

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

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Contractor to:

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USGS EROS Data Center



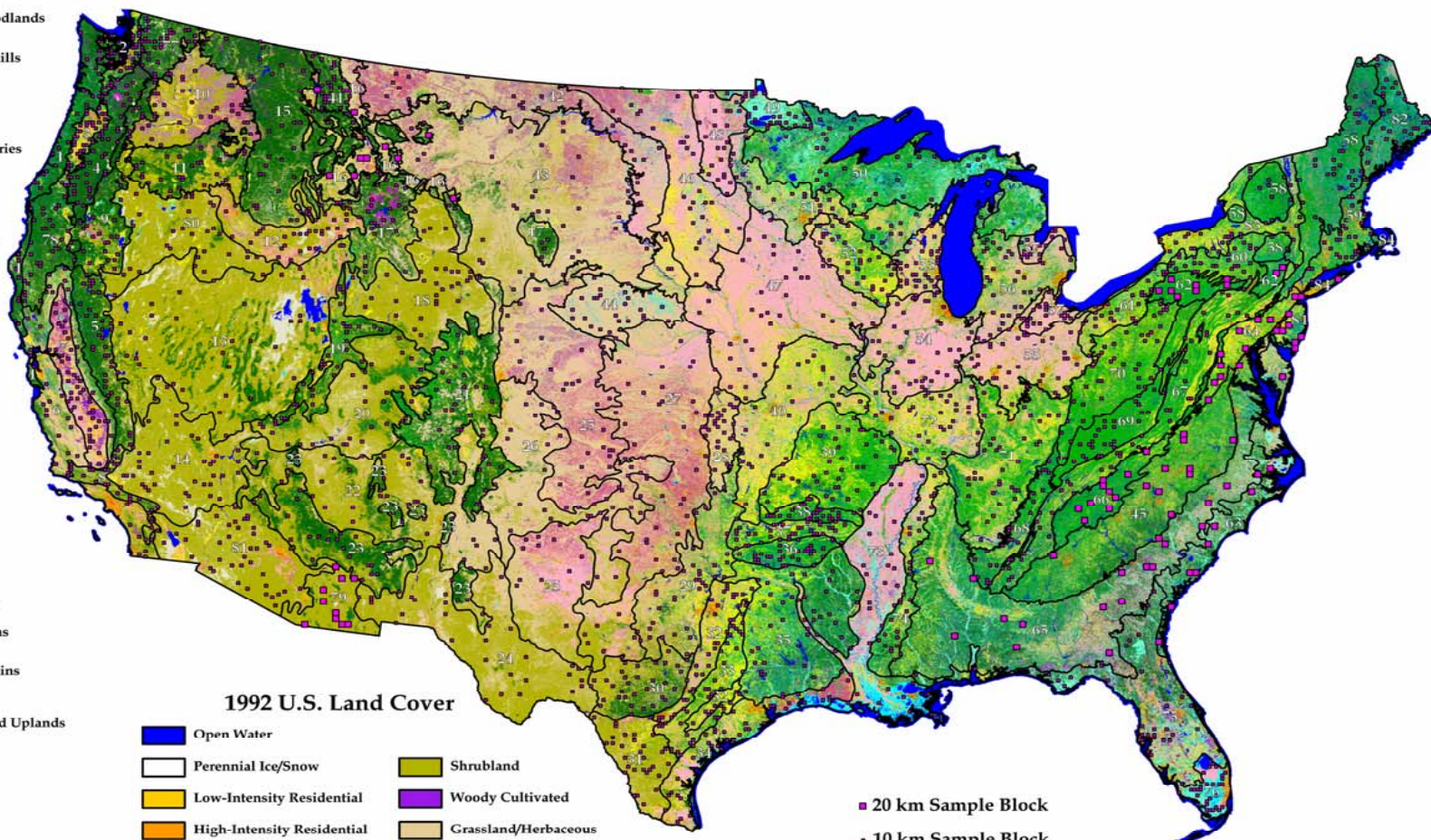
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

Level III Ecoregions
March 1999 Edition

United States Land Cover Trends

National Center for Earth Resources Observation and Science (EROS)

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

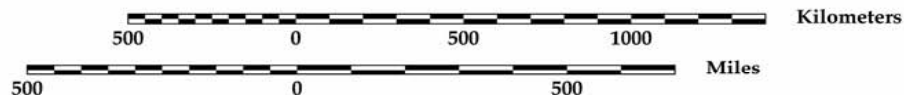


1992 U.S. Land Cover



■ 20 km Sample Block

• 10 km Sample Block





Land Cover Trends Atlantic Coastal Pine Barrens

Ecoregion Description

The Atlantic Coastal Pine Barrens is a disjunct ecoregion covering approximately 6,200 square miles of the coastal plain of New Jersey, New York's Long Island, and Massachusetts's Cape Cod, Martha's Vineyard, Nantucket, and nearby islands. Hydrology, soils, fire regimes, and vegetation combine to distinguish this ecoregion from its neighbors. The region has a wide variety of ecological systems, including cedar swamps, meadows, stunted pitch pine and oak forests, sphagnum bogs, heathlands, coastal salt ponds, dune systems, and the nation's only maritime grasslands on Martha's Vineyard and Long Island.

Rainfall averages around 48 inches per year, but the soil is sandy, extremely porous, and drains very quickly. Soils and water in the ecoregion are generally very acidic, which limits both naturally occurring flora, fauna, and suitable agricultural crops. Acid tolerant shrubs, such as those of the heath family (blueberries, laurels, staghorn), are common. Agricultural activity in many areas is limited to acid loving crops such as blueberries and cranberries, although parts of the ecoregion with richer soils support fruits, vegetables, and other crops. Aquatic fauna must also be acid-tolerant, resulting in relatively few species of freshwater fish and amphibians.

Historically, fire is the major disturbance factor influencing vegetation composition in the ecoregion. In its natural state, frequent fires sweep across the landscape, giving the advantage to species able to cope, such as pitch pine, scrub oak, heath shrubs, and bracken fern.

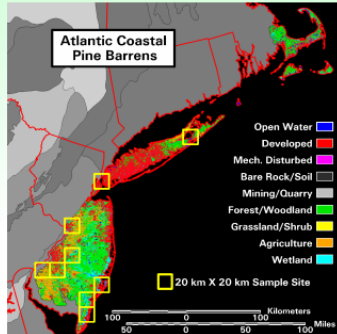
USGS Land Cover Trends Project

The Land Cover Trends project is a joint effort between the U.S. Geological Survey and the U.S. Environmental Protection Agency to study contemporary land cover change in the conterminous United States. Eighty-four "ecoregions", areas containing a geographically distinct assemblage of environmental conditions, natural communities, and species, serve as separate reporting units. A sampling approach using randomly selected sample blocks is used to estimate land cover change in each ecoregion. Historical Landsat multispectral scanner (MSS) and thematic mapper (TM) satellite imagery, along with historical aerial photography, are used to derive land cover maps for five separate dates (1973, 1980, 1992, 1999, and 2000). The sample block land cover data are used to analyze the spatial, temporal, and sectoral dimensions of change. A full discussion of project methodology can be found in Loveland *et al.*, 2002.

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

USGS Fact Sheet XXXXXX
July 2003

The greater New York City/Northern New Jersey metropolitan area was also encroaching from the north into central New Jersey. The Philadelphia metropolitan area grew into the ecoregion from the west as the New Jersey suburbs expanded. Development in the coastal areas continued as more seasonal and second homes were built along the Jersey shore, Cape Cod, Martha's Vineyard, and the Hamptons of eastern Long Island.



The Atlantic Coastal Pine Barrens. The areas in color represent land cover types for the Atlantic Coastal Pine Barrens ecoregion. The nine 20 km X 20 km sample sites for the Land Cover Trends project are shown in yellow.

While parts of the ecoregion represent some of the best-preserved habitat in the eastern United States, other portions of the ecoregion are among the most highly developed lands in the country. The western half of Long Island, as well as much of the Jersey Shore and Cape Cod, is very densely populated and developed.

Historical Land Use and Land Cover

Early land use and land cover change was largely based on natural resource extraction, much of it based on the use of vast timber resources. Rot-resistant white cedar was in high demand for shingling, ship building, and other uses. Pitch pine provided a source of strong, dense, high quality wood for flooring, furniture making, construction lumber, and fuel, and the pine's resin was widely used for naval stores. The enormous demand for wood, coupled with uncontrollable forest fires, drastically changed the landscape of the region from its prehistoric form (Berger and Sinton 1985, 117).

Early in the 19th century, a booming iron industry began. The New Jersey Pine Barrens were rich with "bog iron", natural deposits of iron rich material. Clay and oyster shells from the shoreline were harvested to provide lime required for smelting, while the vast forestlands provided the fuel. However, the production of bog iron ended by the 1860s, as higher grade iron

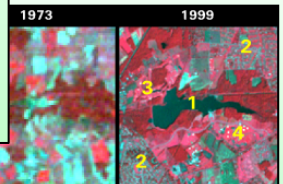
Early Land Use and Land Cover Change

Land Cover Trends project analyzed land use and land cover in the Atlantic Coastal Pine Barrens ecoregion using framework and historical Landsat satellite imagery change data for the nine sampled data blocks depicted above to provide estimates of change for the ecoregion. The overall rates of land cover conversion were steady, hovering around 1.5% change per time interval.

	'73 to '80	'80 to '86	'86 to '92	'92 to '00
Change	1.5%	1.7%	1.4%	1.5%

Year	Sq. miles	Transition Type
1973	34	Forest to Urban
1980	29	Agriculture to Urban
1986	8	Mechanical Disturbed to Urban
1992	51	Agriculture to Urban
1999	37	Forest to Urban
2000	7	Forest to Mining
1992	46	Agriculture to Urban
1999	22	Forest to Urban
2000	5	Mechanical Disturbed to Urban
2000	44	Agriculture to Urban
2000	22	Forest to Urban
2000	5	Mechanical Disturbed to Urban

all change rates are relatively low, significant land cover changes are apparent. The table above shows the three most land cover transitions by time interval, listed descending by general trends show gradually increasing developed land cover, with parallel reductions in the amount of agricultural land. Other forms of land cover change were generally minor. Although the total percentage of land cover change was small, the vast majority of that change was the transformation of other land cover types to developed uses. Over 325 square miles of land was converted from 1973 to 2000, resulting in the loss of 190 square miles of agricultural land, 115 square miles of forest, and 20 square miles of other land cover types.



Multi-date satellite imagery, showing some of the typical changes found in the ecoregion. The image on the left is Landsat MSS data from 1973, while the image on the right is Landsat ETM+ data from 1999. Changes in this time span include: 1) New reservoir, 2) New residential developments, mostly at the expense of agricultural land, 3) New golf course, supporting the high recreational demands in the ecoregion, and 4) Ball fields and a park complex.



New homes along the Jersey Shore

the heavily developed urban corridor running from Washington D.C. in the south, through Baltimore, Philadelphia, and New York City, to Boston in the north.

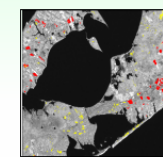
Land Cover Trends: Telling the story of Change

	Population	Persons per sq. mile
1970	9,585,784	1,574
1980	9,599,396	1,576
1990	10,081,769	1,656
2000	11,017,900	1,810

Population Growth: Both overall population and population densities have substantially increased since 1970.

Drivers of Contemporary Land Use Change

Between 1970 and 2000, population in the ecoregion increased fifteen percent from 9.6 to 11.0 million. Locally, population increases have been more dramatic, with Cape Cod experiencing a doubling in population over the same time period (from roughly 100,000 to over 220,000). Accommodating this growth was the primary driver of land change.



Loss of agricultural land on a portion of Long Island. Red areas depict agricultural land lost to urbanization since 1973, while yellow areas depict losses of other land cover types.

National Reserve and later as a United States Biosphere Reserve (Mason 1992; Walker and Solecki 1999).

Nonetheless, urban pressures continue to exert a powerful force. The region's population continues to grow, and many residents desire a less crowded lifestyle than previous generations. Much of the growth occurs at or near major highway intersections and in high amenity coastal zones. Recently, retirement communities have become a substantial land use development trend. Increased populations, especially those of retired persons, with large amounts of free time, have also resulted in an increased demand for recreational facilities, such as golf courses and public beaches.

Increased urbanization in the ecoregion has also resulted in aggressive fire suppression, resulting in changes in composition in many of the ecoregion's plant communities. With prolonged fire suppression, vegetational succession leads to the replacement of pine barrens by oak forest. In addition, the fuel build-up leads to very intense fires that kill all vegetation, including the naturally fire-resistant pitch pines. Impacts of increased land management can thus change land cover composition in areas remote from actual development.

One response to the increased population was a 25 percent decrease in farmland since 1970. Some farmers sold their land for development (Hart, 1991), while others switched from vegetables to higher value nursery stock, flowers, or sod. Environmental protection efforts have effectively slowed or stopped growth in many environmentally sensitive areas, however (Walker and Solecki 1999). For example, New Jersey and the federal government have cooperated to protect the New Jersey Pine Barrens. The Pinehills were designated as the nation's first



Recreational uses, such as golf courses, vacation homes, and local gambling, are economically and socially important in parts of the ecoregion.

Future Trends

Given the continued pressures of expansion from neighboring urban centers, the demand for recreational opportunities in the ecoregion, and the growth of retirement communities, it is expected that urban development will continue to be the primary and use conversion for the foreseeable future. While development of forestland outstripped development of agricultural land during the early part of this study, the development of agricultural land became the increasingly dominant form of urbanization through each time interval. With increased environmental awareness and the desire to protect "natural" habitats, it is expected that development pressures will result in the continued loss of agricultural land, with somewhat less but still significant pressure on the Pine Barrens themselves.

References

- Berger, Jonathan, and John W. Sinton, 1985. *Water, Earth, and Fire: Land Use and Environmental Planning in the New Jersey Pine Barrens*. Baltimore, MD: The Johns Hopkins University Press.
- Hart, J.F., 1991. *The metropolitan bay area*. *Geographical Review* 81(1): 35-51.
- Mason, Robert J., 1992. *Contested Lands: Conflict and Compromise in New Jersey's Pine Barrens*. Philadelphia, PA: Temple University Press.
- Loveland, T.R., T.L. Sohl, S.V. Stehman, A.L. Gallant, K.L. Saylor, and D.E. Napton, 2002. *A Strategy for Estimating the Rates of Recent United States Land Cover Changes*. *Photogrammetric Engineering and Remote Sensing* 68(10): 1091-1100.
- Suffolk County Department of Health Services (SCDHS), 1987. *Suffolk County Comprehensive Water Resources Management Plan*. Division of Environmental Quality, Hauppauge, New York, January 1987.
- Walker, R.T., and W.D. Solecki, 1999. *Managing Land Use and Land Cover Change: The New Jersey Pinehills Biosphere Reserve*. *Annals of the Association of American Geographers*, 89(2): 220-237.

