Land Cover Trends: Geographic Dimensions of U.S. Regional Change

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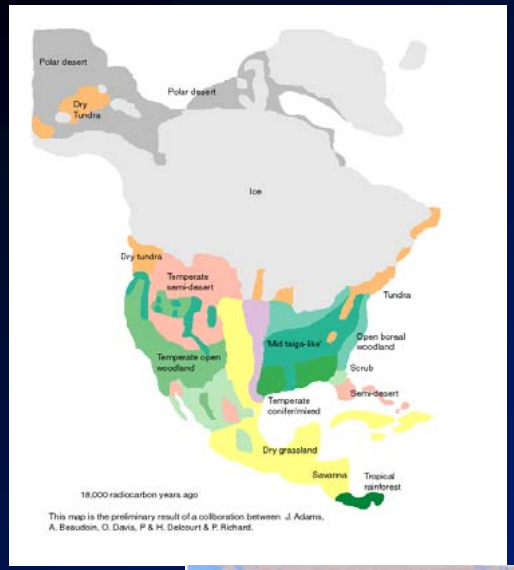
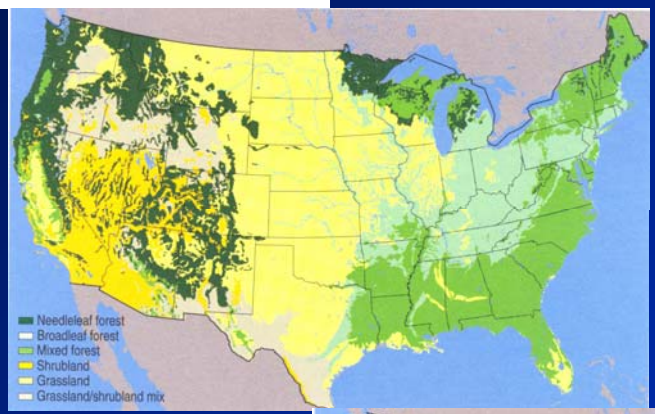
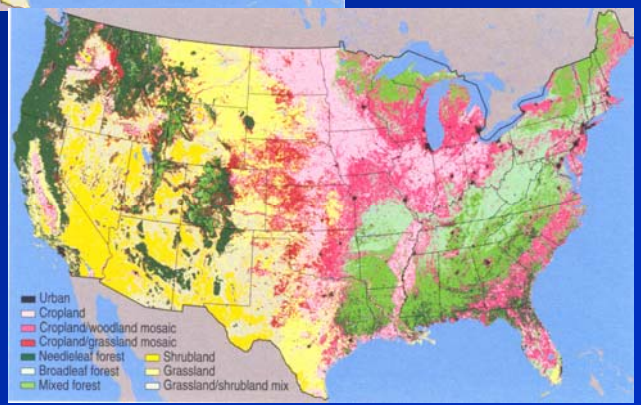
USGS science for a changing world

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



Ecosystems change with time, as do the goods and services they provide





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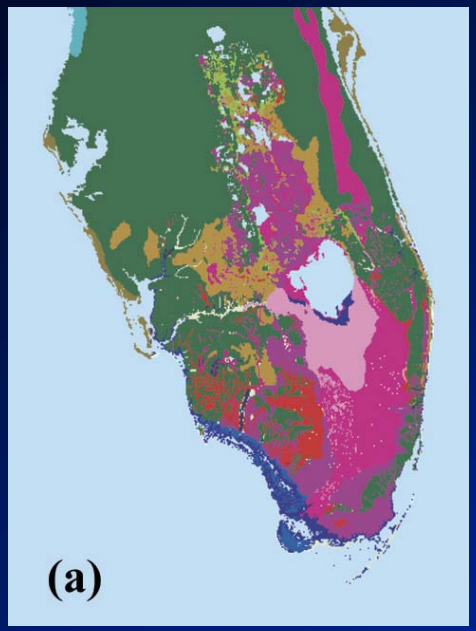
Ecosystem Services

- Maintain hydrological cycles
- Regulate climate
- Cleanse water and air
- Maintain the gaseous composition of the atmosphere
- Pollinate crops and other important plants
- Generate and maintain soils
- Store and cycle essential nutrients
- Absorb and detoxify pollutants
- Provide beauty, inspiration, and recreation

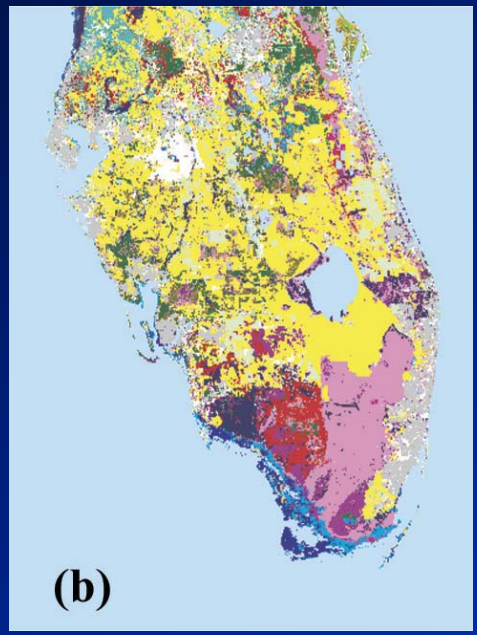
Ecosystem Goods

- Food
- Construction materials
- Medicinal plants
- Wild genes for domestic plants and animals
- Tourism and recreation

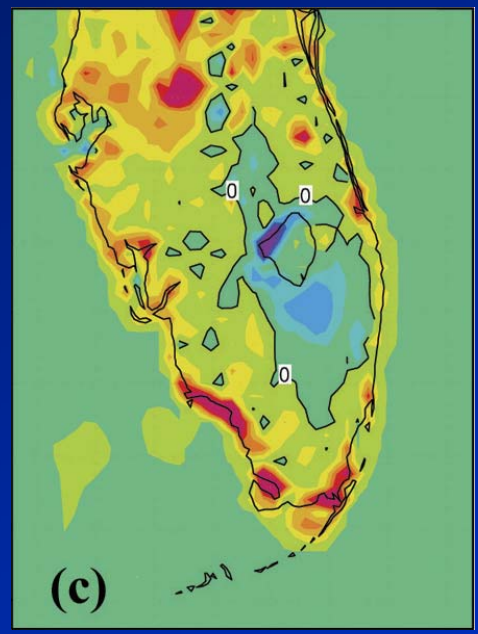
Land Cover Change Results in Colder Temperatures and Long Freeze Periods in Key Florida Agricultural Regions



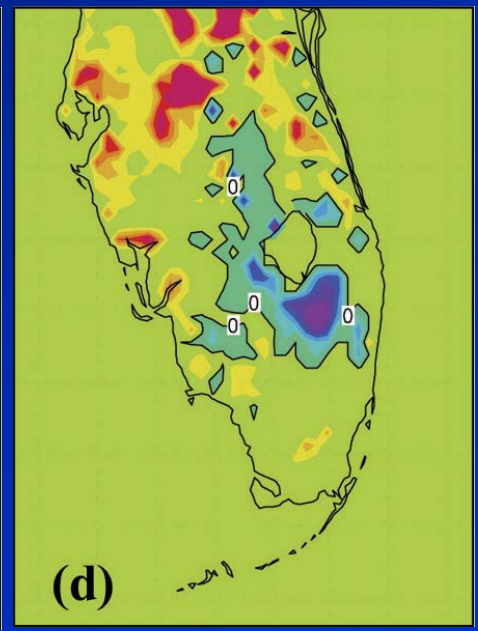
1900-era Land Cover



1993 Land Cover



Model difference in minimum temperature



Model difference in duration of freeze temperatures

Areas where wetlands were converted to cropland had colder minimum temperatures and longer freezing periods. Wetlands once held heat from the day, often keeping area temperatures above freezing throughout the night.

USGS

Marshall, C.H. Jr., R.A. Pielke Sr., and L.T. Steyaert, 2003. Crop freezes and land-use change in Florida. Nature, 426, 29-30.

Objectives and Approach -Sampling Strategy

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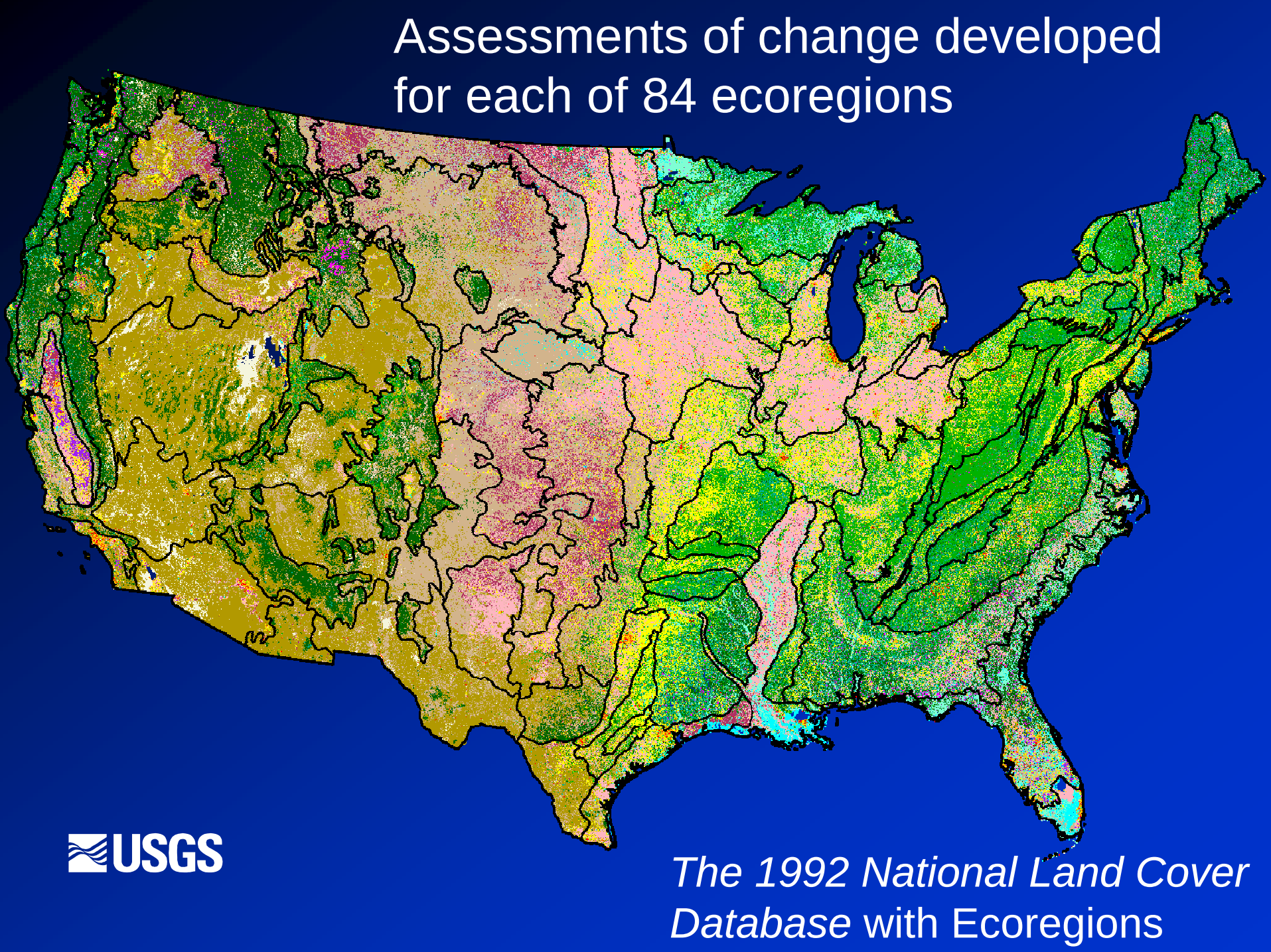
U.S. Land Cover Trends

- **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**.

Assessments of change developed for each of 84 ecoregions



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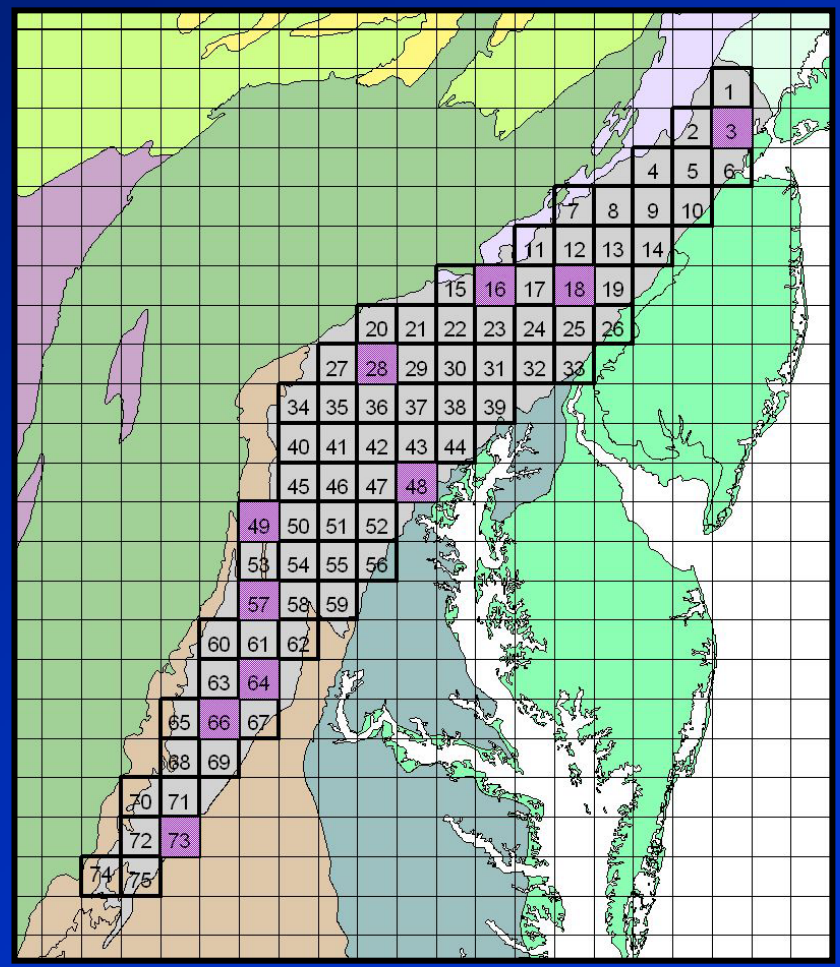
The 1992 National Land Cover Database with Ecoregions

Probability-based sampling strategy used to provide efficient and reliable estimates of change over large areas.

- Sampling units are 20- or 10-km^2.
- Sample size based on expected spatial variability of change in the strata.
- Goal is to detect within one percent of actual change at 85% confidence level.
- Samples randomly selected within strata.



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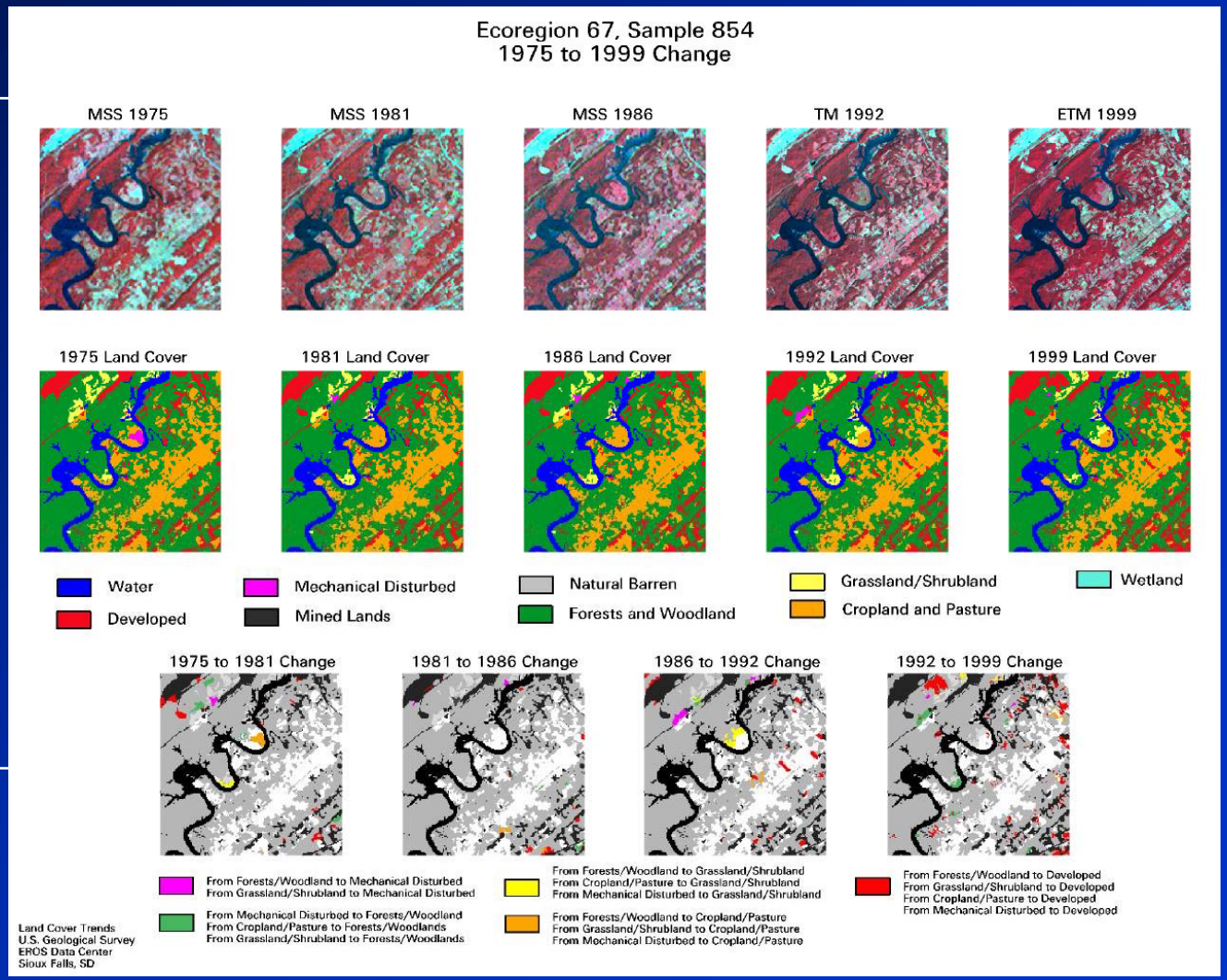
Manual interpretation of 1973, 1980, 1986, 1992, and 2000 Landsat images is used to estimate ecoregion land cover change.

