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

Research Hypothesis: Land use and land cover changes are significant forcing factors for modifying land surface hydrology and regional weather and climate variability.

Lou Steyaert, NASA LCLUC Science Team Meeting, Jan 11-13, 2005

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Project Team

- PI: Tom Loveland, USGS "land data; project design"
- Co-Is: Lou Steyaert, USGS "land data; LSP; validation"
  Roger Pielke Sr., CSU "model experimental design"
  Chris Hiemstra, CSU "model simulations; ecology"
  Darrell Napton, SDSU "regional trend forcing factors"
  Terry Sohl, USGS "land use forecasts; validation"
  Kristi Sayler, USGS "LU forecast model; land data"

Collaborator: Bob Knox, NASA/GSFC "eastern forest ecology"

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Presentation Overview

- Science Questions and Project Objectives
- Approach
- Ongoing Contributing Research Activities

- 2004 Results
  -- dataset development
  -- land use change forecast modeling
- 2005 Plans

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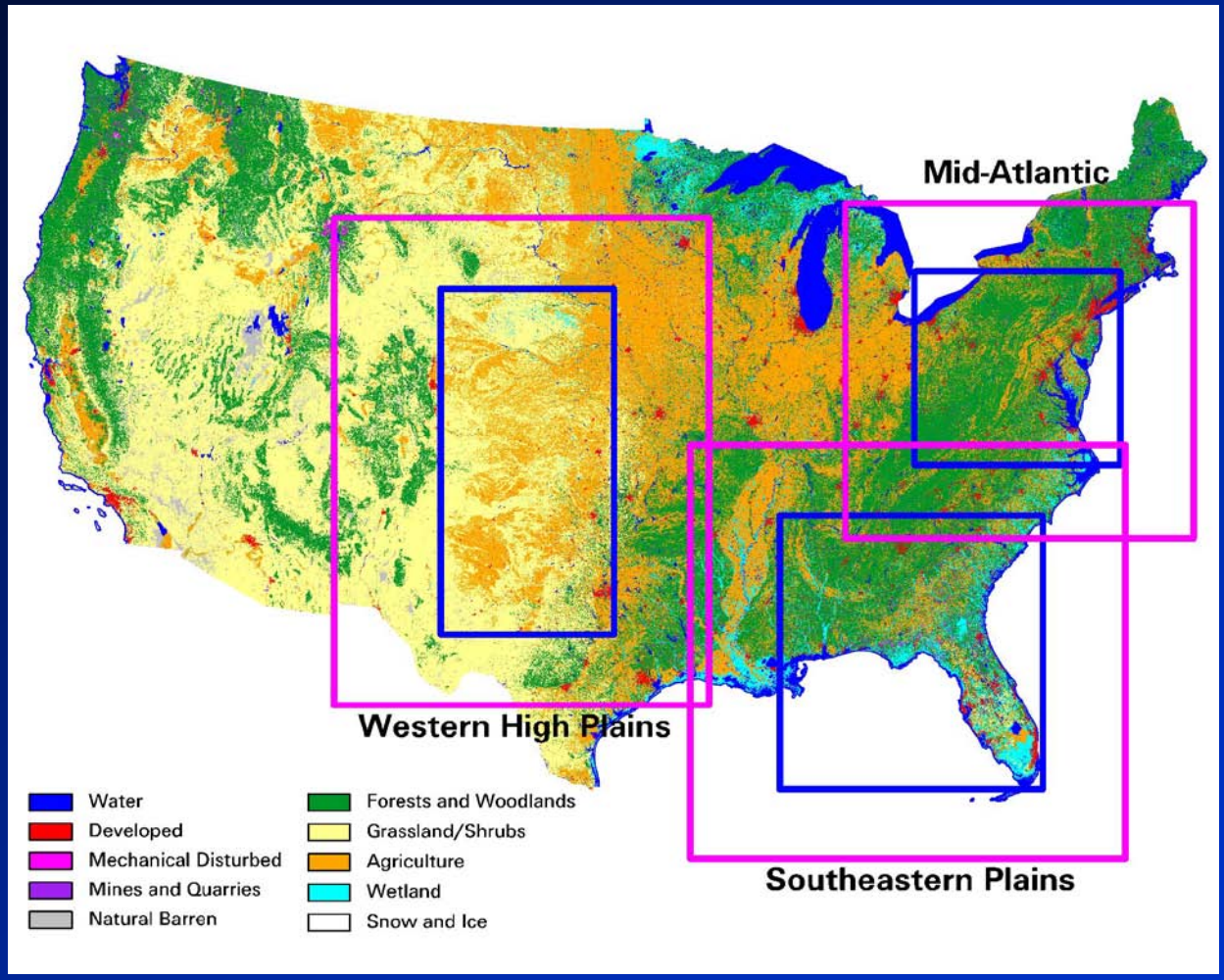
Study Areas



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Objectives

1. What are the LULC characteristics (i.e., types, extent, biophysical properties and spatial configuration) of the project study areas for the following periods: pre-European settlement, 1920, and 2000?
2. Based on current rates, characteristics, and drivers of change in each study area, what are the likely land cover patterns and biophysical properties for 2020?
3. *What is the impact of LULC change on land surface hydrology and regional weather and climate variability?*
4. What is the feedback between future LC patterns and regional weather and climate variability, and how do the feedbacks affect the vulnerability of each region to drought, flooding, severe storms, or other stresses?

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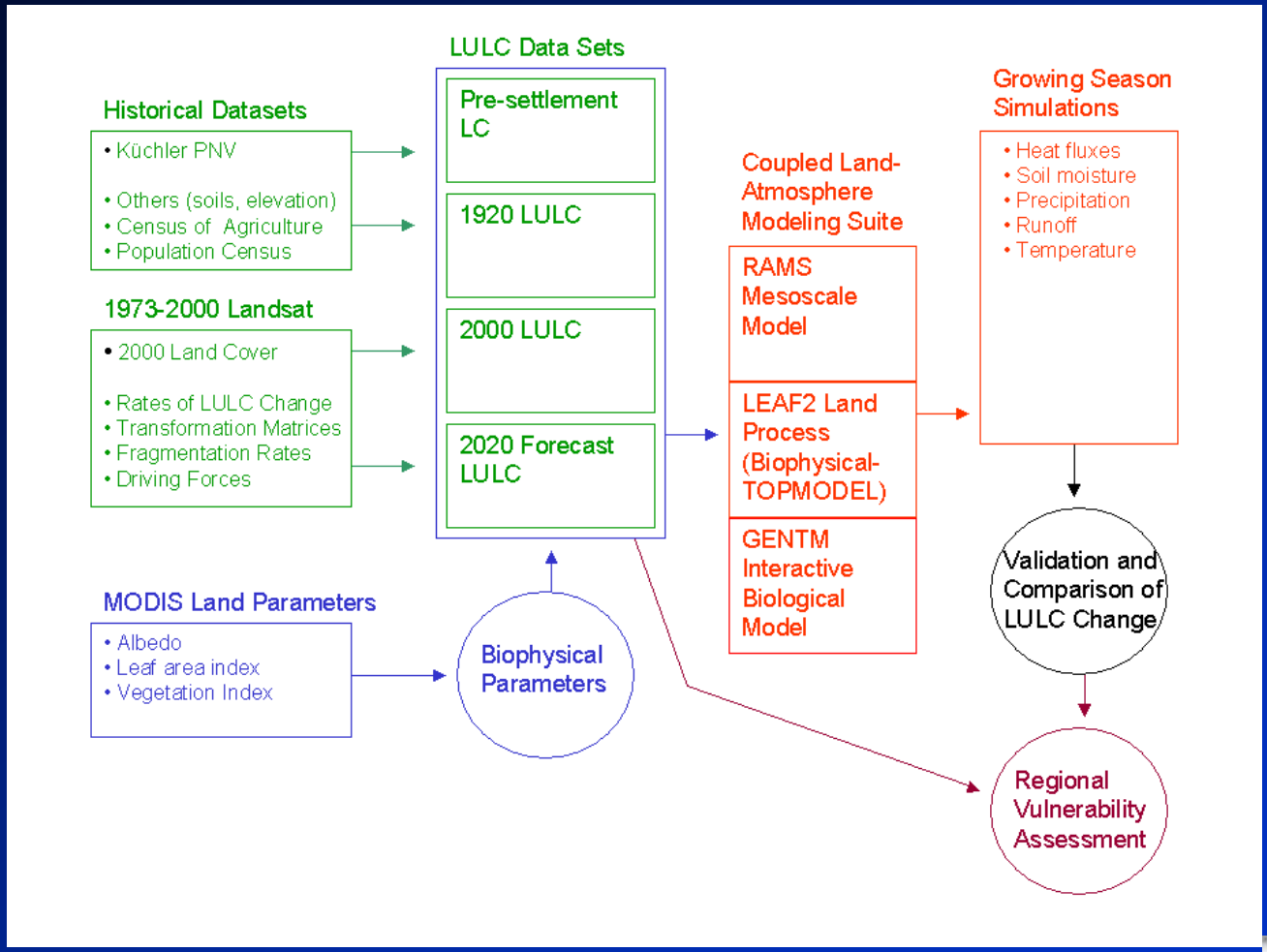
Approach



