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Experiences of Mapping Land Use and Land Cover And Deriving Trends over the Vast West African Region

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Earth Resources Observation and Science Center (EROS)

Space Tools and Solutions for Monitoring the Atmosphere and Land Cover

Austrian Academy of Sciences, Institute for Space Research

Graz, Austria 9-12 September, 2008

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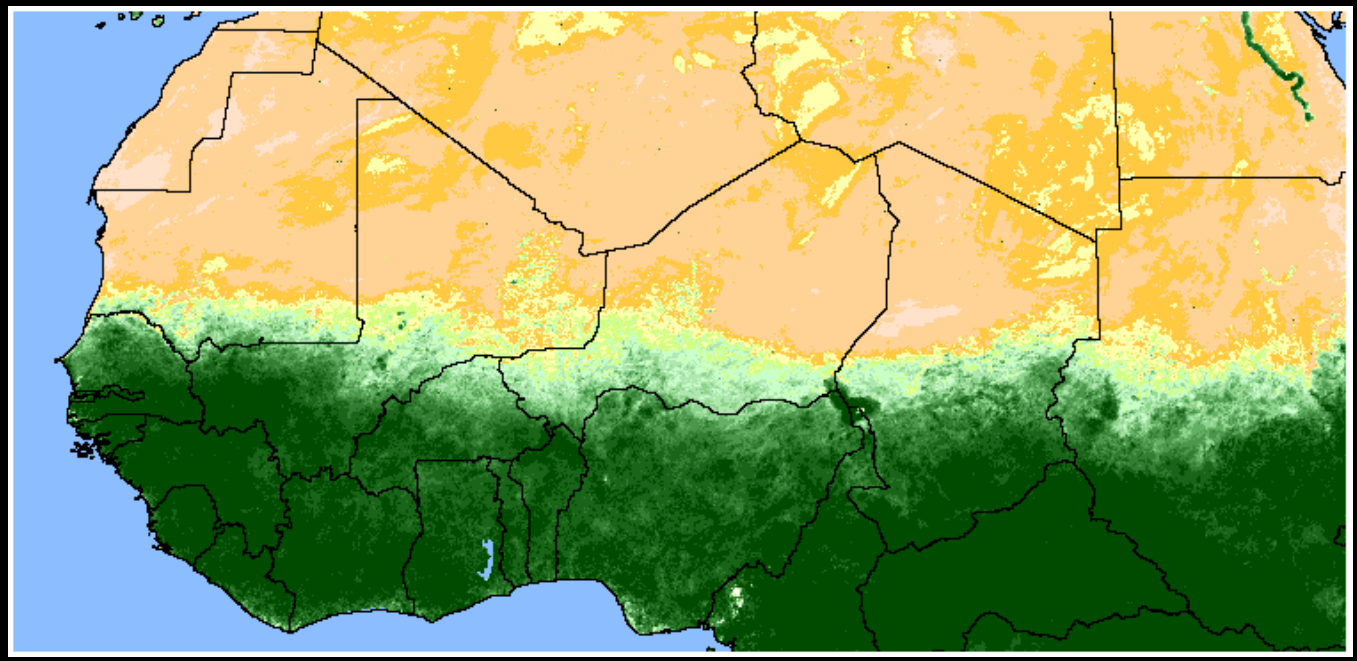
U.S. Department of the Interior
U.S. Geological Survey

Presentation Outline

1. EROS and its Support to Regional Remote Sensing Centers
2. Land Use and Land Cover: Concepts and Mapping Challenges
3. Rapid Land Cover Mapper Tool
4. Local Successes in Natural Resource Management



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The U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center's vision is to be the world's leading source of land information for exploring our changing planet.

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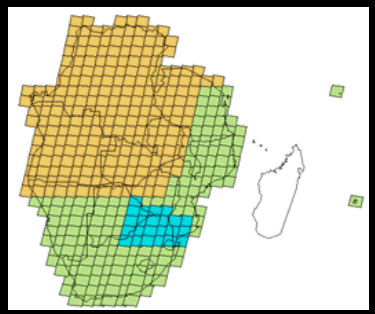
Support to Regional Centers and Continental Capacity Building

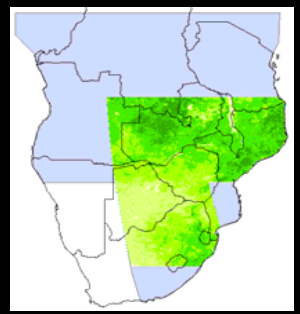
AGRHYMET Regional Centre
GeoCover (1970s, 1980s, 2000) + Landsat archive (EROS) + MODIS/ ASTER/ SRTM data

Regional Centre for Mapping & Resources for Development

Landsat 1990s

SADC Regional RS Unit
Landsat (1970s/90s, 2000); MODIS NDVI





EROS Support to Regional Remote Sensing Centers

- **collection/dissemination of RS data**
- **Landsat, SRTM, MODIS, ASTER**
- **training in applications of RS data**

Landsat 2000

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2. Land Use and Land Cover: Concepts and Mapping Challenges

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Much Diversity in West African Land Cover

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Land Use and Land Cover: Definitions

- Land cover: refers to the attributes of a part of the Earth's land surface, including biota, soil, topography, water, and human structures

- Land use: refers to the purposes for which humans exploit the land cover

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Major Environmental Concerns in West Africa

- Rainfall has declined (Sahel)
- Natural resources degrading under increasing human pressure (agricultural expansion, wood cutting, etc.)
- Land Use and Land Cover changes occurring at unprecedented rates
- Forest cover diminishing
- Biodiversity has declined (flora and fauna)

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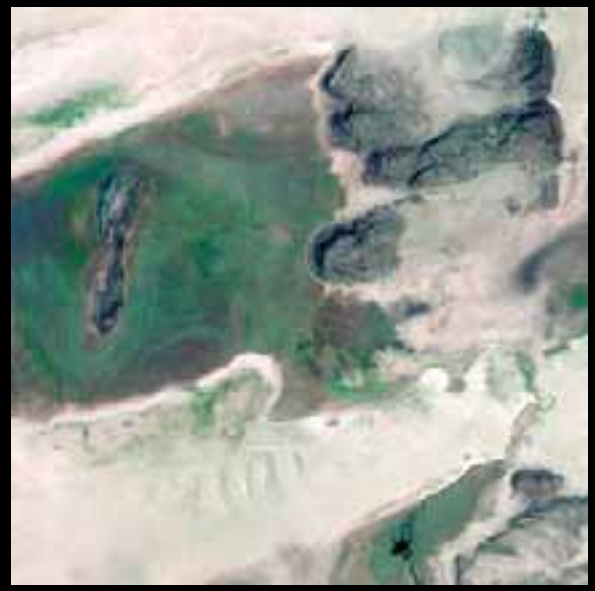
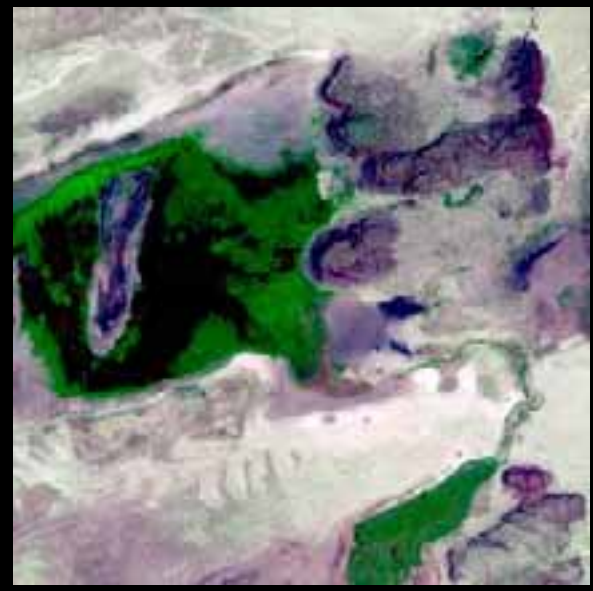
Lake Faguibine, Mali: A view through time with Landsat

