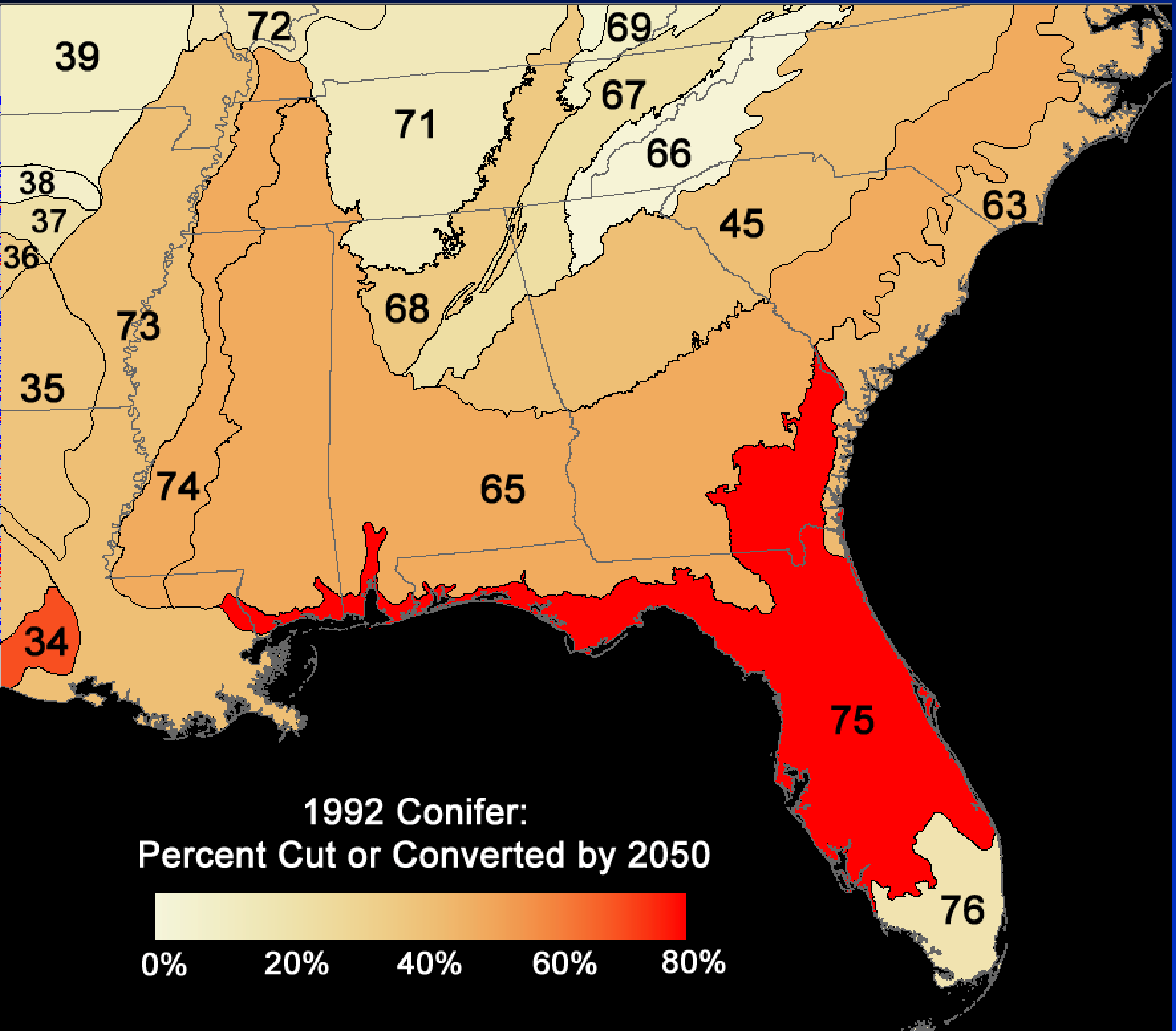
# 1992 Conifer – Percent changed by 2050




| 1992 Conifer | |
|---|---|
| Ecoregion | % Changed, 1992 - 2050 |
| Eco. 34 | 68.9% |
| Eco. 35 | 38.6% |
| Eco. 36 | 36.4% |
| Eco. 37 | 24.3% |
| Eco. 38 | 9.7% |
| Eco. 39 | 11.8% |
| Eco. 45 | 42.3% |
| Eco. 63 | 44.9% |
| Eco. 65 | 49.1% |
| Eco. 66 | 4.7% |
| Eco. 67 | 27.4% |
| Eco. 68 | 38.0% |
| Eco. 69 | 12.7% |
| Eco. 70 | 6.7% |
| Eco. 71 | 16.2% |
| Eco. 72 | 20.2% |
| Eco. 73 | 42.0% |
| Eco. 74 | 50.8% |
| Eco. 75 | 79.6% |
| Eco. 76 | 19.8% |