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Contributing Research Activities

- Regional Land Cover Change Modeling (CSU-USGS)
- Reconstructed Land Cover Data (USGS-GSFC)
- USGS Land Cover Trends (USGS-SDSU-NASA-EPA)

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Potential Consequences of Land Cover Change on Regional Weather and Climate Variability:

Reconstructed Land Cover History and Landsat-Derived Land Cover Datasets for Regional Atmospheric Modeling (RAMS) at Colorado State University (CSU) "Pielke Group"

Focus (1996-2004): South Florida and Chesapeake Bay Regions

R. Pielke Sr., C. Marshall, R. Walko, P. Vidale, J. Eastman, L.Steyaert, R. Knox, D. Willard

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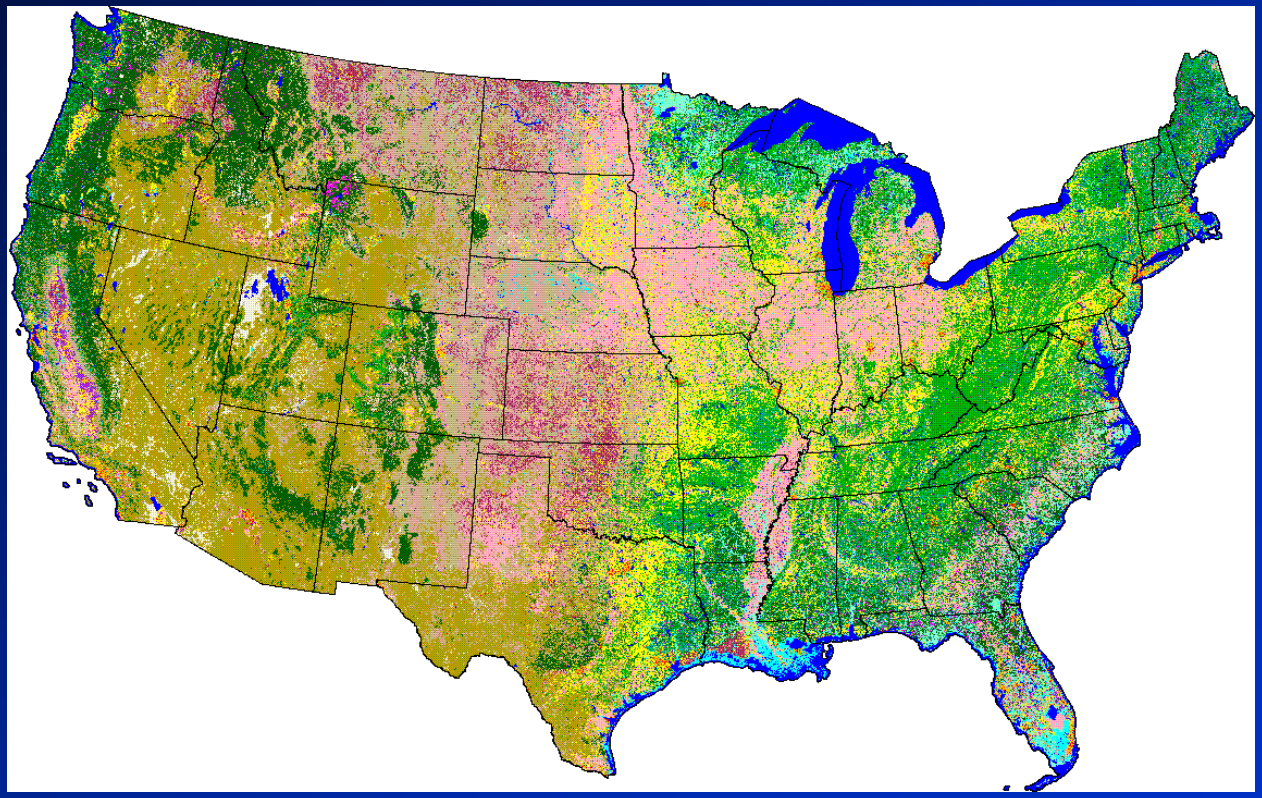
USGS National Land Cover Dataset (NLCD)

Derived from 1992/93 Landsat TM: Seamless 30-m Dataset with 21 Land Cover Classes for the Conterminous United States



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Vogelmann et al. (2001)

South Florida LCLUC Effects Study:

(illustrates the approach)

- Reconstructed pre-1900 Natural Vegetation Scenario
- Tailored Current LCLU Data from NLCD and GAP Datasets Derived From Landsat TM by USGS
- Used RAMS/Leaf-2 with Heritage Biophysical Parameters Adapted for Mean Hydro-period Estimate of Wetlands
- Conducted Warm and Winter Season Simulations.

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Source: Marshall et al. (2004a, b)

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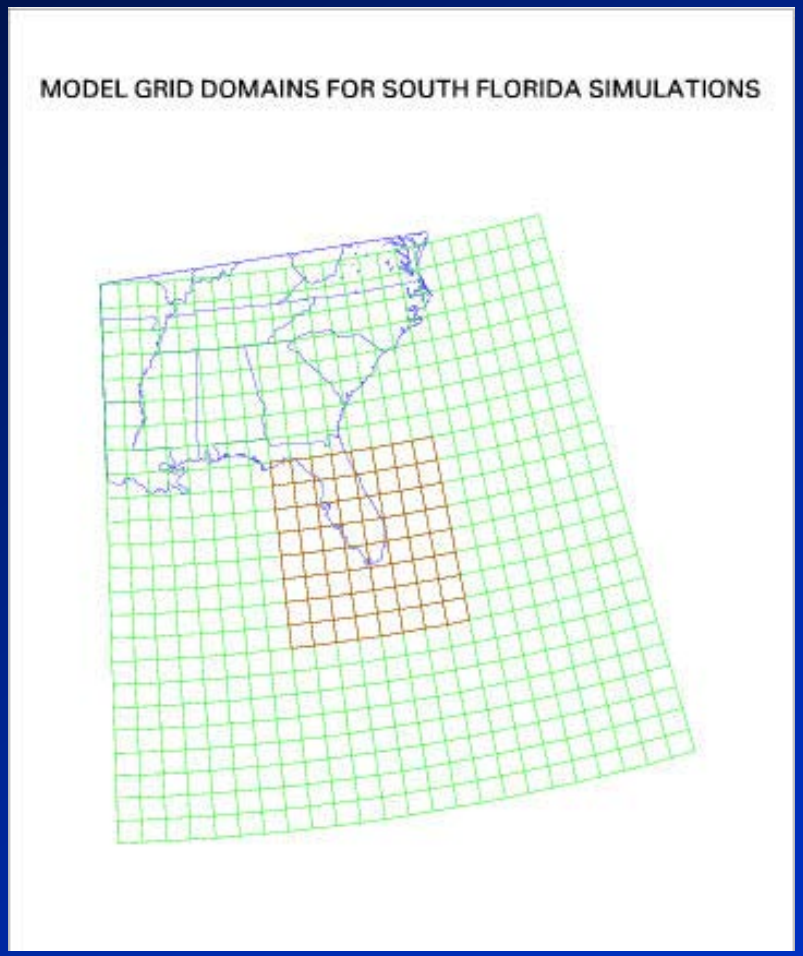
Nested Grids for CSU Simulations

Source: Marshall et al. (2004a, b)