Manual interpretation minimizes problems associated with:

- Sensor differences
- Inter-sensor calibration
- Lack of anniversary date images
- Spectral ambiguities



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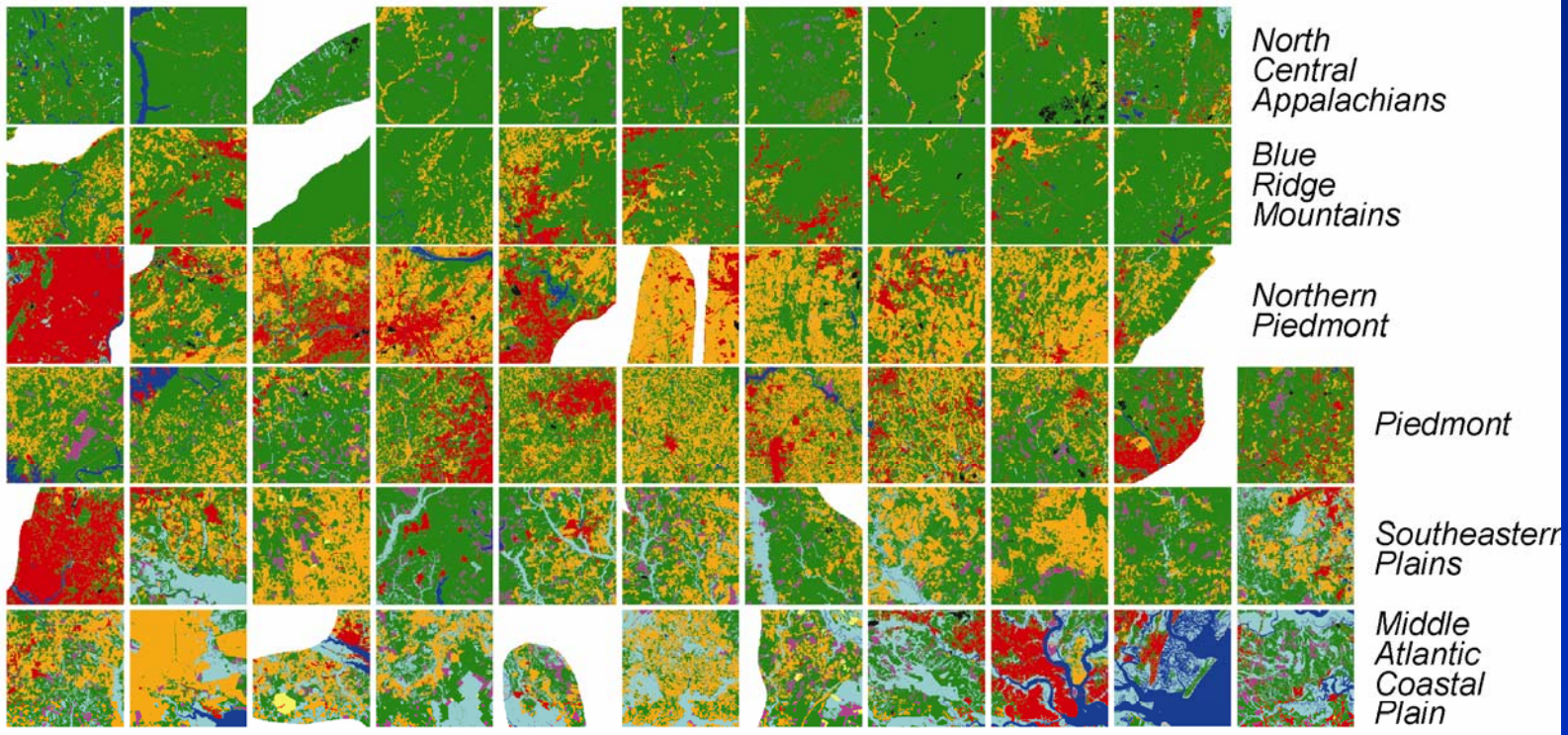
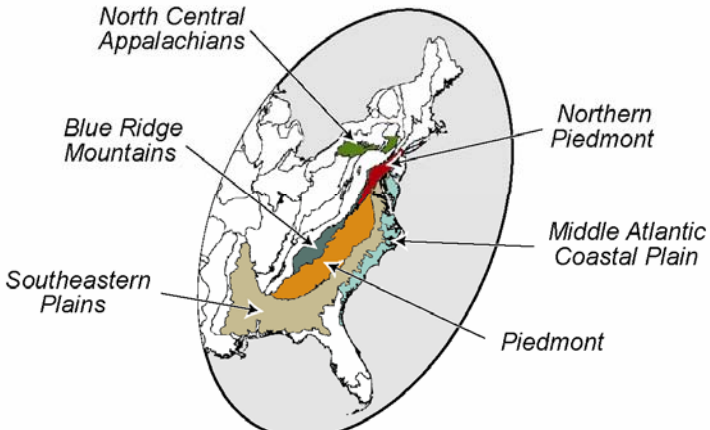

North Central Appalachians
Blue Ridge Mountains
Northern Piedmont
Piedmont
Southeastern Plains
Middle Atlantic Coastal Plain
Forest
Agriculture
Grass/shrub
Water
Wetland
Developed
Mechanically disturbed
Non-mech. disturbed
Mining
Barren


North Central Appalachians
Blue Ridge Mountains
Northern Piedmont
Middle Atlantic Coastal Plain
Southeastern Plains
Piedmont

Driving Forces
& Scenarios of Change

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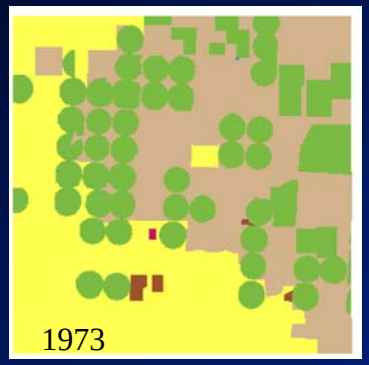
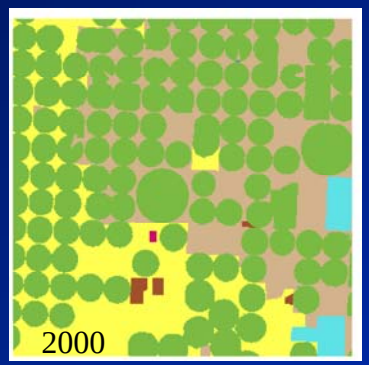
Linking Landscape Change to Socioeconomic Driving Forces





Summary of Timeline

1969 – 1978	Economic boom
	Low need/incentive for land retirement programs (Polsky 2004)
1970s	Strong farm prices, expanding trade, high inflation, speculation (NASS)
1974	Strong demand, high prices (Polsky 2004)
	Rise in the price of wheat
	(~330% increase in five years- Skold 1995)
1970s	Centre pivot, increased regional use
1978	Energy crisis; Drought (Polsky 2004)
1982	Debt crisis, recession (Polsky 2004)
Mid-1980s	Surpluses, decline in agricultural land values (NASS)
1984-87	Land values dropped by 25% (second largest drop in 20th century) (NASS)
	(Many farmers with large debt could not continue)
1986	Conservation Reserve Program begins
1988-2000	Steady increase in national agricultural land values (NASS)

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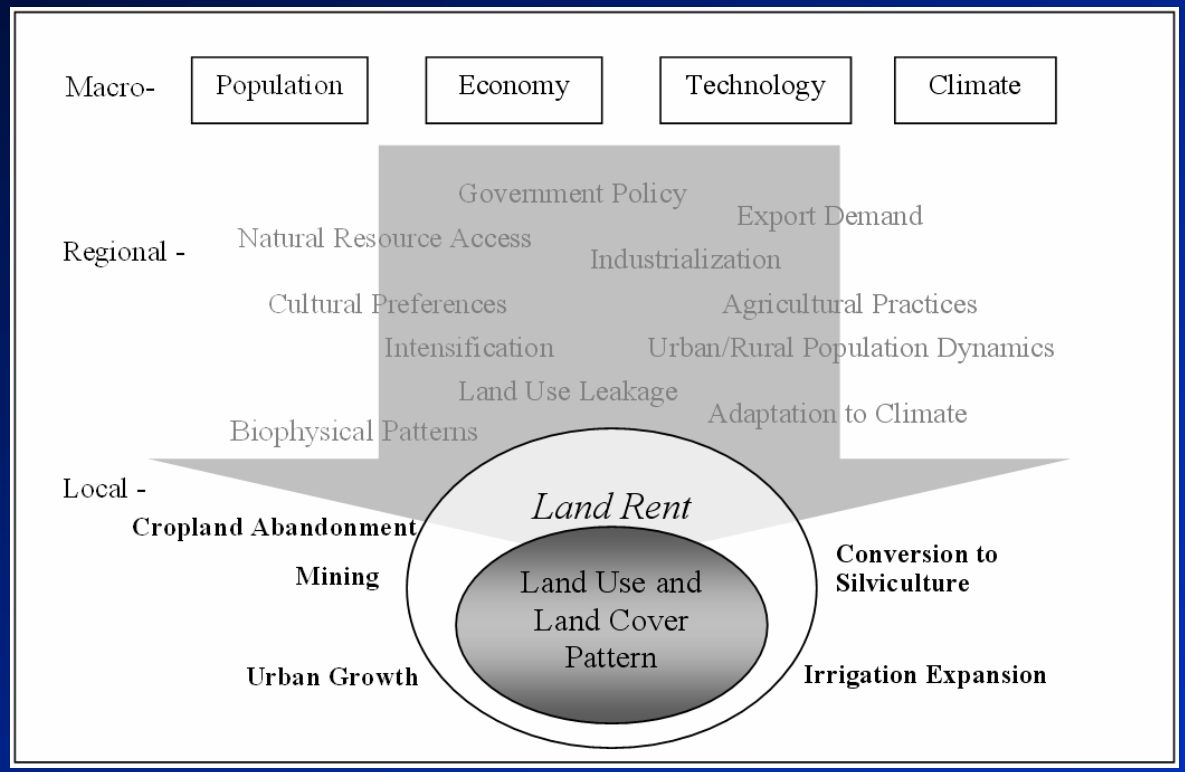
Driving Forces…to Scenarios of Change



2000

Water access

Energy costs

Global demand

Farm policy

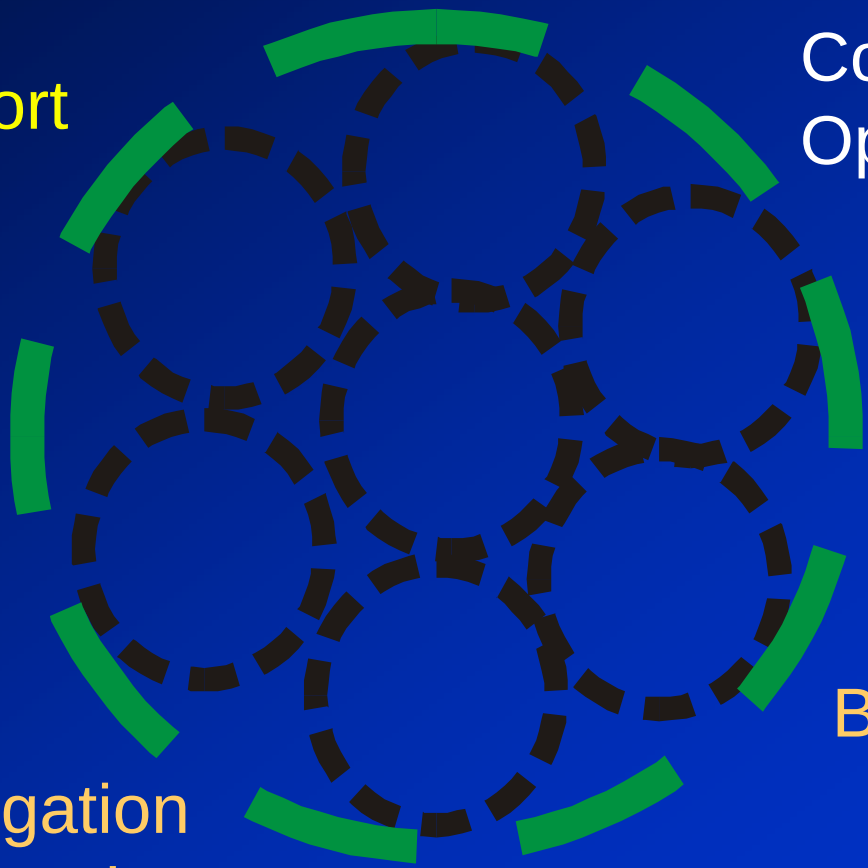
Biotechnology

Climate variability

2020

USGS

Driving Force Cluster: Western High Plains



Global Export Demands

Confined Animal Operations

Water access

Adaptation to Climate Variability

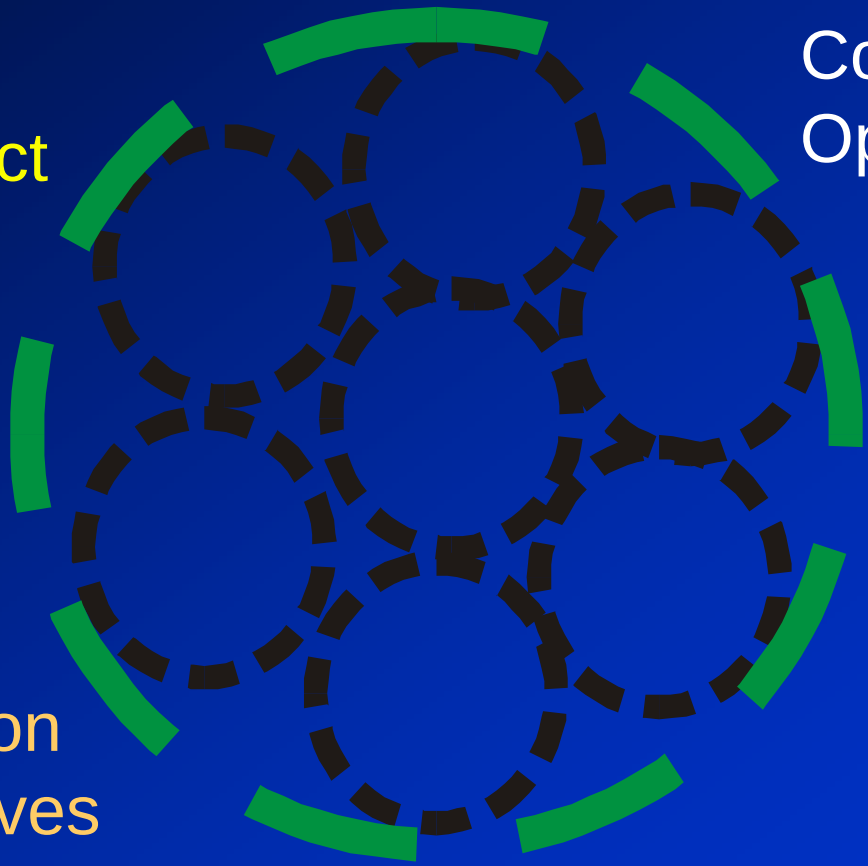
Farm Policy – CRP Renewal

Biotechnology

Irrigation incentives

USGS

Driving Force Cluster: Southeastern Plains



Wood product demands

Confined Animal Operations

Boll weevil eradication program

Public policies

Drainage subsidies

Irrigation incentives

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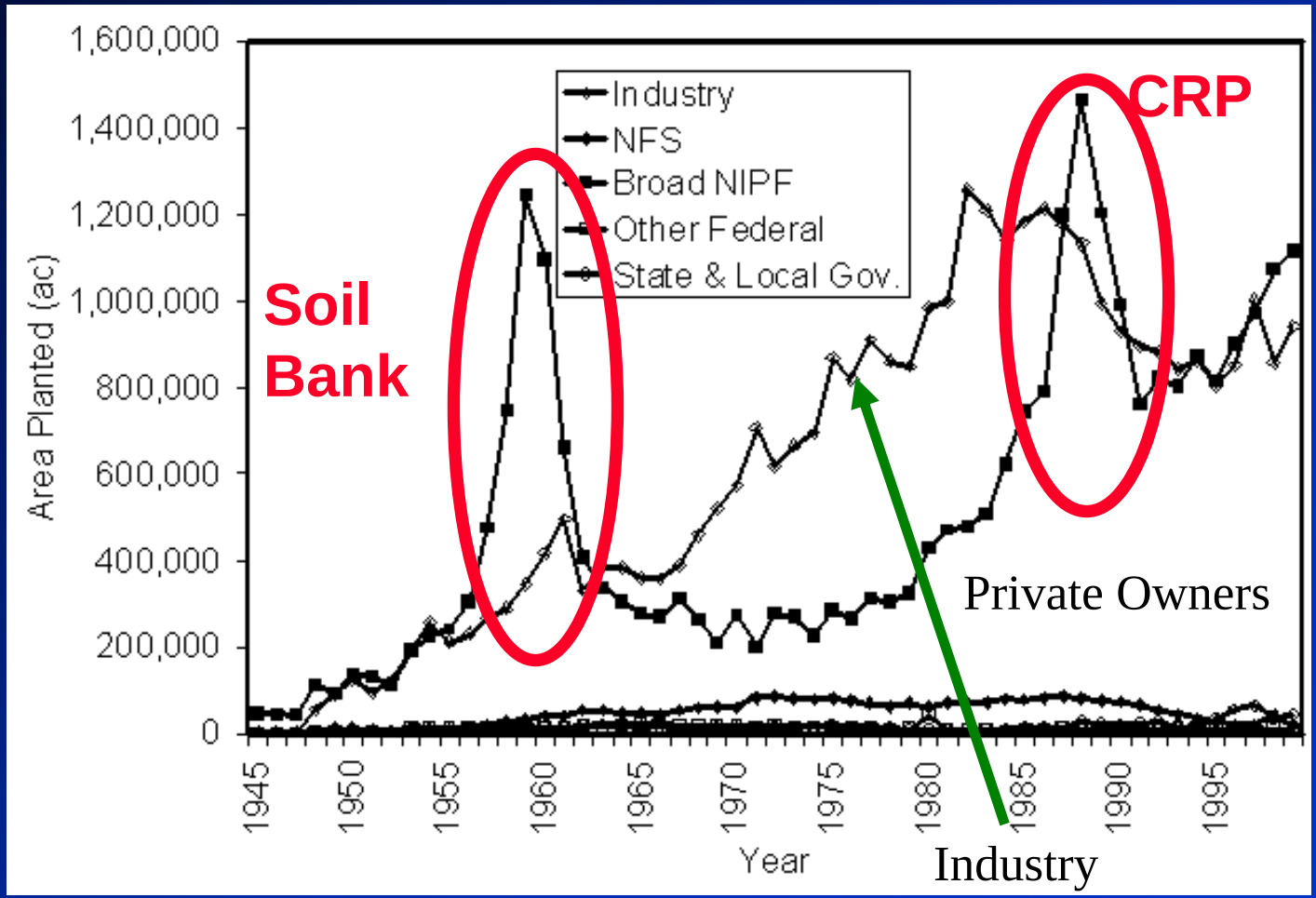
Government Policy - Tree Planting in the South by Major Owner Group, 1945-1999.