Land Cover Trends and The National Map

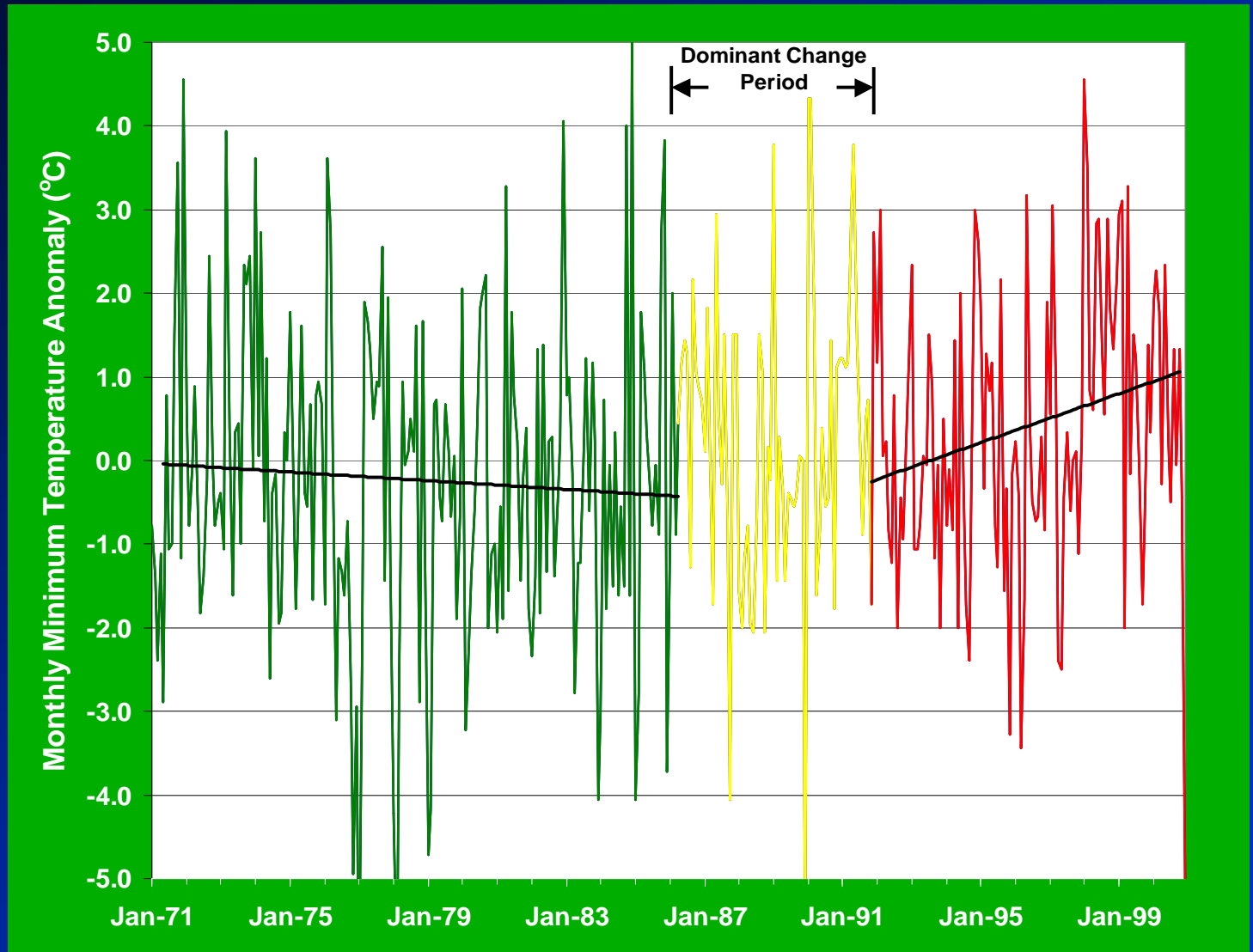
The National Map is a consistent framework for geographic knowledge needed by the Nation. It provides public access to high quality geospatial data and information from multiple partners to help informed decision making by resource managers and the public. The National Map enhances America's ability to assess, integrate, and apply geospatial data at global, national, and local scales. Web site: www.nationalmap.usgs.gov

resources, and thus increase the probability of groundwater contamination from surface pollution sources. Overpumping of groundwater resources is also an issue, as even modest reductions in water table elevation can have severe negative effects on the sensitive wetlands in the ecoregion (SCDHS, 1987).

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

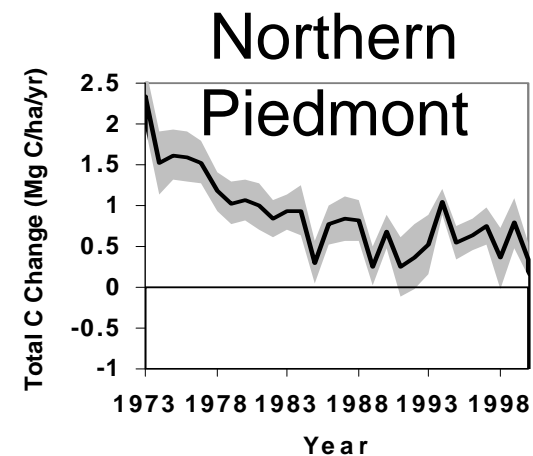
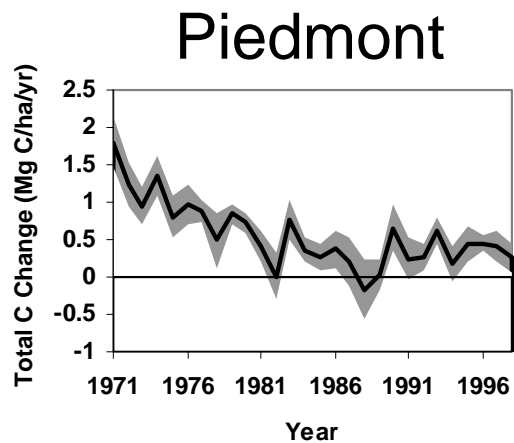
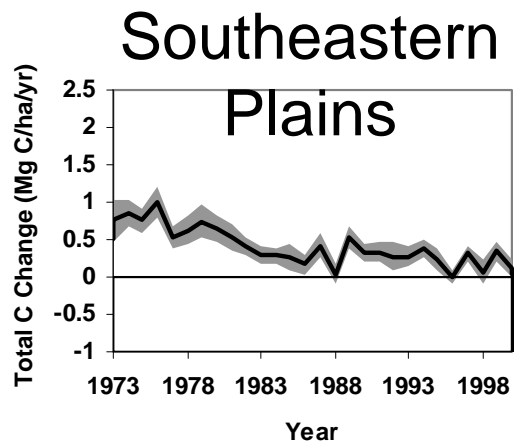


Pre-change trend: -0.03 ± 0.06 °C/yr

Post-change trend: 0.15 ± 0.12 °C/yr

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



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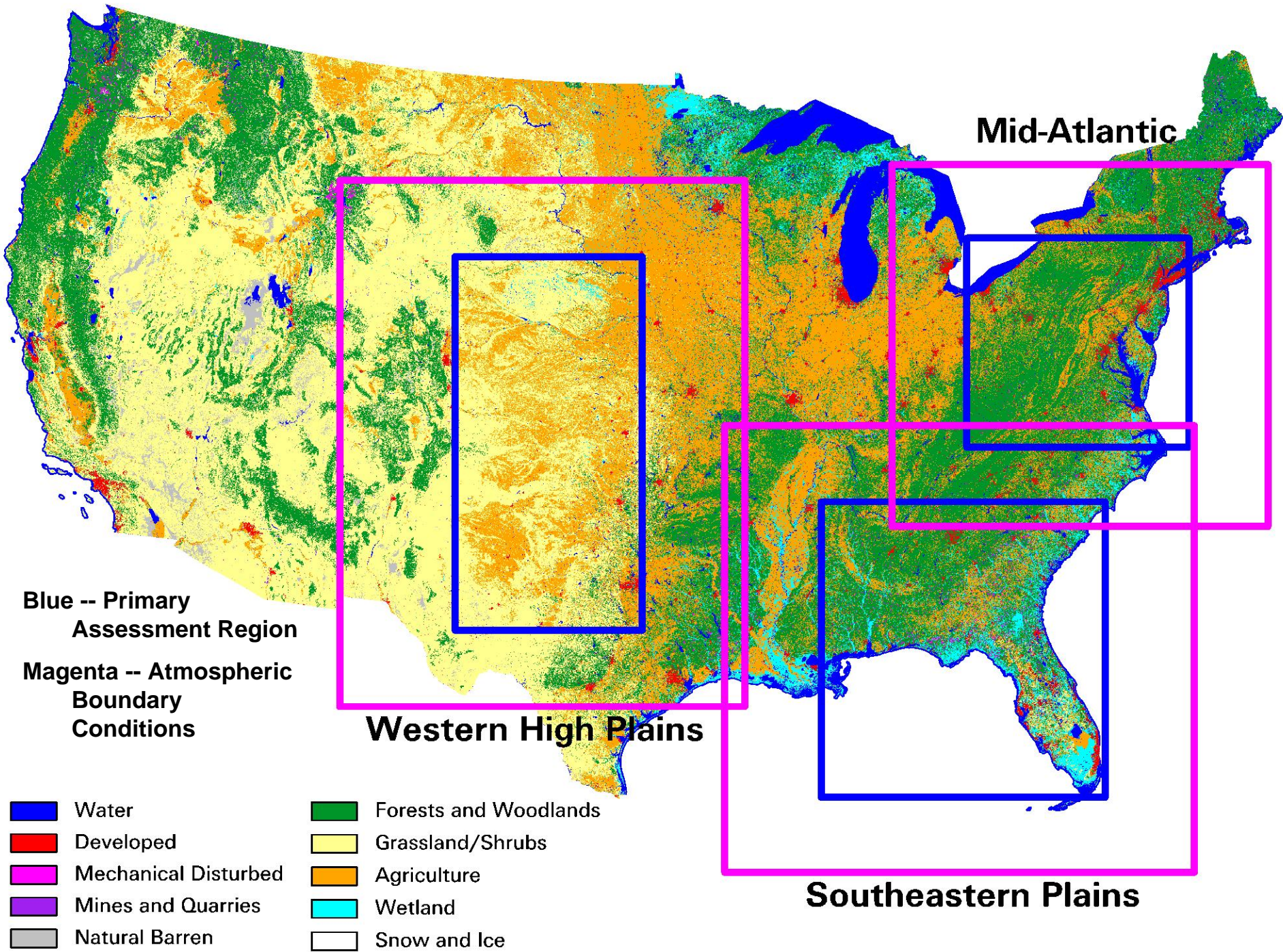
Applications of Land Cover and Land Cover Change Data – Conservation Issues

- 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





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

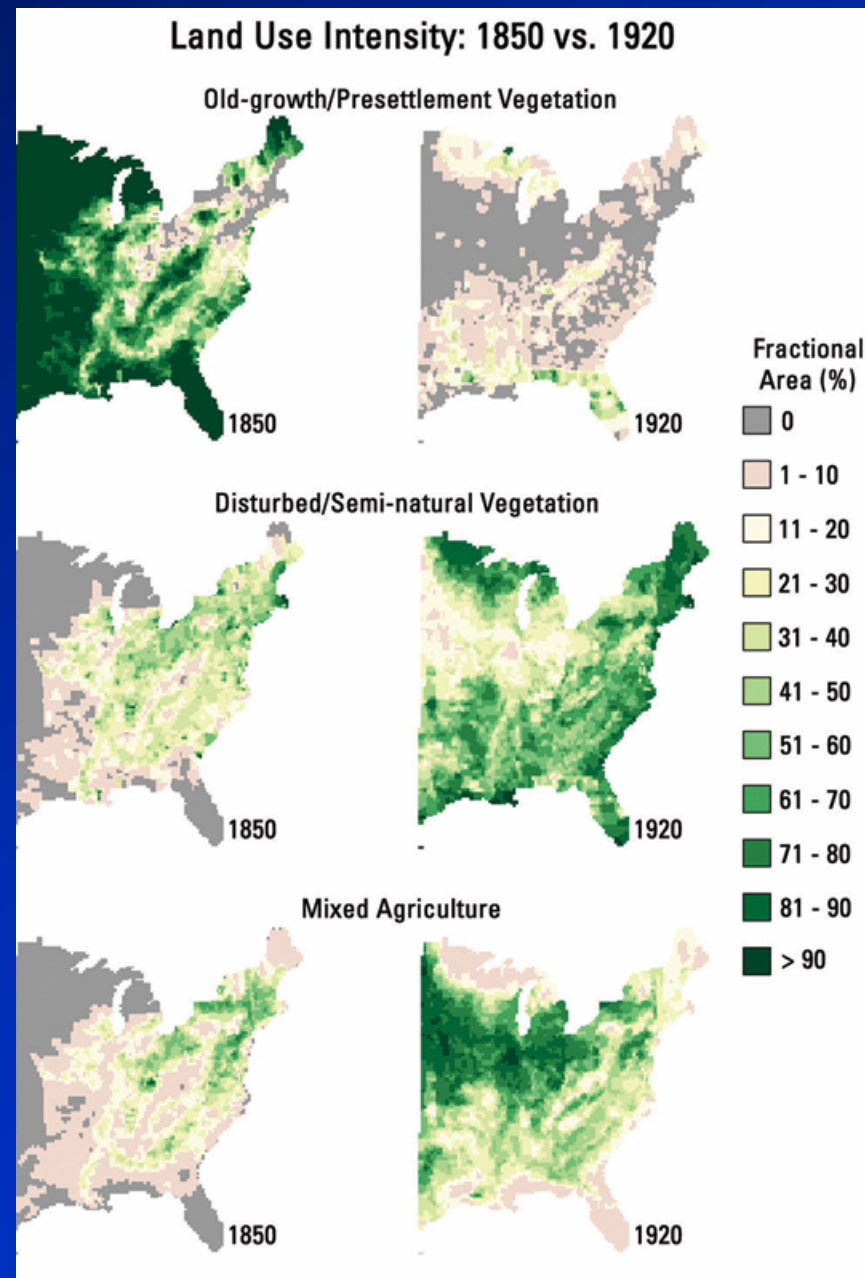


Historical Land Cover Reconstruction

- 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



USGS EROS Data Center



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

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

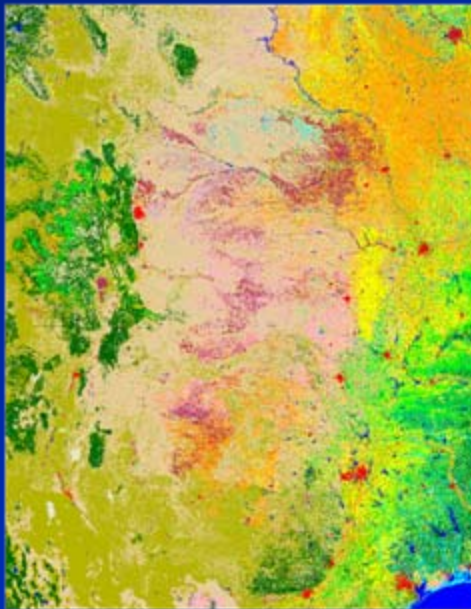
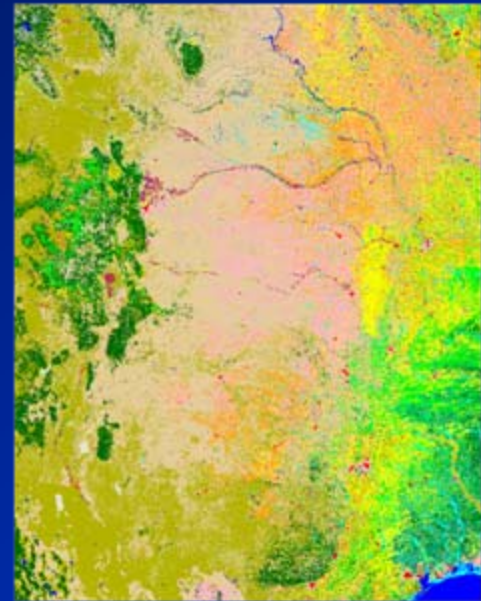