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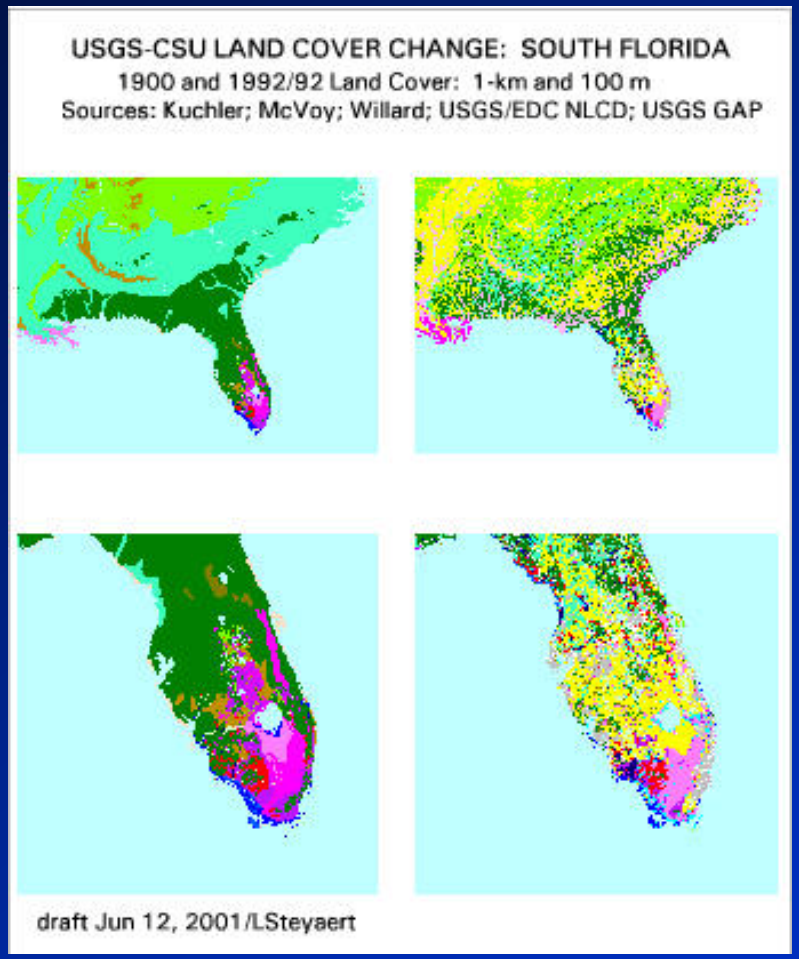
Nested Grid Land Cover Data



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Estimating Rates, Causes, and Consequences of Regional and National Land Cover Change

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U.S. Land Cover Trends

- **Determine the spatial, temporal, and sectoral variability of Conterminous United States land cover change from 1973 to 2000.**
- **Document the regional driving forces of change.**
- **Assess the local, regional, and national consequences of Conterminous United States land cover change.**

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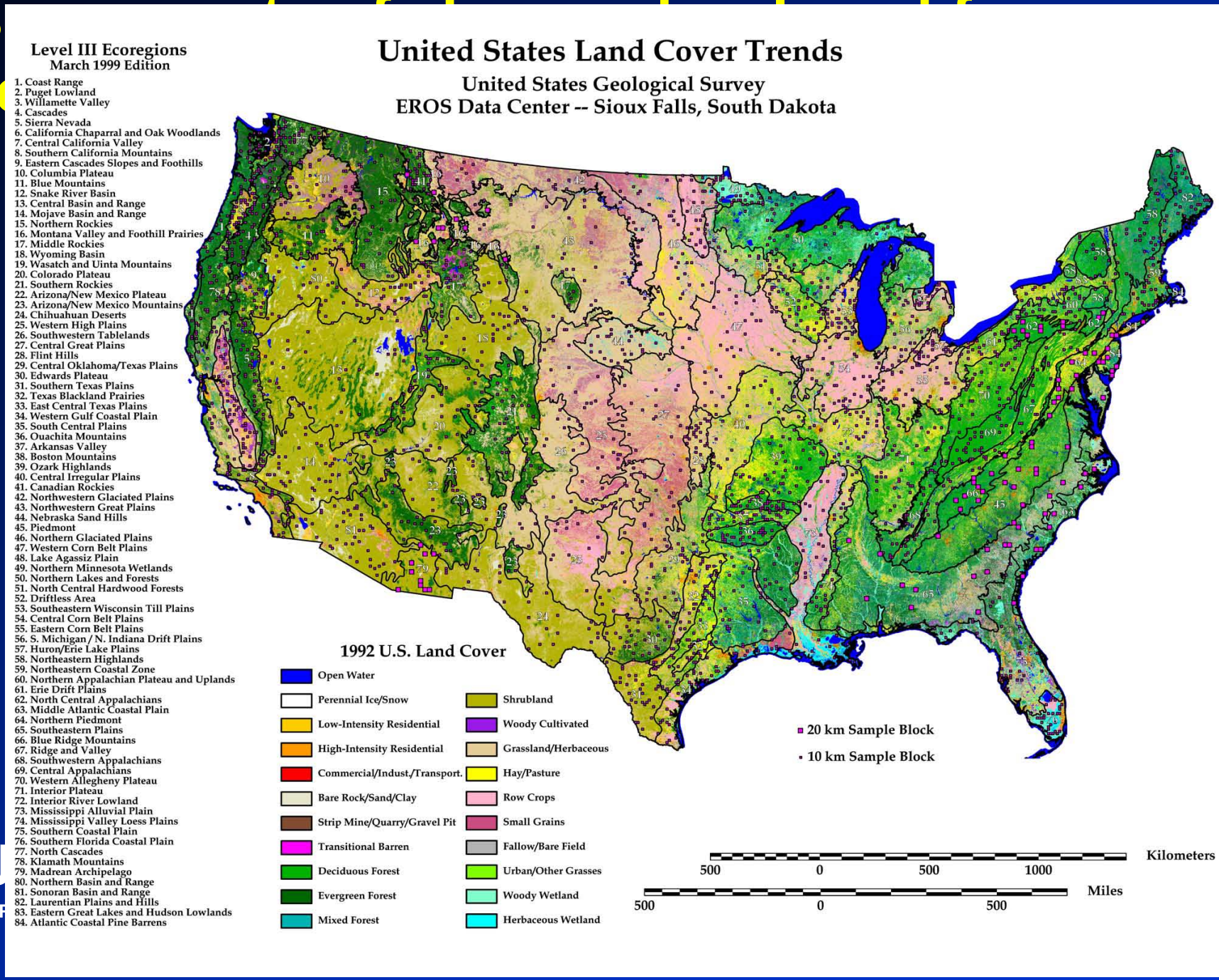
Level III Ecoregions
March 1999 Edition
1. Coast Range
2. Puget Lowland
3. Willamette Valley
4. Cascades
5. Sierra Nevada
6. California Chaparral and Oak Woodlands
7. Central California Valley
8. Southern California Mountains
9. Eastern Cascades Slopes and Foothills
10. Columbia Plateau
11. Blue Mountains
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
United States Land Cover Trends
United States Geological Survey
EROS Data Center -- Sioux Falls, South Dakota
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
500 0 500 1000 Kilometers
500 0 500 Miles

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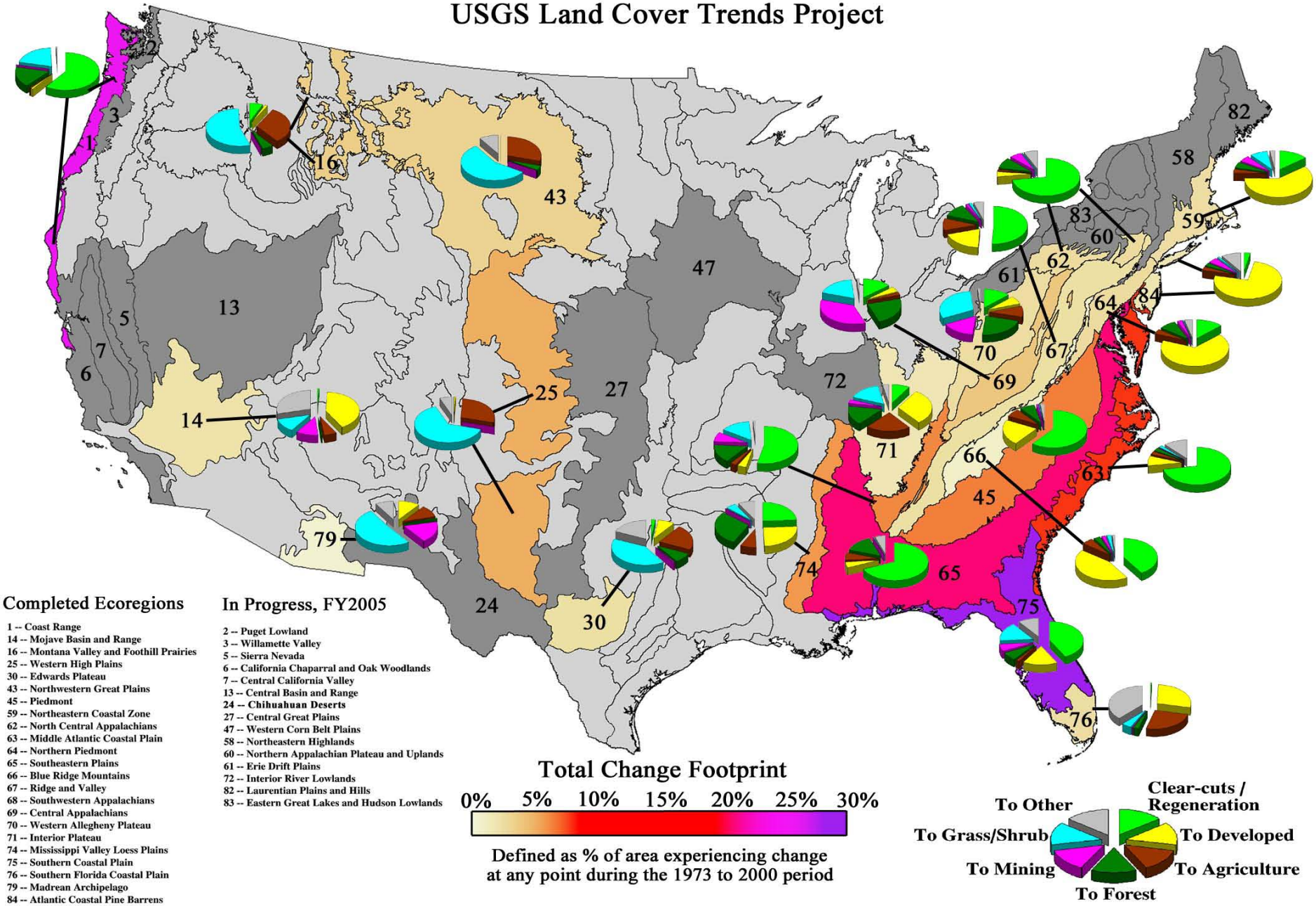
United States Land Cover Change -- 1973 to 2000