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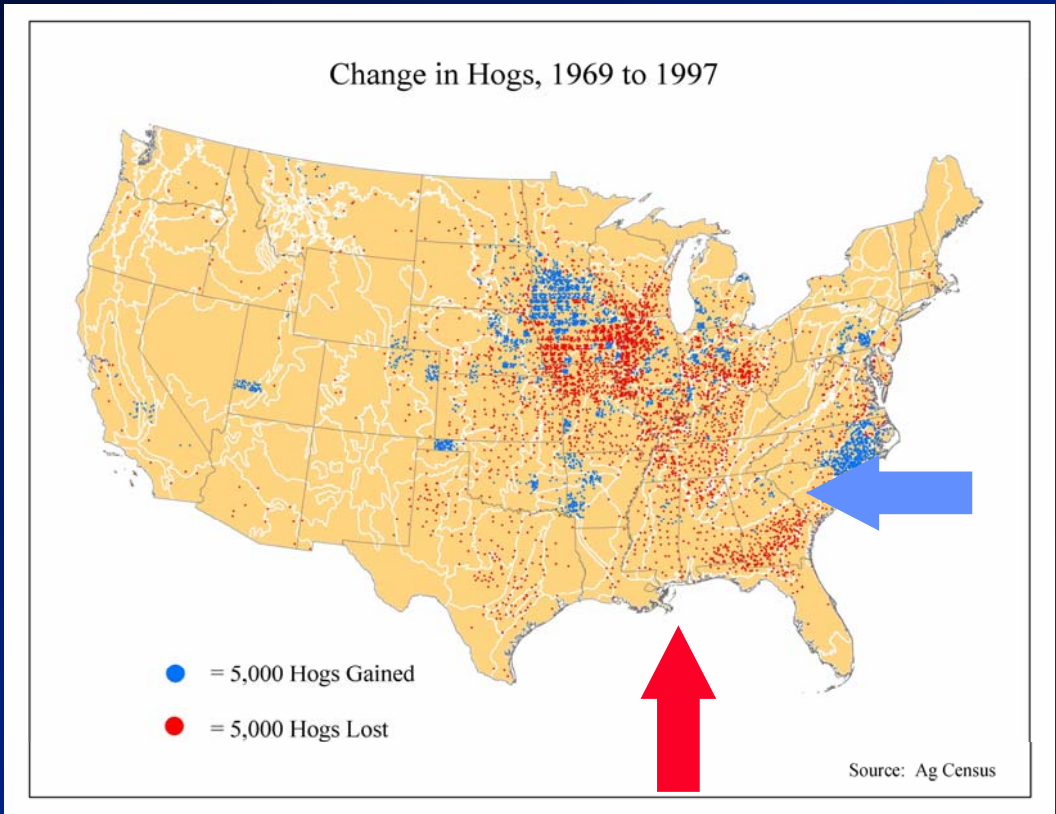
Southern Forest Resource Assessment

Technological Change – Confined Animal Feeding Operations



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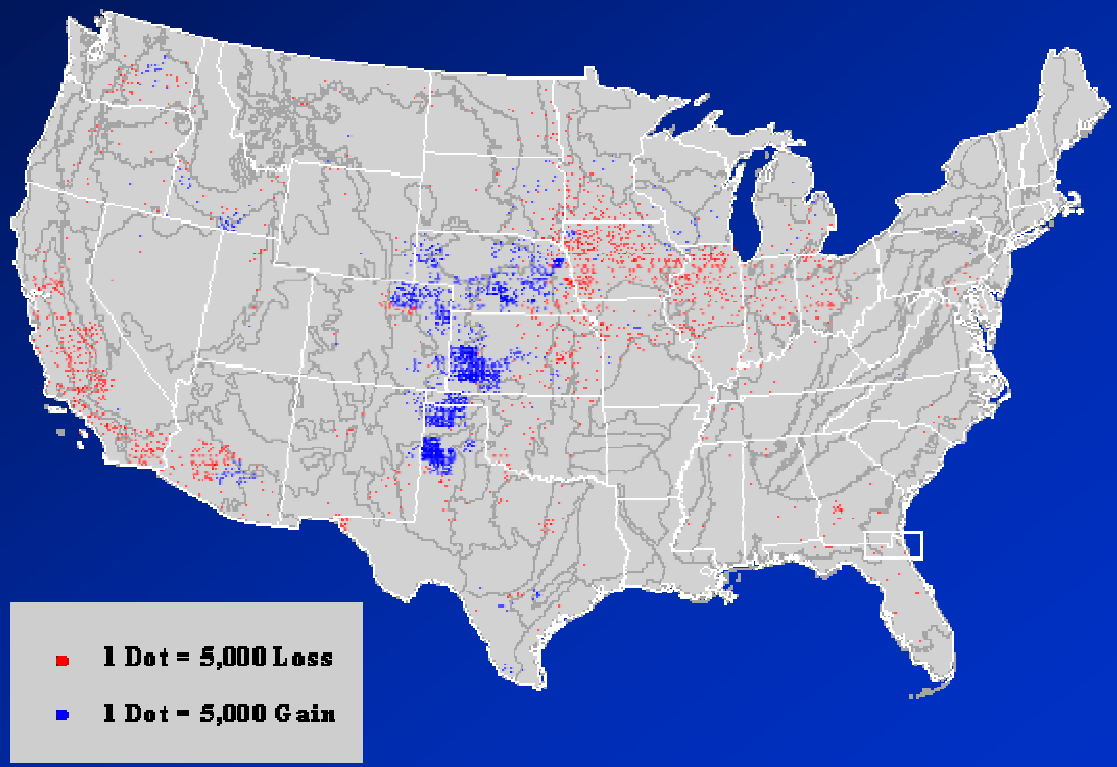
Fattened Cattle, 1964 to 1997



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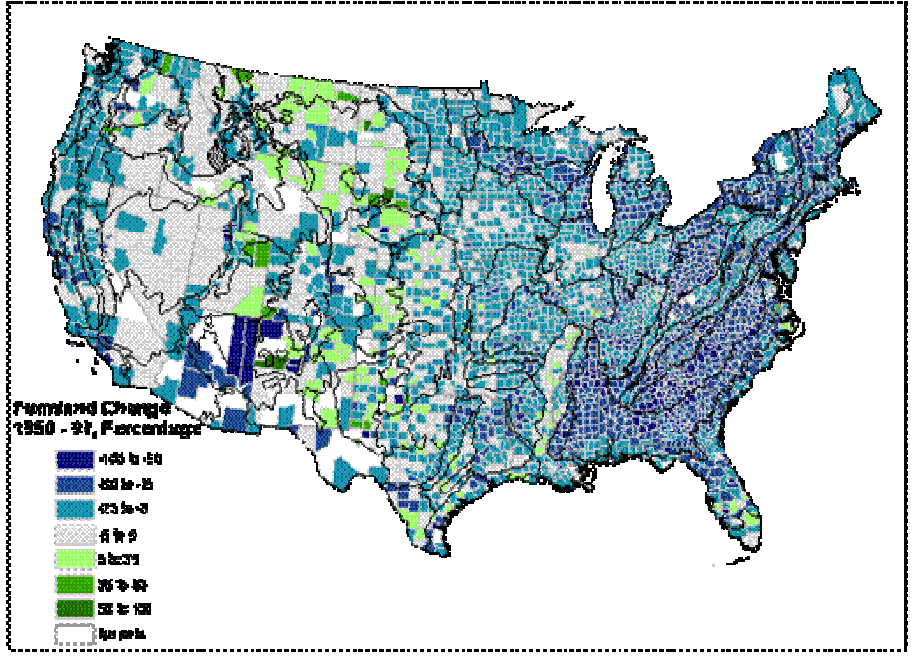
Agricultural Practices

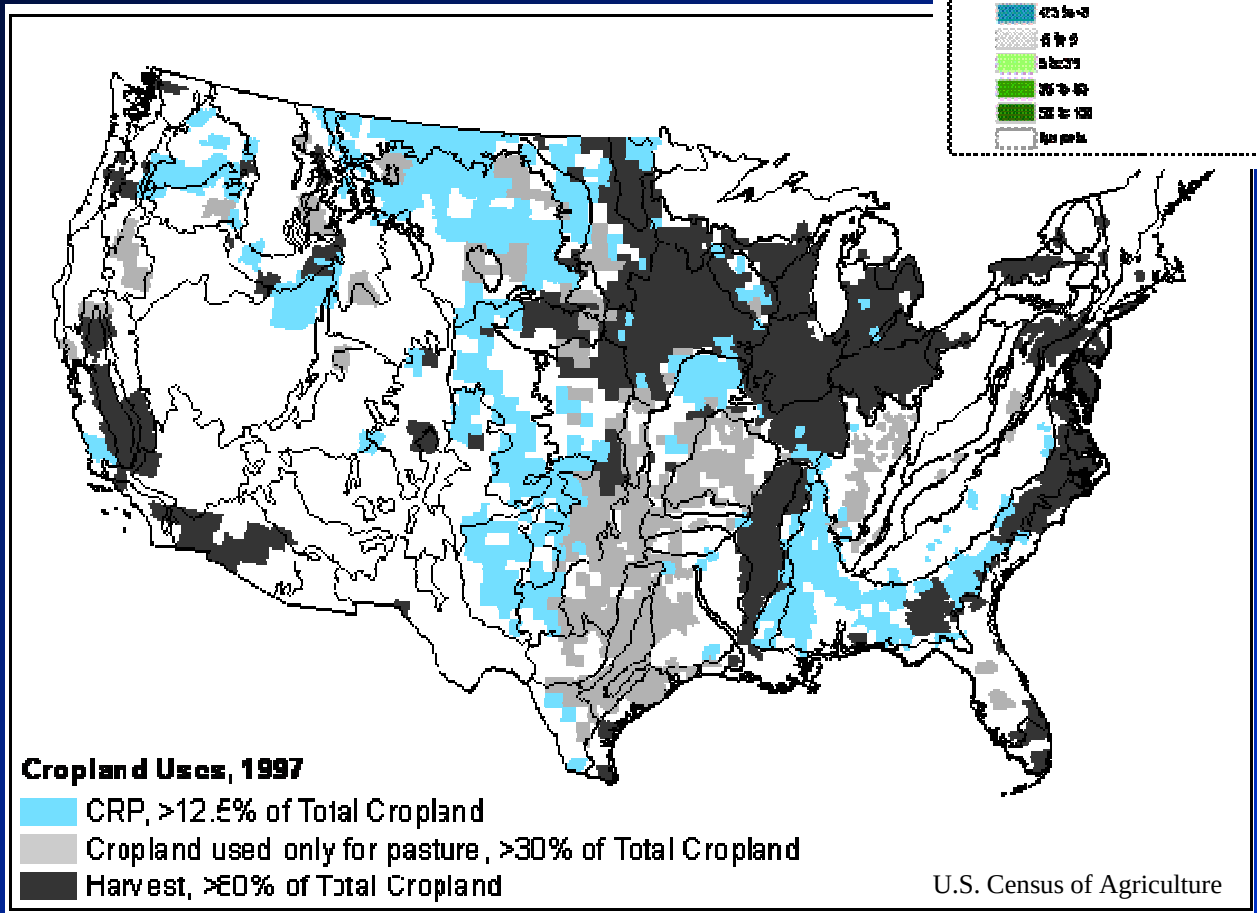
Switch from Wheat-Fallow rotation

To Wheat-Corn-Millet

Or Wheat-Sunflower-Millet

Farmland Abandonment & Intensity of Cropland Use





Ecoregion Assessment
-Great Plains

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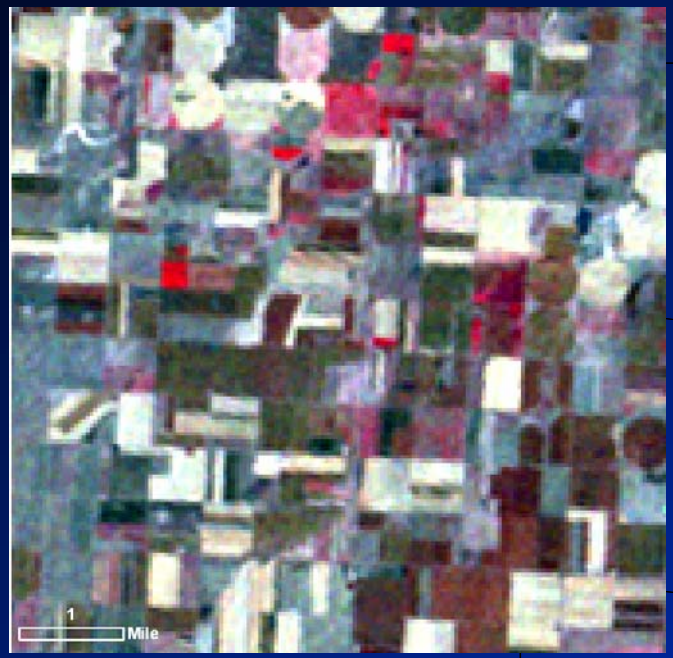
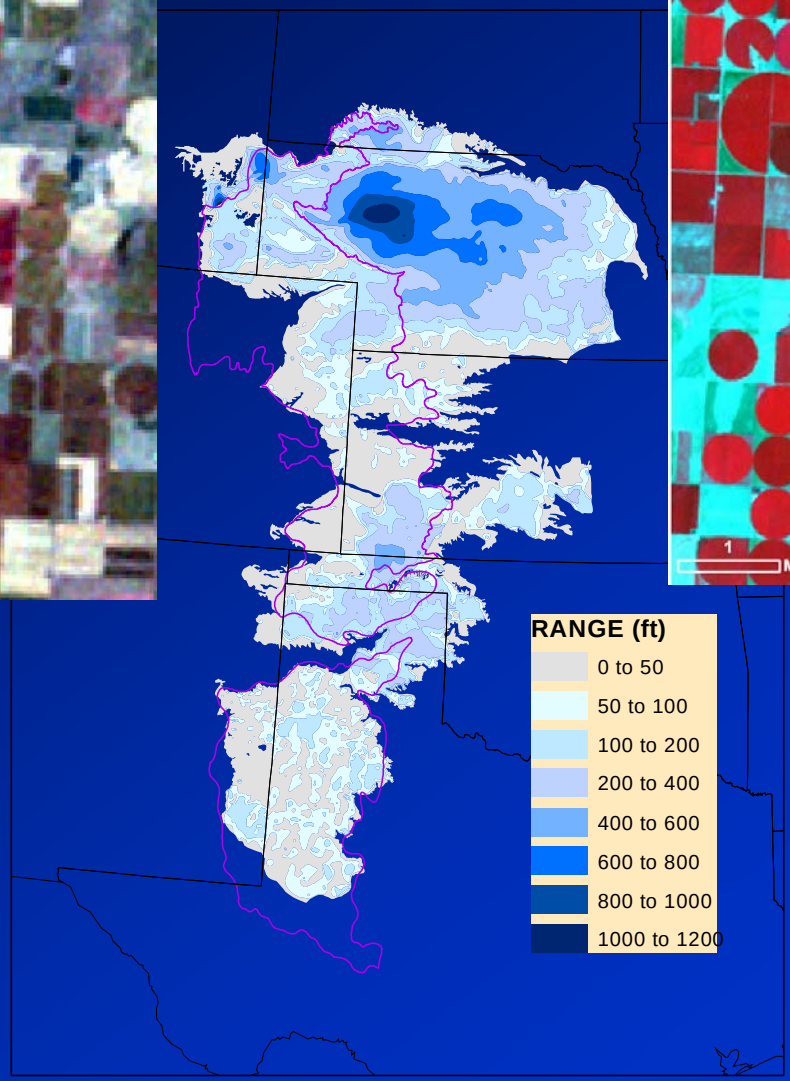
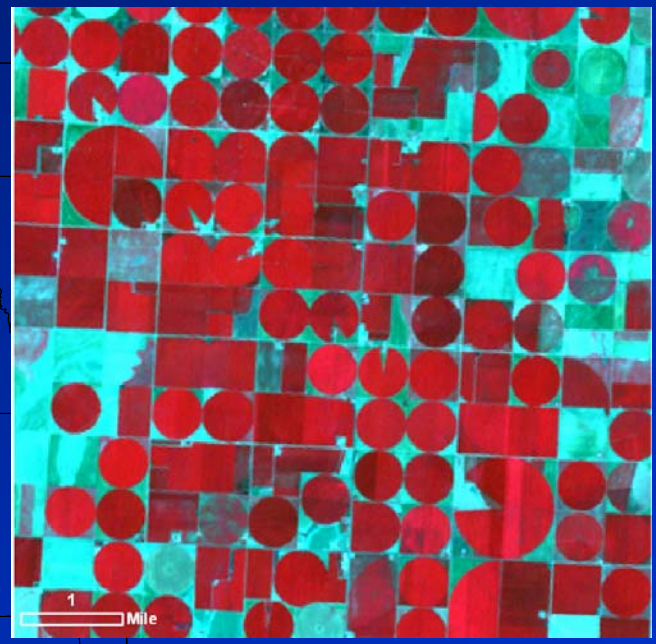
Western High Plains