1972

1985



2000



26 km

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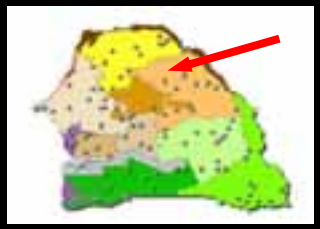
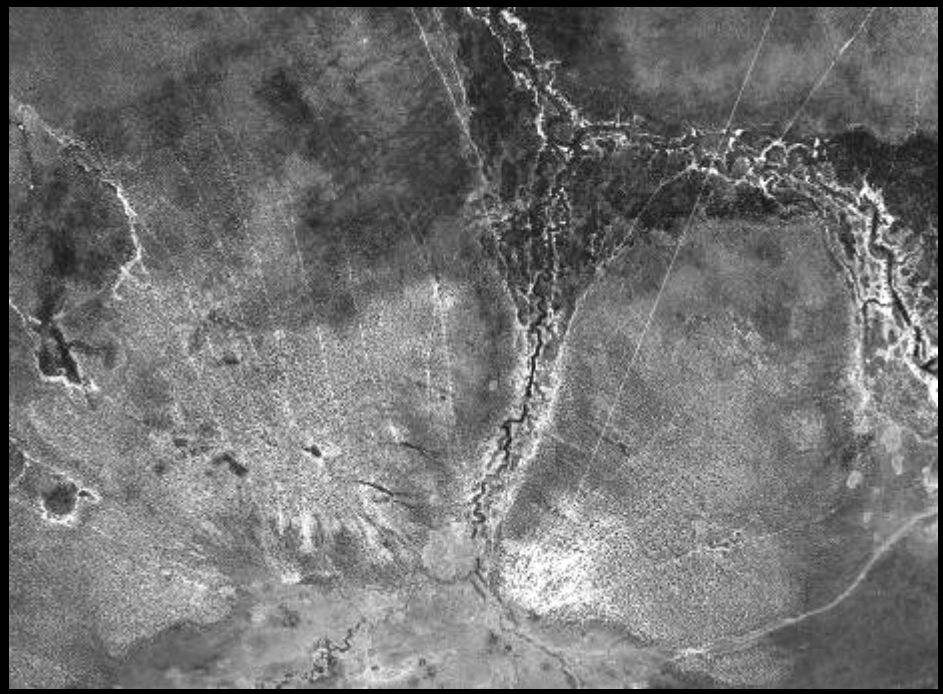


Spread of degraded and barren surfaces (Senegal)

Revane area, Dec. 1965, Corona



Revane area, Oct. 1999, Landsat

Percent Woody Cover

1965: 10 – 20 %

1994: 5 – 15 %

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Spread of degraded and barren surfaces (Senegal)

1995

2007

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Increase in Agricultural Land at the Expense of Various Land Cover Types

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What is the development problem?

Understanding land use/land cover change and land management will help countries balance food production with preserving their natural resources

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What Types of Geographic Data Do We Need To Map, Monitor, and Model LULC?

- Climate data*
- Soils data
- Vegetation data*
- Land Use and Land Cover data*
- Population data*
- Land Management data
- Land Productivity data

* Time-series data preferably

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Changes in Land Use and Land Cover

- How are the natural and human landscapes changing?
- What are the rates and magnitudes of change?
- What are the causes and mechanisms of change?
- What impacts are the changes having?

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Land Cover Conversion versus Modification

- Land Cover Conversions: the replacement of one cover type by another

- Land Cover Modifications: subtle changes that affect the character of the land cover without changing its overall classification; they are as important as land cover conversions

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Land Cover Conversion:
Woodland to Agriculture (Senegal)

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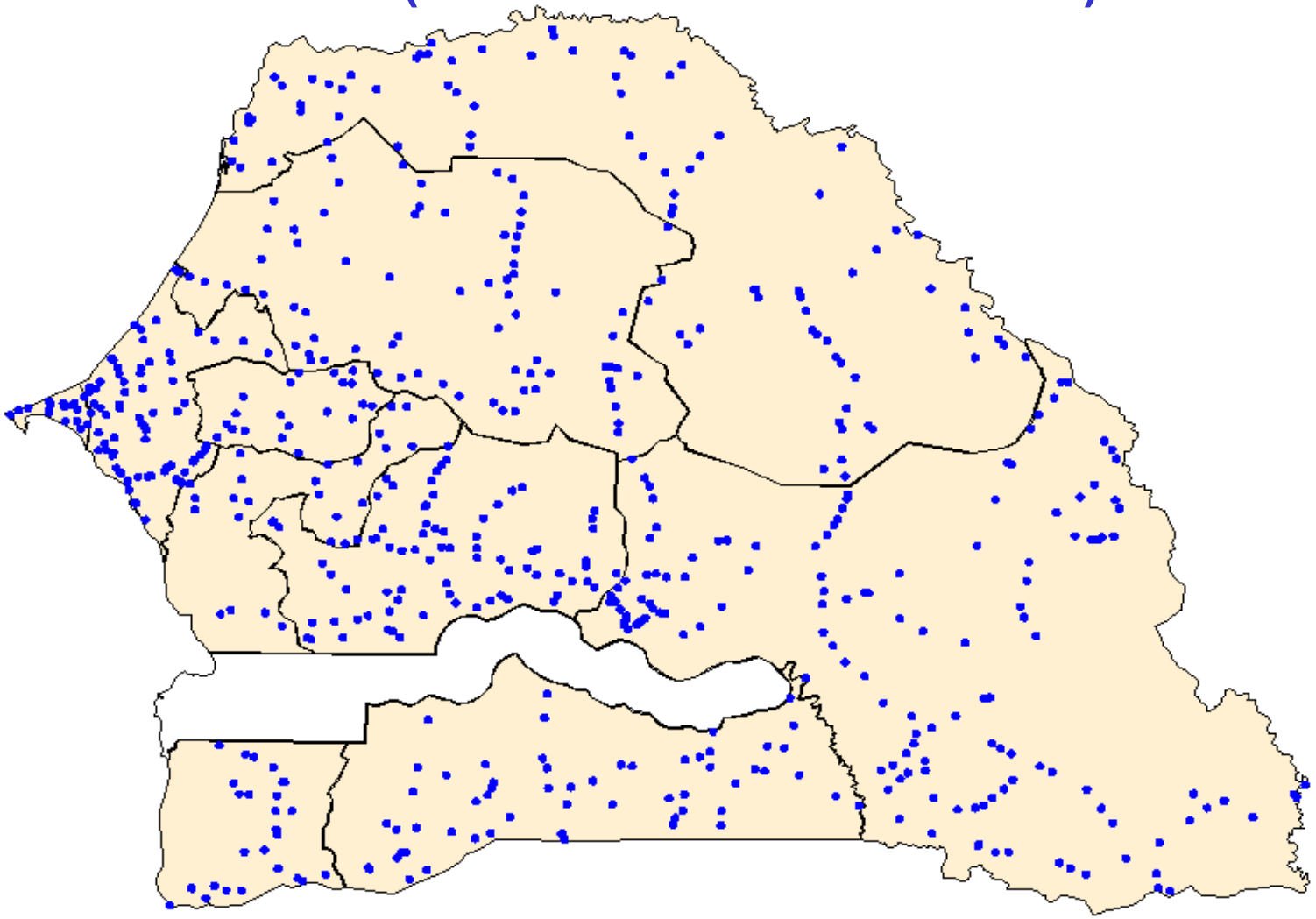
Permanent Monitoring Sites in Senegal (Established in 1982-1983)



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Land Cover Conversion:

Woodland to Agriculture (Senegal)

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Land Cover Modification:

Quality changes in a shrub savanna (Senegal)

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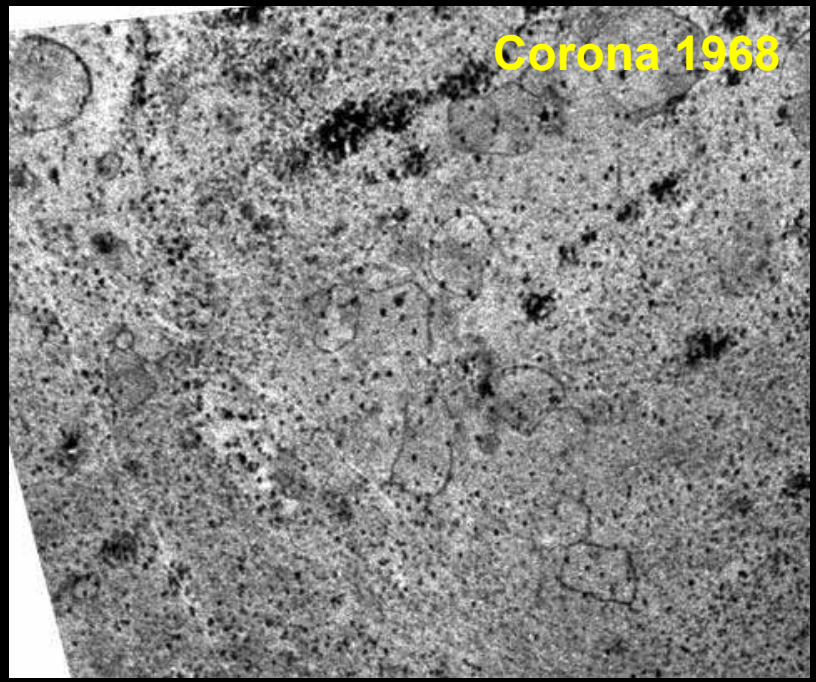
Tree Density Changes in the Pastoral Region, Northern Senegal

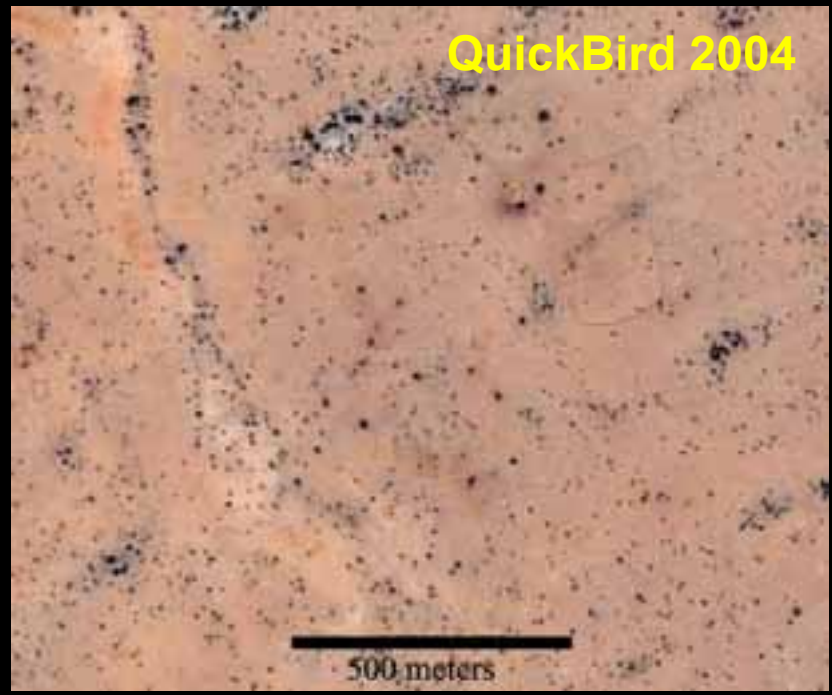
- 8.6 trees & shrubs/ha
- 5.3 tons woody biomass/ha*
- 2.5 tons C in woody biomass/ha*
- 4 woody species/ha

*(based on measurements at comparable sites in the pastoral zone)

- 6.3 trees & shrubs/ha
- 3.8 tons woody biomass/ha*
- 1.8 tons C in woody biomass/ha*
- 2 woody species/ha

*(based on measurements at comparable sites in the pastoral zone)





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Land Cover Modification: Changes in Biodiversity (Senegal)

Woody Species at Site 403 – Mar. 1984

Combretum micranthum
Combretum nigricans
Combretum glutinosum
Bombax costatum
Adansonia digitata
Acacia macrostachya
Acacia polyacantha
Gardenia ternifolia
Grewia bicolor
Lannea acida
Lonchocarpus laxiflorus
Sclerocarya birrea
Sterculia setigera
Strychnos spinosa
Feretia apodanthera
Boscia angustifolia
Guiera senegalensis
Pterocarpus lucens

Woody Species at Site 403 – Feb. 1994

Combretum micranthum
Combretum nigricans
Combretum glutinosum
Bombax costatum
Acacia macrostachya
Adansonia digitata
Grewia bicolor
Sterculia setigera
Boscia angustifolia
Guiera senegalensis
Pterocarpus lucens

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Land Cover Stability in a Protected Woodland: (Niokolo-Koba, Senegal)

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Challenges in Land Cover Data

- Land cover data are often not up-to-date
- Time-series mapping of land cover is problematic
- Land cover classifications are not consistent
- Spatial resolution of land cover data is often insufficient
- Accuracy of data is called into question

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Challenges of Monitoring Land Use and Land Cover Change

- Approach: wall-to-wall or sampling
- Wall-to-wall generally based on coarse resolution satellite imagery
- Frequent monitoring versus snapshots
- High resolution imagery is costly
- Coarse resolution imagery less expensive, easier to handle, has full phenological information, global coverage
- Difficulty of manually classifying numerous images
- Seasonality issues
- Difficulty of identifying land cover classes
- Poor identification of LULC change that occurs at spatial scales finer than that of the sensor
- Time-series mapping presents another set of challenges