USGS EROS Data Center

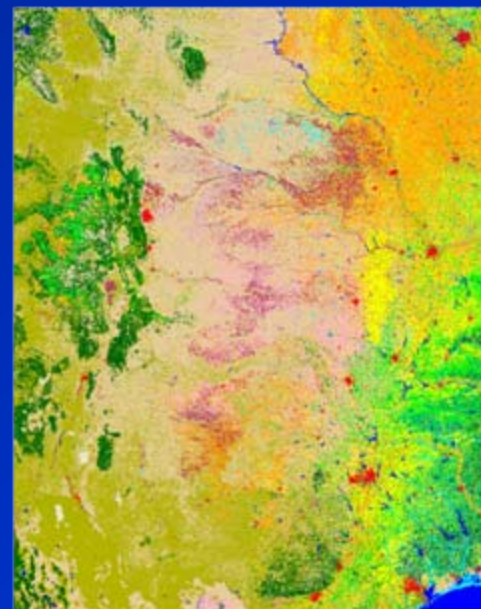
Pre-Settlement



1920



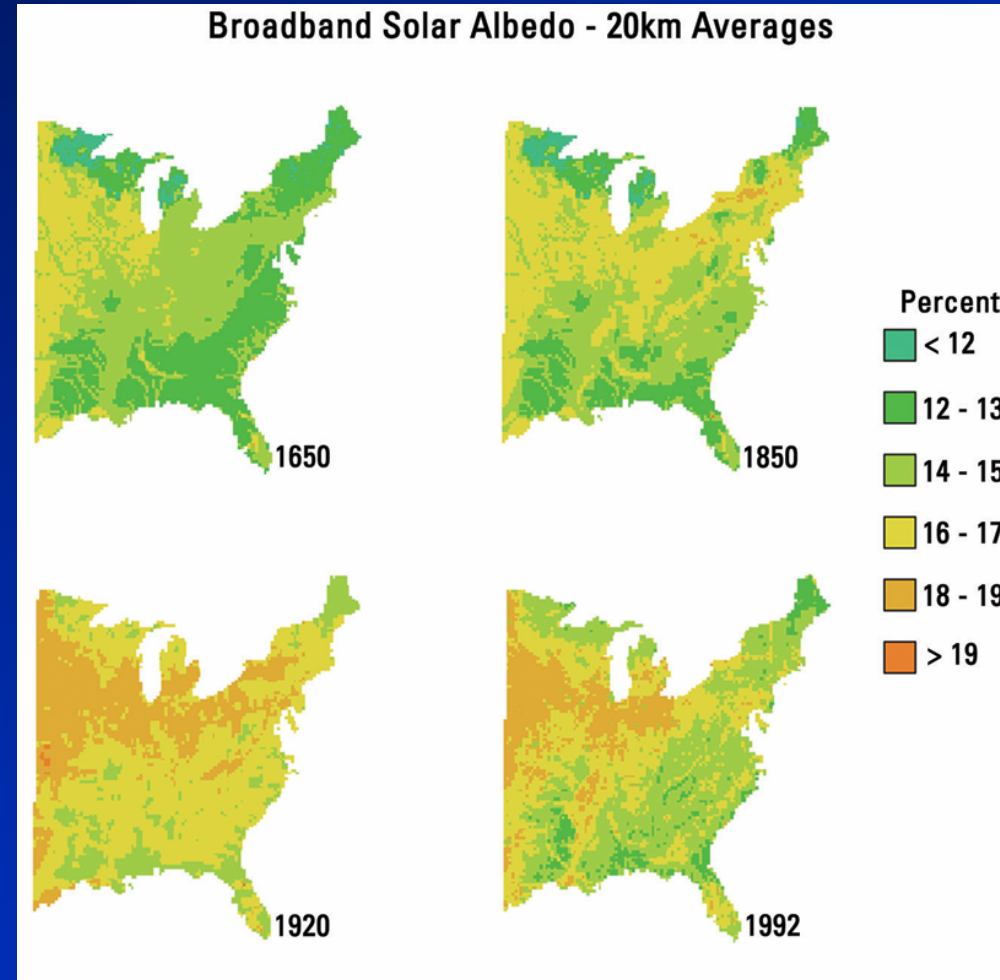
1992



2020

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



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

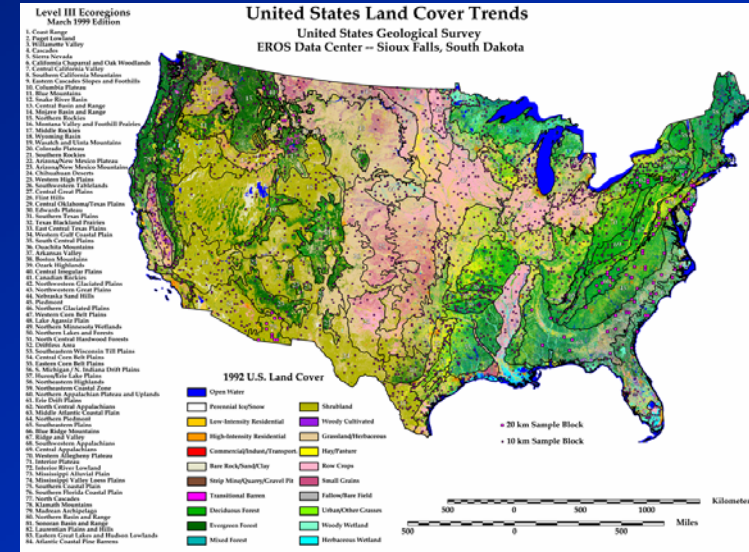
- ◆ Driven by macro-level socioeconomic drivers
- ◆ Drivers often not spatially explicit, not able to be mapped quantitatively
- ◆ Non-spatial...calculates area change for all land use types at the aggregate level

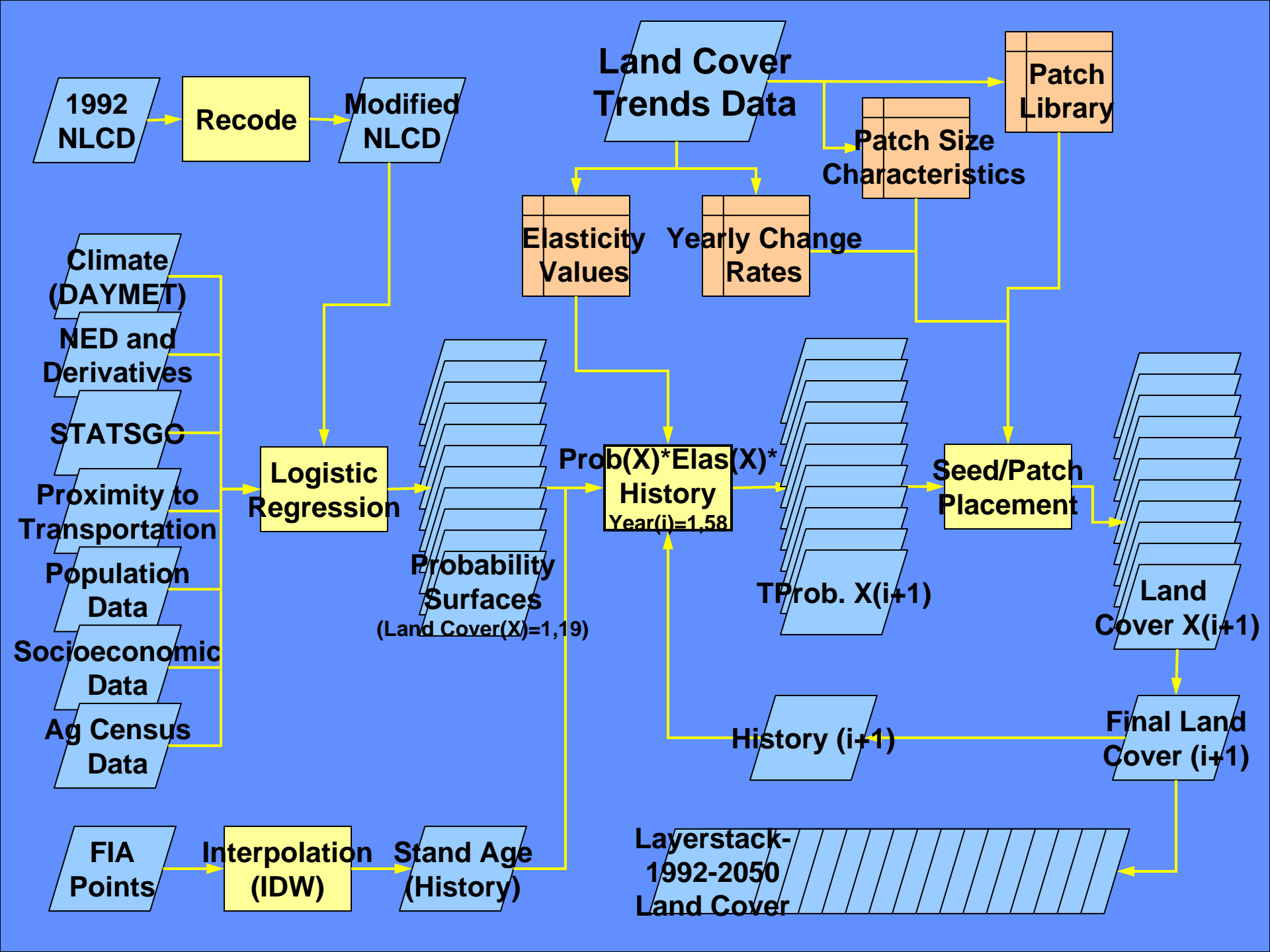
● Spatial Allocation Module

- ◆ 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

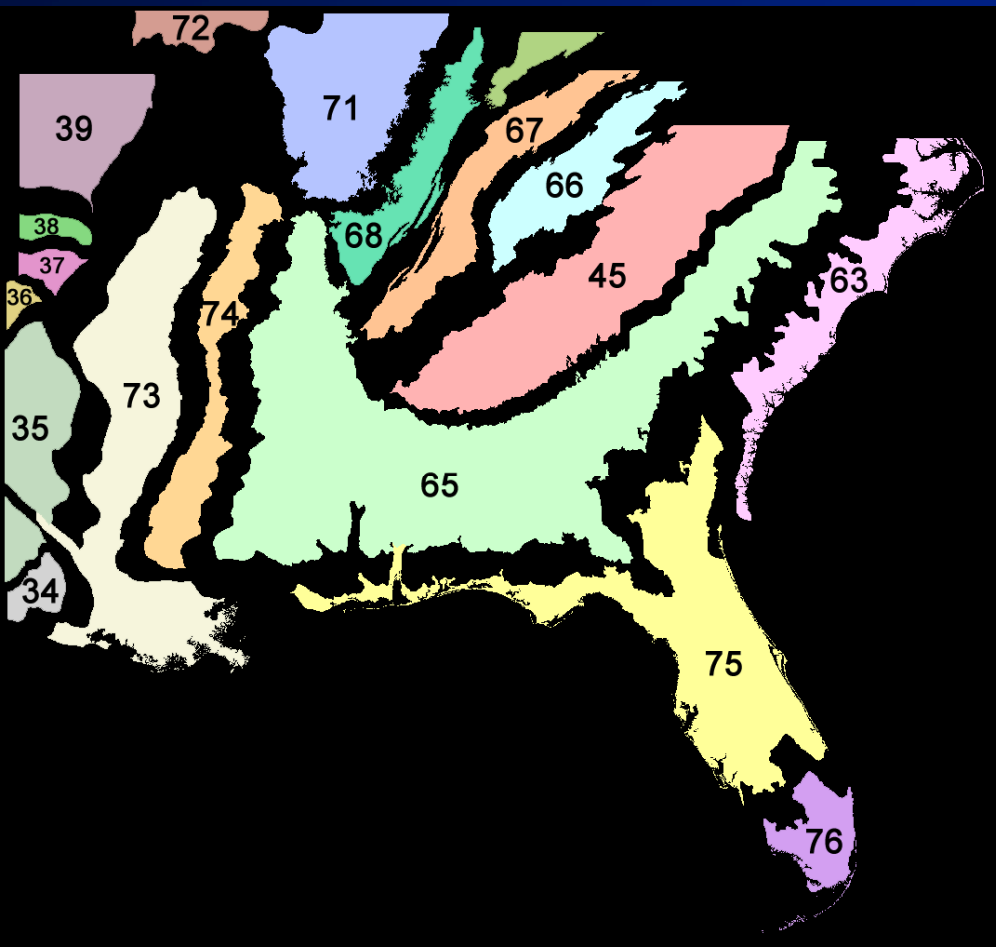
- Use of Land Cover Trends project data
 - We have empirical data on contemporary land cover change in the three study areas (change rates, patch characteristics, habitat fragmentation, drivers of change)
 - Incorporation of Trends information -- Gives us an advantage that many modelers of LULC change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





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

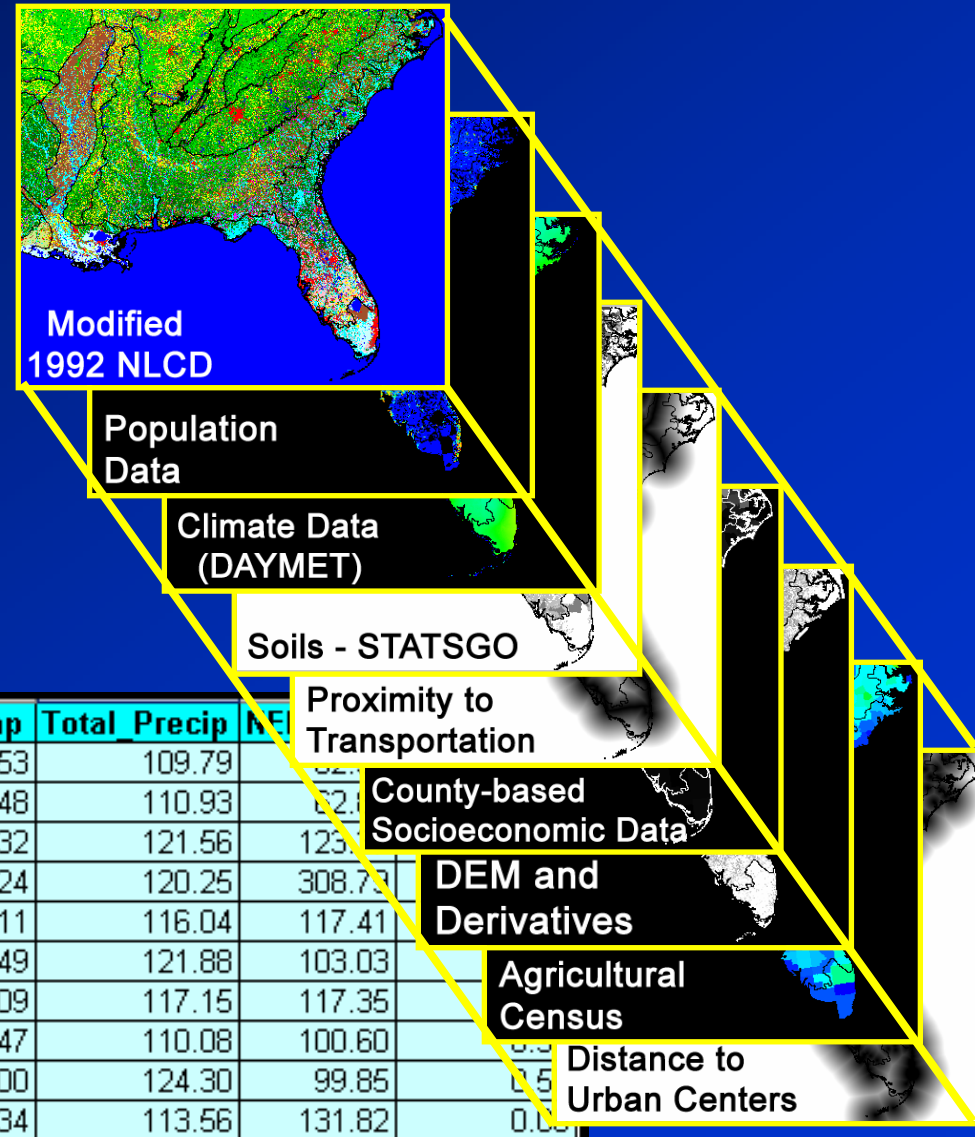


Clear-cutting			
	Annual Area (km2)	Mean Patch Size (ha)	Std. Deviation (ha)
Eco. 45	292.0	18.6	32.1
Eco. 63	231.2	26.7	57.9
Eco. 65	1470.7	22.9	37.6
Eco. 66	8.0	11.6	13.1
Eco. 67	47.5	8.8	18.2
Eco. 68	56.8	9.3	24.4
Eco. 69	3.9	10.6	15.9
Eco. 70	0.6	4.6	6.8
Eco. 71	19.7	6.5	19.4
Eco. 74	70.0	21.1	34.7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