USGS Land Cover Trends Project



Completed Ecoregions

1 -- Coast Range
14 -- Mojave Basin and Range
16 -- Montana Valley and Foothill Prairies
25 -- Western High Plains
30 -- Edwards Plateau
43 -- Northwestern Great Plains
45 -- Piedmont
59 -- Northeastern Coastal Zone
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
74 -- Mississippi Valley Loess Plains
75 -- Southern Coastal Plain
76 -- Southern Florida Coastal Plain
79 -- Madrean Archipelago
84 -- Atlantic Coastal Pine Barrens

In Progress, FY2005

2 -- Puget Lowland
3 -- Willamette Valley
5 -- Sierra Nevada
6 -- California Chaparral and Oak Woodlands
7 -- Central California Valley
13 -- Central Basin and Range
24 -- Chihuahuan Deserts
27 -- Central Great Plains
47 -- Western Corn Belt Plains
58 -- Northeastern Highlands
60 -- Northern Appalachian Plateau and Uplands
61 -- Erie Drift Plains
72 -- Interior River Lowlands
82 -- Laurentian Plains and Hills
83 -- Eastern Great Lakes and Hudson Lowlands

Total Change Footprint

0% 5% 10% 15% 20% 25% 30%

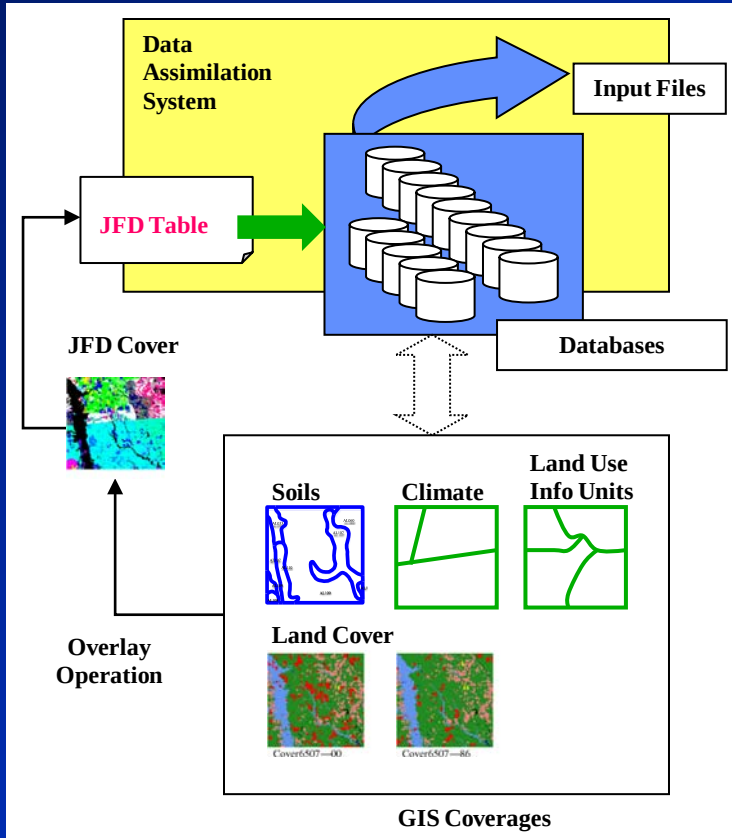
Defined as % of area experiencing change
at any point during the 1973 to 2000 period

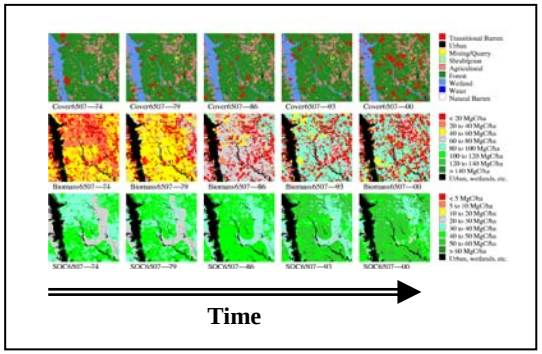
Regional Carbon Trends

Spatially-Explicit Biogeochemical Modeling

The General Ensemble biogeochemical Modeling System (GEMS) was developed to simulate carbon dynamics within each of the sample blocks. It consists of

- ✓Encapsulated ecosystem biogeochemical model (CENTURY).
- ✓Data assimilation system
- ✓Input/output processor
- ✓User-friendly GUI





Spatial and Temporal Changes of Land Cover, Carbon Stock in Vegetation and Soils

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2004 Progress

- Organized Team: Apr and Oct 2004 Team Meetings
- Added CSU RAMS Modelers Sep ’04 (Pielke, Hiemstra)
- Finalizing Reconstructed Eastern U.S. LCLU/Bioparam Data with Manuscript in Progress (Steyaert and Knox)
- Finalizing Land Cover Data for “Western High Plains”
- Initiated Analysis of Selected MODIS Land Products
- Developed and Tested Pro-type Land Use Model

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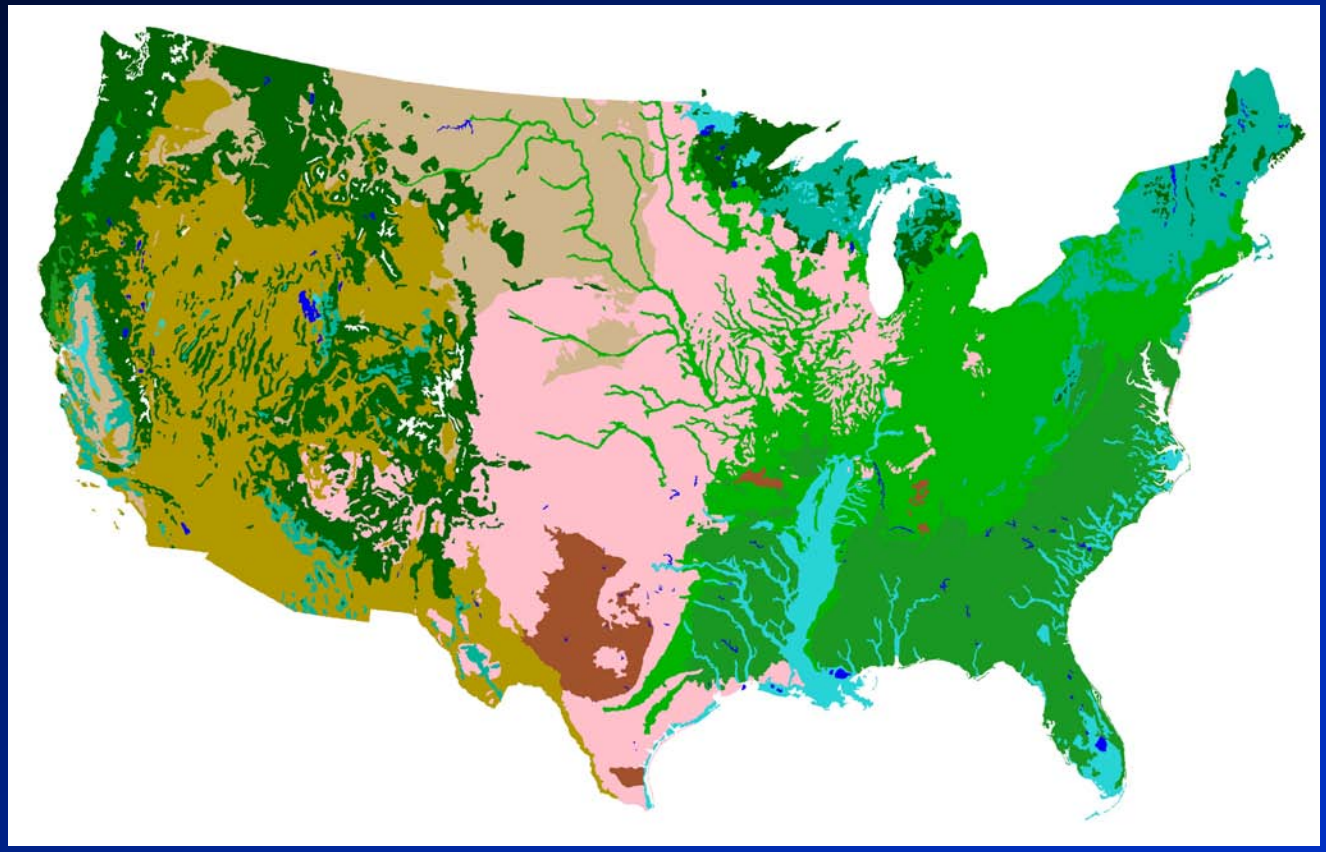
Kuchler PNV as Proxy for Early 1600s:
Remapped to VEMAP Vegetation Classes