Irrigation Expansion & Water Access



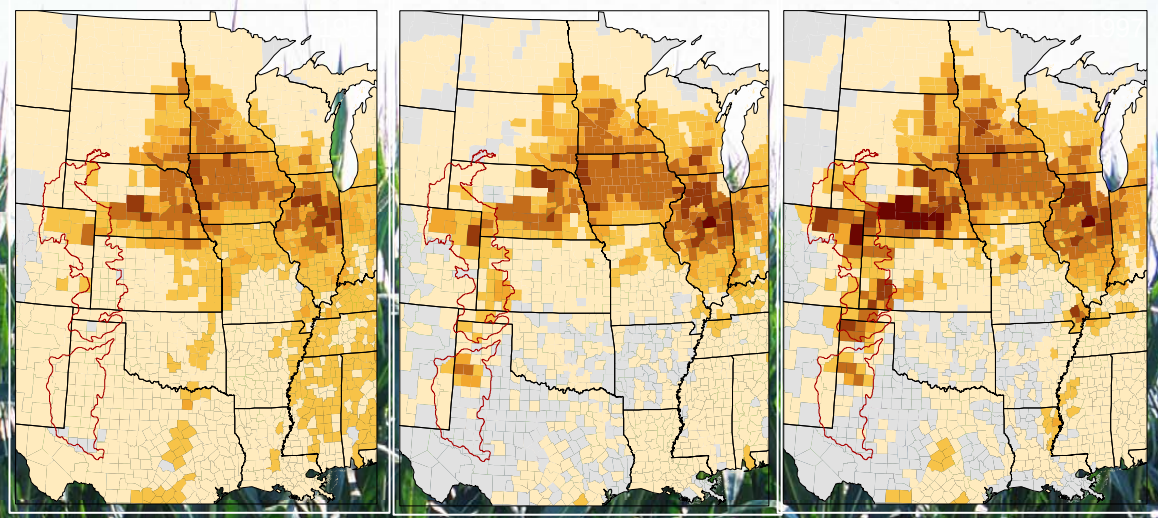
1973





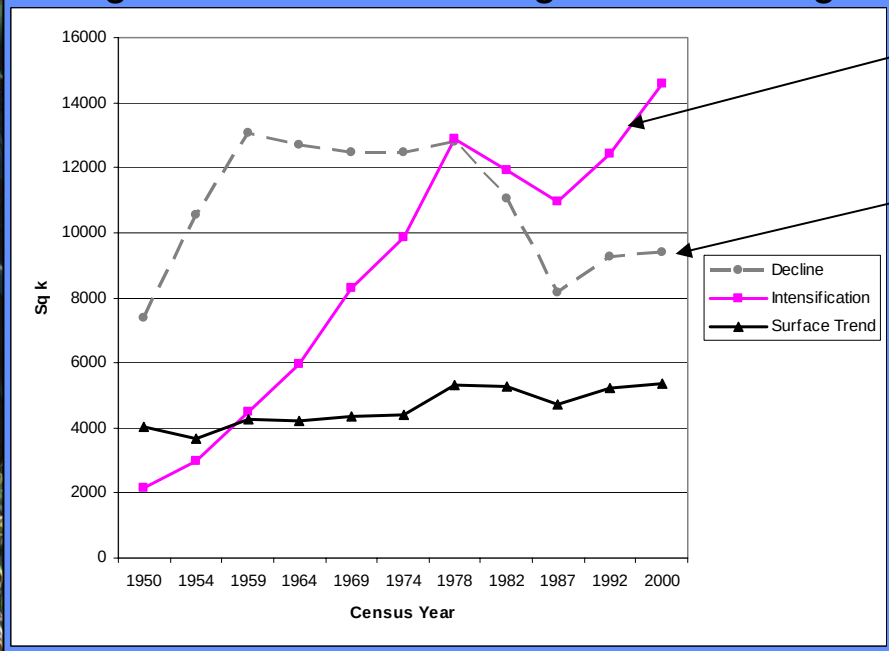
2000

USGS



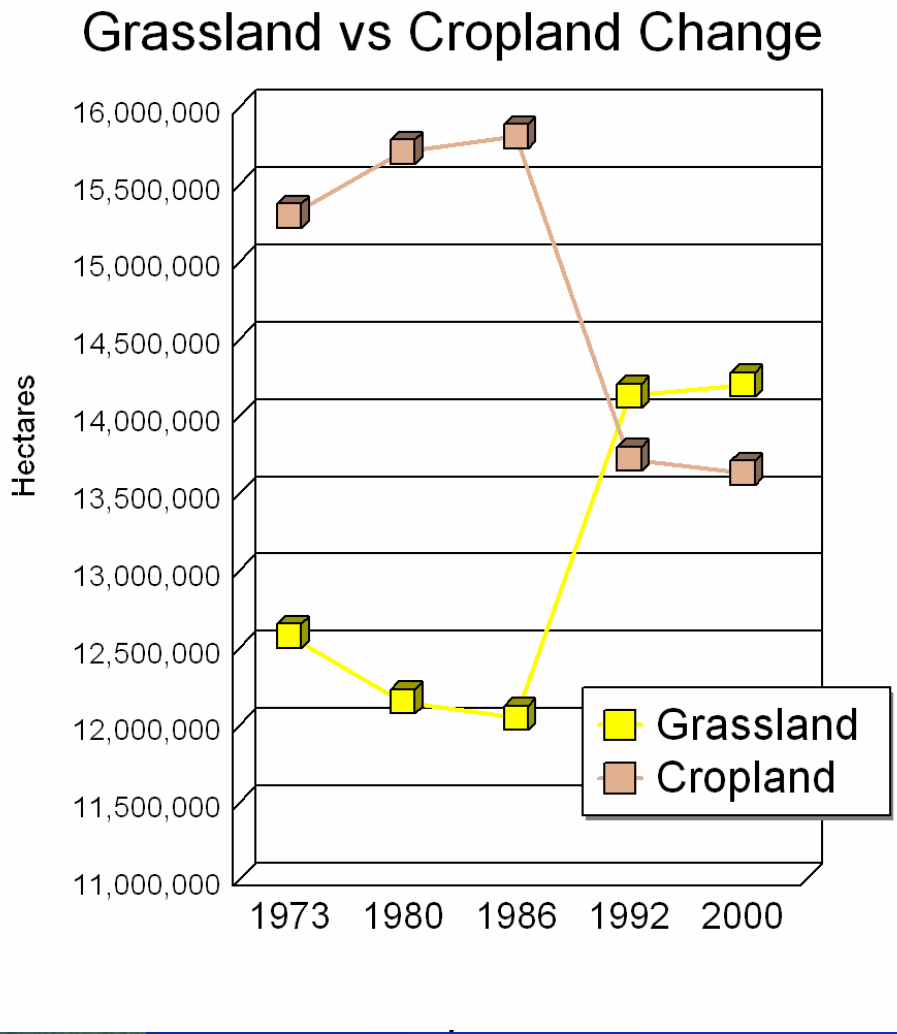
Western Expansion of Corn

Irrigated Area – Western High Plains Ecoregion



Corn region

Cotton region



Western High Plains

Ecoregion Assessment -Southeastern U.S.

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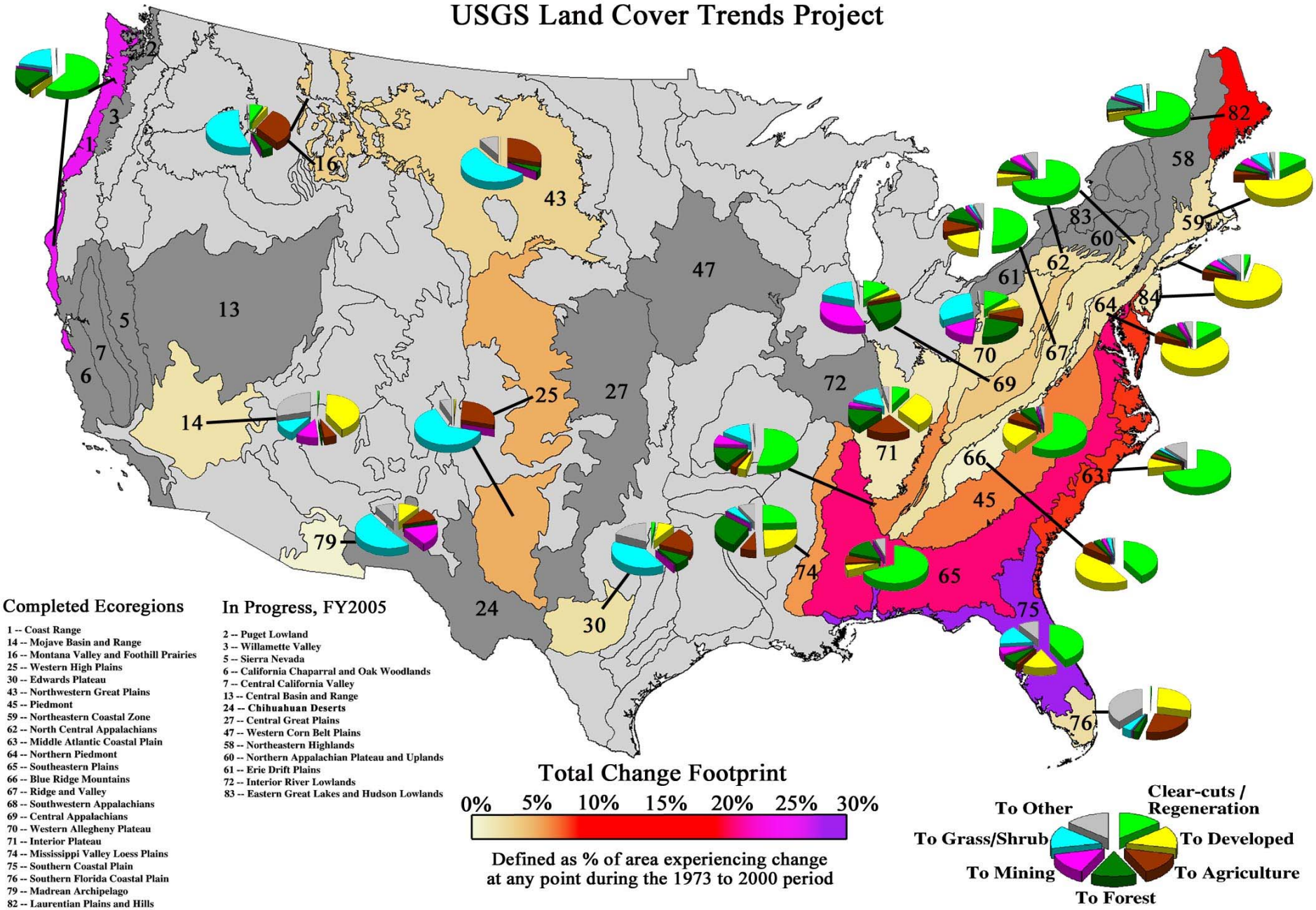
United States Land Cover Change -- 1973 to 2000

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
82 -- Laurentian Plains and Hills
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
83 -- Eastern Great Lakes and Hudson Lowlands

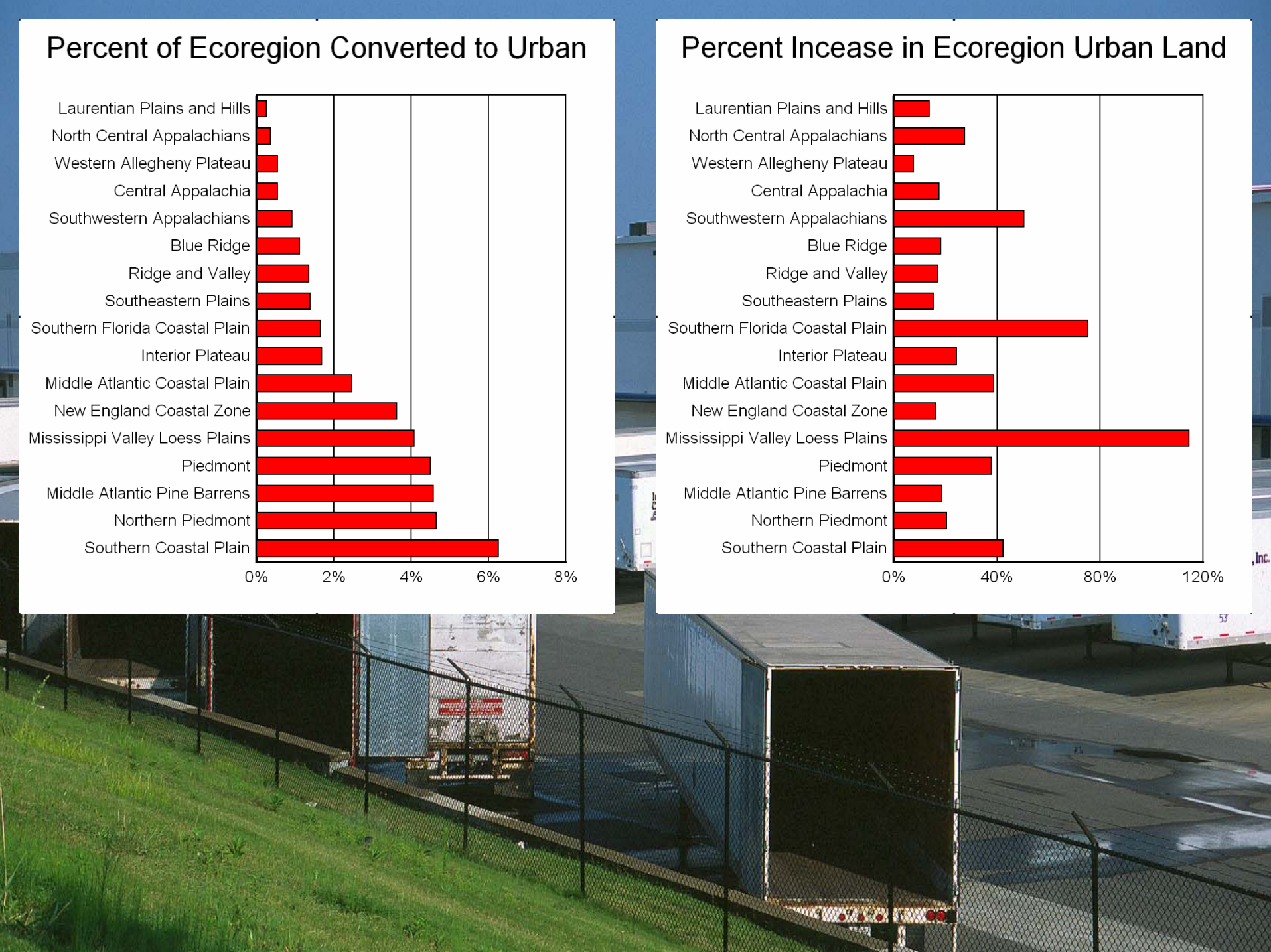
Total Change Footprint

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

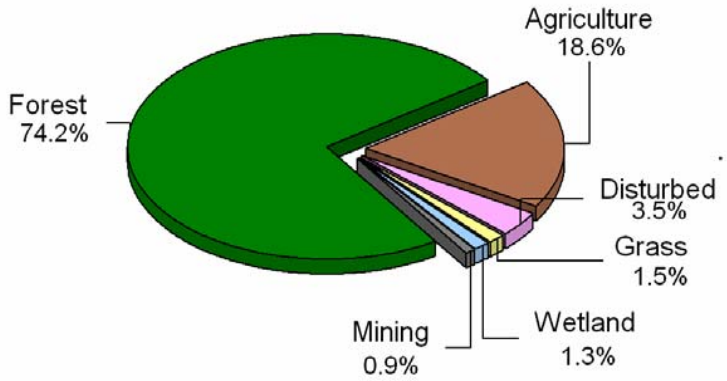
Defined as % of area experiencing change
at any point during the 1973 to 2000 period

1973 to 2000 Eastern Ecoregions Land Change Gains and Losses

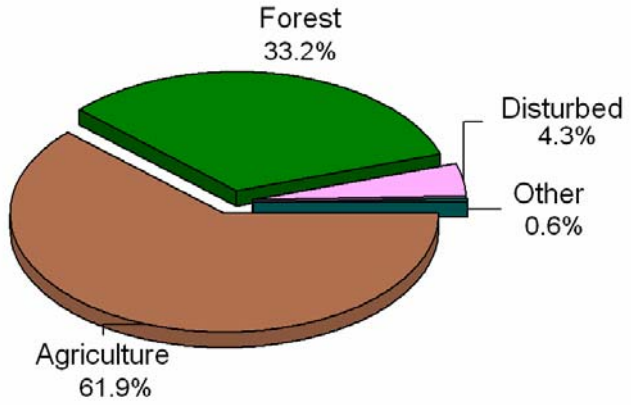
- Gains
  - Urban lands – 3,329,272 ha (12, 854 miles^2)
  - Mechanically disturbed lands – 1,819,486 ha (7025 miles^2)
- Losses
  - Forests – 2,952,955 ha (11,400 miles^2)
  - Agriculture – 2,328,361 ha (8989 miles^2)


Percent of Ecoregion Converted to Urban
Laurentian Plains and Hills
North Central Appalachians
Western Allegheny Plateau
Central Appalachia
Southwestern Appalachians
Blue Ridge
Ridge and Valley
Southeastern Plains
Southern Florida Coastal Plain
Interior Plateau
Middle Atlantic Coastal Plain
New England Coastal Zone
Mississippi Valley Loess Plains
Piedmont
Middle Atlantic Pine Barrens
Northern Piedmont
Southern Coastal Plain
0%
2%
4%
6%
8%
Percent Incease in Ecoregion Urban Land
Laurentian Plains and Hills
North Central Appalachians
Western Allegheny Plateau
Central Appalachia
Southwestern Appalachians
Blue Ridge
Ridge and Valley
Southeastern Plains
Southern Florida Coastal Plain
Interior Plateau
Middle Atlantic Coastal Plain
New England Coastal Zone
Mississippi Valley Loess Plains
Piedmont
Middle Atlantic Pine Barrens
Northern Piedmont
Southern Coastal Plain
0%
40%
80%
120%

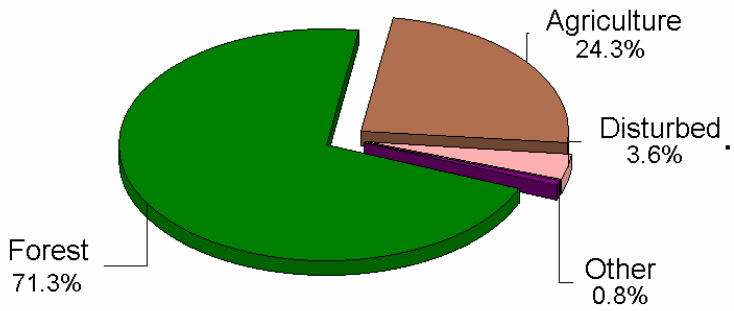
Conversion to Urban Cover in the New England Coastal Zone



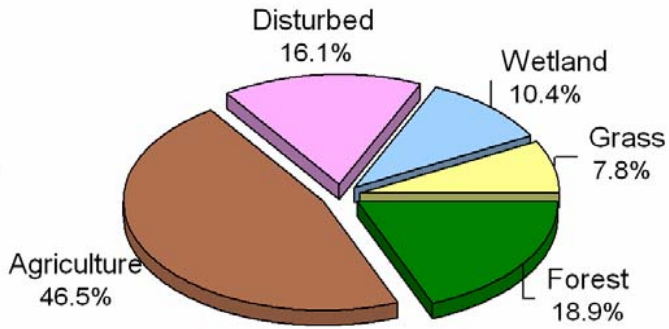
Conversion to Urban Cover in the Northern Piedmont