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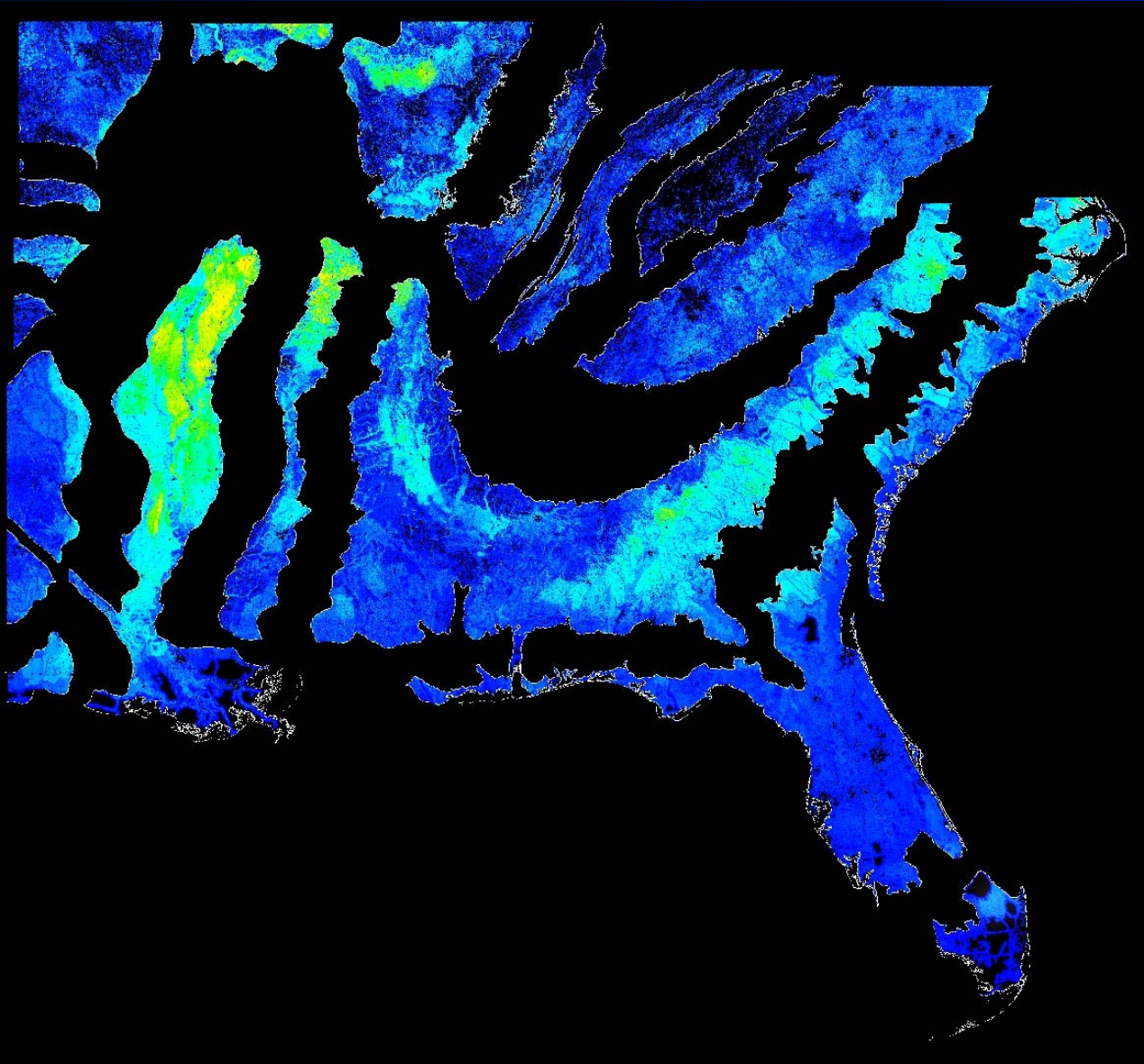
Ancillary Data – Used in Logistic Regression

- 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			
1	1492.00	65.89	275.25	14.53	109.79	102.1	102.1	102.1
14	396.44	87.33	267.33	14.48	110.93	102.1	102.1	102.1
14	1011.56	25.78	52.33	13.32	121.56	123.5	123.5	123.5
3	510.67	453.00	192.83	13.24	120.25	308.73	308.73	308.73
1	135.11	675.67	237.33	14.11	116.04	117.41	117.41	117.41
7	1185.78	194.58	208.89	13.49	121.88	103.03	103.03	103.03
9	62.22	686.44	248.44	14.09	117.15	117.35	117.35	117.35
15	805.33	217.33	243.56	14.47	110.08	100.60	100.60	100.60
3	597.33	372.00	375.67	14.00	124.30	99.85	99.85	99.85
8	352.00	287.44	120.33	14.34	113.56	131.82	131.82	131.82

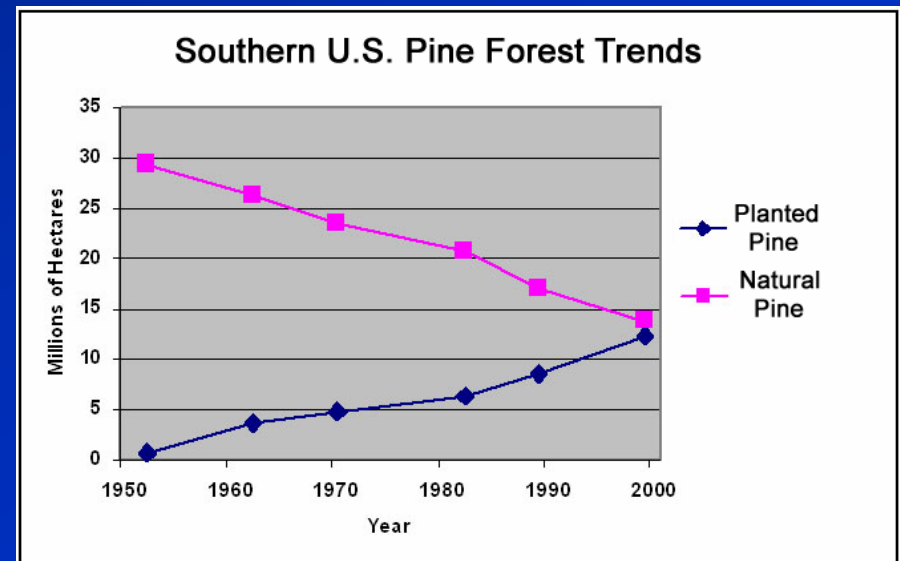
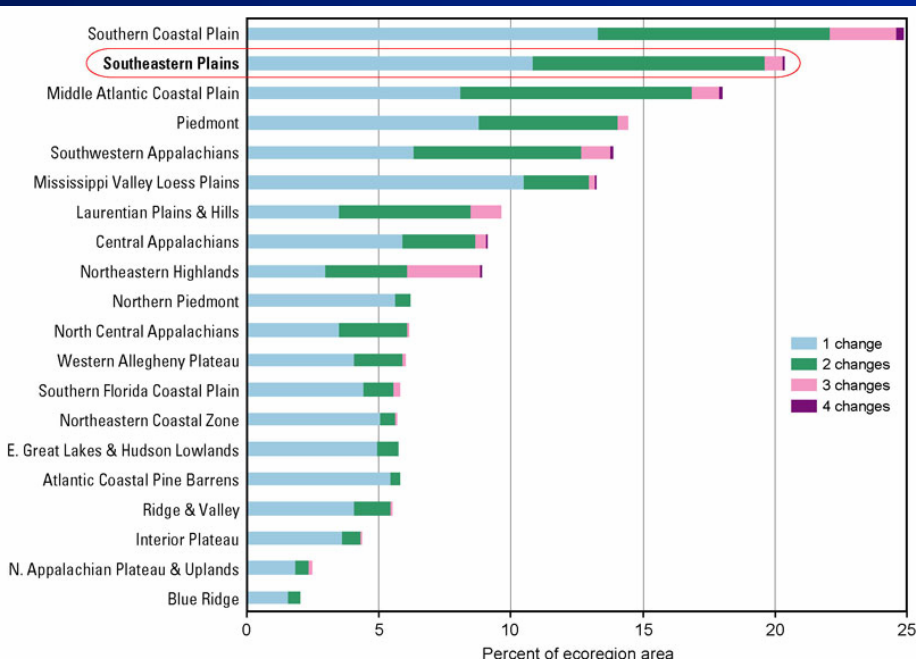
Regression-based Probability Surfaces



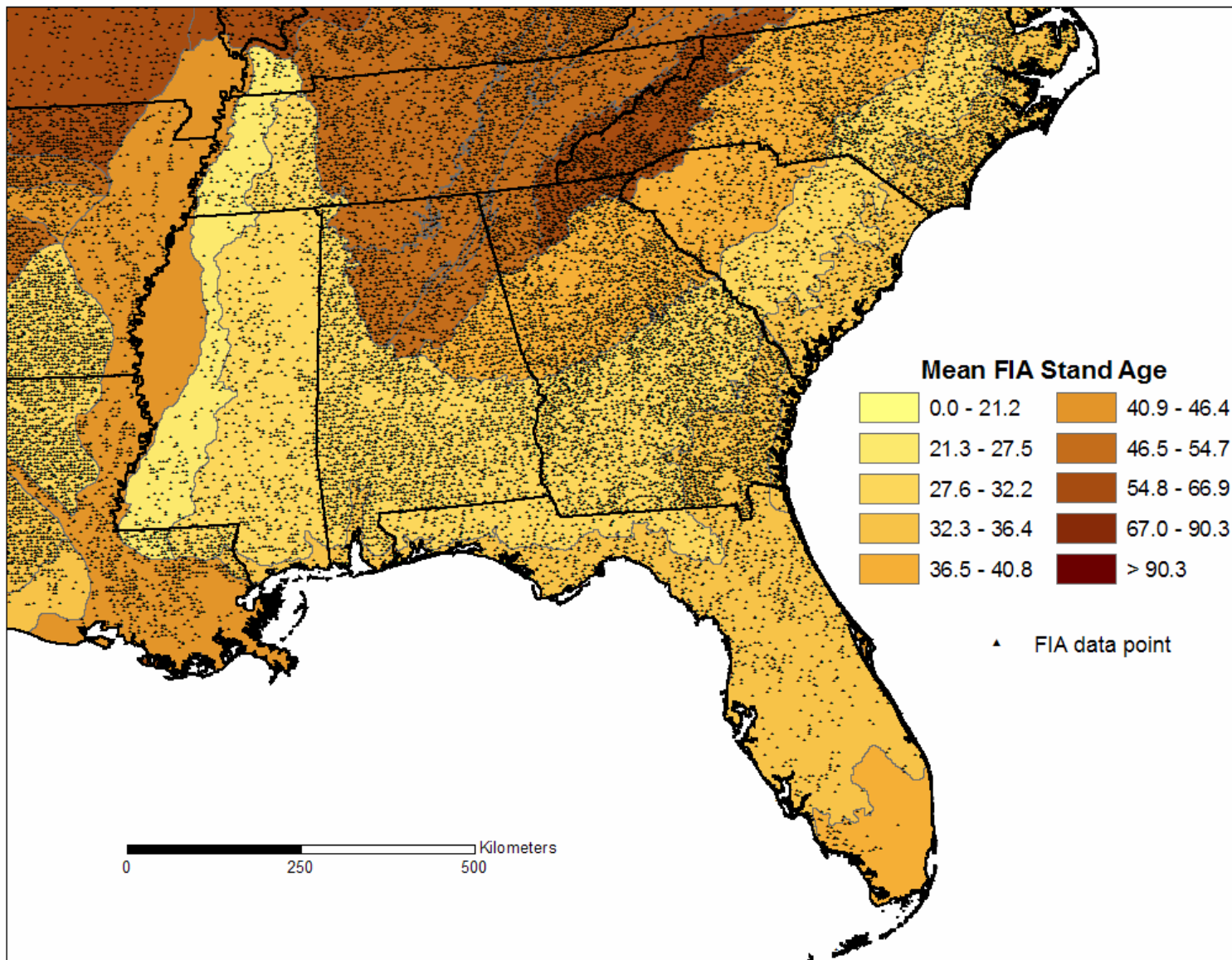
- Logistic regression used to analyze relationships between each land cover type and ancillary data sets
- Probability surfaces constructed for each land cover type

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



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														
T O C L A S S	ECO 65	Water	Low-Int Res.	Mining	Transiti onal	Decidu ous	Mixed	Evergre en	Natural Grass	Hay/Pa sture	Row Crops	Small Grains	Woody Wet	Herby Wet
	Water	0	0	0	5	7	7	7	8	10	8	8	0	10
	Urban	0	0	6	9	10	10	10	10	10	10	10	7	7
	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
	Deciduous	0	0	0	0	0	0	0	10	10	8	8	0	0
	MixedFor	0	0	0	0	0	0	0	10	10	8	8	0	0
	Evergreen	0	0	0	0	0	0	0	10	10	8	8	0	0
	Natural Grass	0	0	10	0	0	0	0	0	0	0	0	0	0
	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
 - $TPROB = \text{Baseline Probability} * ELASTICITY * \text{Function}(\text{HISTORY}) * PAD$
- 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

Baseline Probability

Existing Cover

Elasticity

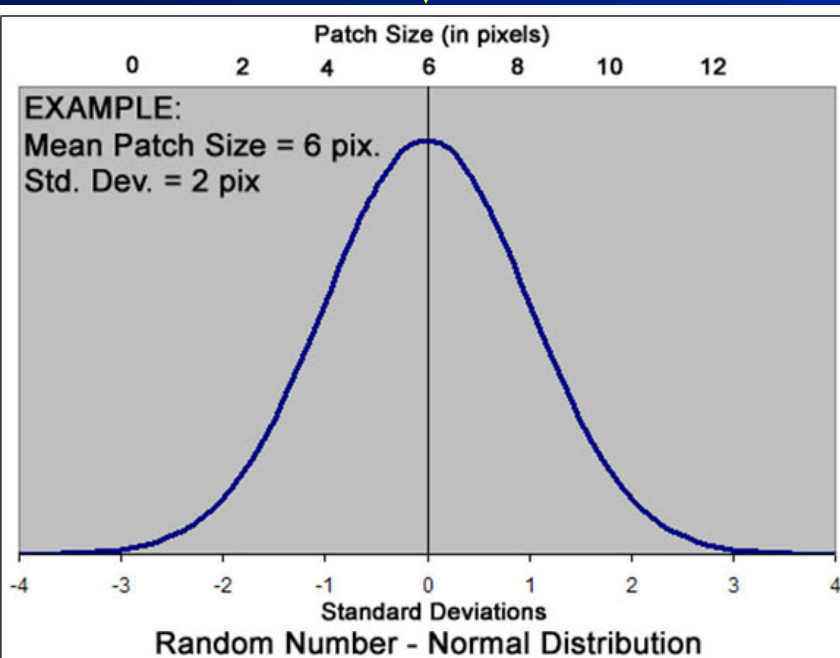
History

PAD

Total Probability

Generating Change Polygons

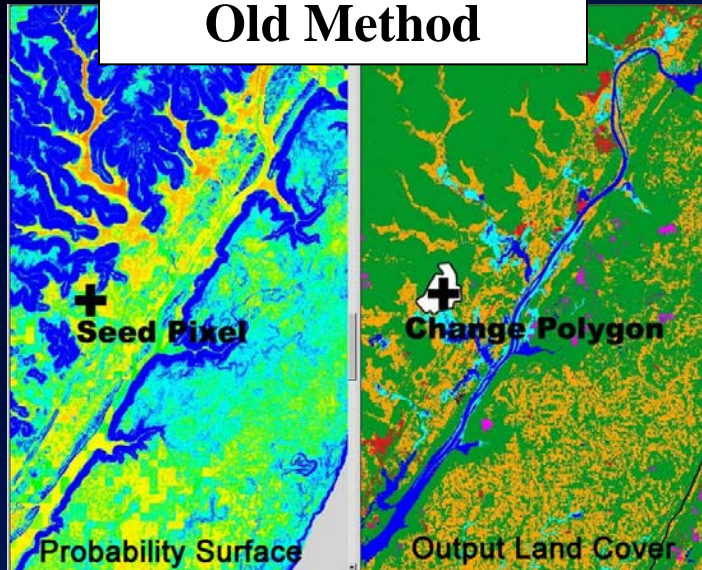
TRANSITION TYPE	Mean Patch Size	Standard Deviation
Grass/shrub to Urban	7.10	5.84
Grass/shrub to Mining	1.37	2.40
Grass/shrub to Agriculture	57.14	114.22
Grass/shrub to Wetland	2.88	1.08
Agriculture to Urban	3.75	3.54
Agriculture to Mining	6.84	8.41
Agriculture to Grass/shrub	58.43	103.17
Agriculture 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:

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

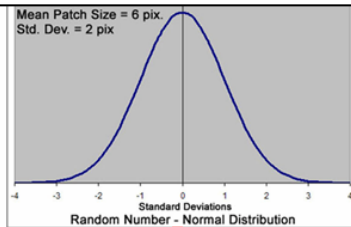
Old Method



Generating Change Polygons and FORE-SCE run time

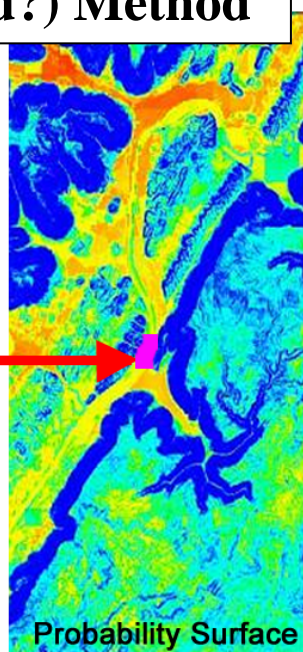
- Once seed size is determined, a change patch centered on that seed is placed
- Old method – Region grow function into adjacent pixels of similar (or higher) probability
 - Patches more “organic”, dependent upon probability surface characteristics
 - Problem – Model Run times were 2-3 real days per yearly model iteration
- New method – 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