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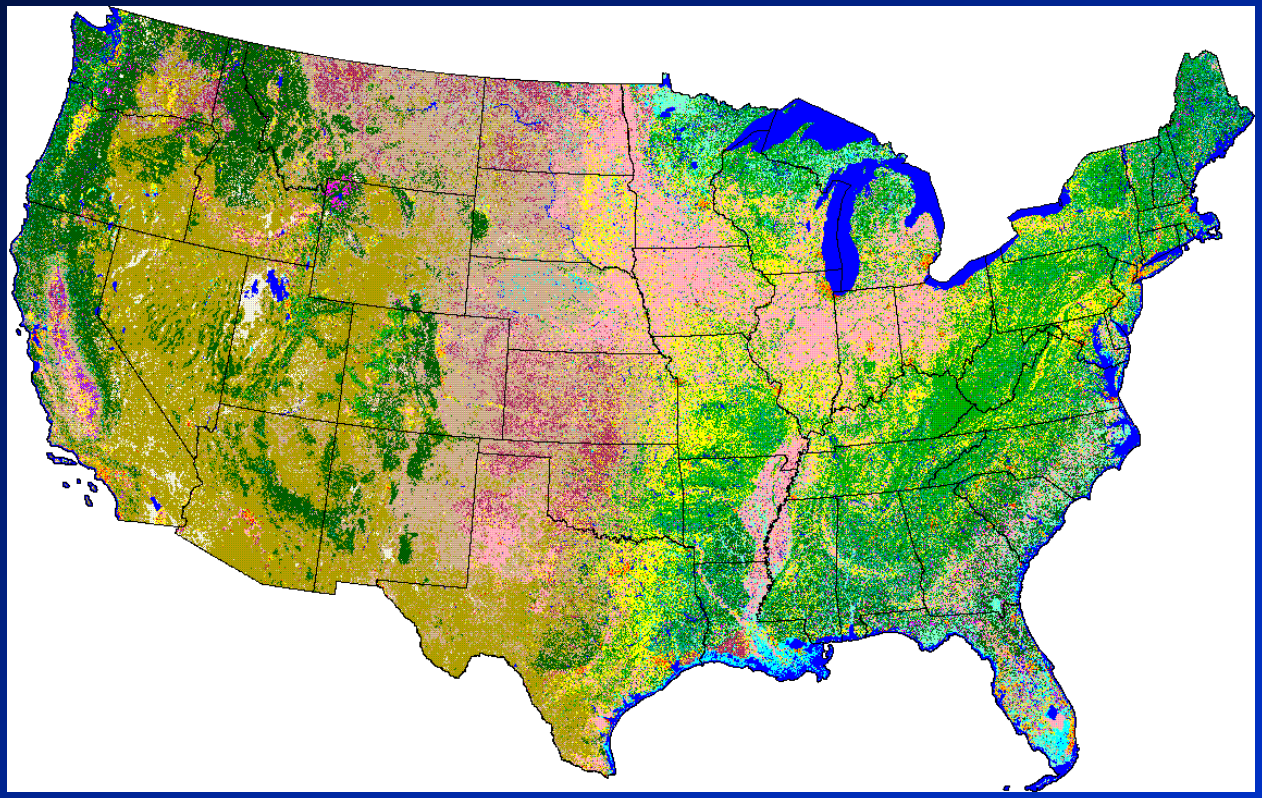

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Vogelmann et al. (2001)

Reconstructed Land Cover History-Biophysical Parameter Dataset for the Eastern USA:

Source: L. Steyaert and R. Knox (paper in preparation)

- Eastern Forest Region (Braun, 1950)
- For Water, Energy, and Carbon Studies (~10 km grid)
- Time Slices: early-1600s, 1850, 1920, 1992
- Consistent LC and Biophysical Parameter Classes
- Used Kuchler PNV, Census, Ancillary, NLCD, other…
- Products: Class Fractional Area Layers & Bio-params

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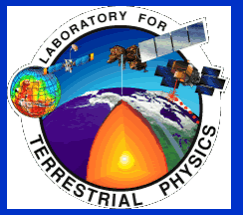
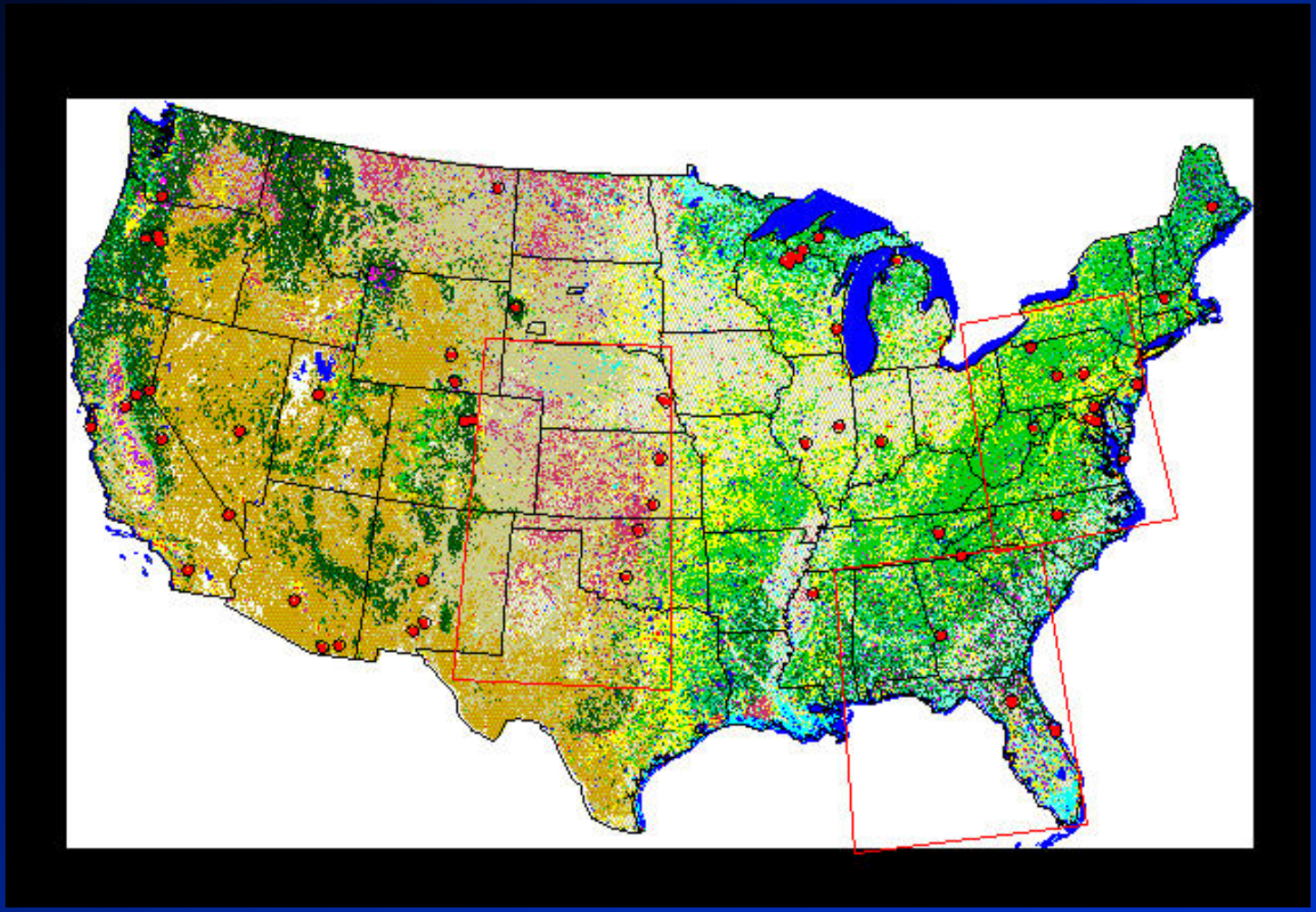