Conversion to Urban Cover in the Piedmont



Conversion to Urban Cover in the Southern Florida Coastal Plain



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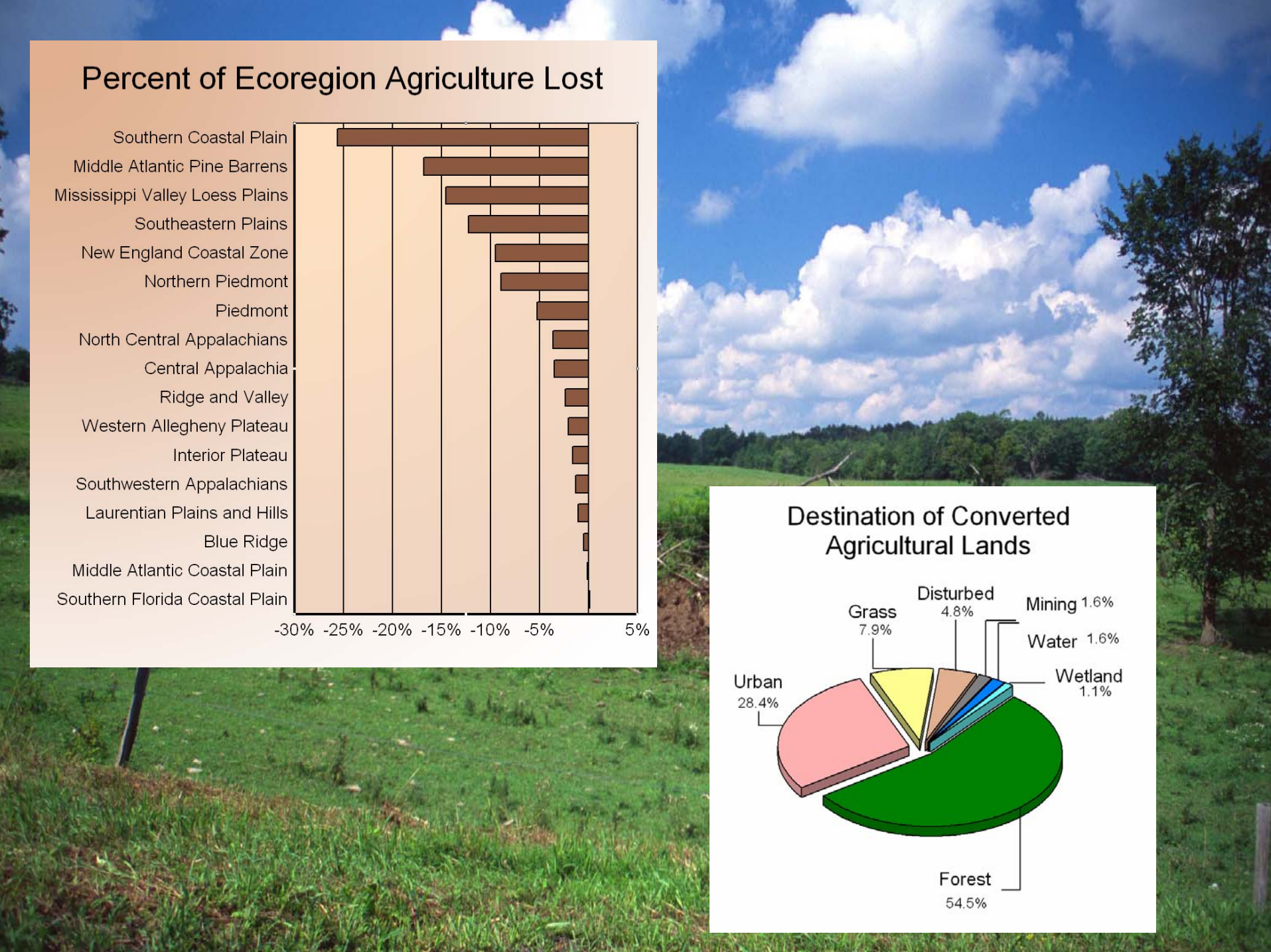
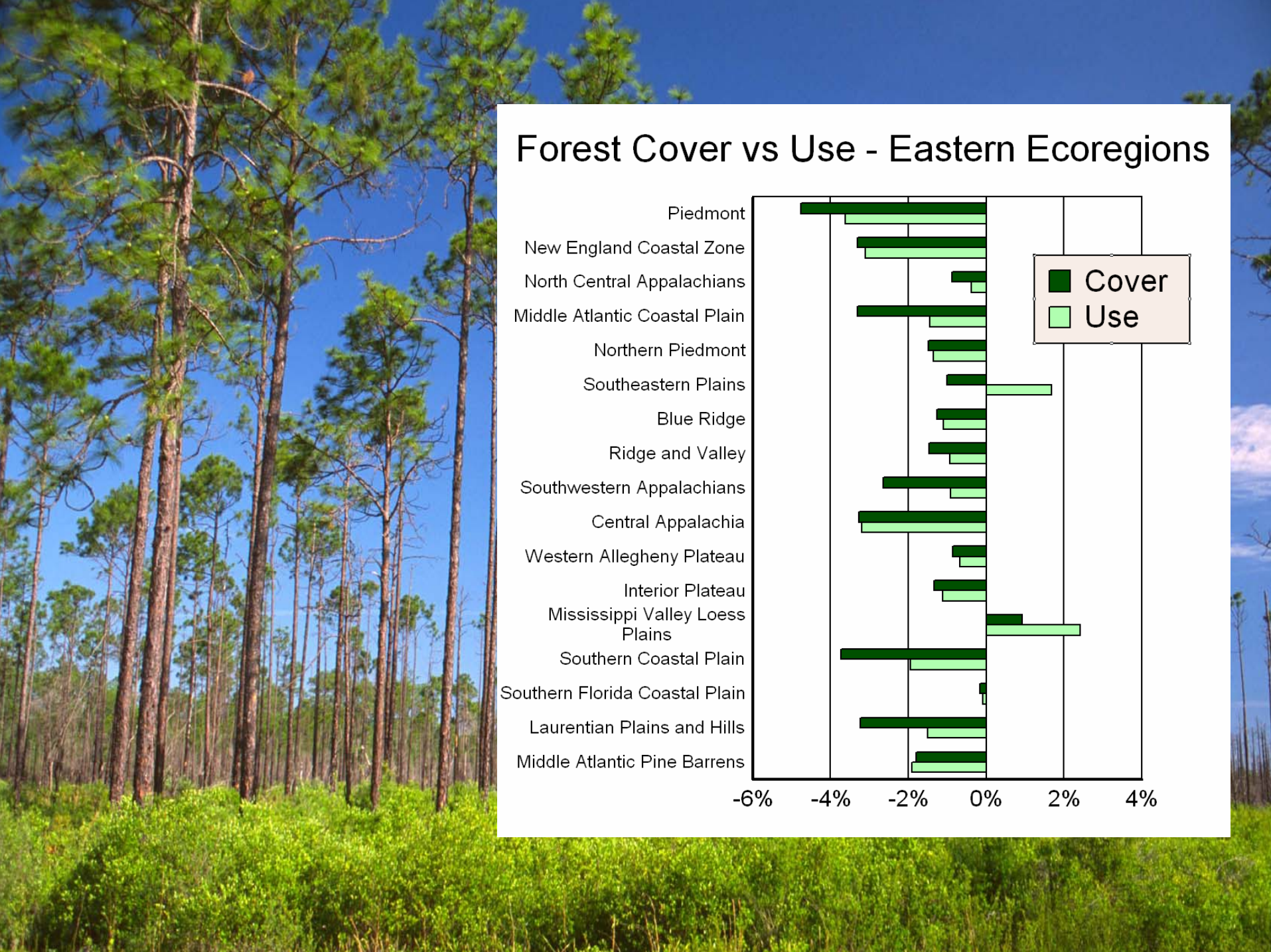
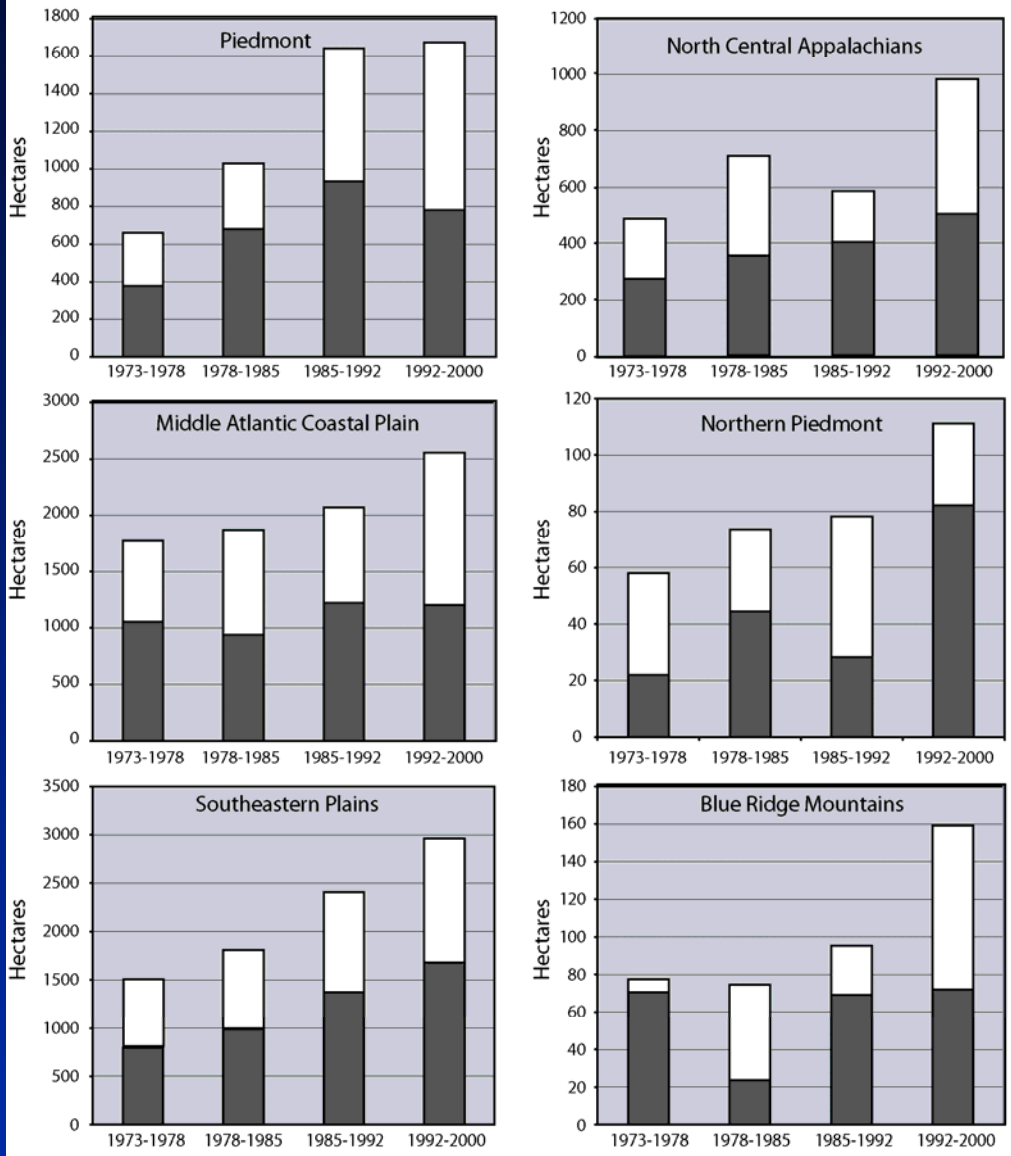

Percent of Ecoregion Agriculture Lost
Southern Coastal Plain
Middle Atlantic Pine Barrens
Mississippi Valley Loess Plains
Southeastern Plains
New England Coastal Zone
Northern Piedmont
Piedmont
North Central Appalachians
Central Appalachia
Ridge and Valley
Western Allegheny Plateau
Interior Plateau
Southwestern Appalachians
Laurentian Plains and Hills
Blue Ridge
Middle Atlantic Coastal Plain
Southern Florida Coastal Plain
-30% -25% -20% -15% -10% -5% 5%
Destination of Converted Agricultural Lands
Grass 7.9%
Disturbed 4.8%
Mining 1.6%
Water 1.6%
Wetland 1.1%
Urban 28.4%
Forest 54.5%


Forest Cover vs Use - Eastern Ecoregions
Piedmont
New England Coastal Zone
North Central Appalachians
Middle Atlantic Coastal Plain
Northern Piedmont
Southeastern Plains
Blue Ridge
Ridge and Valley
Southwestern Appalachians
Central Appalachia
Western Allegheny Plateau
Interior Plateau
Mississippi Valley Loess Plains
Southern Coastal Plain
Southern Florida Coastal Plain
Laurentian Plains and Hills
Middle Atlantic Pine Barrens
Cover
Use
-6%
-4%
-2%
0%
2%
4%

Cyclic Disturbance

Forest<--->Timber Harvest

Mean Area Changed per Sample



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Piedmont

Piedmont: Dominant Change – Forest to Disturbed

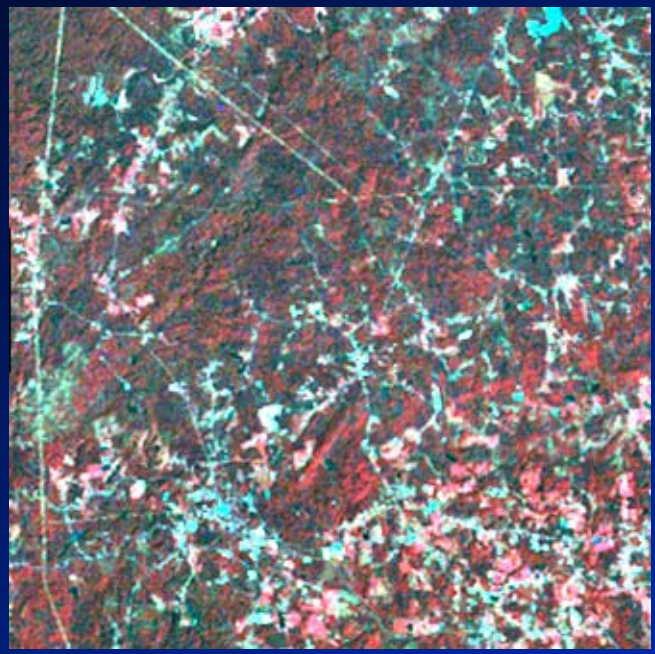
Overall rate of spatial change: 14.9%

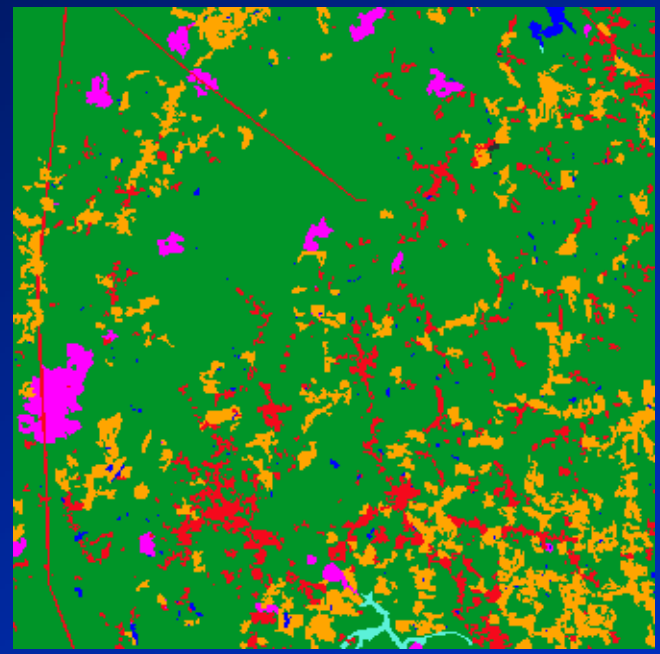

Piedmont forest cover lost 768,902 ha
(2968 miles^2) between 1973 and 2000

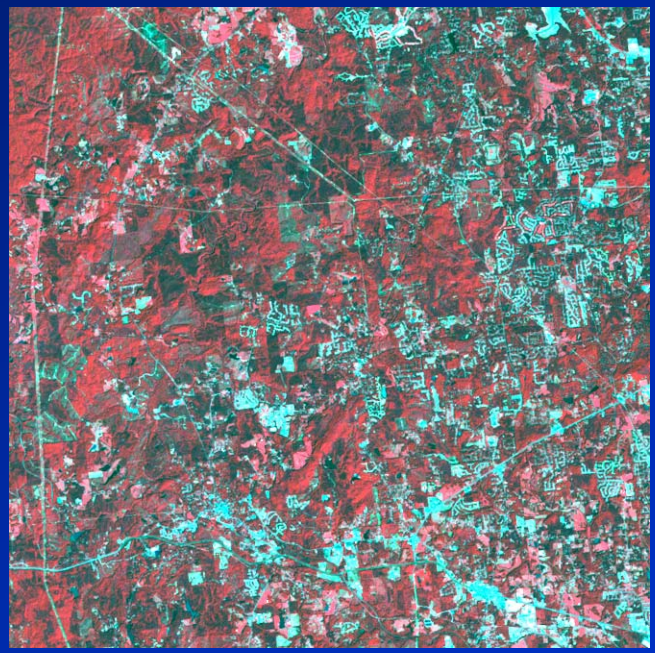
Between 1973 and 2000, urban growth expanded to cover an additional 4.5% of the Piedmont – an increase of 728,400 ha (2812 miles^2)

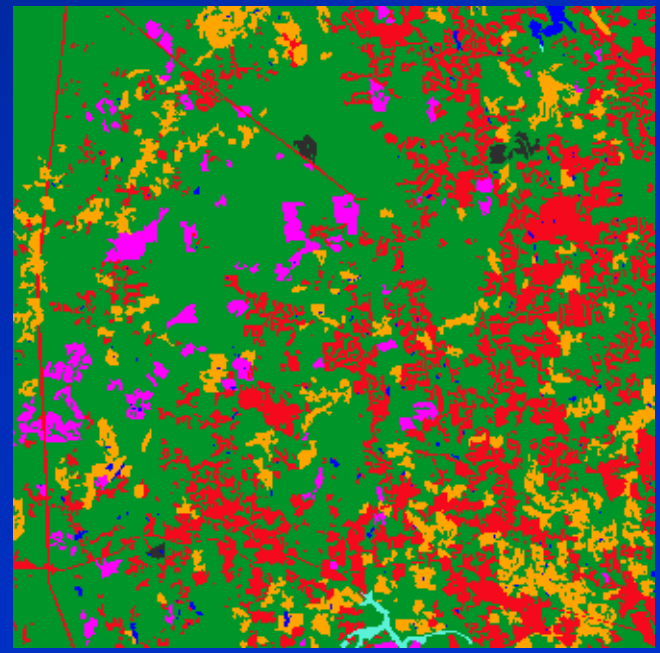
Exurban growth on the rural landscape: 1974 to 2000