New (improved?) Method

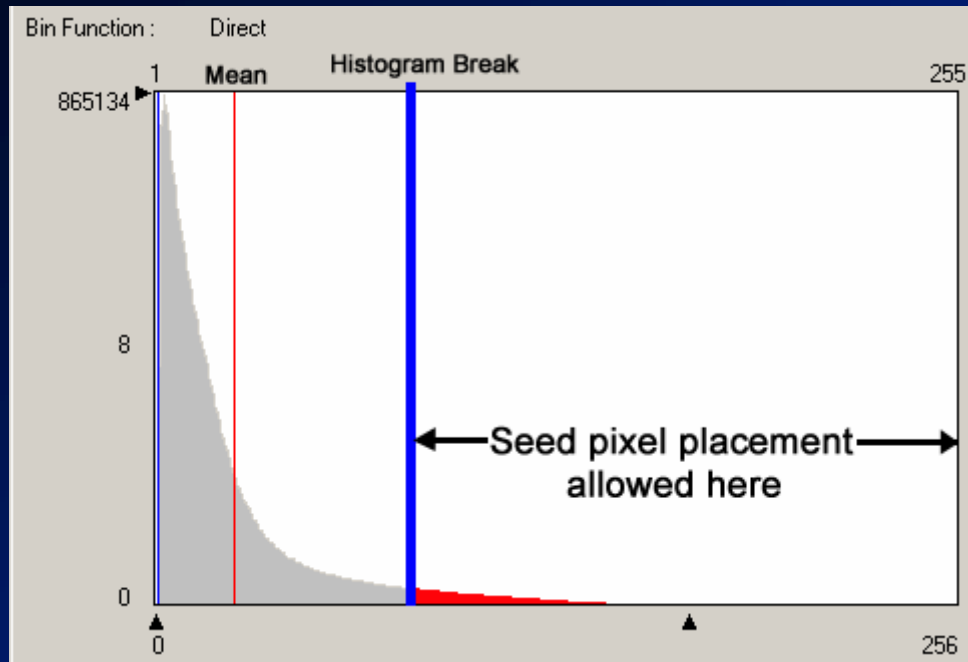


Patch Size

Patch Shape



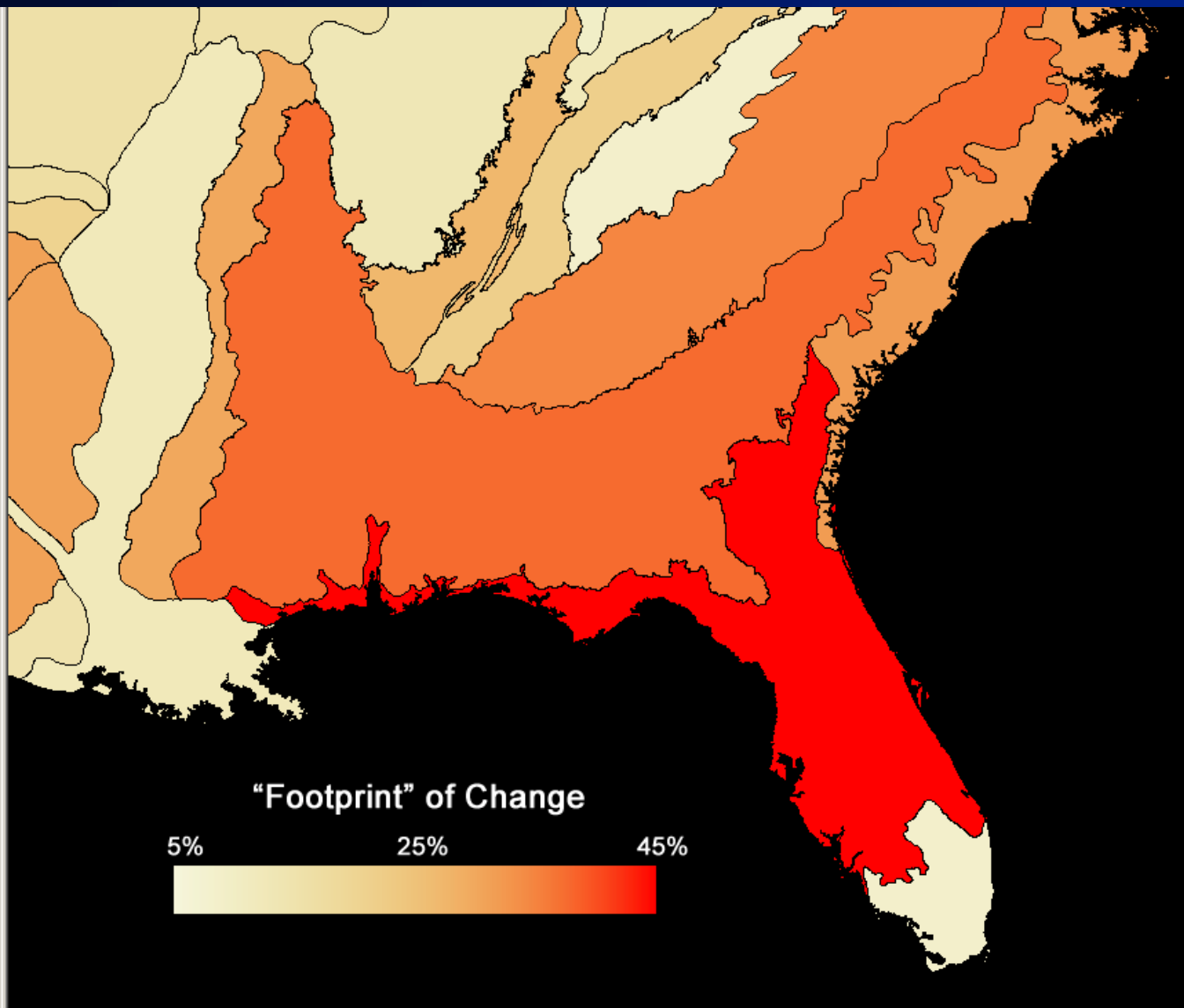
Controlling “Clumpiness” of LULC change



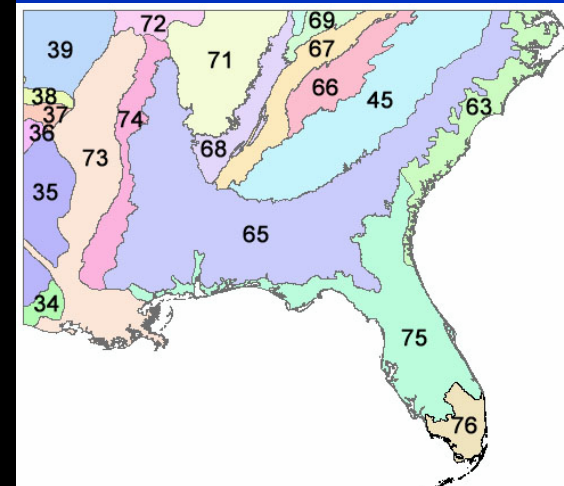
Histogram Breakpoints - Portion of histogram allowed for seed placement											
	Water	Developed	Mining	Transitional	Deciduous	Mixed	Evergreen	Grass	Hay/Pasture	Row Crops	Small Grains
Eco. 34	99	97	85	85	85	85	85	0	85	85	85
Eco. 35	95	97	85	85	85	85	85	0	85	85	85
Eco. 36	95	95	85	85	85	85	85	0	85	85	85
Eco. 37	95	95	85	85	85	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%

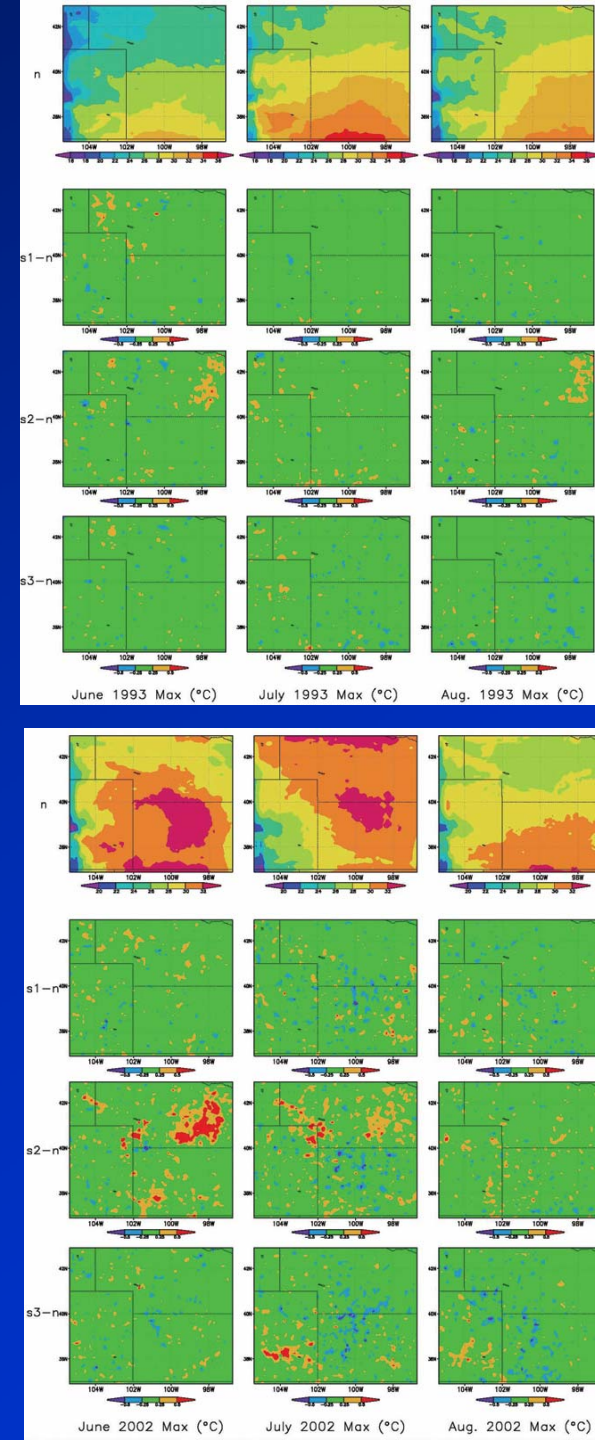


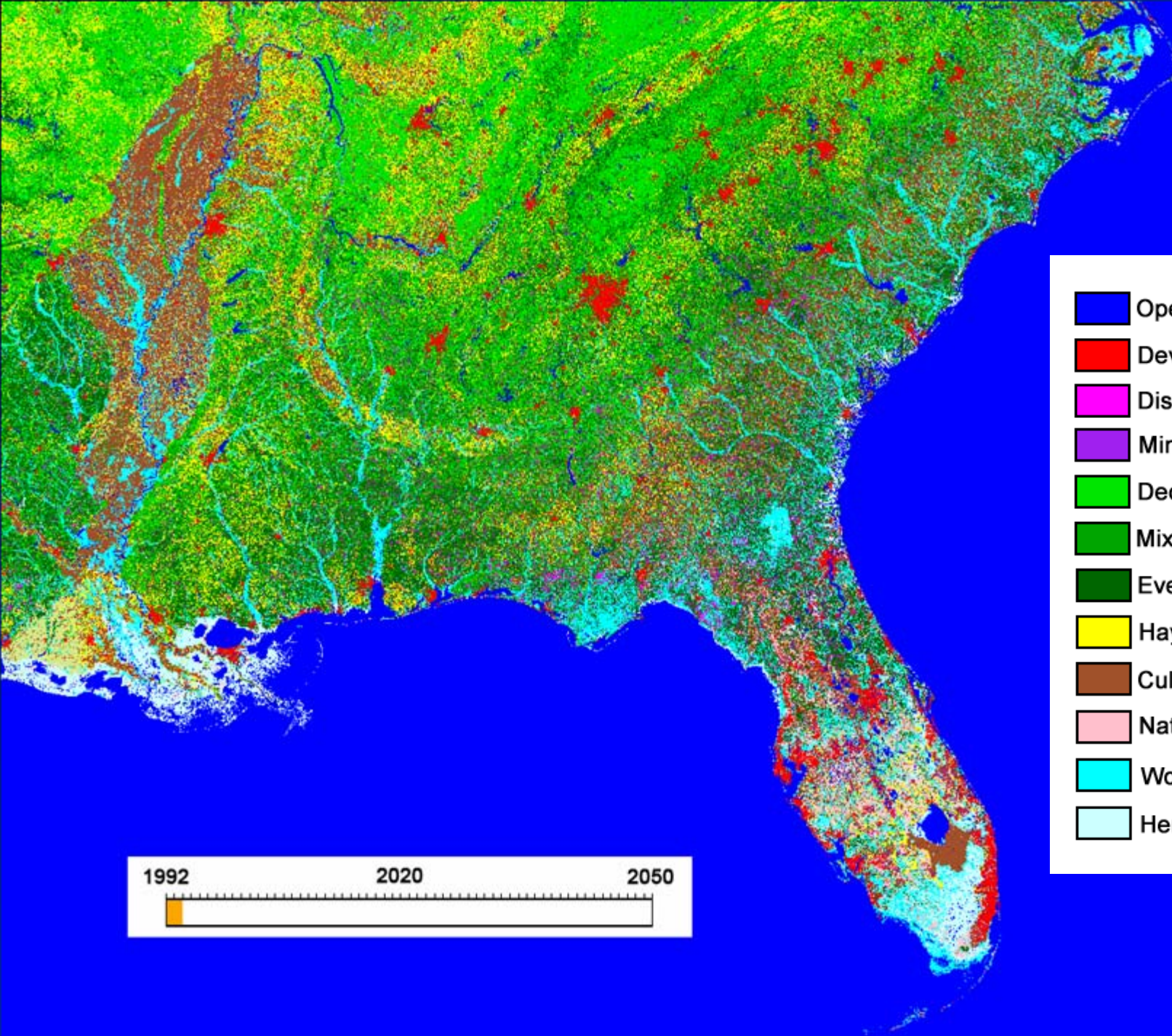
RAMS/LEAF2/GEMTM Modeling

- 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

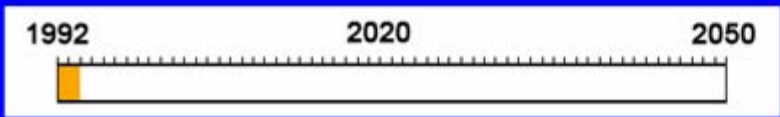


USGS EROS Data Center



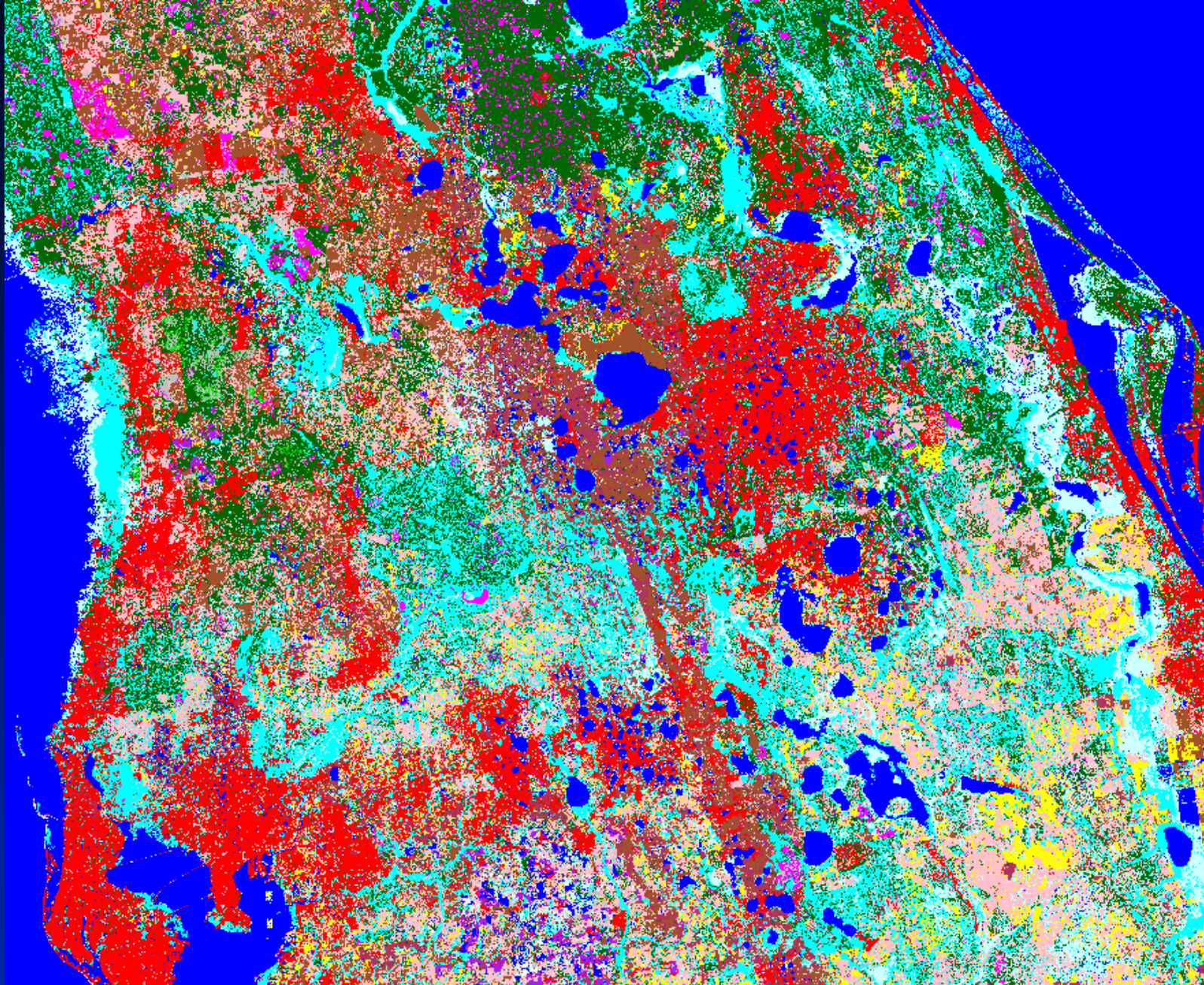


- Open Water
- Developed
- Disturbed (Cut)
- Mining/Quarry
- Deciduous Forest
- Mixed Forest
- Evergreen Forest
- Hay/Pasture
- Cultivated Crops
- Natural Grassland
- Woody Wetland
- Herbaceous Wetland