# Red-cockaded Woodpecker – Conifer Stand Age

- Only bird in North America that regularly nests in cavities in living pine trees
- Longleaf Pine is preferred nesting tree
- Seek out Longleaf pine suffering from a fungal infection, “Red-heart disease”
  - Causes inner wood to rot, become conducive for cavity building
- Longleaf pine and other pines don’t become susceptible to red-heart disease until an average age of 80-120 years old
- Also prefers contiguous patches of suitable habitat > 120 acres
- Even-aged, short rotation forestry management in the Southeast eliminates suitable nesting and foraging habitat

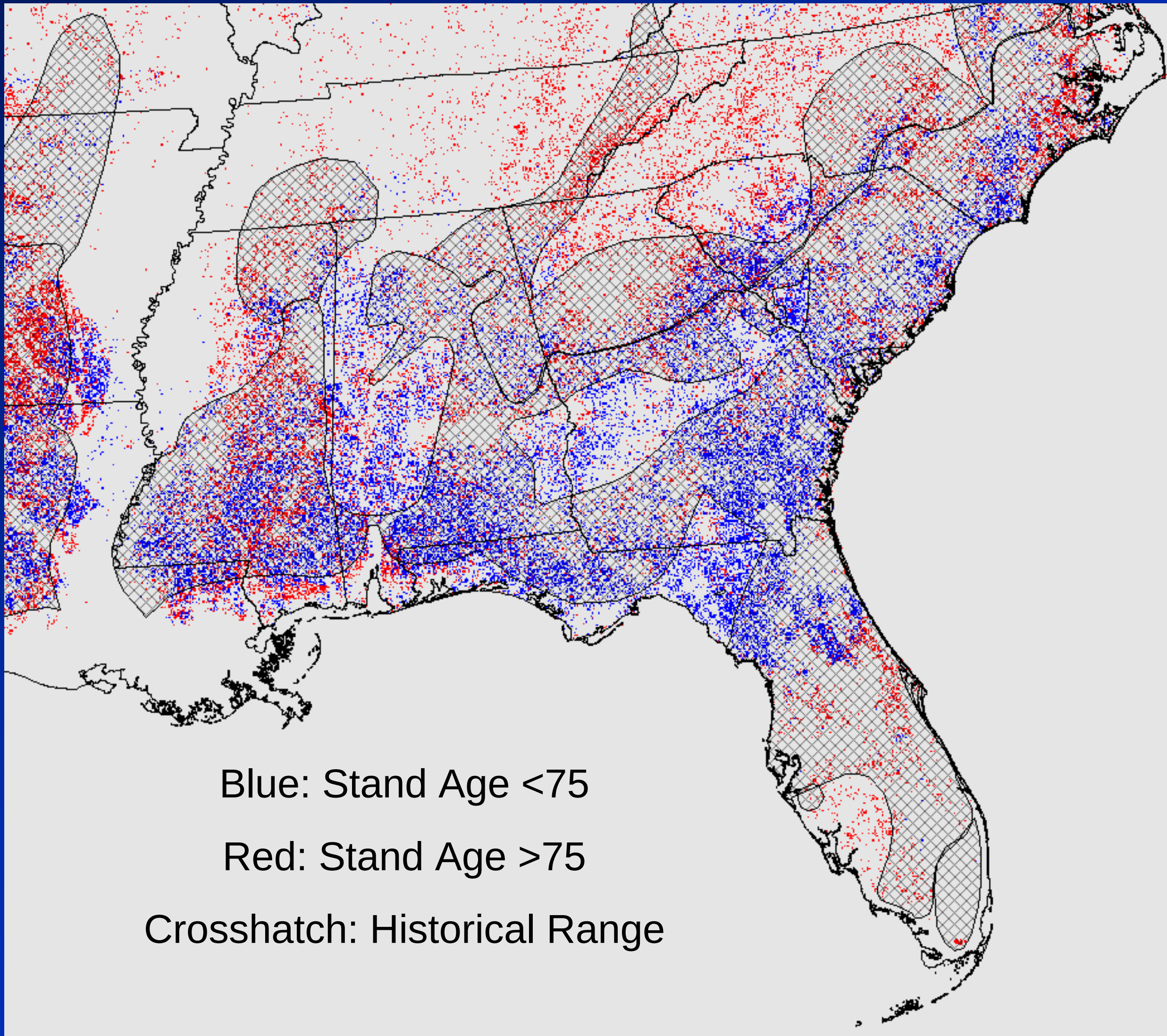
# Red-cockaded Woodpecker – Conifer Stand Age