60 Miles West of Atlanta









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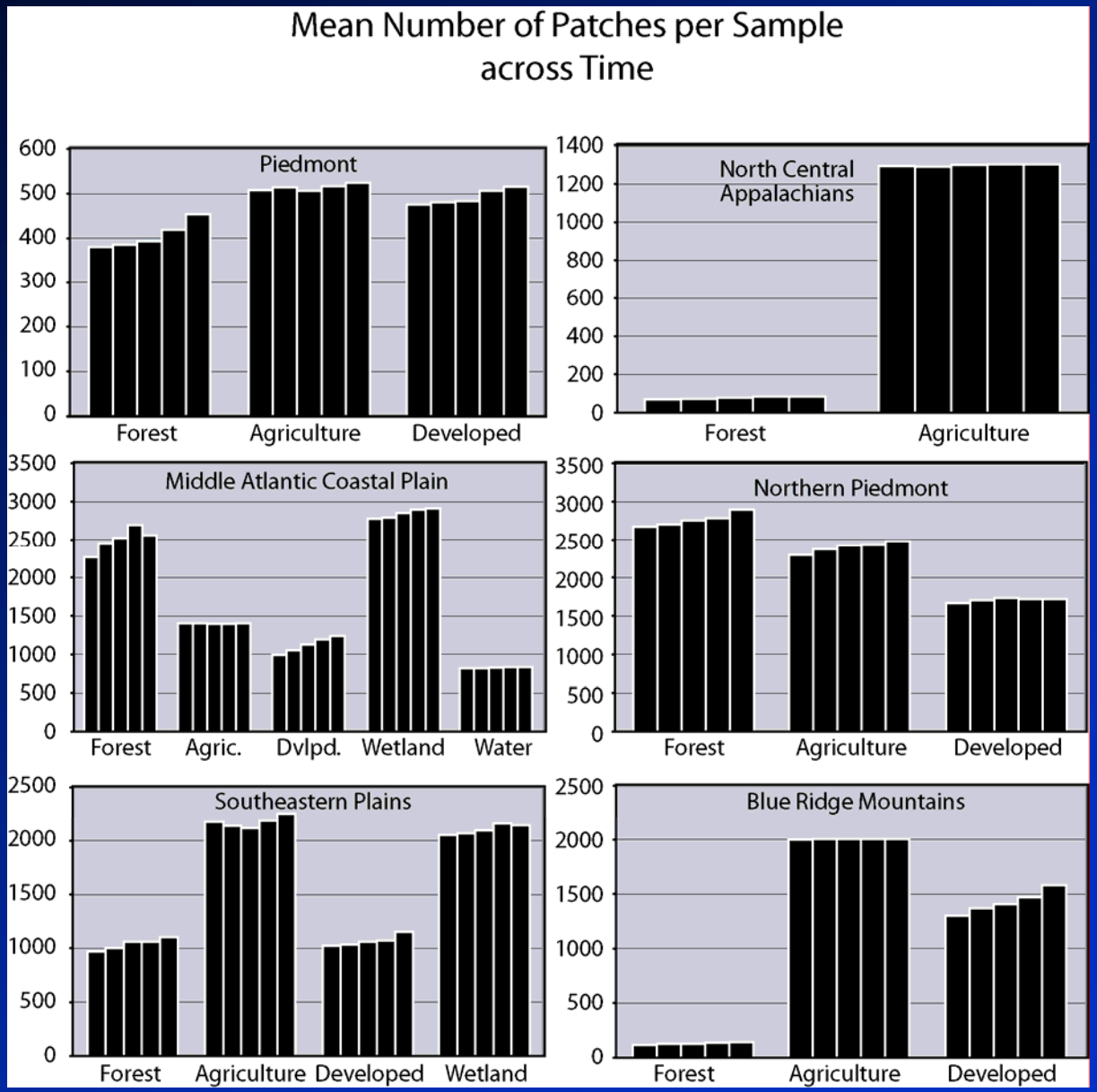
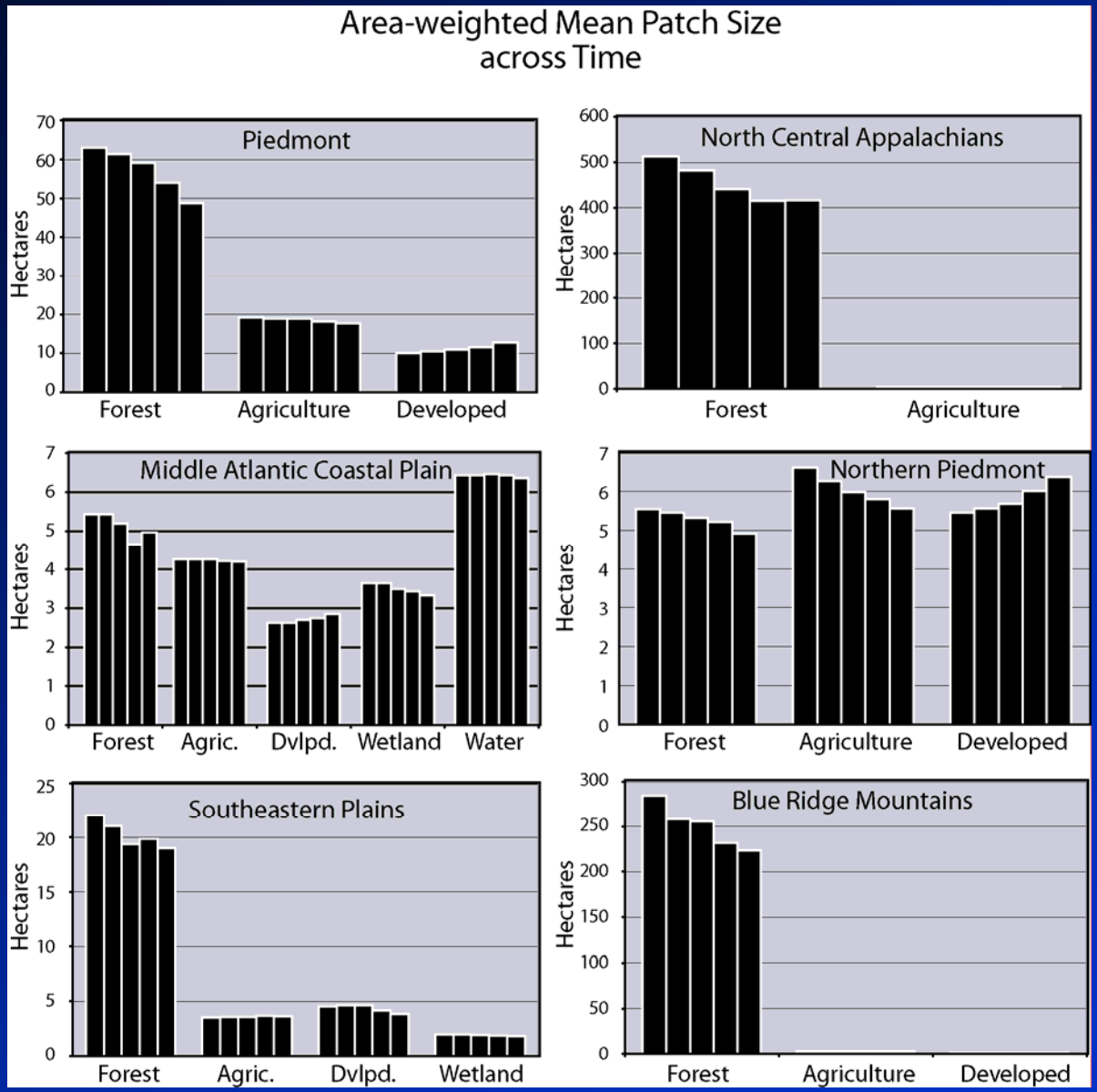

Mean Number of Patches per Sample across Time
Piedmont
600
500
400
300
200
100
0
Forest
Agriculture
Developed
North Central Appalachians
1400
1200
1000
800
600
400
200
0
Forest
Agriculture
Middle Atlantic Coastal Plain
3500
3000
2500
2000
1500
1000
500
0
Forest
Agric.
Dvlpd.
Wetland
Water
Northern Piedmont
3500
3000
2500
2000
1500
1000
500
0
Forest
Agriculture
Developed
Southeastern Plains
2500
2000
1500
1000
500
0
Forest
Agriculture
Developed
Wetland
Blue Ridge Mountains
2500
2000
1500
1000
500
0
Forest
Agriculture
Developed

USGS


Area-weighted Mean Patch Size
across Time
Piedmont
Hectares
70
60
50
40
30
20
10
0
Forest
Agriculture
Developed
North Central Appalachians
Hectares
600
500
400
300
200
100
0
Forest
Agriculture
Middle Atlantic Coastal Plain
Hectares
7
6
5
4
3
2
1
0
Forest
Agric.
Dvlpd.
Wetland
Water
Northern Piedmont
Hectares
7
6
5
4
3
2
1
0
Forest
Agriculture
Developed
Southeastern Plains
Hectares
25
20
15
10
5
0
Forest
Agric.
Dvlpd.
Wetland
Blue Ridge Mountains
Hectares
300
250
200
150
100
50
0
Forest
Agriculture
Developed

USGS

The Piedmont is likely to transform from ‘Spersopolis’ into the first inland Megalopolis. Natural systems in the ecoregion will be significantly stressed.

NASA Earth Science Enterprise
USGS GAM Program

Landscape Change Modeling and Climate Impacts, 1920 -2020

Terry Sohl -- SAIC -- Contractor to USGS/EROS
Kristi Sayler -- USGS/EROS
Thomas Loveland – USGS/EROS
Mark Drummond – USGS Rocky Mountain Mapping Center
Roger Pielke – Colorado State University

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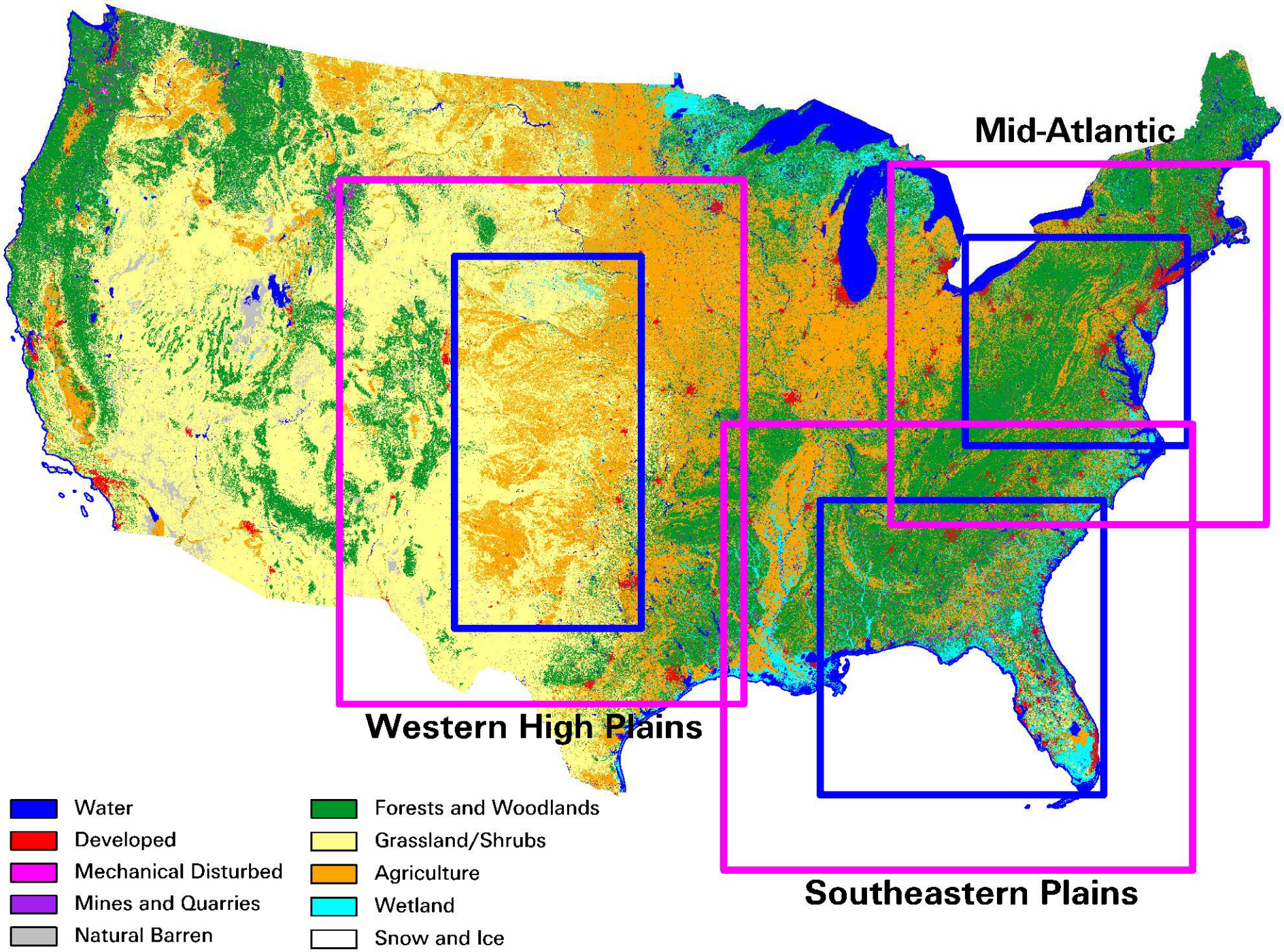
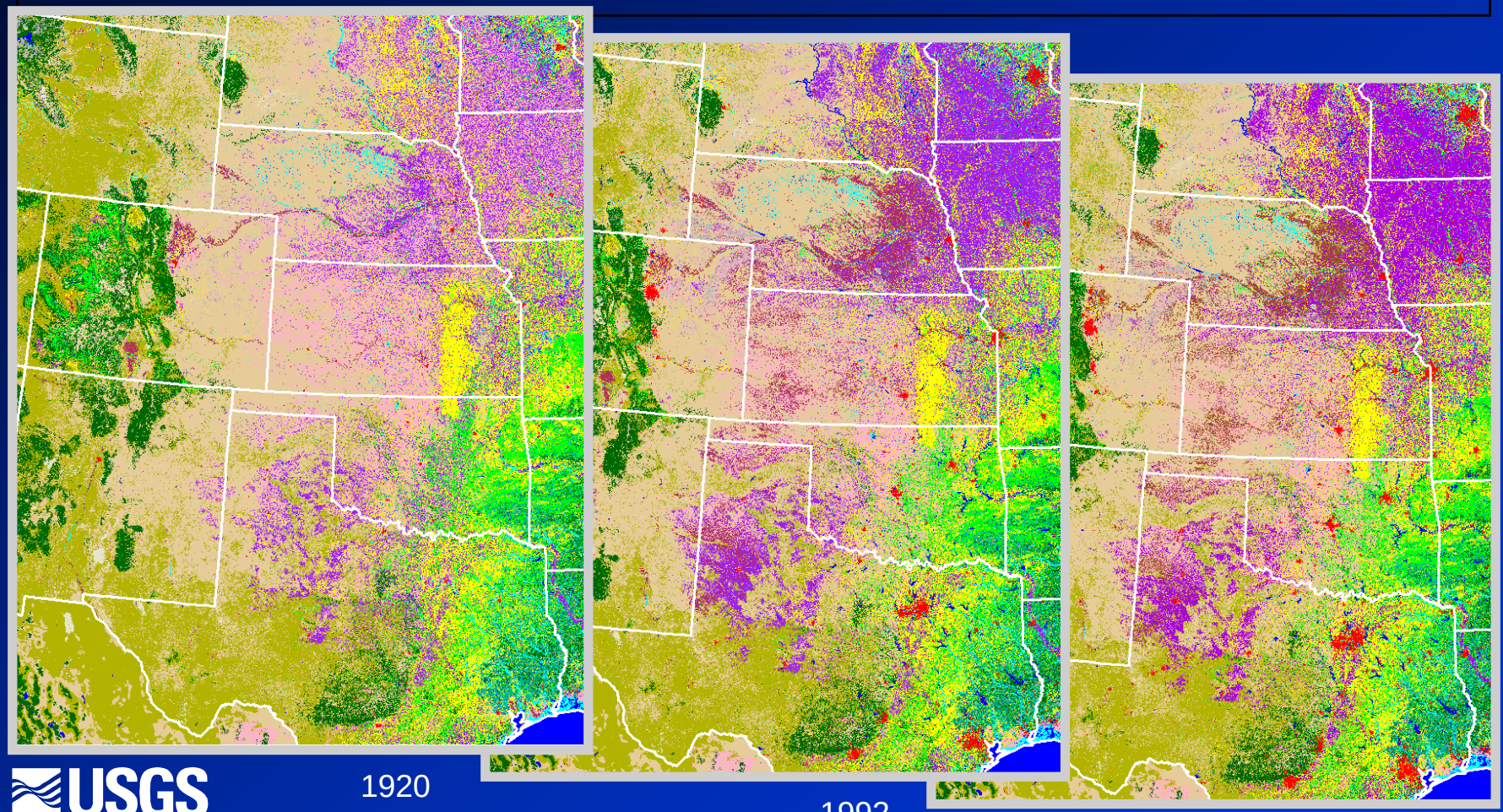

Mid-Atlantic
Western High Plains
Southeastern Plains
Water
Developed
Mechanical Disturbed
Mines and Quarries
Natural Barren
Forests and Woodlands
Grassland/Shrubs
Agriculture
Wetland
Snow and Ice

Great Plains



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1920

1992

2020

Great Plains scenario of

Agricultural Expansion

November 2, 2005

Scenario 3: Agricultural expansion

Study Area	1992 (acres)	2020 (acres)	Total Change (acres)	Percentage Annual Change	Percentage Overall Change
oceans, lakes	11,365,550				
ice caps, glaciers	147,767				
evergreen needleaf forest	53,509,178	53,211,251	-297,927	-0.020%	-0.56%
deciduous needleaf forest	0				
deciduous broadleaf forest	38,800,678	37,072,410	-1,728,268	-0.159%	-4.45%
evergreen broadleaf forest	0				
short grass	203,431,412	183,439,762	-19,991,651	-0.351%	-9.83%
Tall grass (nlcd Hay/pasture)	67,687,069	66,813,483	-873,586	-0.046%	-1.29%
desert	4,645,148				
semi-desert	0				
tundra	0				
evergreen shrub	135,485,952	133,229,379	-2,256,573	-0.059%	-1.67%
deciduous shrub	0				
mixed woodland	10,950,076				
Crops/mixed farming	32,999,616	37,950,184	4,950,568	0.536%	15.00%
Irrigated crop	19,669,452	23,151,350	3,481,898	0.632%	17.70%
bog or marsh	10,260,081				
bare ground	5,642,882				
Row Crop	78,114,832	94,830,370	16,715,538	0.764%	21.40%
Urban and built up	8,159,921	11,097,493	2,937,572	1.286%	36.00%

Agricultural expansion scenario, aided by increased export demand and greater access to water

- greater access to water caused by improved water delivery technology and low energy costs
- a decrease in land conservation driven by economic opportunity of export market and lack of a new federal Farm Bill (and so has a large impact on grassland to cropland conversion in the western plains- ie., ecos 25, 27, 42, 43 and in the northeastern plains – ecos 46, 47, 40)
- Favorable climate, wetter in north
- Fattened cattle, dairy and hogs continue to be important force in the High Plains
- Increase in beef consumption in other parts of the world also causes increase in feed grain production
- Southern plains lose forest to cropland (ie., Central Oklahoma Texas Plains, Texas Blackland Prairies, and Edwards Plateau)
- Hay to Row Crop (incl. soy beans) in the northeastern prairies
- Irrigated Crop increase in the High Plains
- Wheat expansion in the western plains and the Central Great Plains ecoregion

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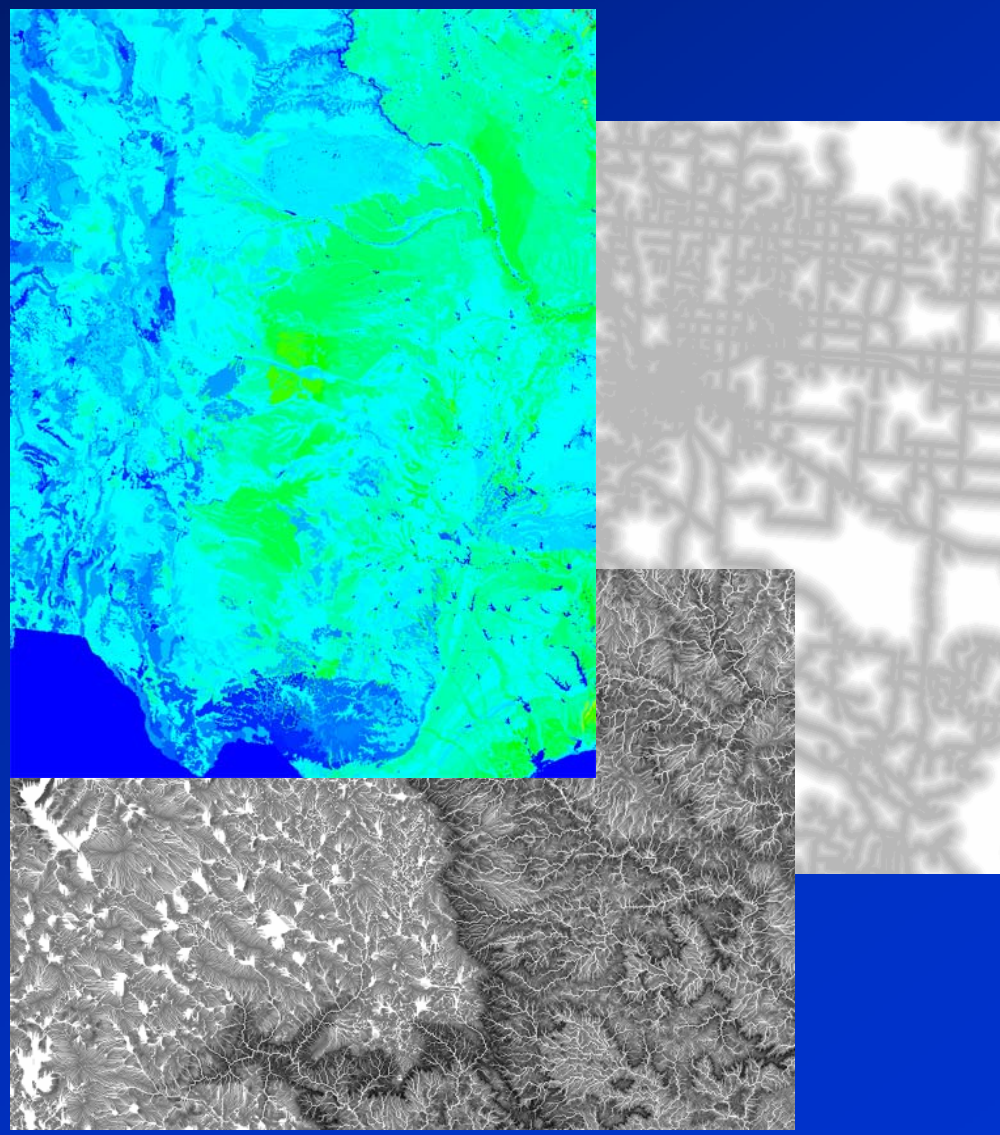
Spatial Allocation Module -- Ancillary variables used to create probability surfaces

- Census data
- Proximity to transportation
- NED and derivatives
- Soils data
- Climate data (DAYMET)
- Phenology data
- County-level Socio-economic data
- Etc., etc., etc….