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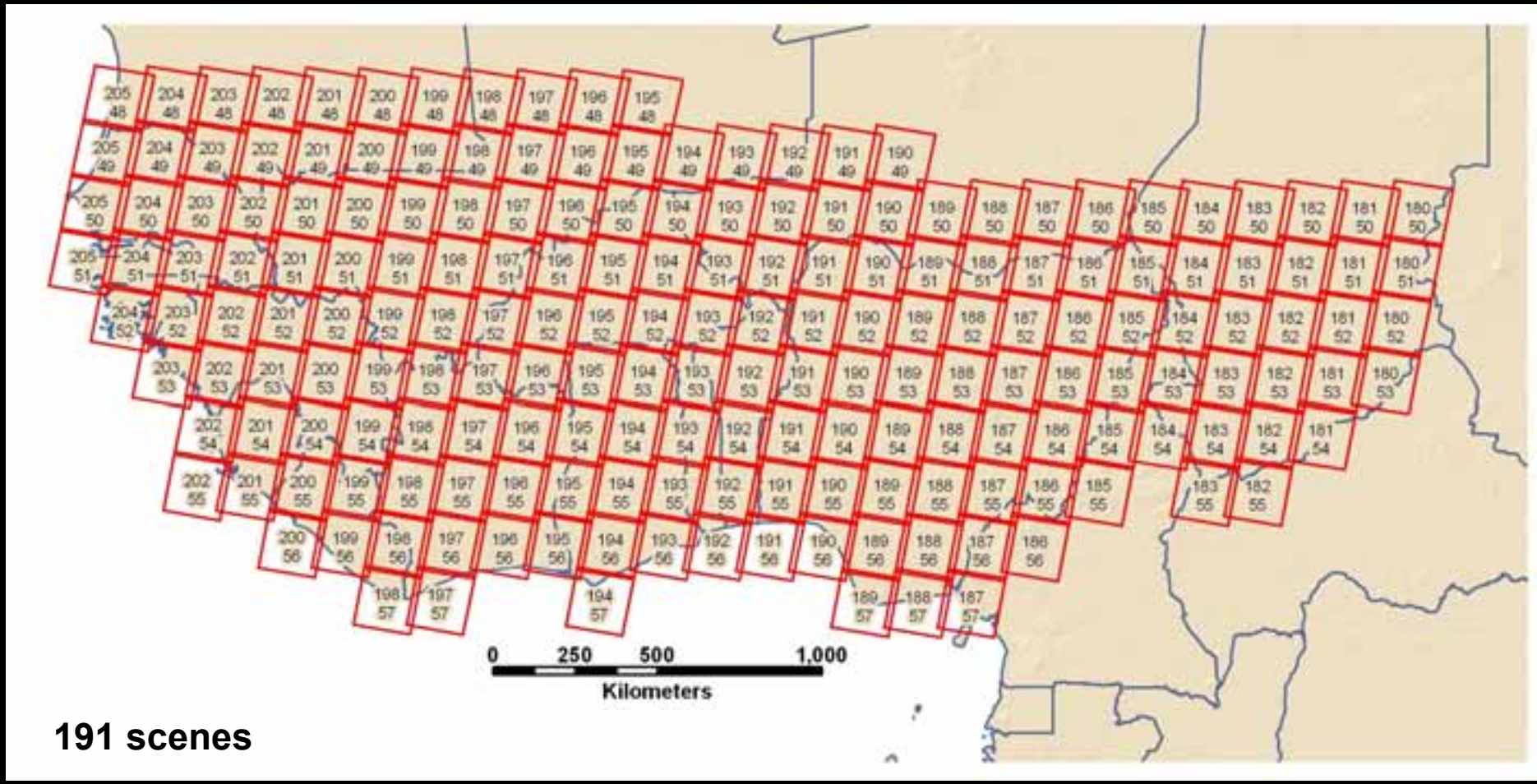
Geographic extent of the West Africa LULC Trends Project as depicted through Landsat scene coverage



191 scenes

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West Africa Land Use/Land Cover Trends Project

- Develop and Implement a West African regional LULC monitoring framework in partnership with AGRHYMET, INSAH, and national institutions
- Produce LULC maps of West Africa for the periods of 1972, 1985, and 2000
- Provide information to CILSS and ECOWAS food security and natural resource management programs
- Engage decision-makers in the results of LULC trends

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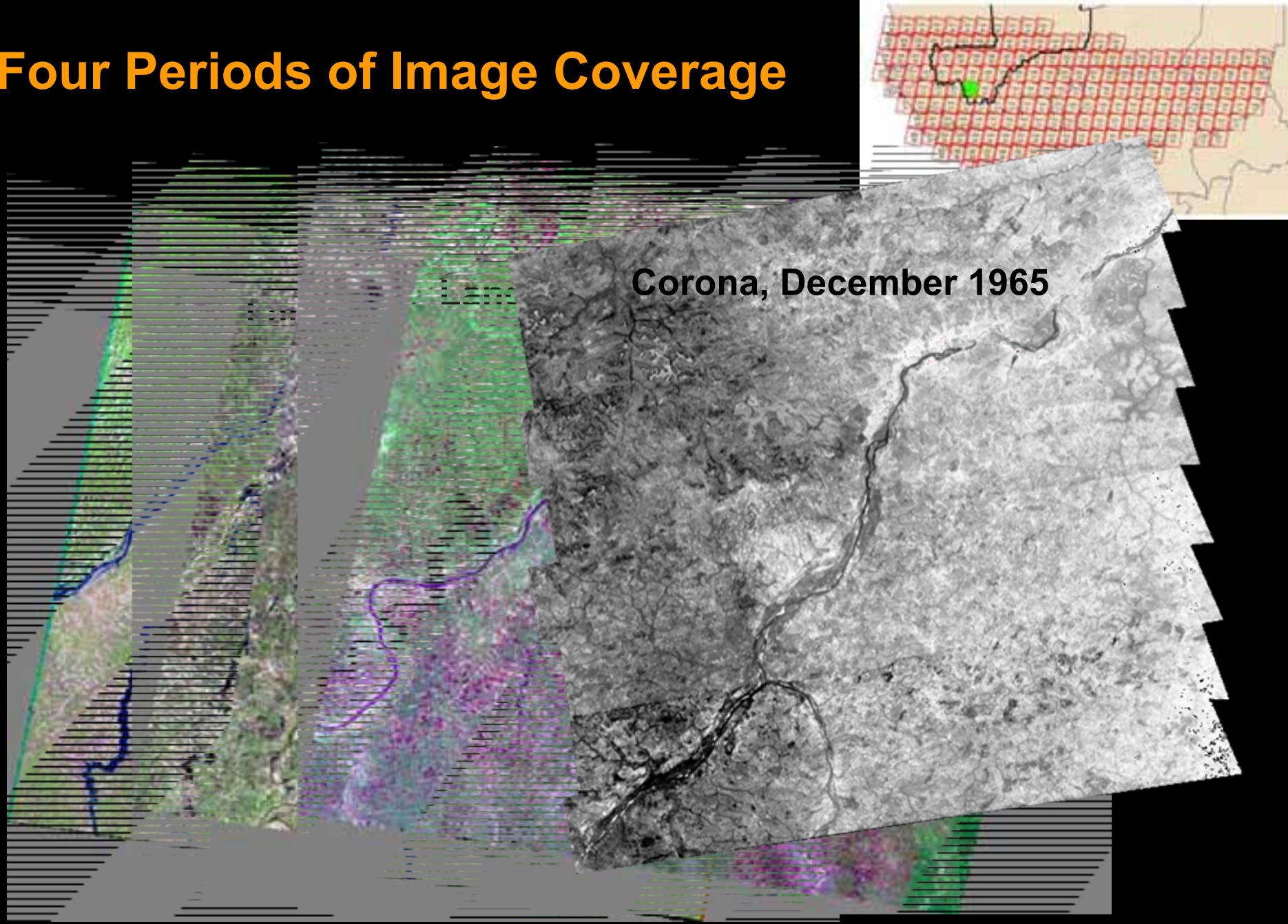
Four Periods of Image Coverage



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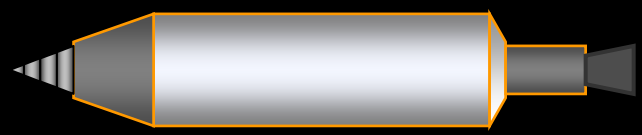
Historical Imagery from the Corona and Argon Satellite Programs

Corona System Overview:

Period of Operation:	1959-1972
Number Missions:	95 successful; 121 total
Orbit:	Near-polar
Altitude:	150 to 203 km
Sensor Type:	Photographic camera, 24” focal length
Film Type:	Kodak panchromatic film
Nominal Photo Scale:	1:305,000
Spectral Region:	Visible
Scan Angle:	70 degrees
Ground Coverage:	19.6 by 266 km
Ground Resolution:	1.5 to 8 meters