1992 to 2050 Projected Change: Florida

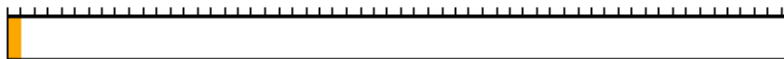
- Open Water
- Developed
- Disturbed (Cut)
- Mining/Quarry
- Deciduous Forest
- Mixed Forest
- Evergreen Forest
- Hay/Pasture
- Cultivated Crops
- Natural Grassland
- Woody Wetland
- Herbaceous Wetland



1992

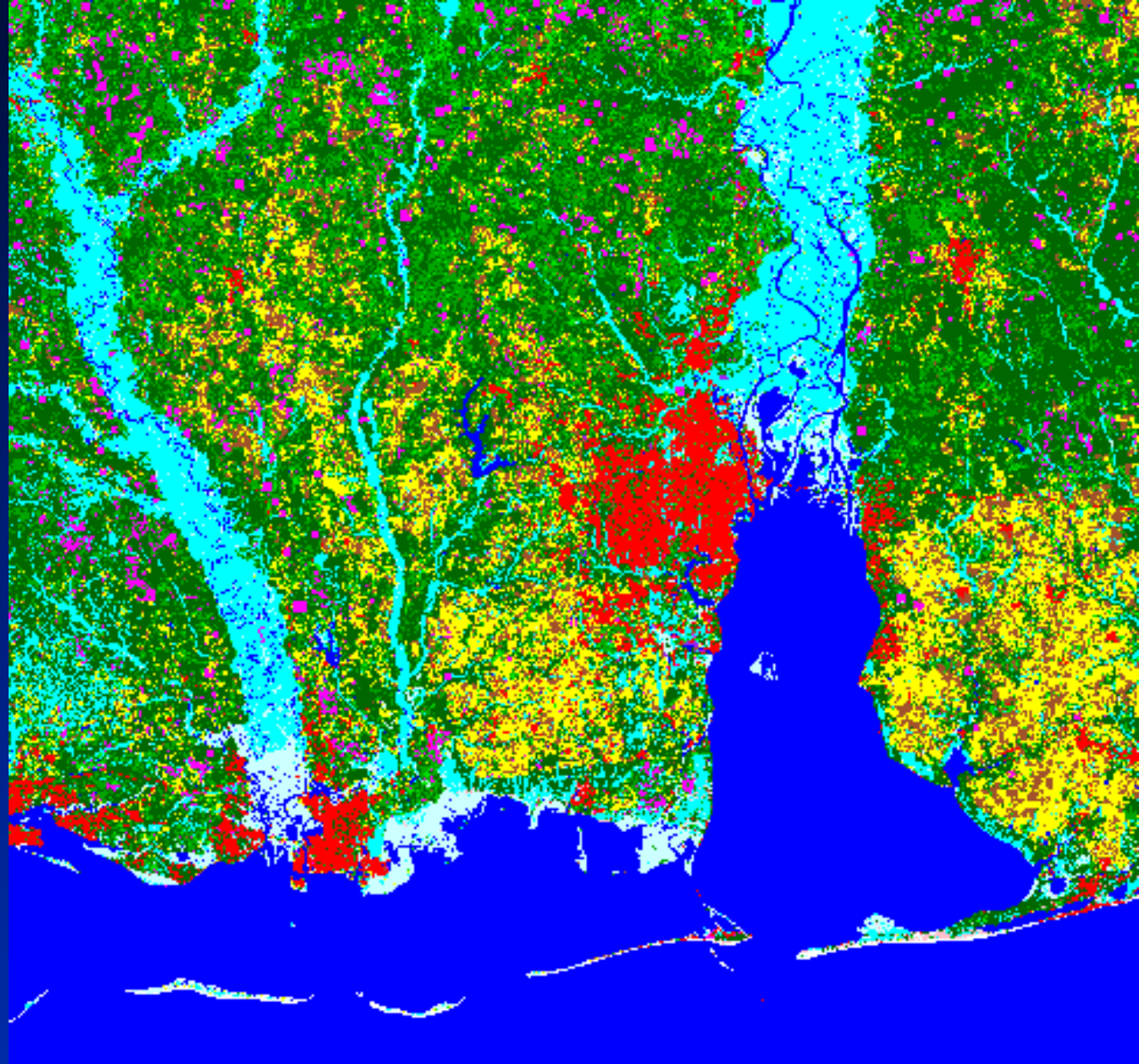
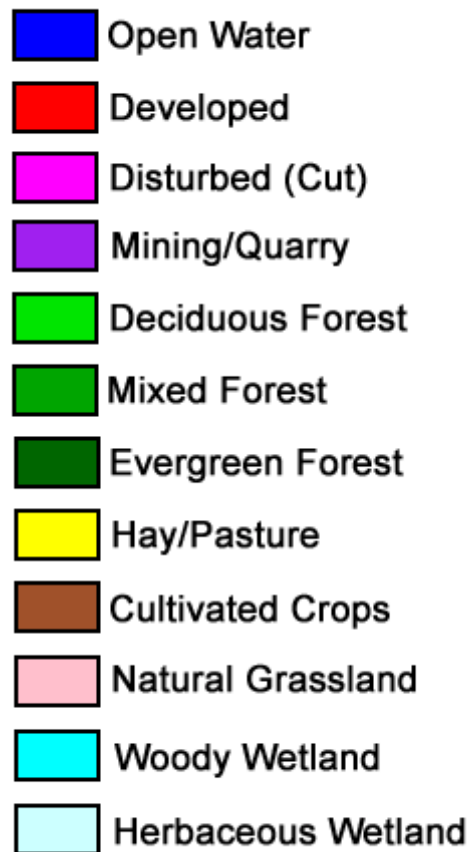
2020

2050



USGS EROS Data Center

1992 to 2050 Projected LULC Change: Mobile, Alabama



1992

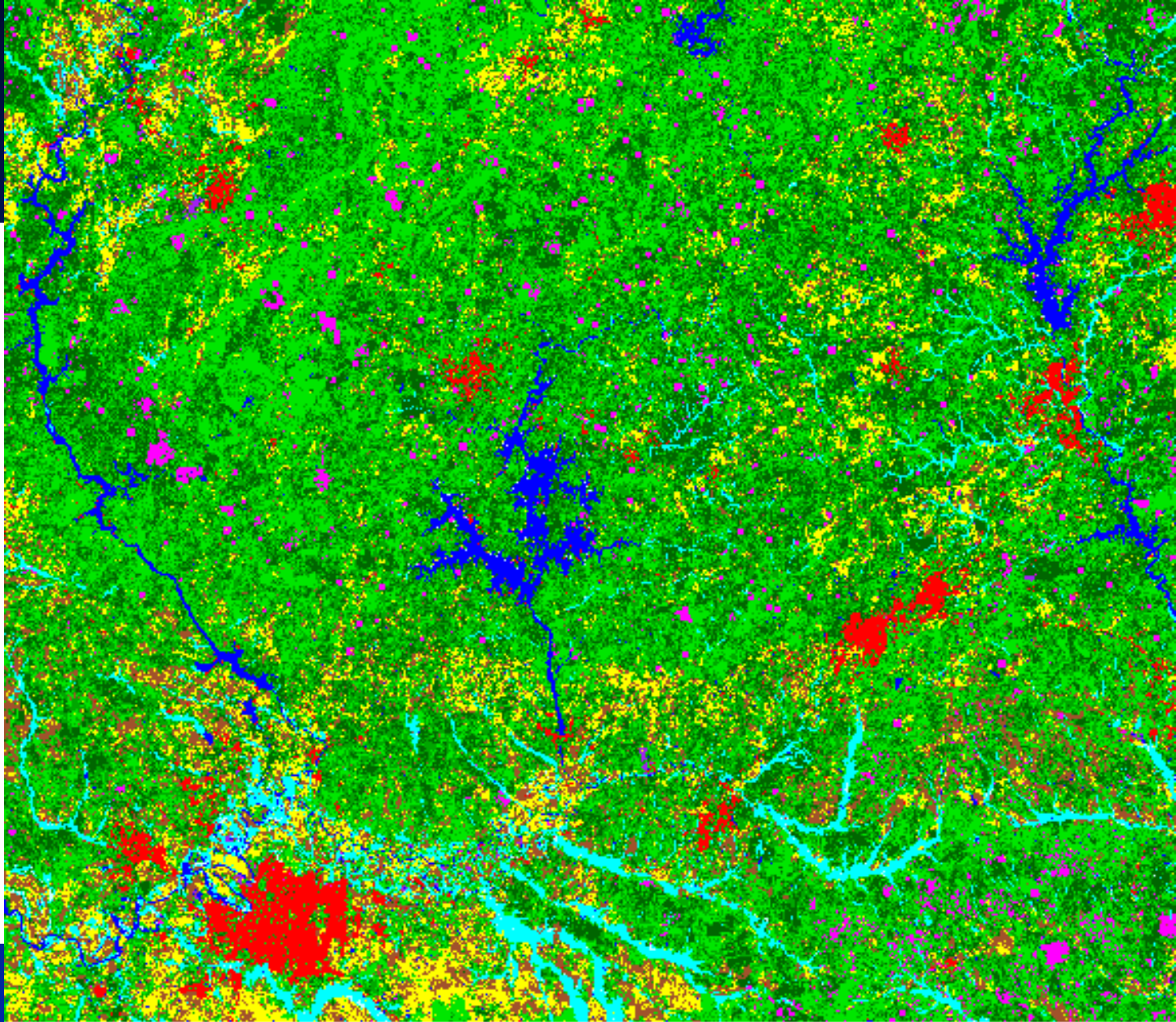
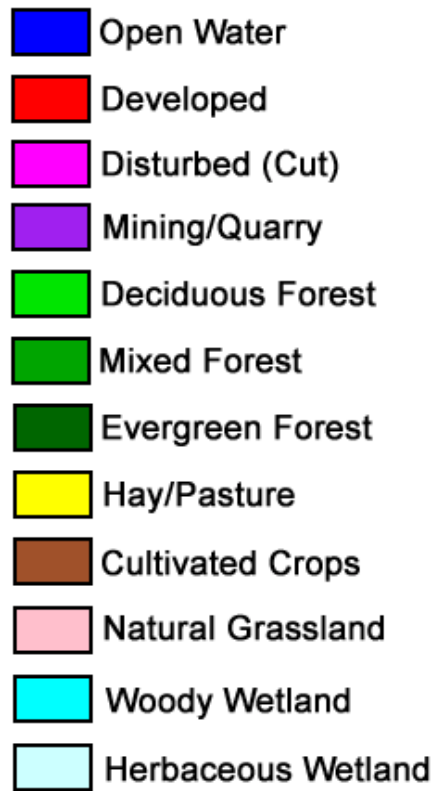
2020

2050



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



1992

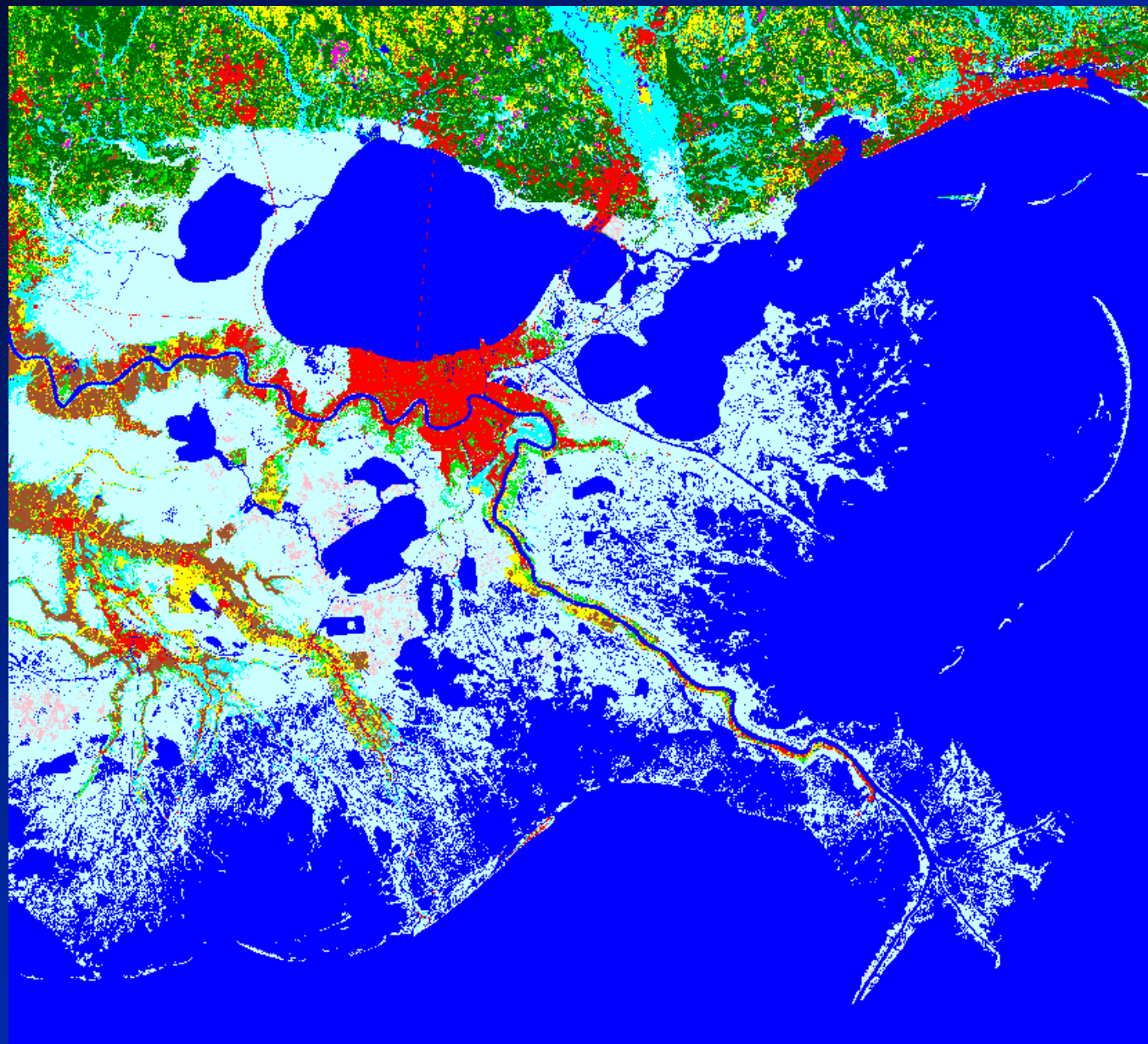
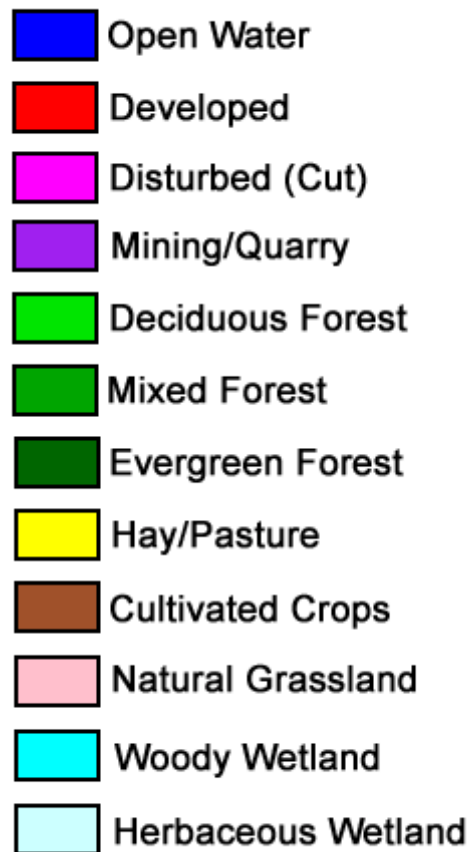
2020