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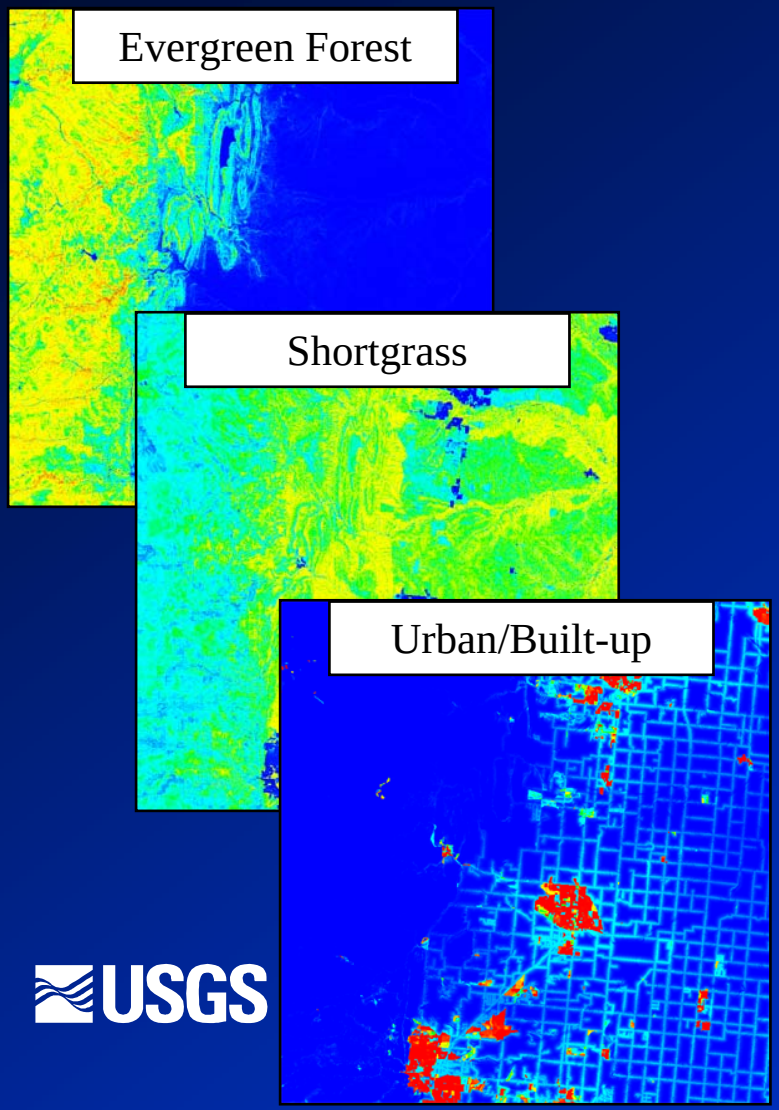
Regression-based Probability Surfaces



- **Stepwise logistic regression used to analyze relationships between LEAF2 land cover types and ancillary data sets**
- **Inclusion of only logical explanatory data sets for each land cover type**
- **Probability surfaces constructed for each LEAF2 land cover type**

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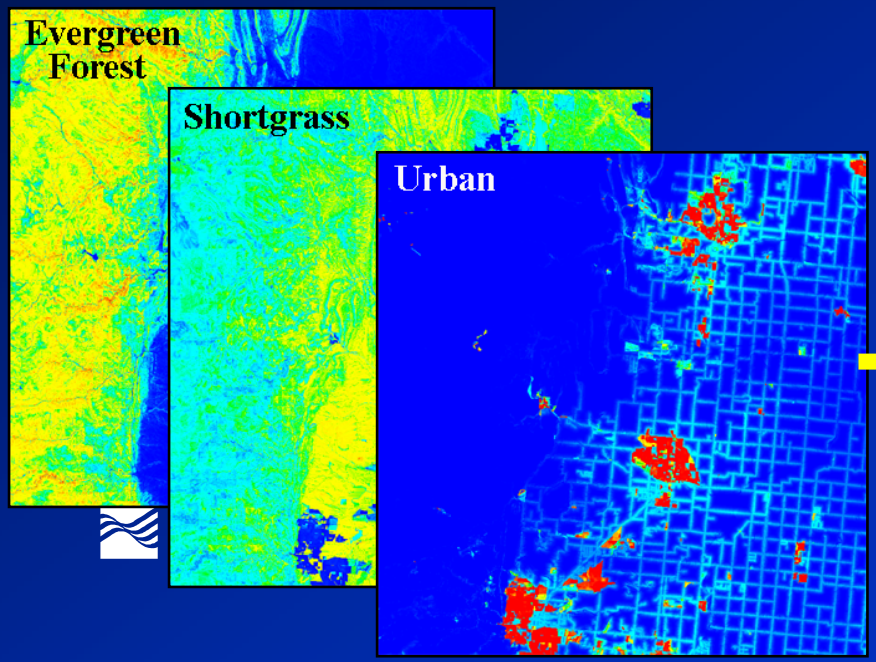
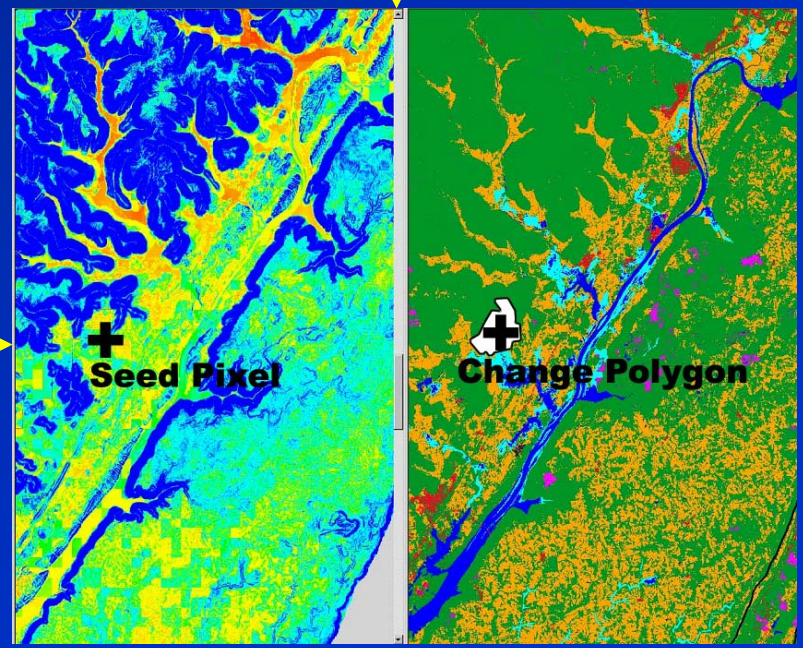
Generating Change Polygons

- **DEMAND module drives # of “seed” pixels**
- **Probability surfaces used in conjunction with Trends information to create change polygons**
- **Competition between LULC types resolved by probability values**

TRANSITION TYPE	Mean Patch Size	Standard Deviation
Grass/shrub to Urban	7.10	5.8416
Grass/shrub to Mining	1.37	2.3973
Grass/shrub to Agriculture	57.14	114.2228
Grass/shrub to Wetland	2.88	1.08
Agriculture to Urban	3.75	3.5425
Agriculture to Mining	6.84	8.412
Agriculture to Grass/shrub	58.43	103.1701
Agriculture to Wetland	3.00	0.7397
Wetland to Agriculture	4.36	6.4408
Wetland to Wetland	3.76	8.8533





Texas Urban Growth

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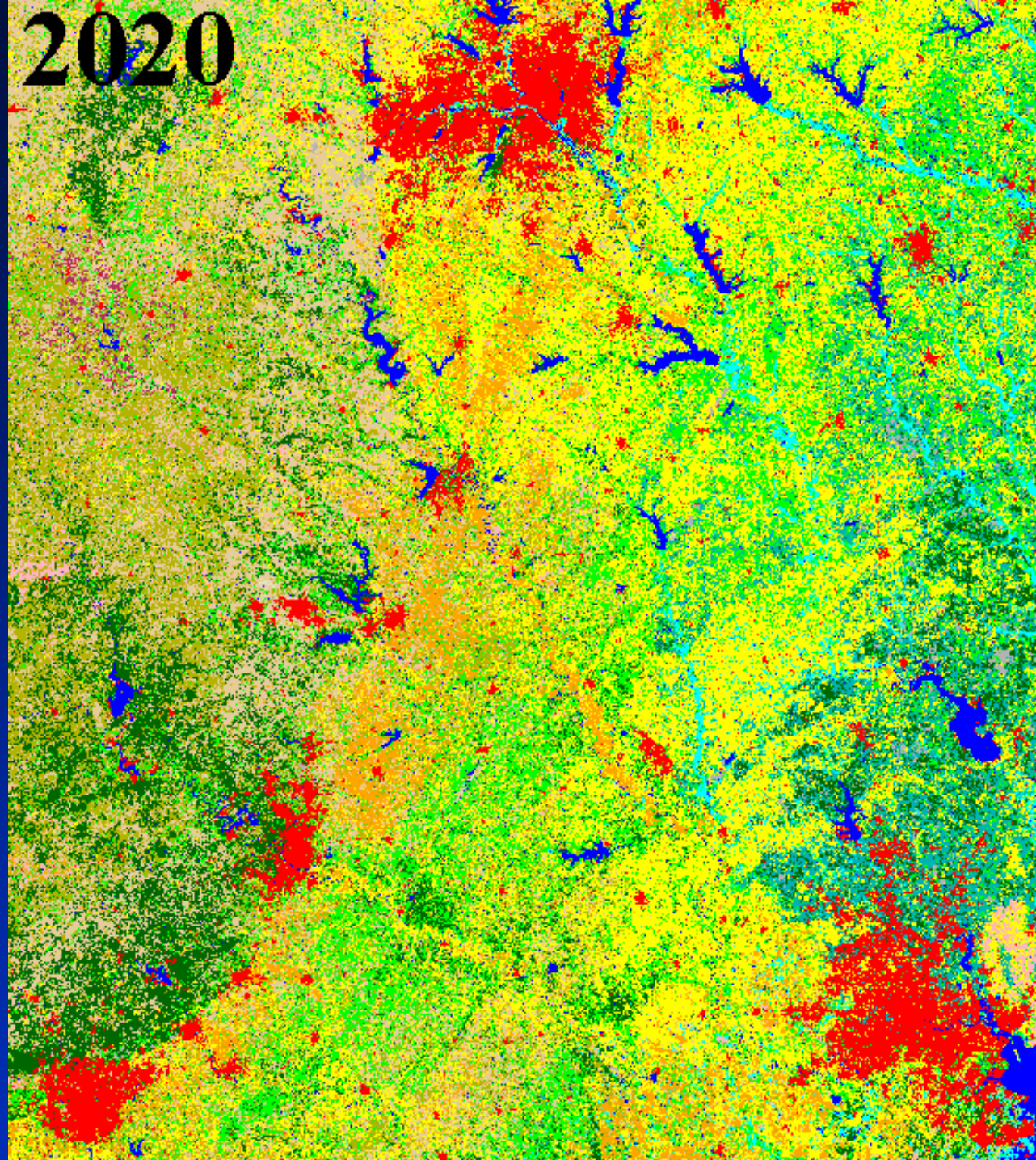
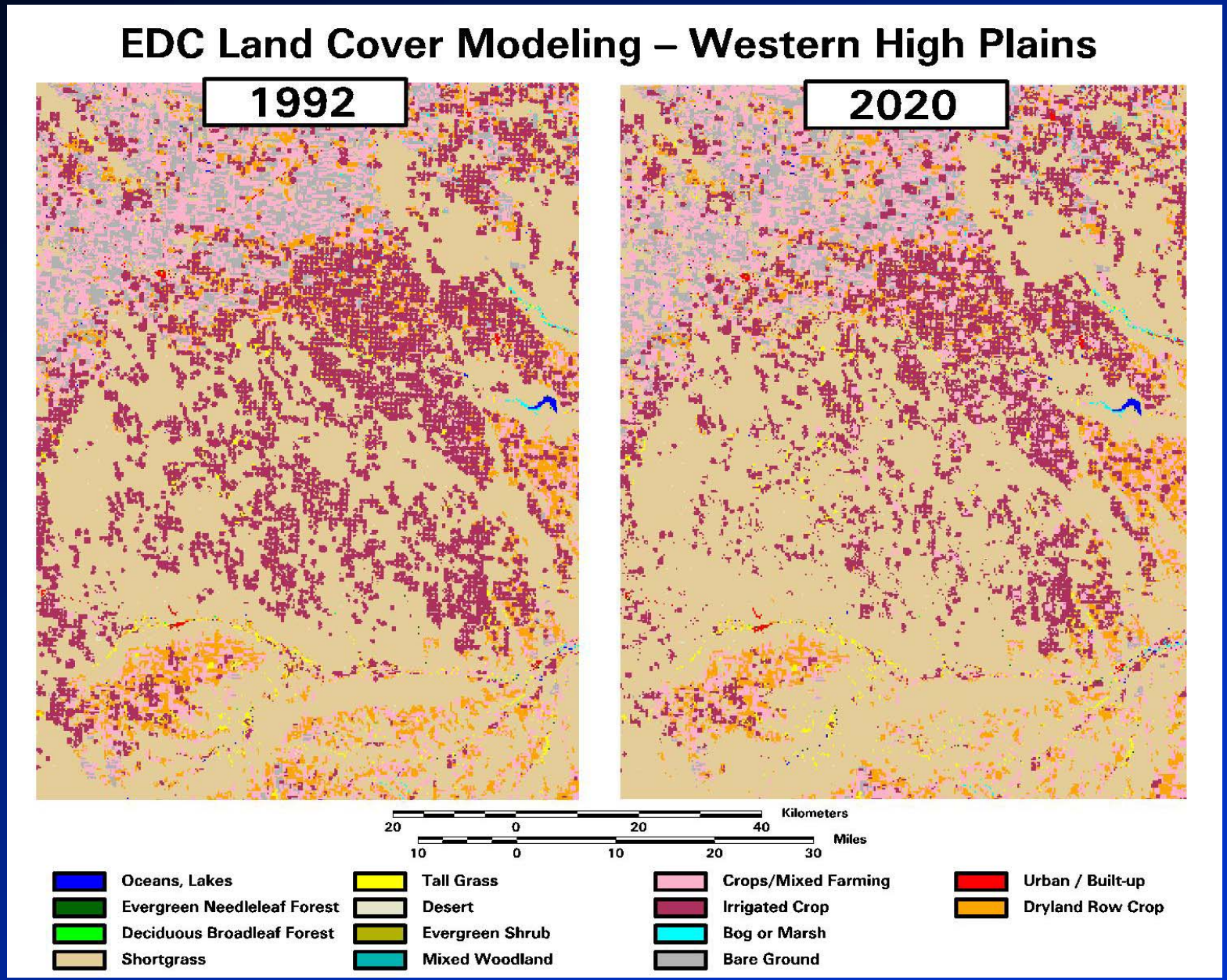
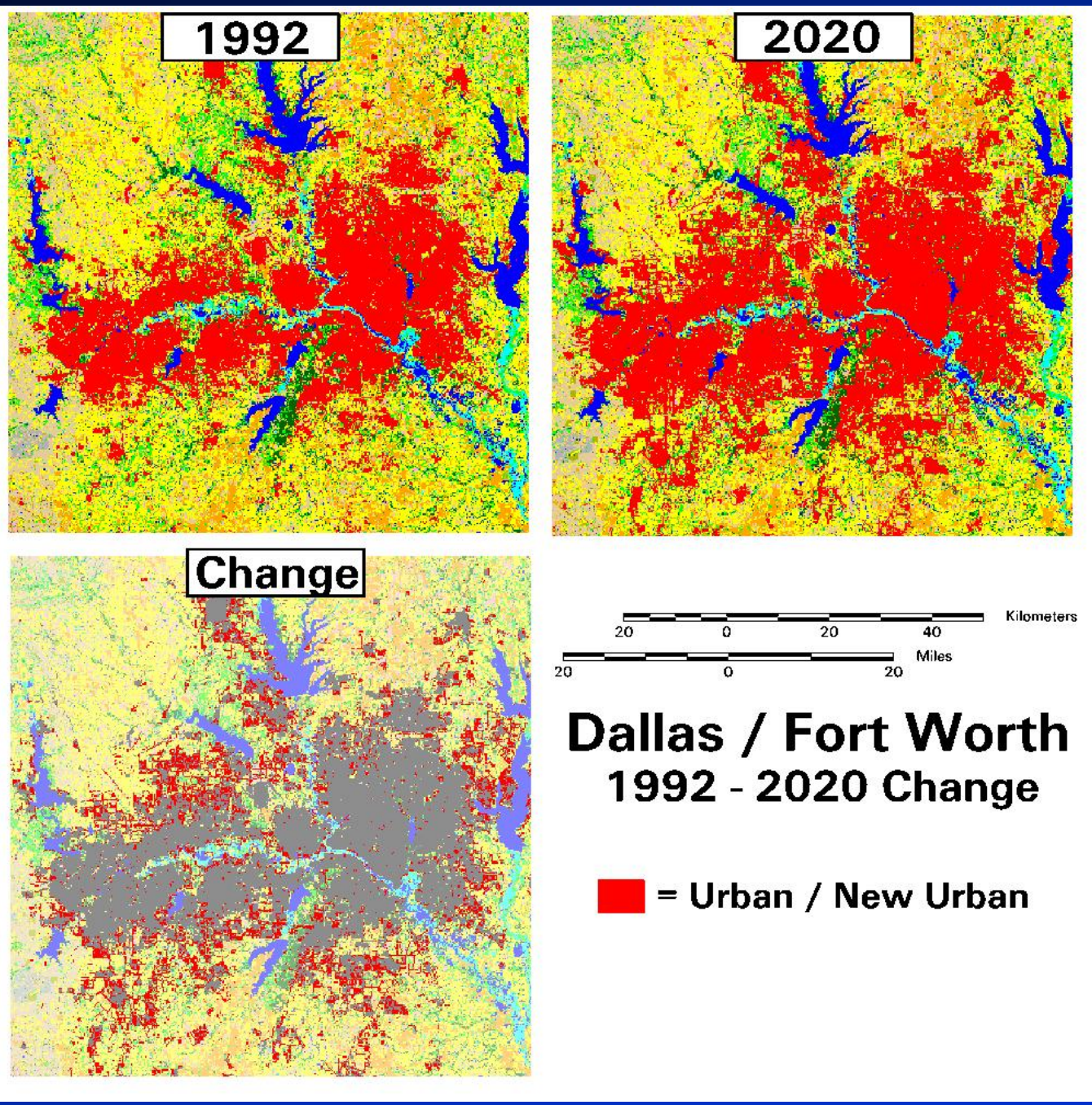