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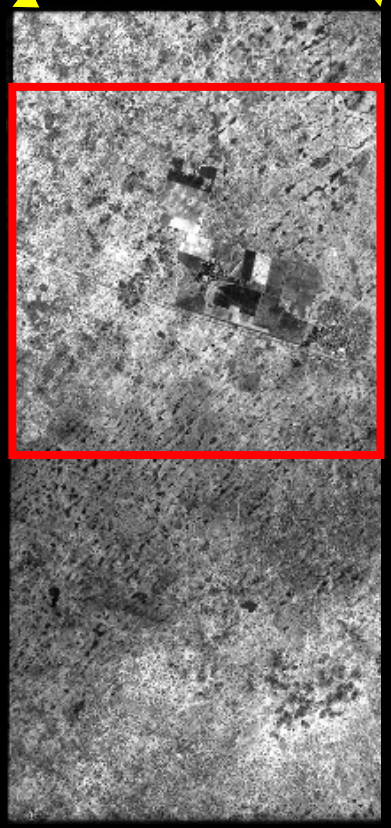
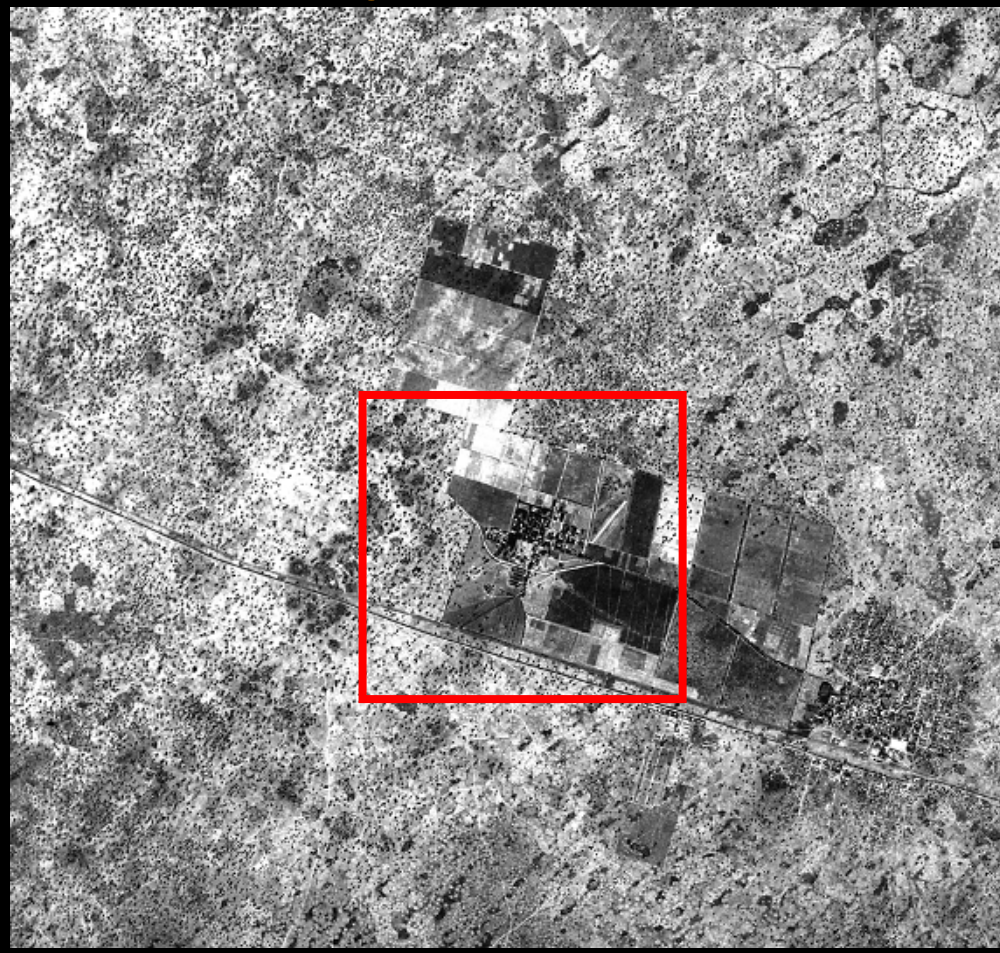
Corona Satellite Photography: Jan. 1968

Full frame: 20 X 266 km



Enlargement: 8 X 8 km



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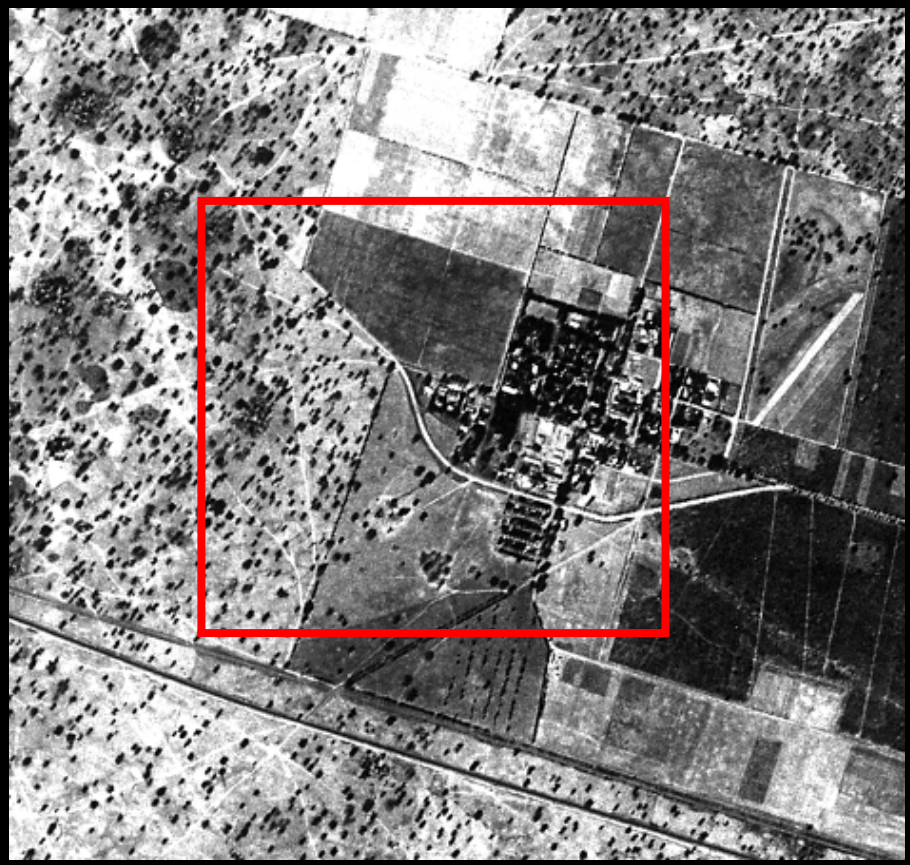
Corona Satellite Photography: Jan. 1968