RCW Family Clusters, 1990-1994

| | Ownership | | | |
|---|---|---|---|---|
| State | Federal | State | Private | Total |
| Alabama | 150 | 8 | 25 | 183 |
| Arkansas | 35 | 0 | 121 | 156 |
| Florida | 1,063 | 128 | 94 | 1,285 |
| Georgia | 431 | 2 | 218 | 651 |
| Kentucky | 5 | 0 | 0 | 5 |
| Louisiana | 422 | 10 | 73 | 505 |
| Mississippi | 152 | 0 | 22 | 174 |
| North Carolina | 408 | 162 | 163 | 733 |
| Oklahoma | 0 | 9 | 1 | 10 |
| South Carolina | 456 | 39 | 186 | 681 |
| Tennessee | 1 | 0 | 0 | 1 |
| Texas | 218 | 26 | 61 | 305 |
| Virginia | 0 | 0 | 5 | 5 |
| Total | 3,341 | 384 | 969 | 4,694 |

**15 Groups of 100+ Family Clusters, all but 1 on public land**

Projected 2050 Conifer Stand Age and Historical RCW Range

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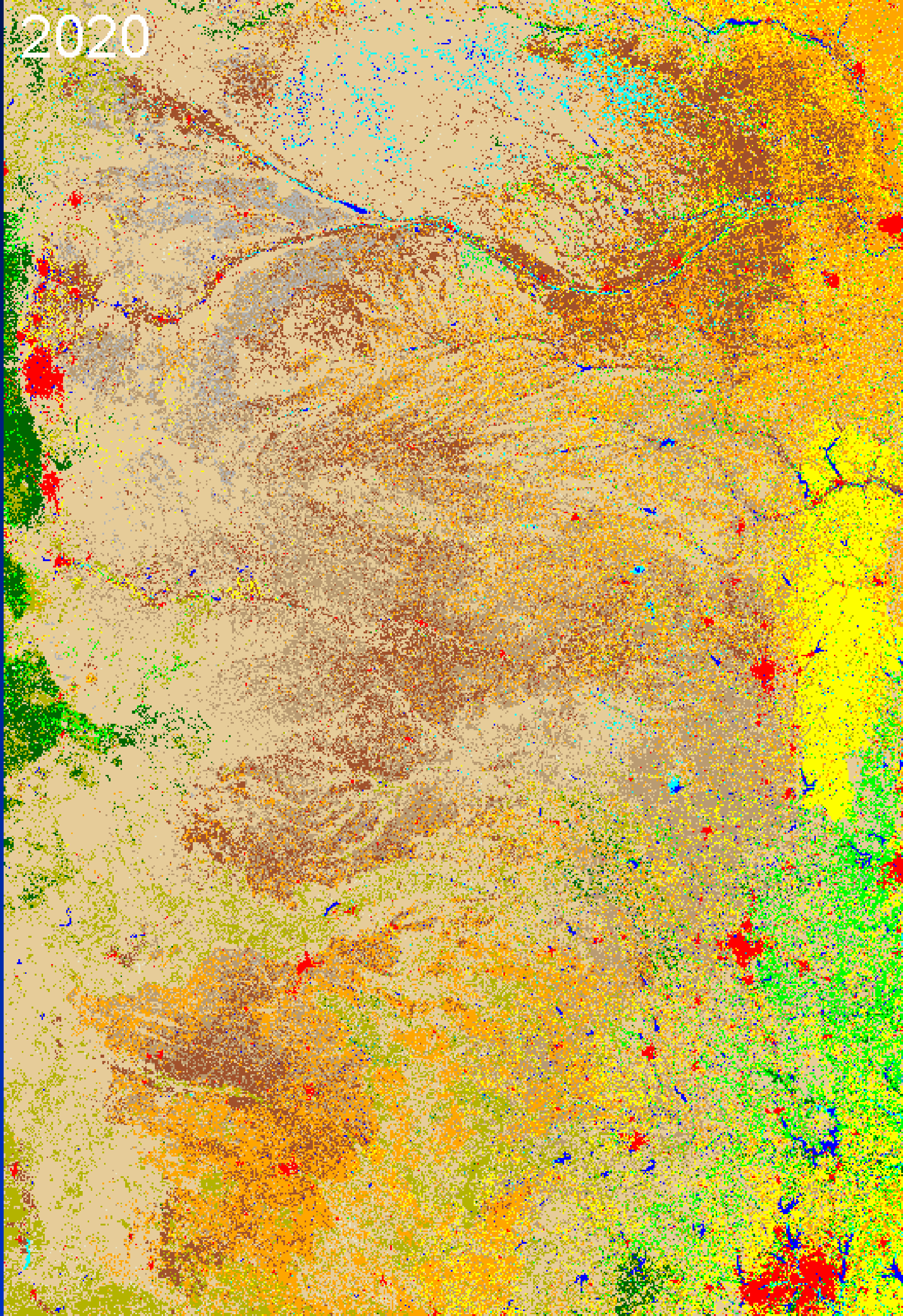
# Great Plains -- 1992 to 2020 Change (Agriculture Expansion Scenario)