Decline in water access; Increased energy costs



Urban Growth



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Consequences of Land Cover Change on Surface Hydrology, Regional Weather and Climate Variability

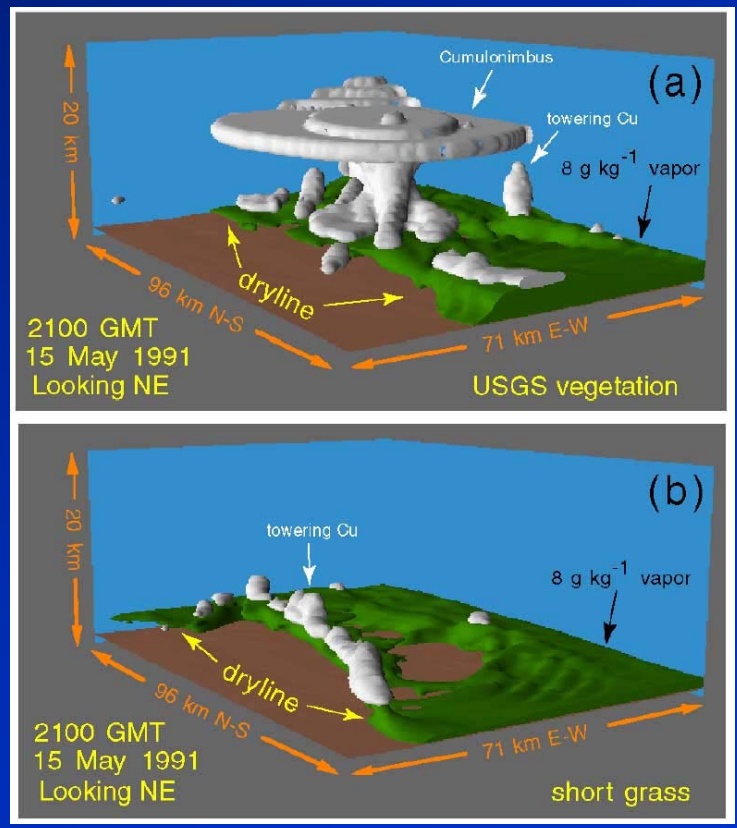
Land – Atmosphere Interactions
1920 - 2020

<u>Scenario-based modeling</u>

Land Cover Trends

Biophysical Parameters

RAMS/LEAF2/GEMTM model sensitivity tests – precipitation, evaporation and transpiration, soil moisture



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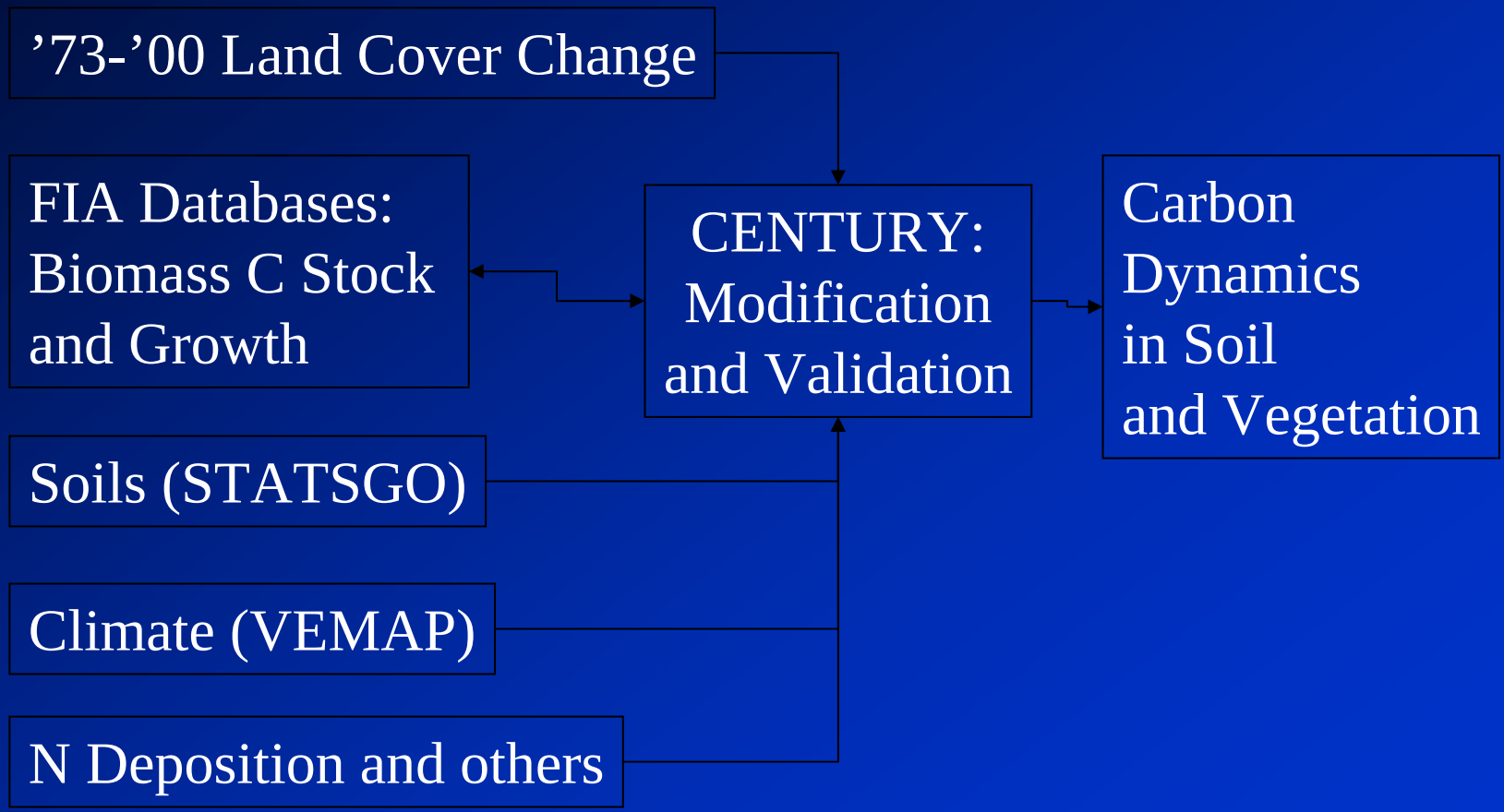
Carbon Modeling
-Shuguang Liu

USGS Center for Earth Resources Observation and Science

USGS

Carbon Modeling Approach



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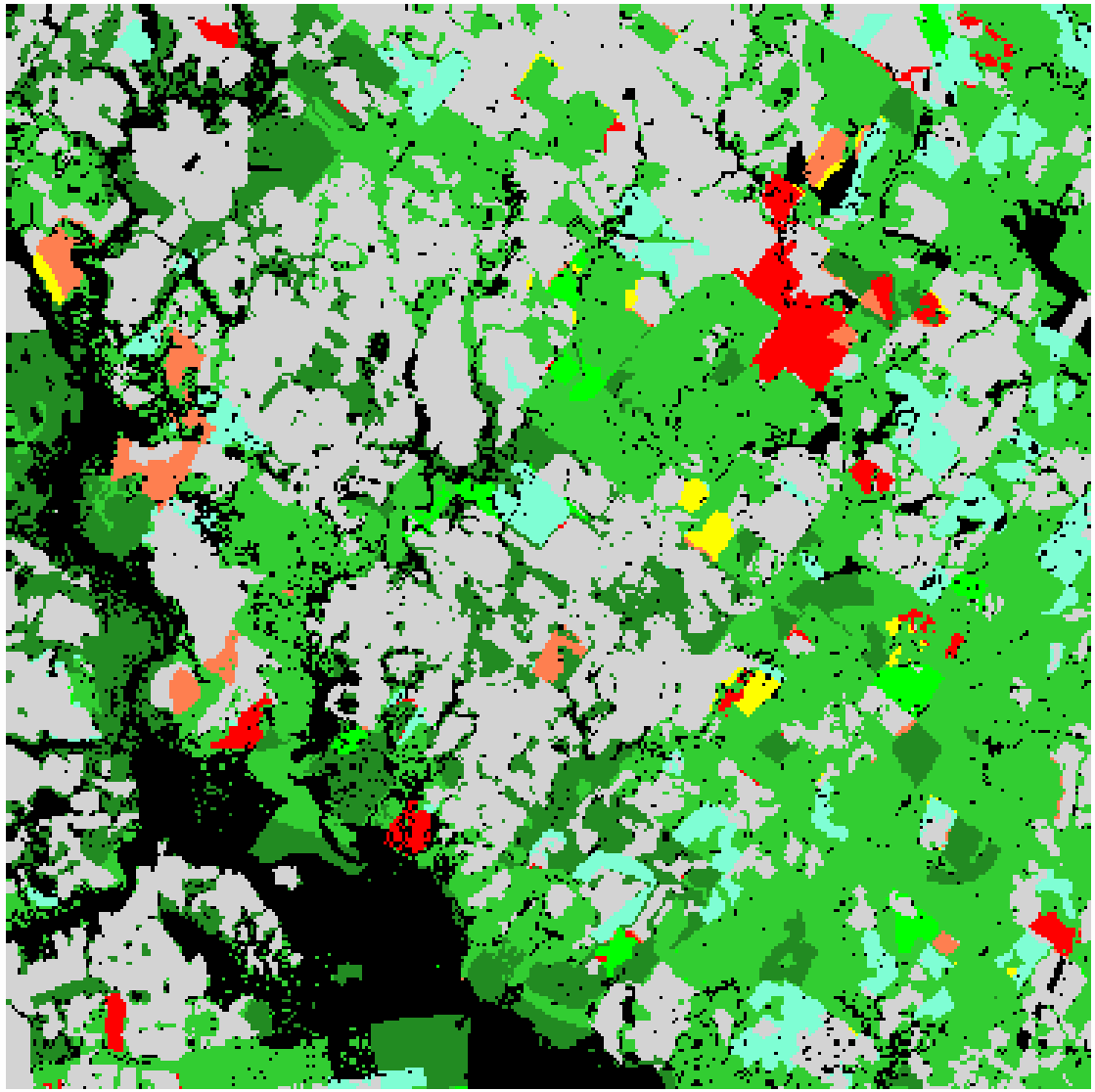
Forest Biomass C Change



Ecoregion: 65
Block: 08
Time: 74 --- 00

Unit: gC/m2

- <-4000
- -4000 to -2000
- -2000 to -500
- -500 to 500
- 500 to 2000
- 2000 to 4000
- 4000 to 6000
- > 6000
- Water, roads, wetlands, etc.

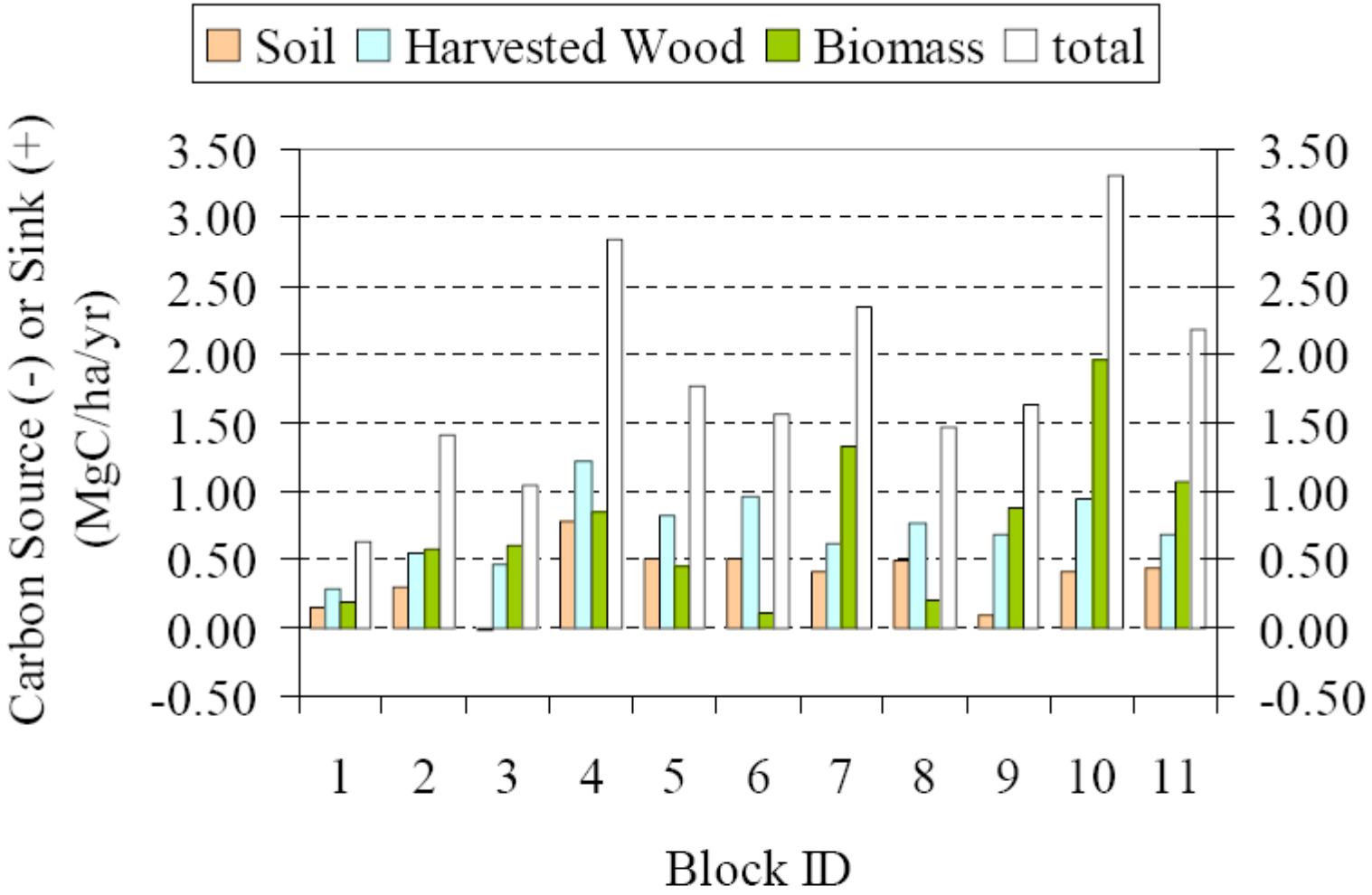
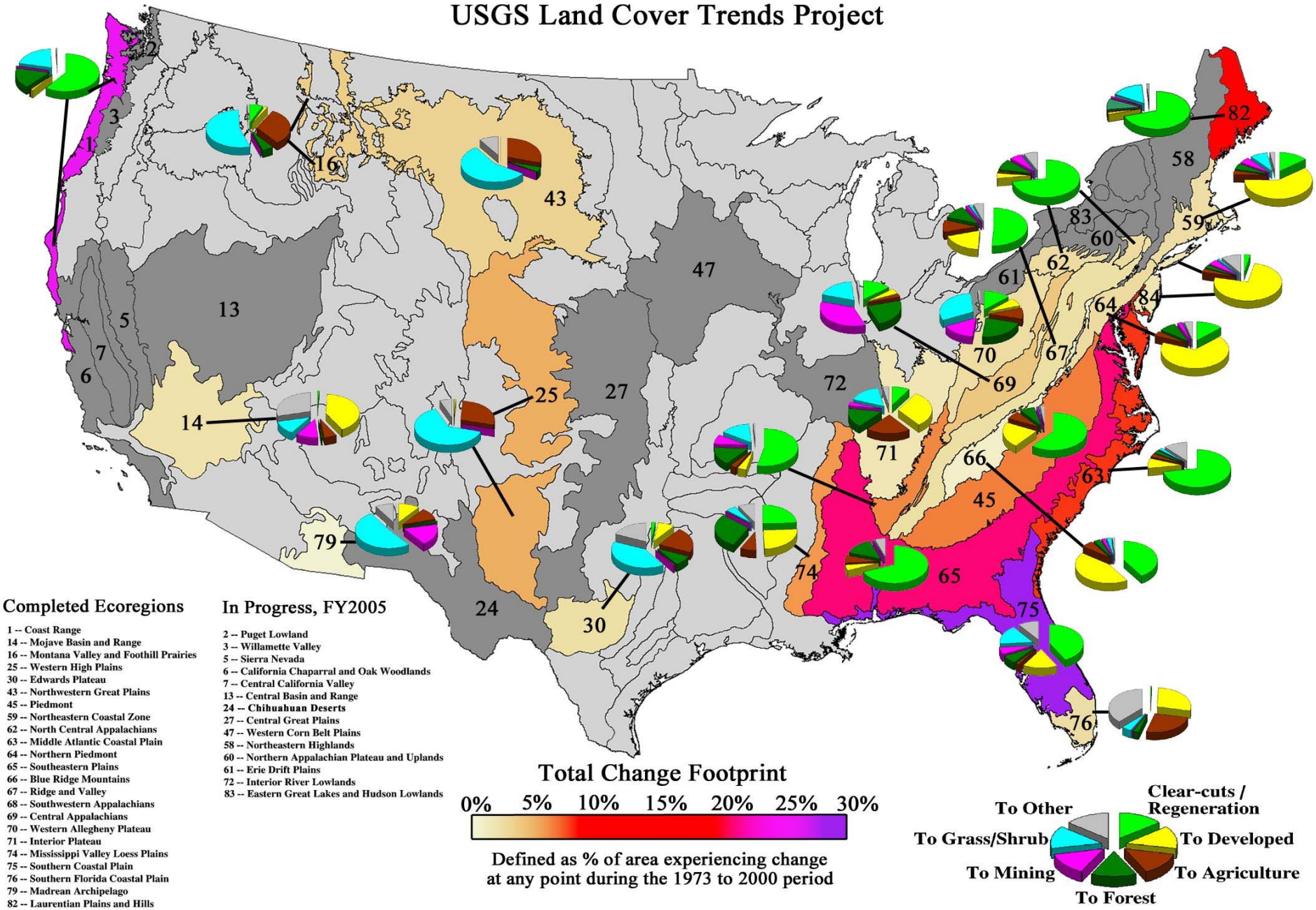


Figure 3. Carbon sources and sinks for sample blocks in Southeastern Plains ecoregion. Overall, the ecoregion is a strong sink, with 0.045 to 0.078 giga tons C/yr (+/- two standard errors) sequestered.

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
82 -- Laurentian Plains and Hills
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
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

Conclusions

- Land uses within ecoregions are continuously adapting to the resource potential created by enabling natural characteristics – as influenced by contemporary drivers, and the influences of historical settlement patterns and traditions.
- Agricultural regions are drifting in different directions with some intensifying and others reducing intensity.
- There is no single profile of agricultural change. Instead there are varying pulses affected by clusters of change agents – especially global market influences, technology, and government policy.

USGS