2050



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1992 to 2050 Projected LULC Change: New Orleans area

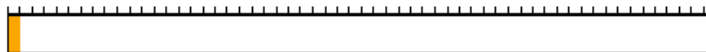


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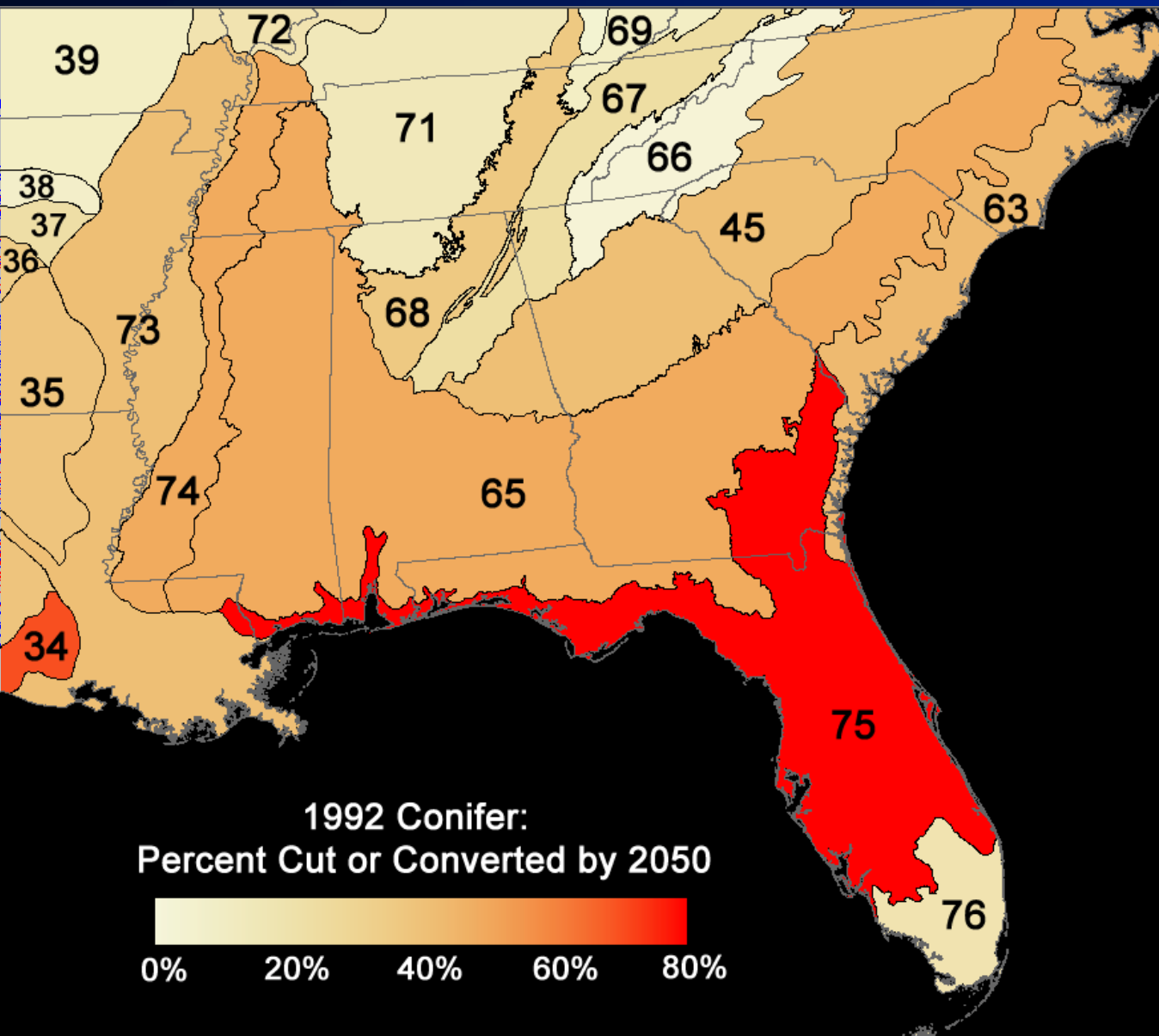
1992

2020

2050



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



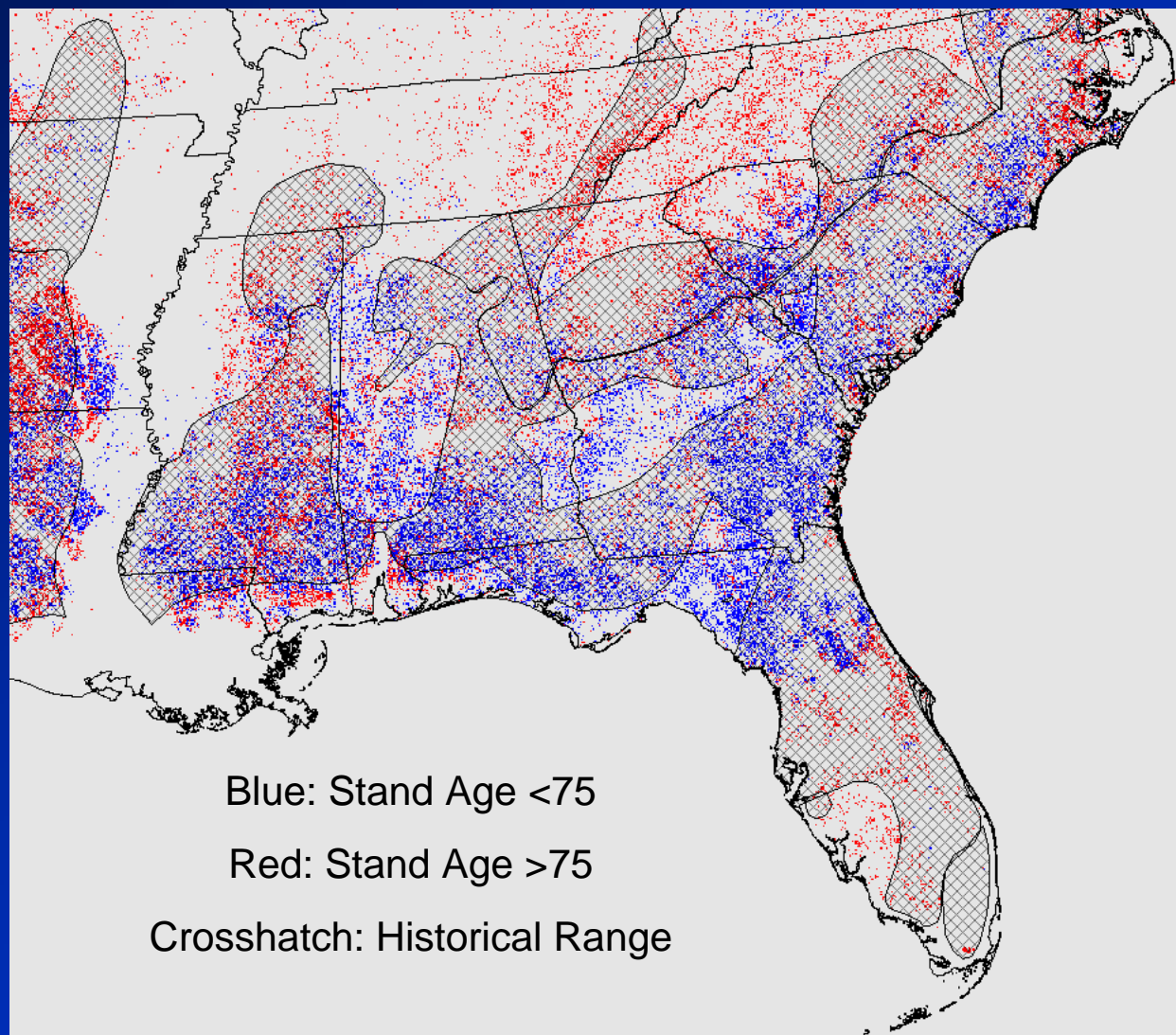
Red-cockaded Woodpecker – Conifer Stand Age

RCW Family Clusters, 1990-1994

State	Ownership			
	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

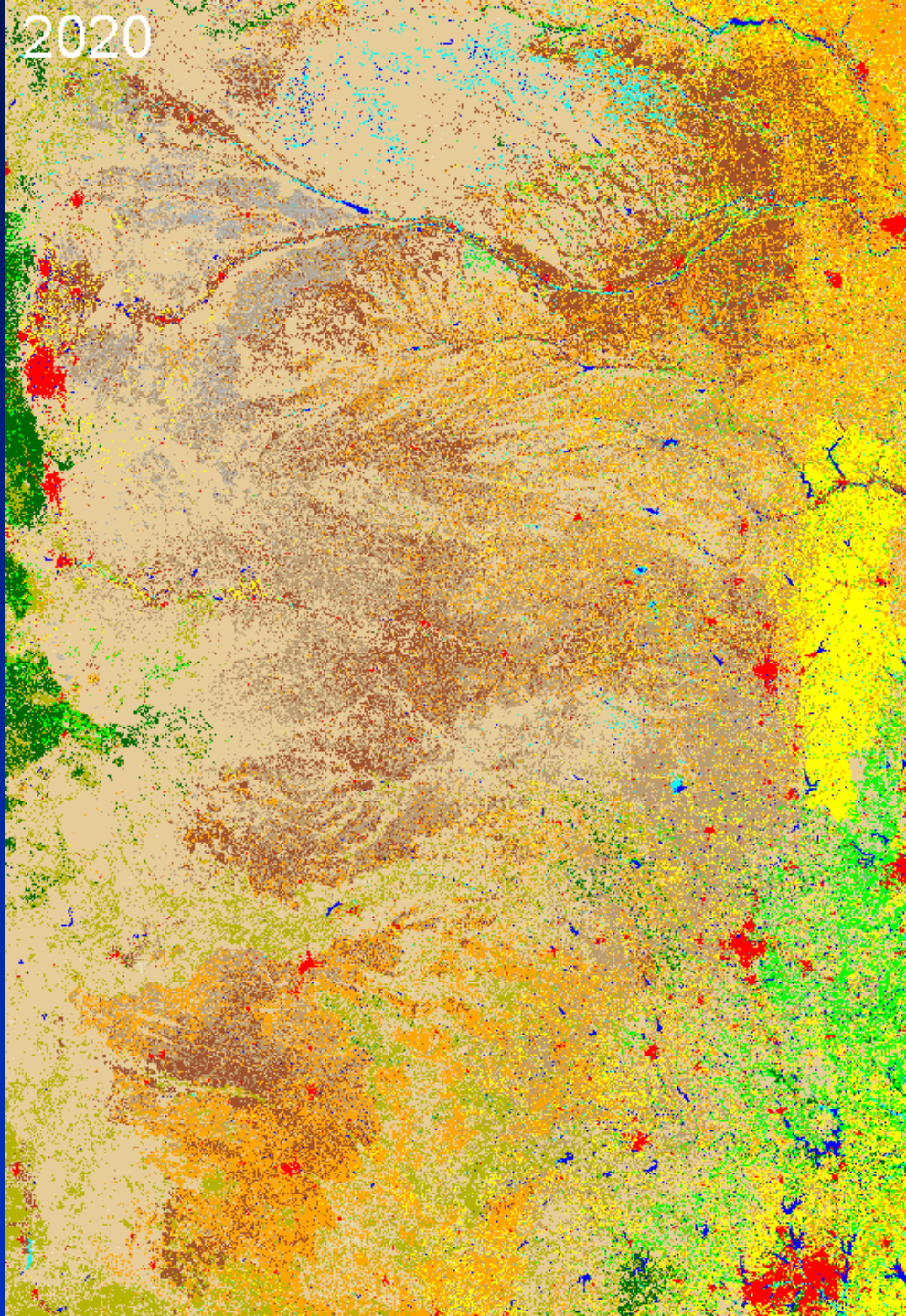
Projected 2050 Conifer Stand Age and Historical RCW Range



USGS EROS Data Center

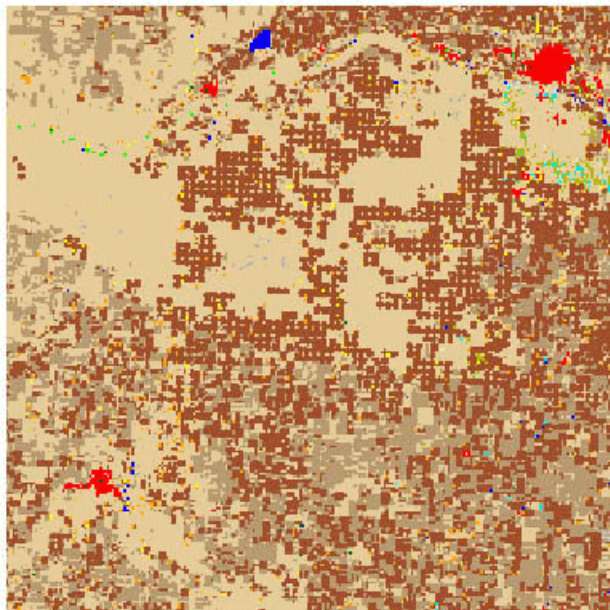
Great Plains -- 1992 to 2020

Change (Agriculture Expansion Scenario)