- Open Water
- Ice Caps, Glaciers
- Evergreen Needleleaf Forest
- Deciduous Broadleaf Forest
- Shortgrass
- Tallgrass
- Desert
- Evergreen Shrub
- Mixed Woodland
- Crops/Mixed Farming
- Irrigated Crop
- Bog or Marsh
- Bare Ground
- Urban and Built-up
- Dryland Row Crop

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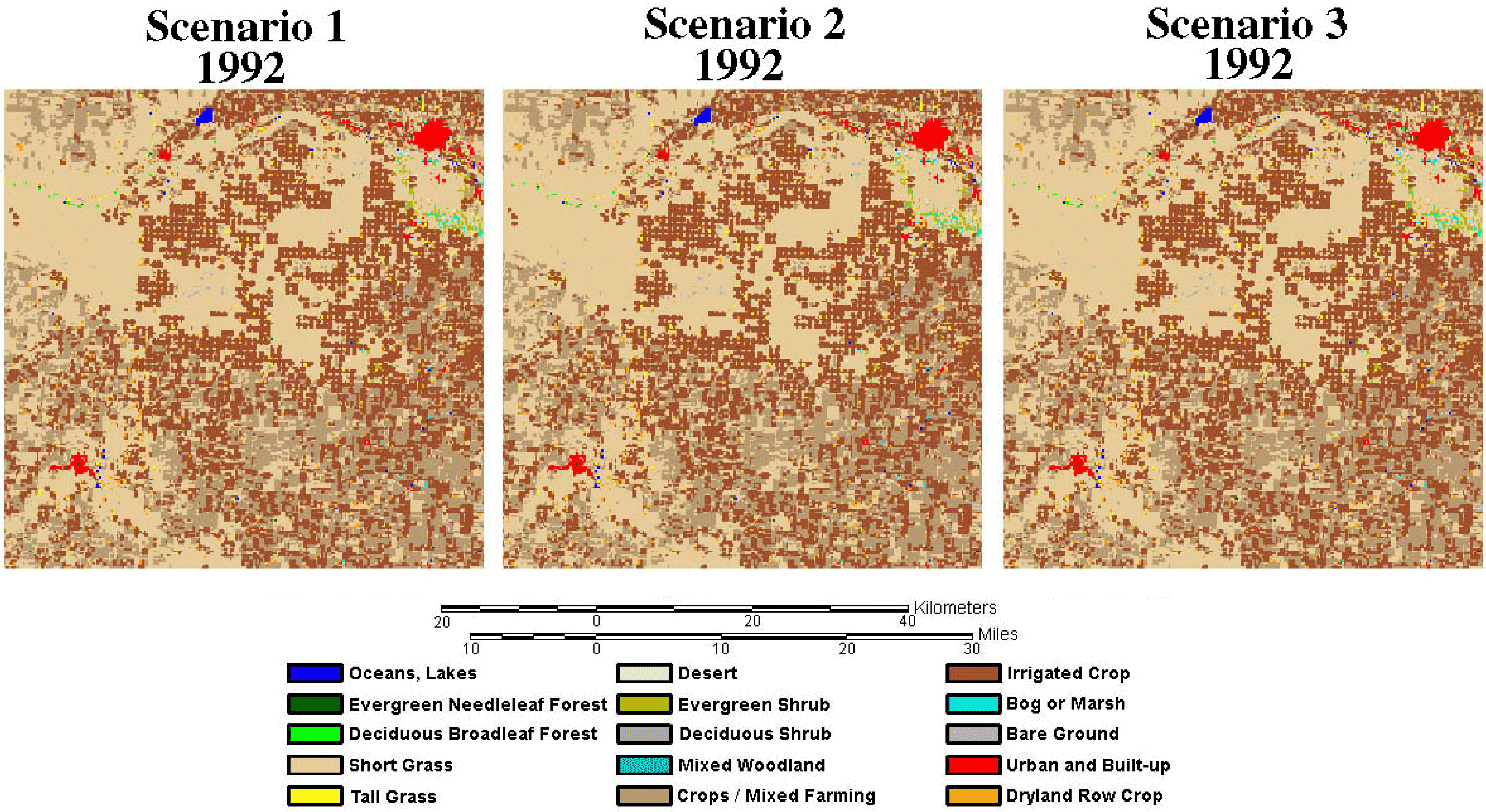
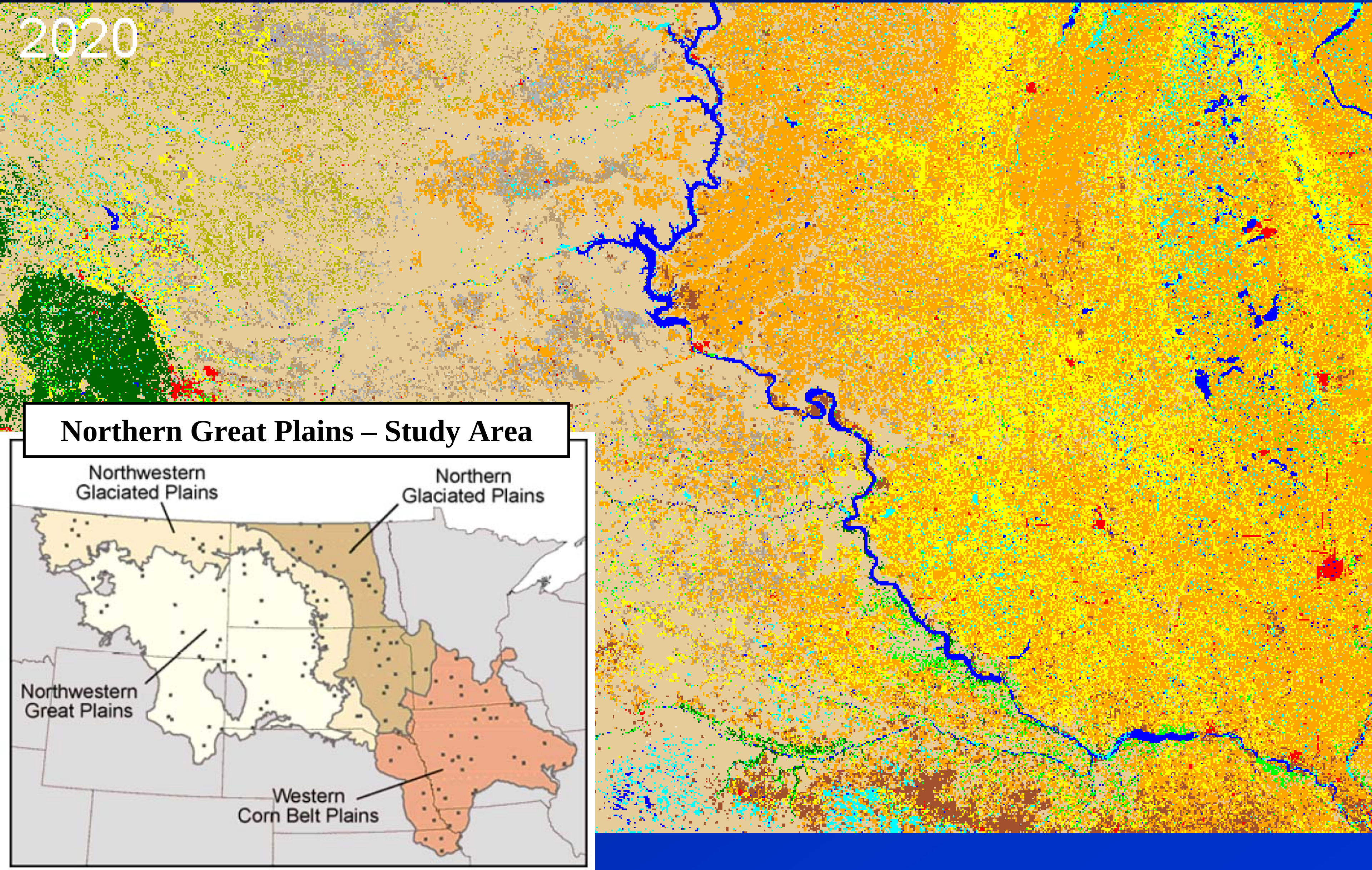
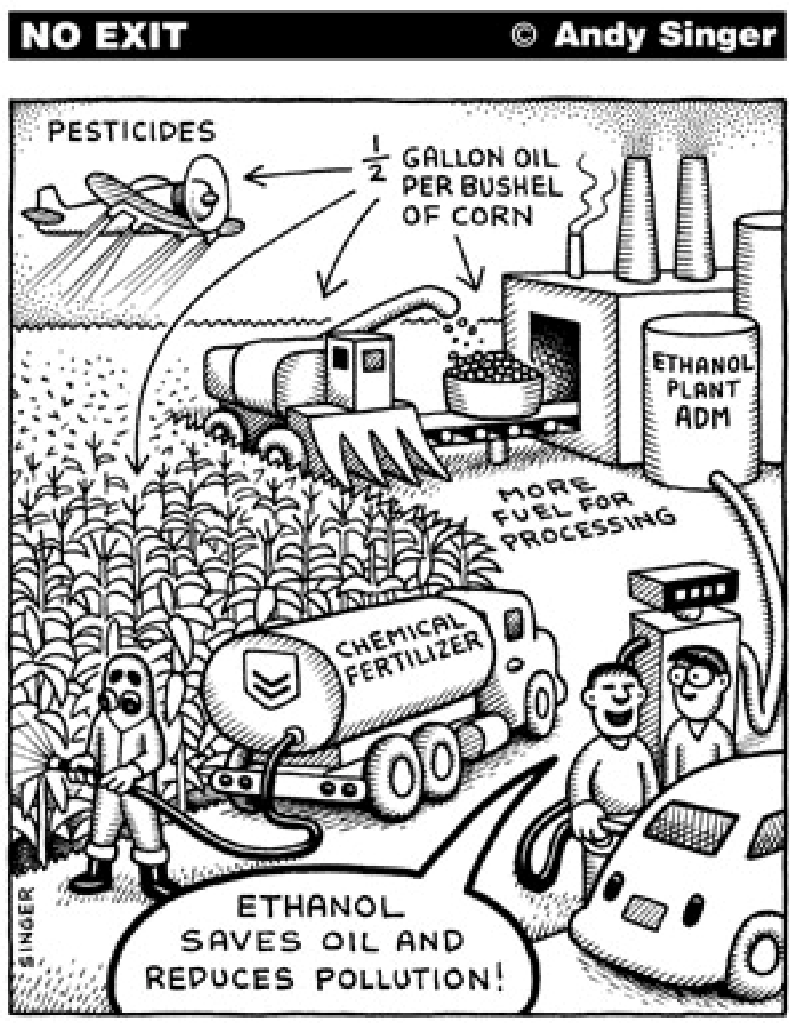
# Scenario Comparison -- SW Kansas