Enlargement: 2.4 X 2.4 km



Enlargement: 1.2 X 1.2 km

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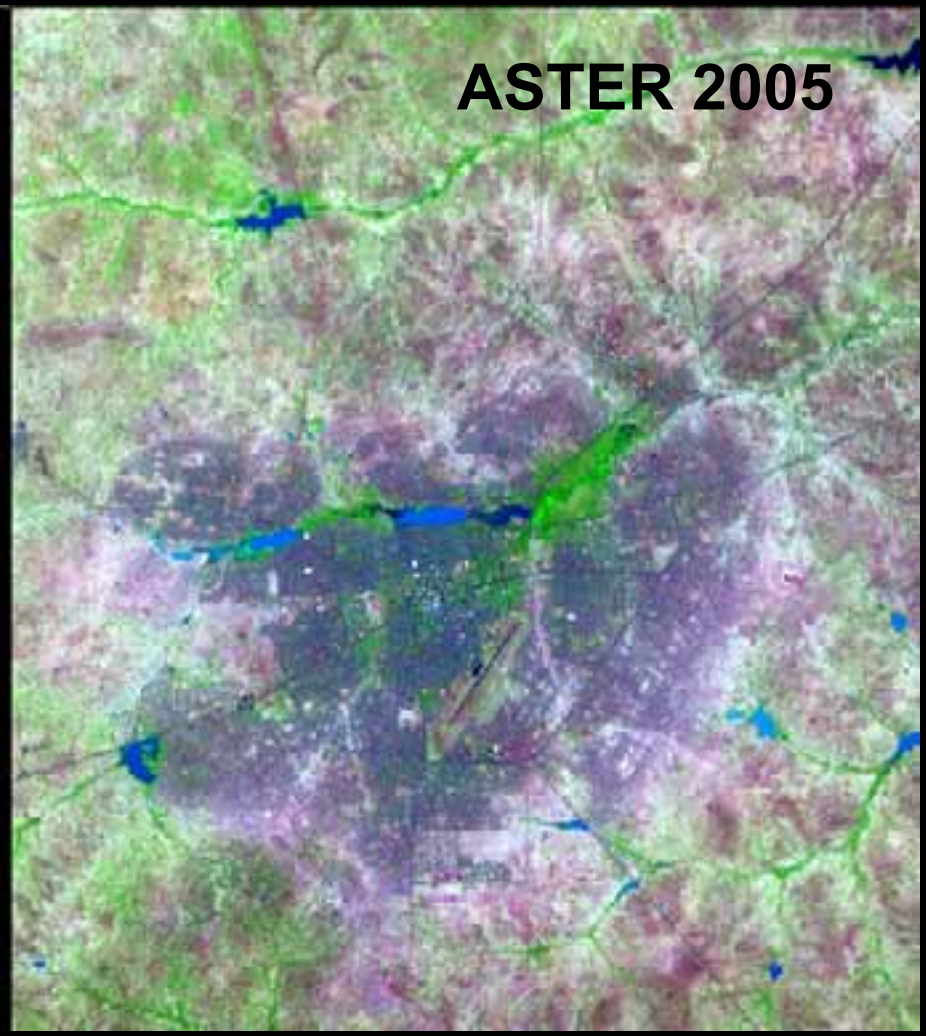
Ouagadougou, Burkina Faso



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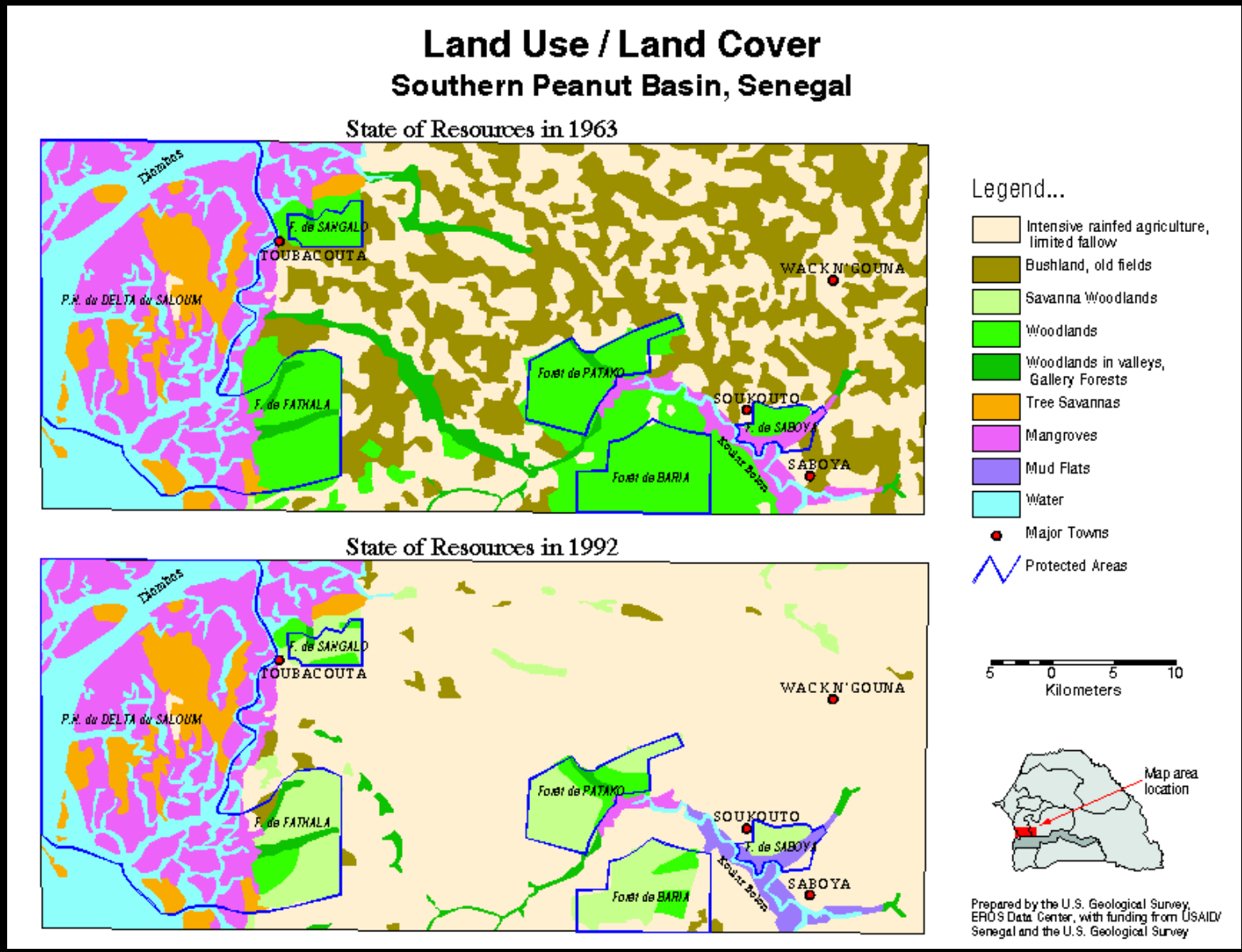
Time-Series Maps Prepared from Corona and Landsat



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Workshop on the Stratification of Ecological Regions
AGRHYMET / Niamey

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Elements of Image Interpretation

- Tone
- Color
- Size
- Shape
- Texture
- Pattern
- Height
- Shadow
- Site
- Association

- Used *together* to understand and recognize visual signatures of features and objects;
- Often applied implicitly, but an explicit vocabulary permits clear documentation and discussion.

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Interpretation Challenges –
Do you see any cropland? (Landsat, Southeast Senegal)

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Interpretation Challenges – naturally occurring open areas (aerial, Southeast Senegal)

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Interpretation Challenges – Ground Photo

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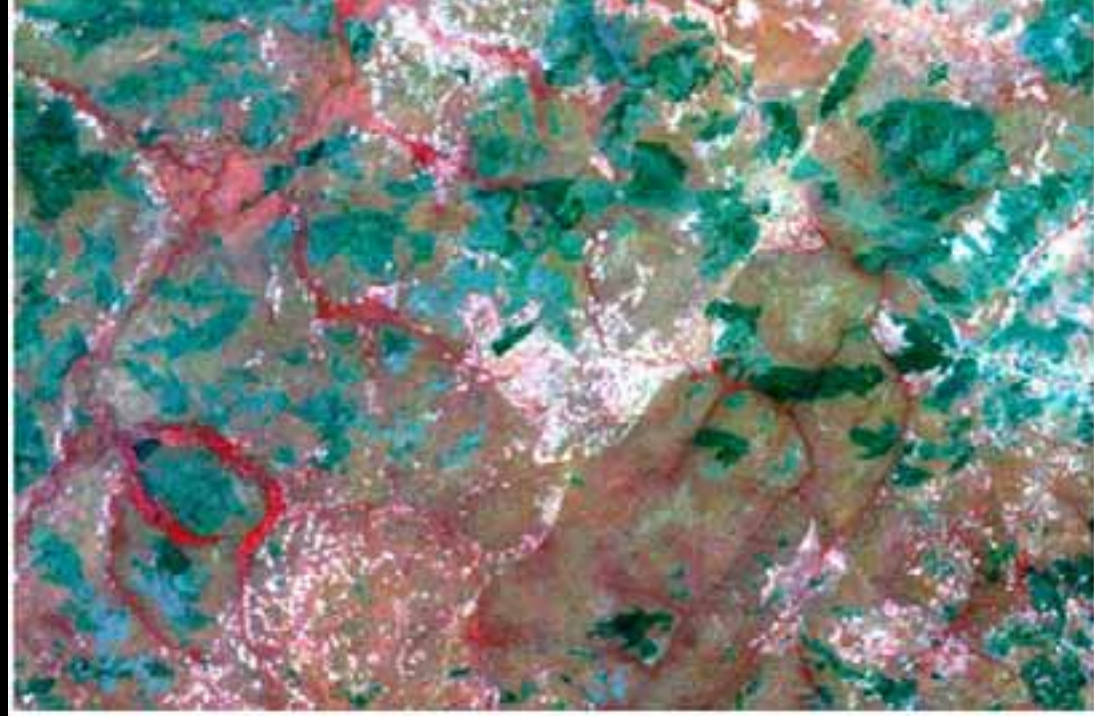
Landsat Time-Series