MODIS Land Data Validation Sites with ASCII Subsets at ORNL DAAC for RAMS LSP Analysis



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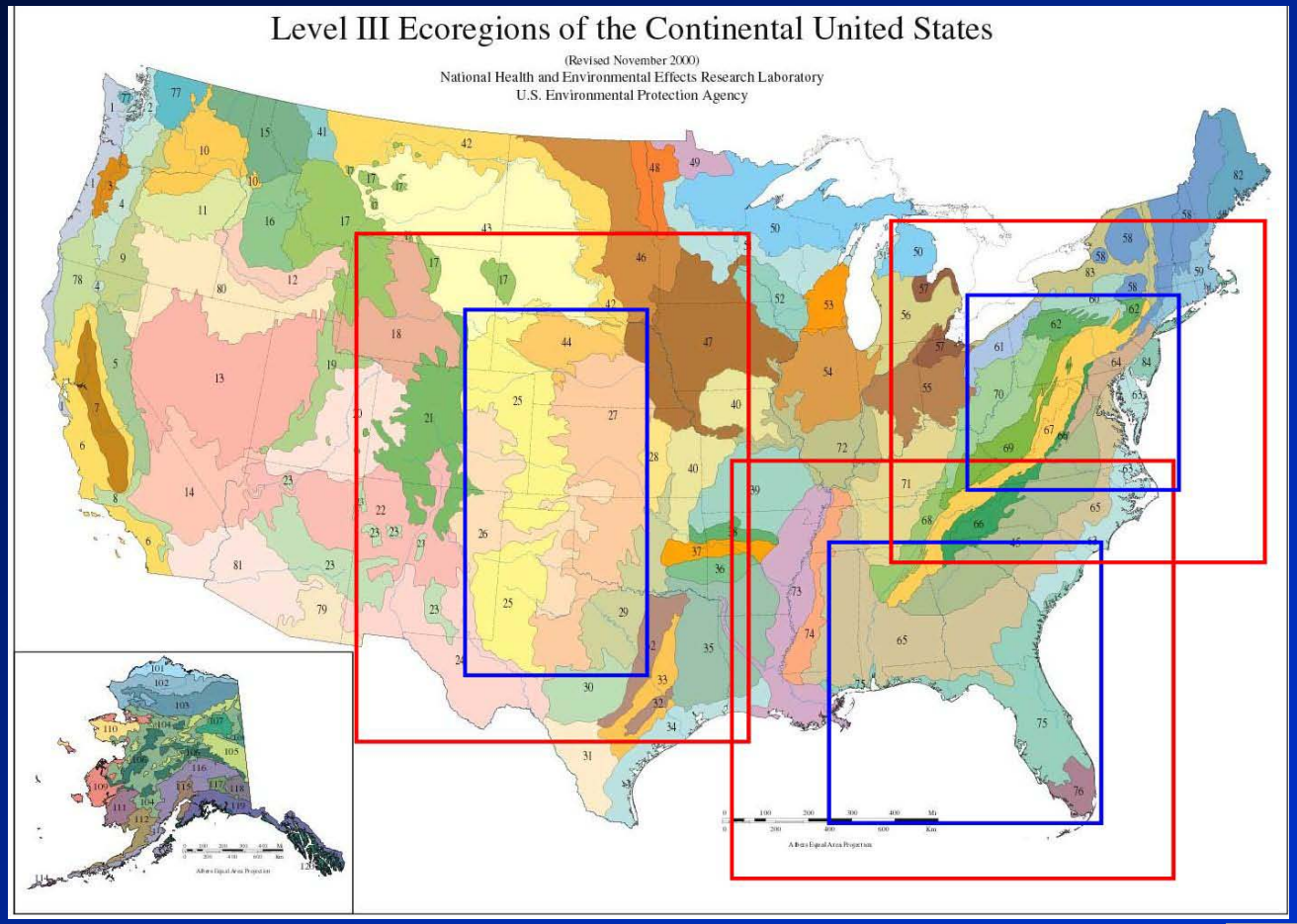
Eco-Region Analysis of MODIS Data:
Albedo, VI, LAI



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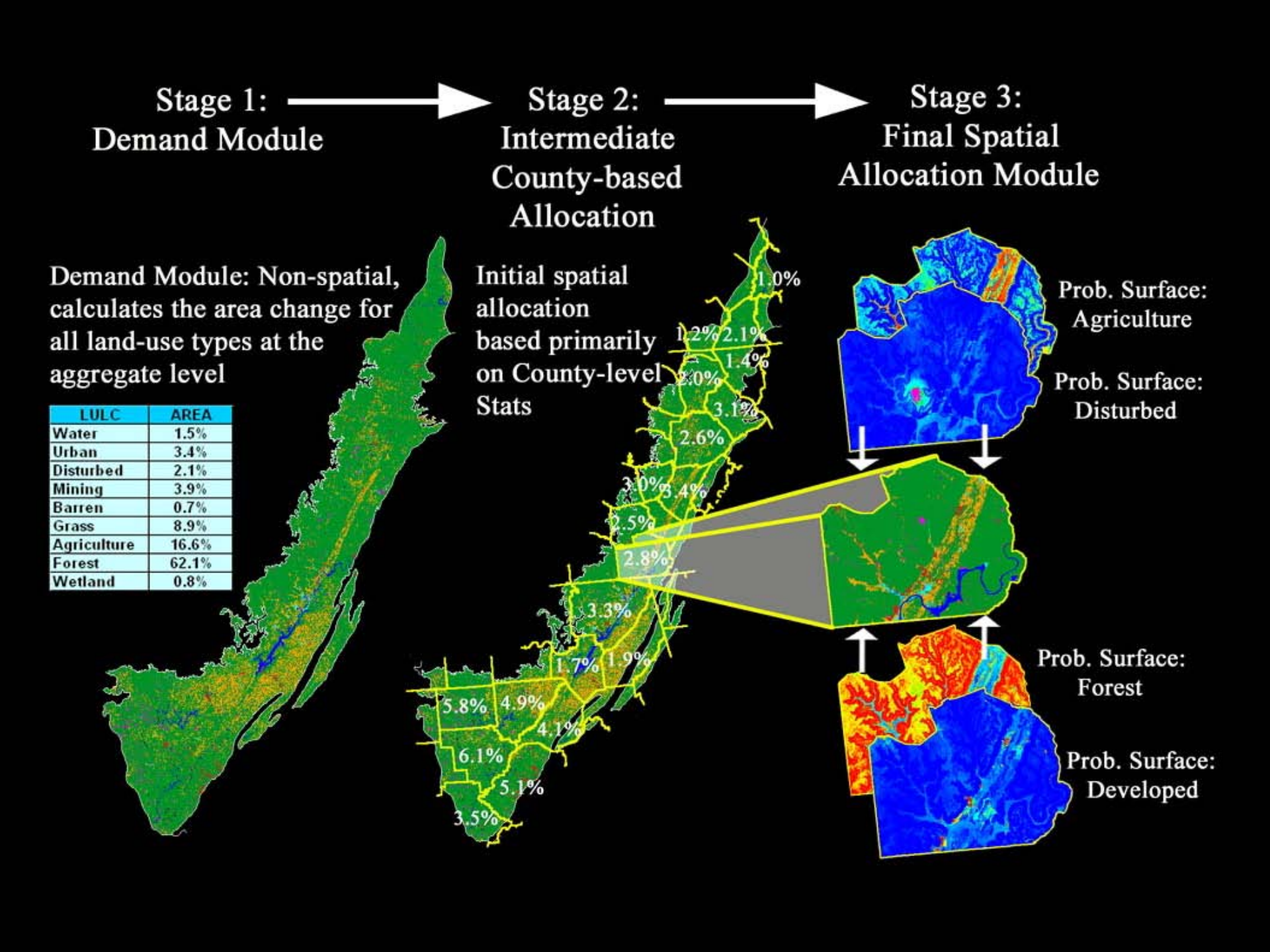
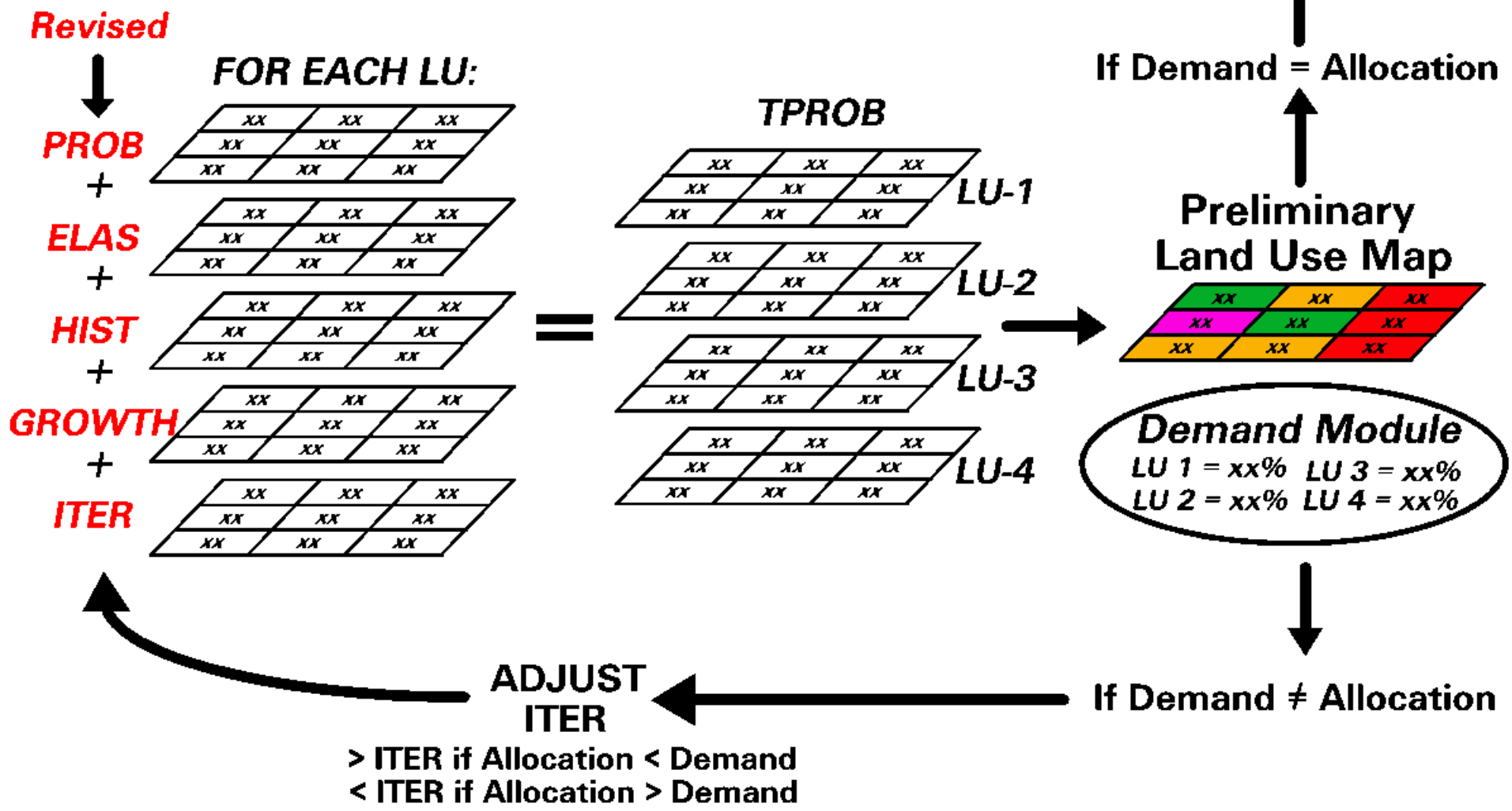
LULC Modeling Techniques
Our Suggested technique