# South Dakota -- 1992 to projected 2020 Change



# FY2008 development: Northern Great Plains – Biofuel-driven Agricultural Change




- Primary goal – To evaluate the effects of an expanded agricultural base for biofuels and concurrent changes in climate on ecosystem sustainability across the Northern Great Plains
- Development of credible land-change scenarios to project alternative landscape futures through 2050
- Analyze results to estimate effects on ecosystem processes and services.

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# Northern Great Plains Biomass for Biofuel: Key Research Questions

- What landscape patterns are likely to result from an expanded biomass-for-biofuel economy and what are our estimates of the uncertainties?
- What are the environmental consequences?
- What are the full economic costs and benefit of biomass production for energy, including agricultural sector profitability?
- How will projected climate change impact agricultural production and profitability?
- How will projected climate change impact the provision of ecosystem services?
- What are the feedbacks among land-use change, economic and policy drivers, climate, biophysical processes, and a variety of ecosystem services?

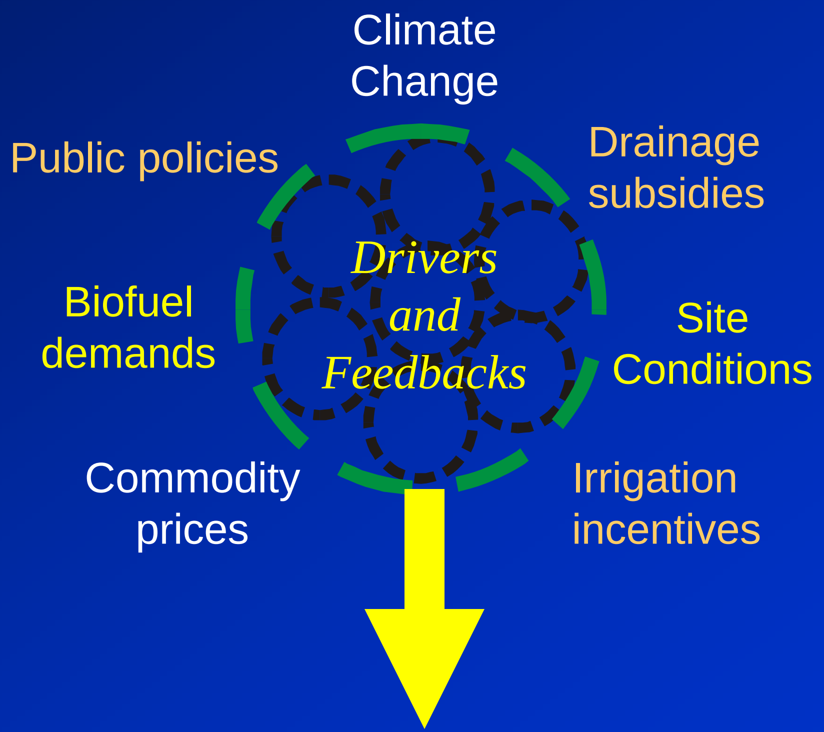
# FY2008 development: Scenarios

- Corn for ethanol – Large-scale production already underway in the Northern Great Plains, with continued expansion
- Soybeans for biodiesel
- Grasses for cellulosic ethanol
  - Switchgrass
  - Miscanthus
  - Mixed Prairie Species

- Climate – IPCC-defined scenarios
  - No change, Low-IPCC, High-IPCC

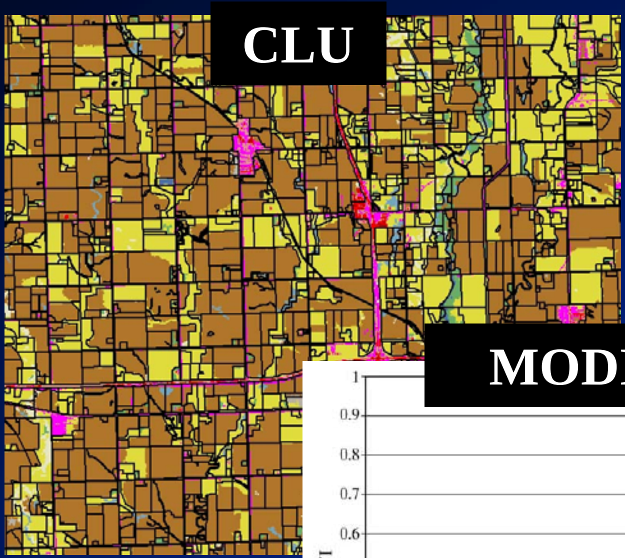
# FY2008 development: DEMAND

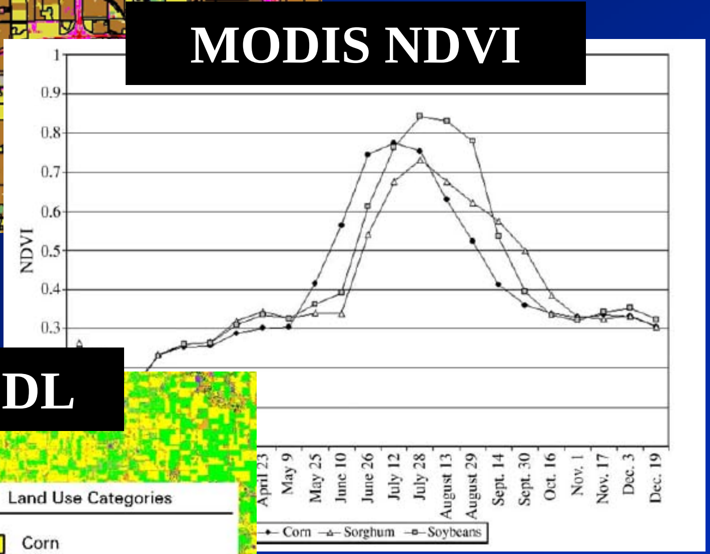
- DEMAND in current FORE-SCE applications has largely been based on extrapolations of historical (L.C. Trends) data
- Priority: Building a DEMAND module that instead is driven by policy, economic costs and returns, and biophysical conditions
  - Prerequisite – Quantifying relationships between these drivers and actual land cover change

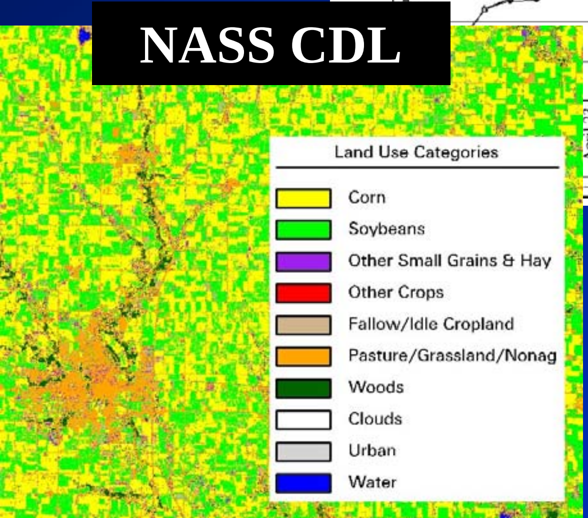



| Land Cover | Hectares |
|---|---|
| Corn | 18,500,000 |
| Soybeans | 12,200,000 |
| Switchgrass | 6,194,000 |
| Hay/Pasture | 23,529,000 |
| Etc. | Etc. |