Western Burkina Faso

1973



1999

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Land Use/Land Cover Map - Burkina Faso 1975

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Land Use/Land Cover Map - Burkina Faso 2000

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Land Use/Land Cover Maps - Ghana

Land Use Land Cover c. 1975

Land Use Land Cover c. 2000

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Land Use/Land Cover Trends for Ghana, 1975-2000

	Total (93.33% of country analyzed)					
	LULC Area (sqkm)				Percent Change	
	c.1975	%A c.'75	c.2000	%A c.'00	By Class	Total Area
NoData	96	0.0%	8	0.0%	-91.7%	0.0%
Forest	16,616	7.0%	13,640	5.7%	-17.9%	-1.2%
Gallery Forest	4,688	2.0%	4,176	1.8%	-10.9%	-0.2%
Degraded Forest	***33,292***	***14.0%***	***24,524***	***10.3%***	***-26.3%***	***-3.7%***
Total Forest	***54,596***	***22.9%***	***42,340***	***17.8%***	***-22.4%***	***-5.1%***
Wetland - Floodplain	4,052	1.7%	4,208	1.8%	3.8%	0.1%
Water Bodies	8,372	3.5%	7,900	3.3%	-5.6%	-0.2%
Steppe	0	0.0%	0	0.0%	0.0%	0.0%
Oasis	0	0.0%	0	0.0%	0.0%	0.0%
Plantation	48	0.0%	68	0.0%	41.7%	0.0%
Mangrove	20	0.0%	20	0.0%	0.0%	0.0%
Agriculture	31,520	13.2%	61,852	25.9%	96.2%	12.7%
Irrigated Agriculture	32	0.0%	136	0.1%	325.0%	0.0%
Total Agriculture	***31,552***	***13.2%***	***61,988***	***26.0%***	***96.5%***	***12.8%***
Sandy Area	16	0.0%	16	0.0%	0.0%	0.0%
Rocky Land	40	0.0%	56	0.0%	40.0%	0.0%
Bare Soil	84	0.0%	176	0.1%	109.5%	0.0%
Settlements	1,440	0.6%	2,144	0.9%	48.9%	0.3%
Shrub and tree savannas	0	0.0%	0	0.0%	0.0%	0.0%
Wooded savannas	33,288	14.0%	27,208	11.4%	-18.3%	-2.6%
Wooded savannas and woodlands	88,924	37.3%	76,284	32.0%	-14.2%	-5.3%
Total Savanna	***122,212***	***51.3%***	***103,492***	***43.4%***	***-15.3%***	***-7.9%***
Open Mine	0	0.0%	112	0.0%	0.0%	0.0%
Cloud Mask	15,896	6.7%	15,896	6.7%	0.0%	0.0%
Area Analyzed	222,528	93.3%	222,528	93.3%	0.0%	0.0%
Total Area (sq km)	238,424	100.0%	238,424	100.0%		0.0%

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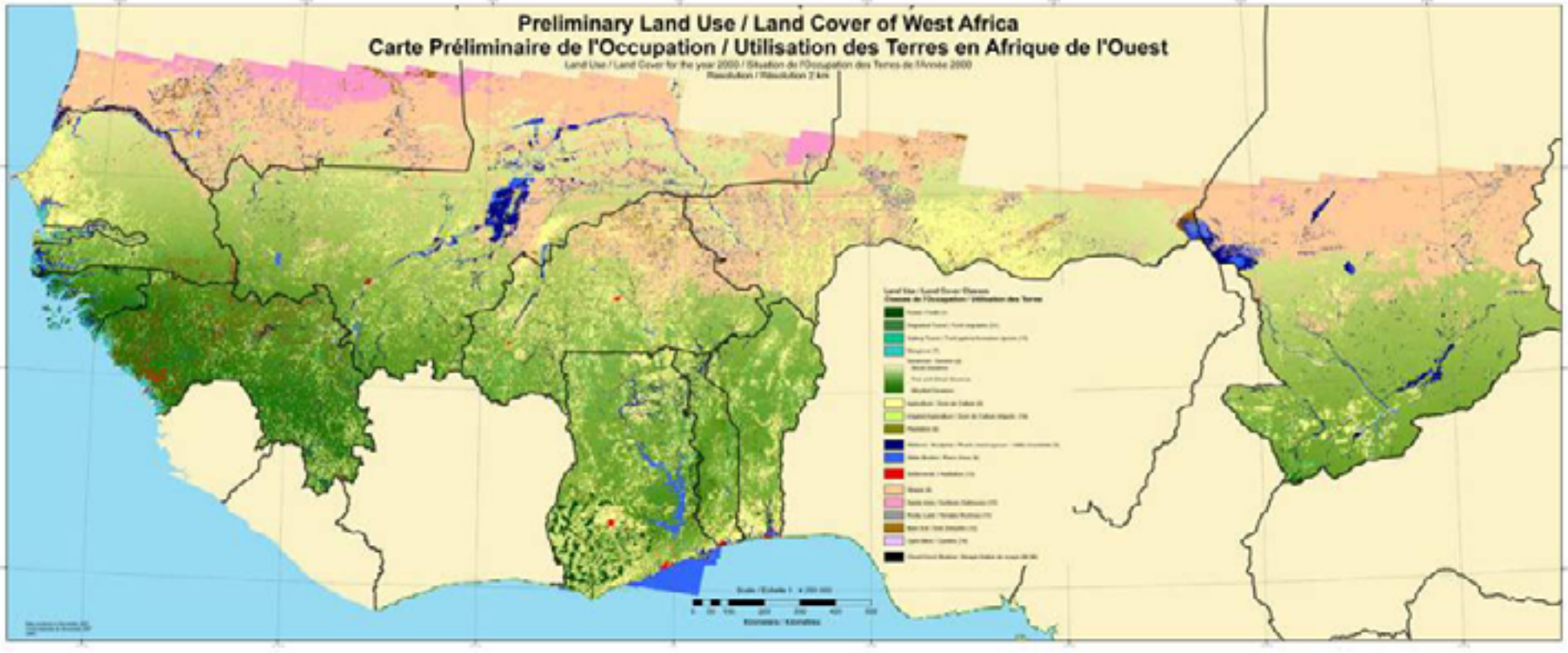
Land Use/Land Cover Map, West Africa 2000



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Land Use and Land Cover Change in West Africa: Major Trends

- Before the 19th Century, land was used for hunting, gathering, herding, and shifting cultivation
- Rapid and dramatic changes occurred after 1930
- Cropland expansion driven by population growth and European demand for export crops
- Population increased as a result of improved public health provision
- 1930s: railroads and other major transport routes were in place, opening up inaccessible areas
- Cropland continues to expand at expense of savannas, wetlands, woodlands, and forests
- Land Cover modification has resulted in significant declines in vegetation density and biodiversity

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3. The Rapid Land Cover Mapper Tool

What is RLCM?

- The RLCM tool is a vector/raster hybrid approach to land use land cover (LULC) mapping. It lends itself to both multiple resolution and time-series mapping of LULC and many other geographic themes.
- Conceptually, it is based on the traditional dot grid method for calculating areas that has long been employed by foresters and other users of aerial photography.