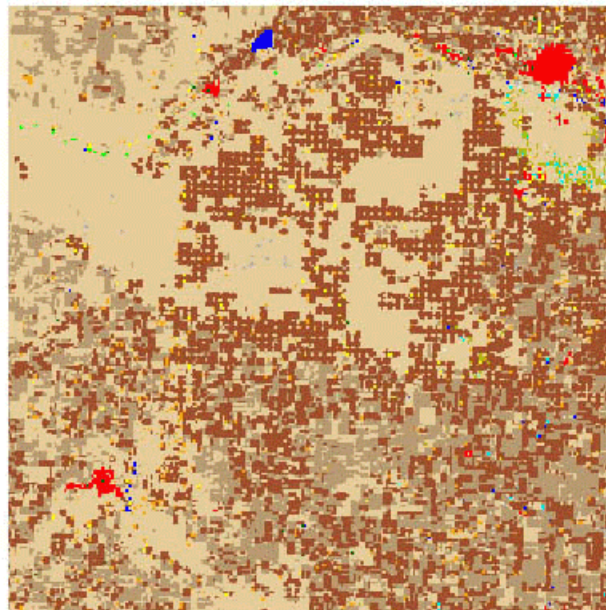


Scenario Comparison -- SW Kansas

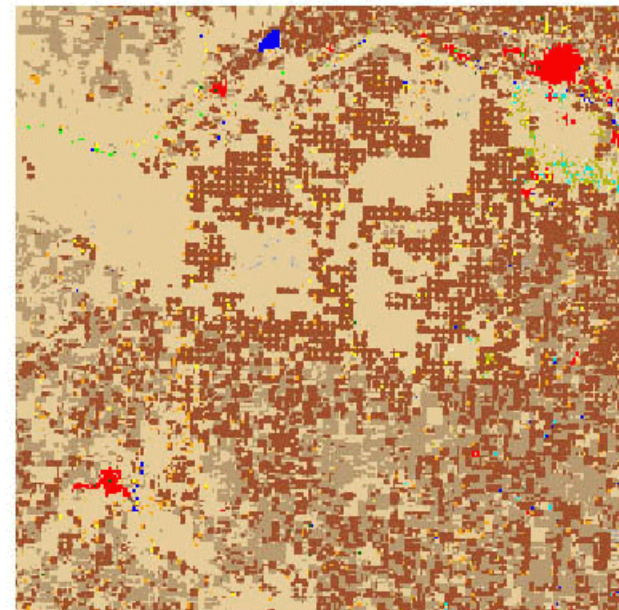
**Scenario 1
1992**



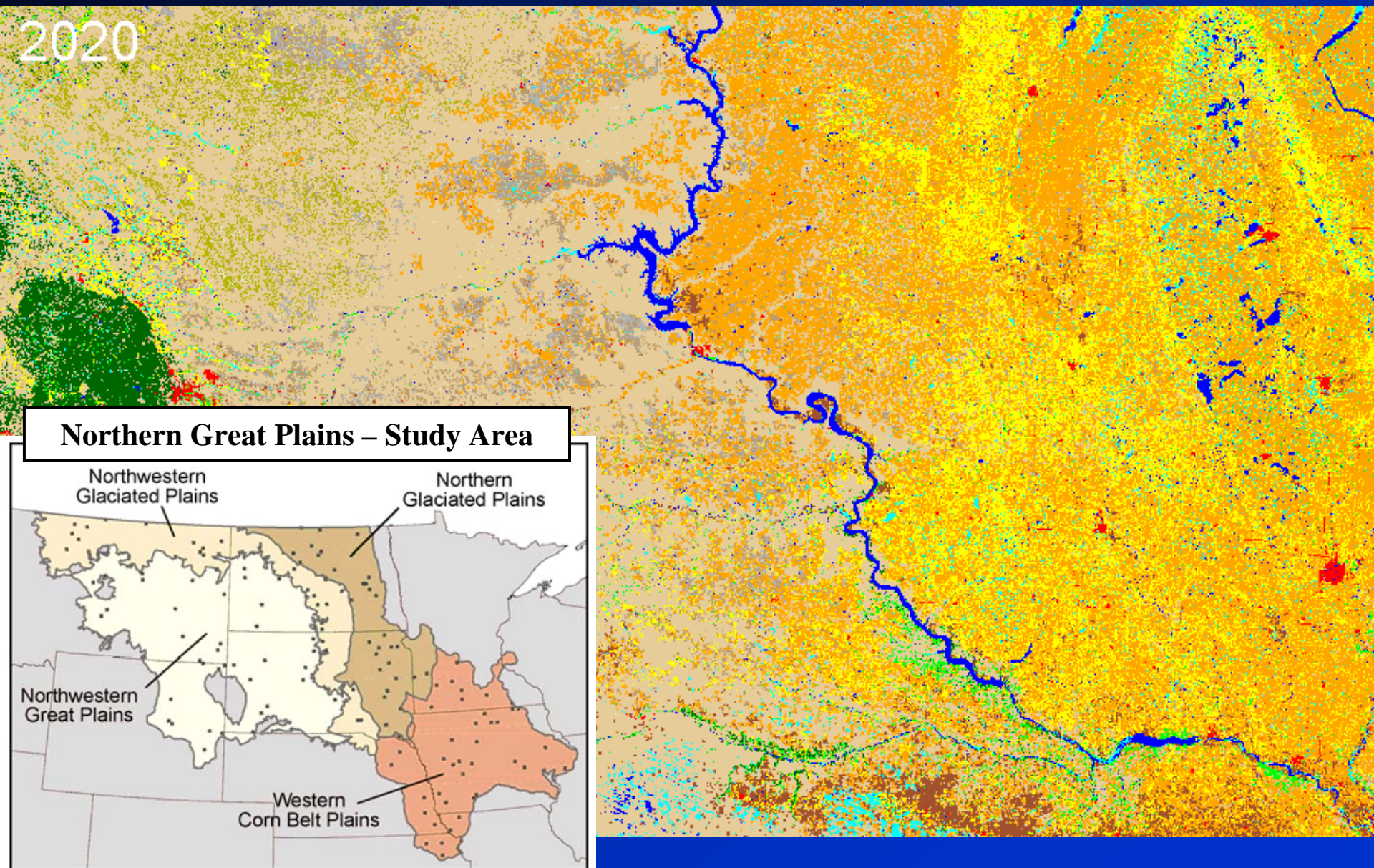
**Scenario 2
1992**



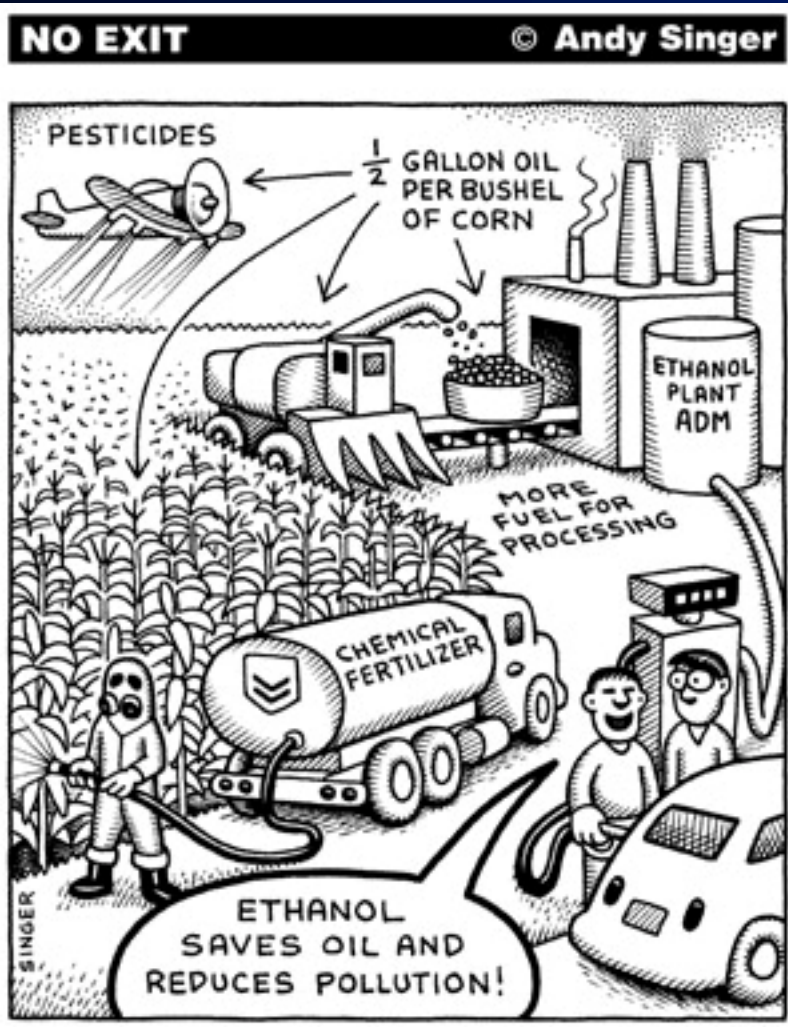
**Scenario 3
1992**



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.

Northern Great Plains Biomass for Biofuel:

Key Research Questions

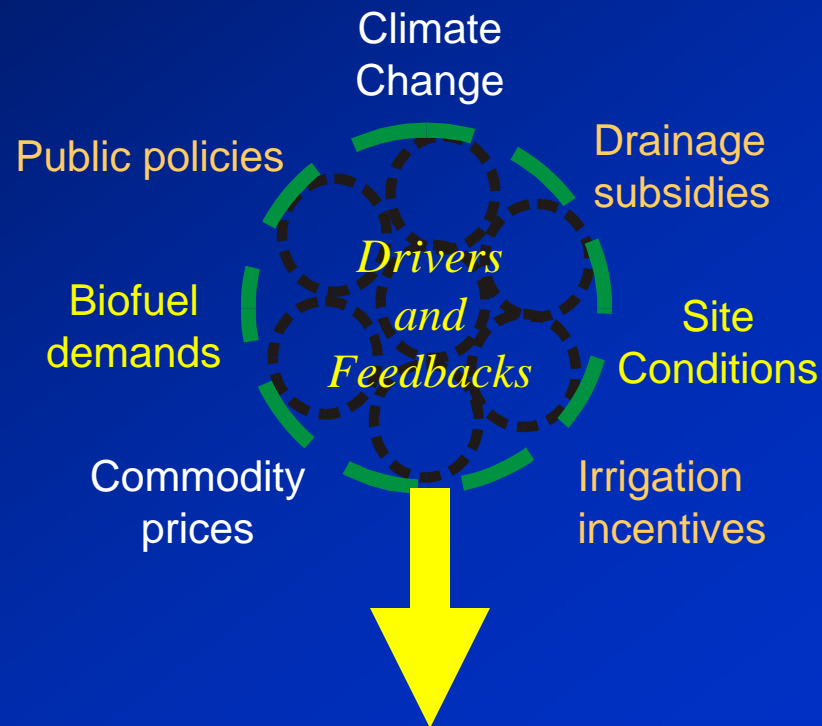
- What landscape patterns are likely to result from an expanded biomass-for-biofuel economy and what are our estimates of the uncertainties?
- What are the environmental consequences?
- What are the full economic costs and benefit of biomass production for energy, including agricultural sector profitability?
- 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

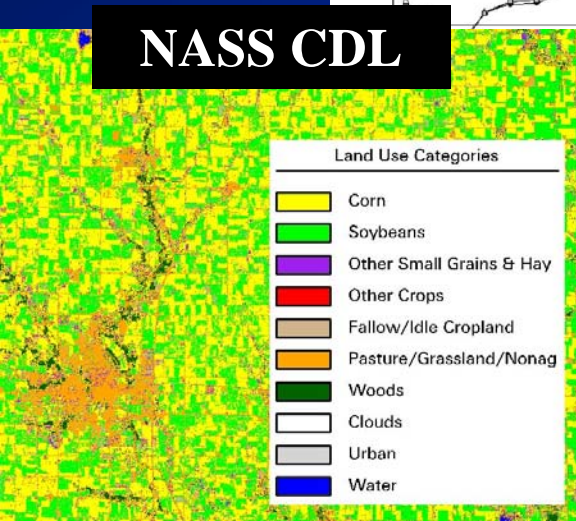
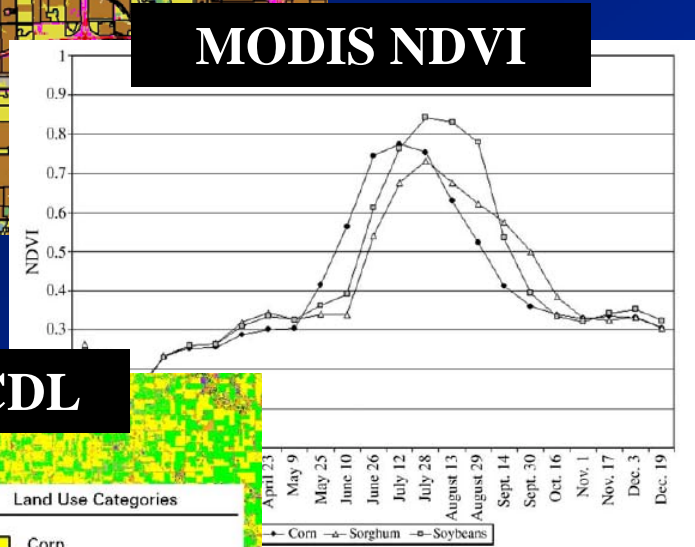
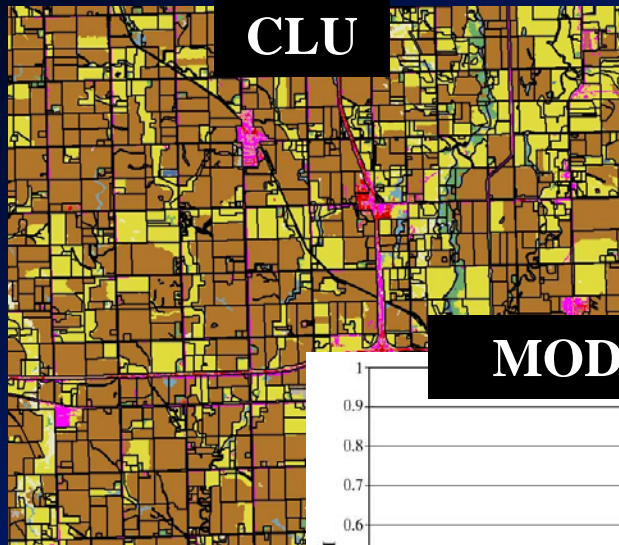
FY2008 development: DEMAND

- 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



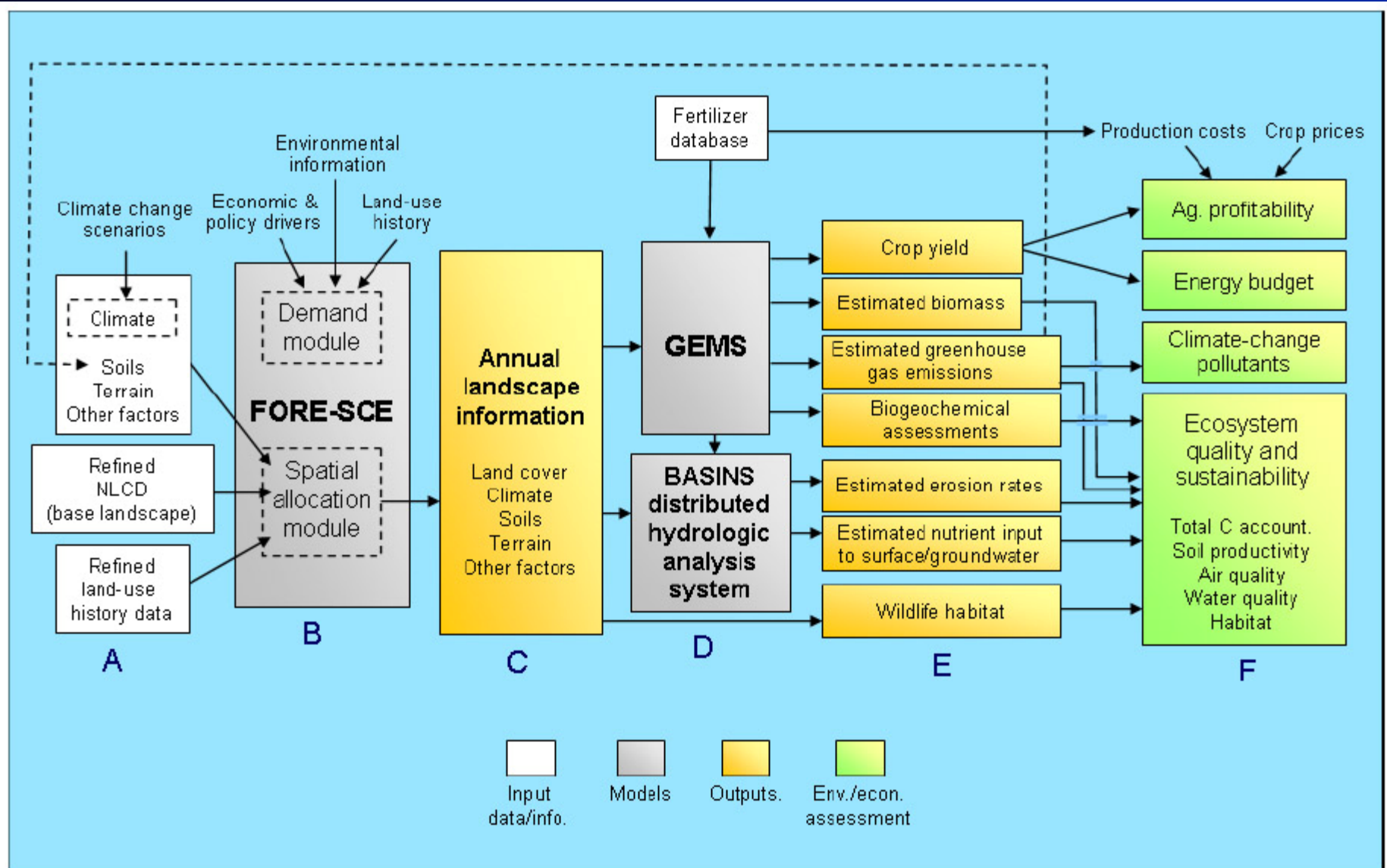
Land Cover	Hectares
Corn	18,500,000
Soybeans	12,200,000
Switchgrass	6,194,000
Hay/Pasture	23,529,000
Etc.	Etc.

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?