# FY2008 development: Parcel (field) based modeling

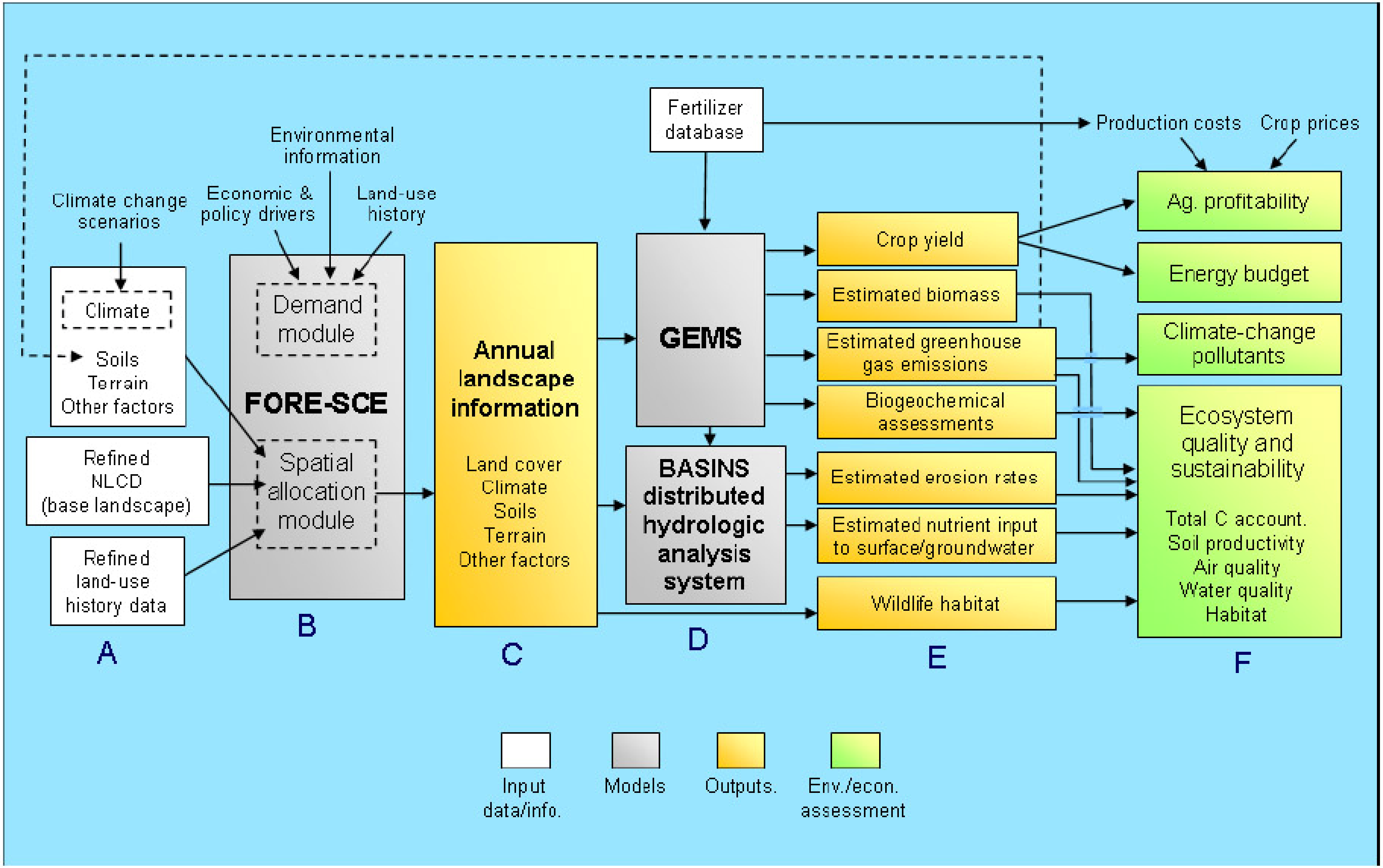



- USDA – Common Land Unit (CLU)
- Smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer in ag land associated with USDA farm programs.
- MODIS 16-day Vegetation Index composites – Used to map crop type, augment 2001 NLCD classification
- NASS Cropland Data Layer (CDL) used to validate MODIS crop-type information

# FY2008 Development – Model integration



# FY2010 and Beyond

- USGS plans for national land-cover monitoring
  - NLCD updates every 5 years
  - NLCD change products
  - Integrate Trends expertise
  - And…land cover projection component?