- Suggested technique is similar to the CLUE, CLUE-S, and derivative models as created by Verburg and Veldcamp, at Wageningen Agricultural University in the Netherlands
- Described by Briassoulis as “an integrated, spatially explicit, multi-scale, dynamic, economy-environment-society-land use model”
- CLUE attempts to account for the entire system of complex interactions between historic and present land use, socio-economic conditions, and biophysical constraints
- Fits well with scenario frameworks
- CLUE originally developed for national and continental level applications, CLUE-S adaptation for regional studies
- CLUE uses land use proportions by cell, while CLUE-S uses discrete land use values for each cell

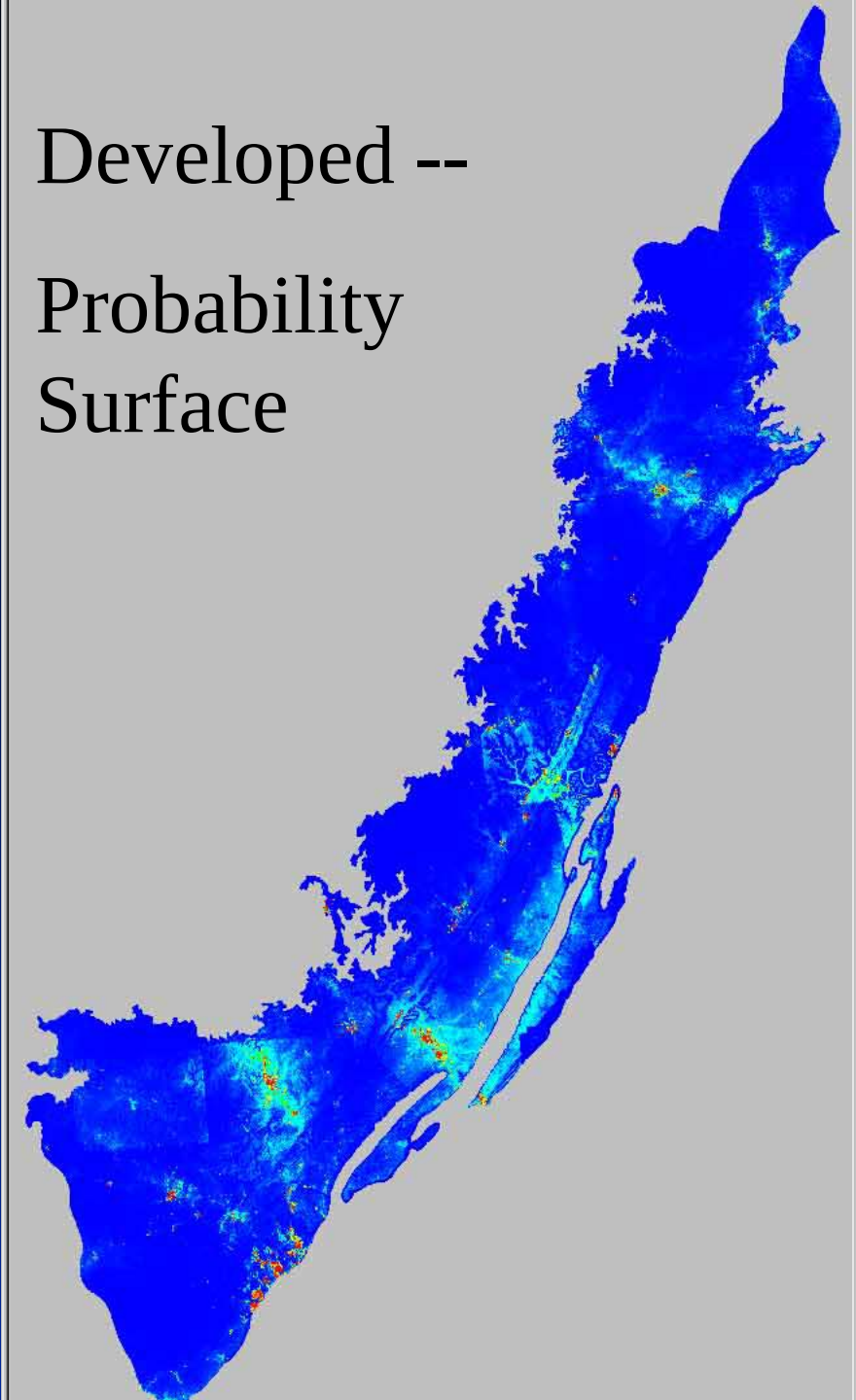

Stage 1:
Demand Module
Stage 2:
Intermediate
County-based
Allocation
Stage 3:
Final Spatial
Allocation Module
Demand Module: Non-spatial, calculates the area change for all land-use types at the aggregate level
LULC AREA
Water 1.5%
Urban 3.4%
Disturbed 2.1%
Mining 3.9%
Barren 0.7%
Grass 8.9%
Agriculture 16.6%
Forest 62.1%
Wetland 0.8%
Initial spatial allocation based primarily on County-level Stats
1.0%
1.2%
2.1%
1.4%
2.0%
3.1%
2.6%
3.0%
3.4%
2.5%
2.8%
3.3%
1.7%
1.9%
5.8%
4.9%
4.1%
6.1%
5.1%
3.5%
Prob. Surface: Agriculture
Prob. Surface: Disturbed
Prob. Surface: Forest
Prob. Surface: Developed

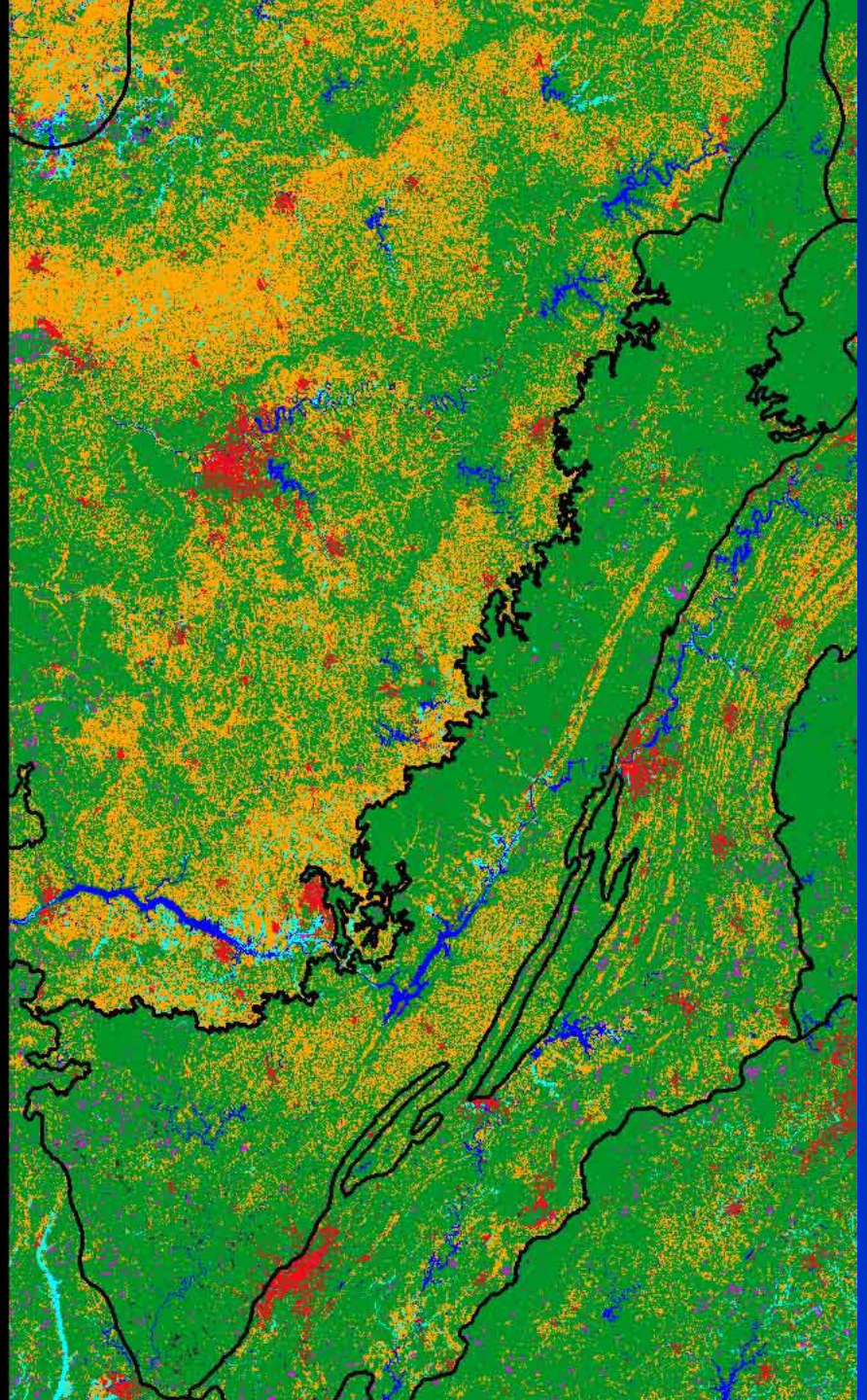
Spatial Allocation
Time t + 2

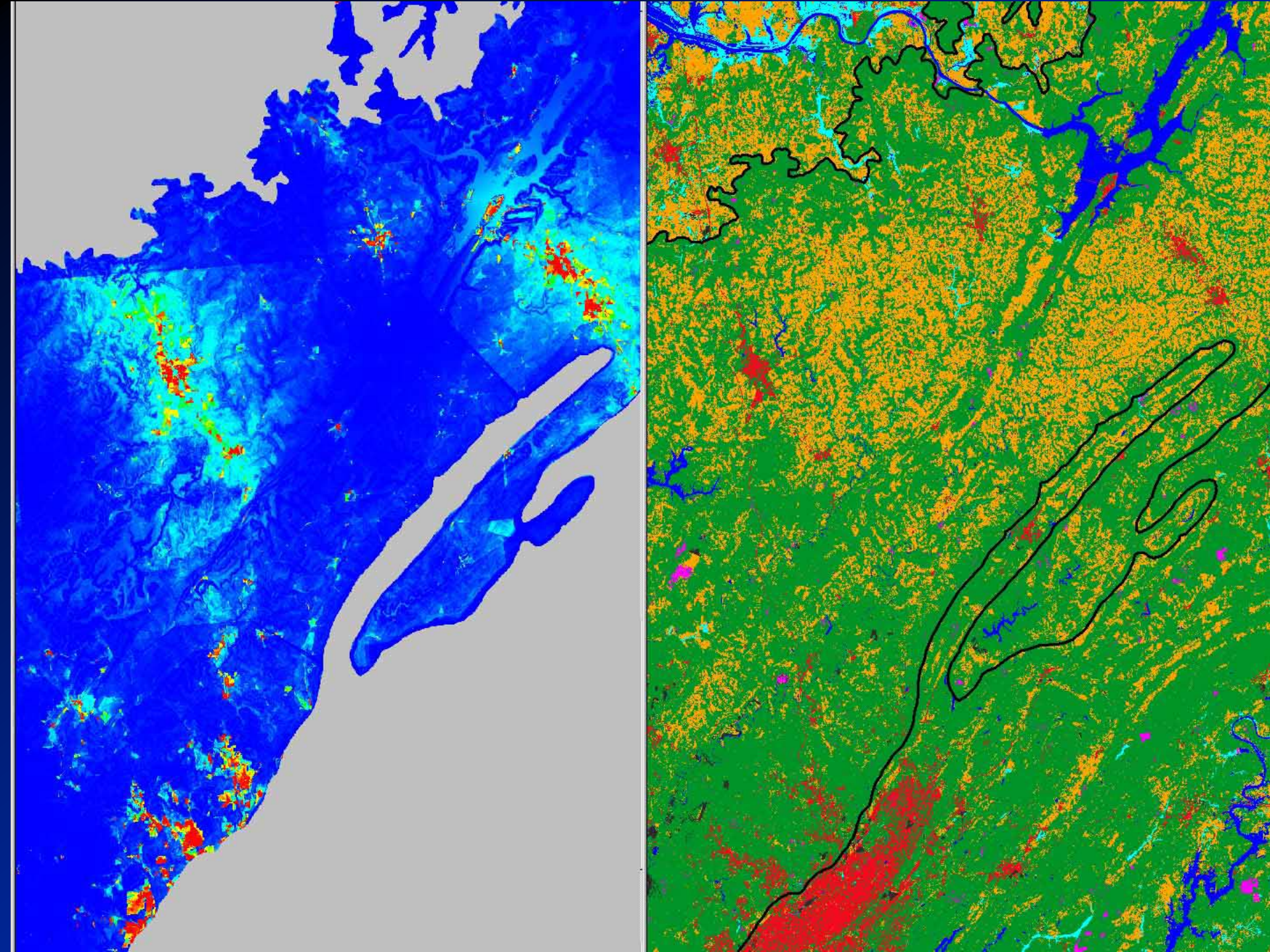


Developed --

Probability Surface







Plans for FY 2005

- Tailor 1600s, 1920, and 1992 Land Datasets for RAMS
- Conduct LCLUC Simulations for Western High Plains (pre-settlement, 1920, 1992) including Sensitivity Tests with Heritage and MODIS LSP
- Test LU Forecast Model for Western High Plains and Conduct CSU RAMS Sensitivity Tests
- Conduct SE Plains Model Simulations
- Begin Model Validation and Assess Effects of LCLUC