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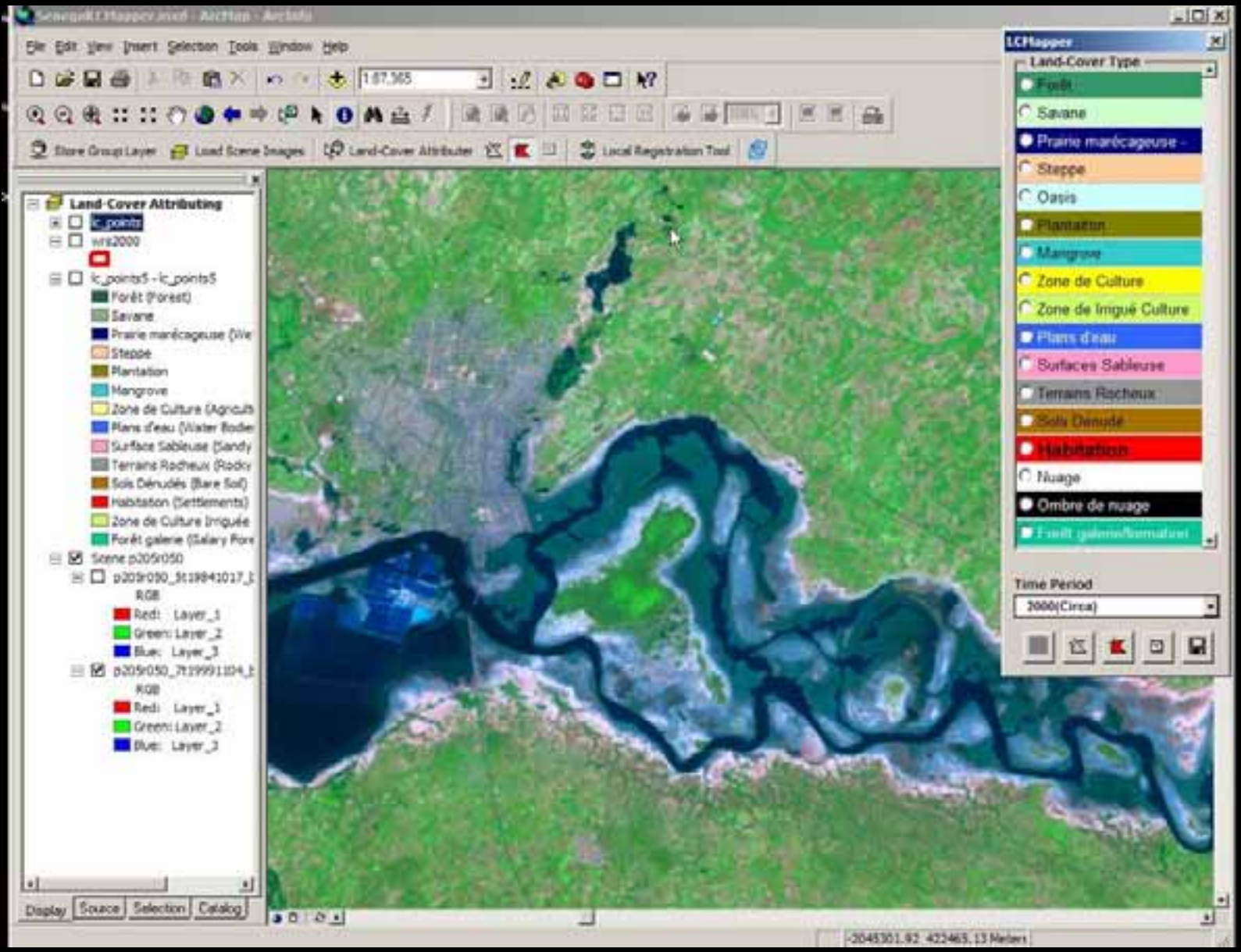
Product Development Workflow: Load Imagery



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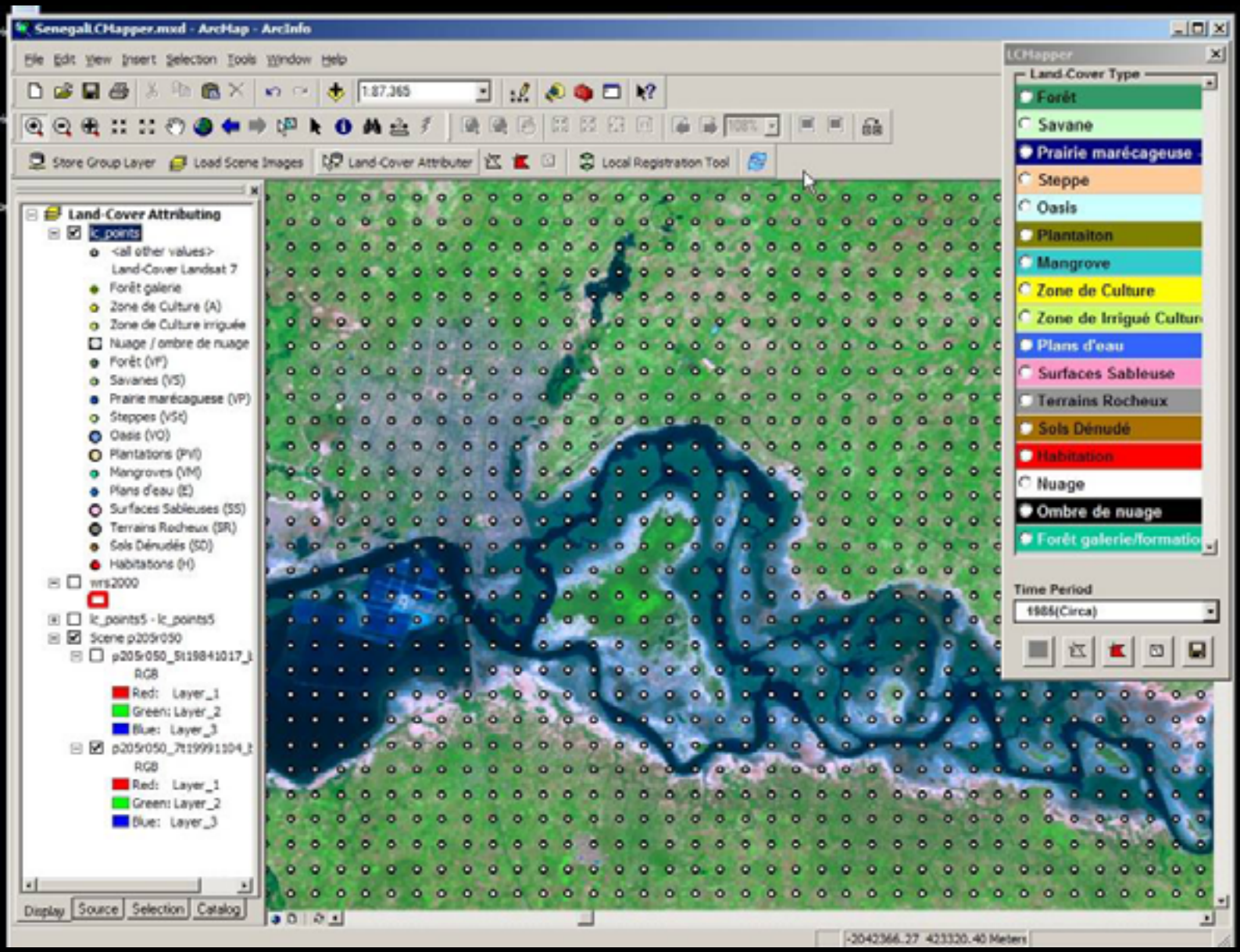
Overlay Study Area Dot Grids



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Select Dots by Land Cover Class

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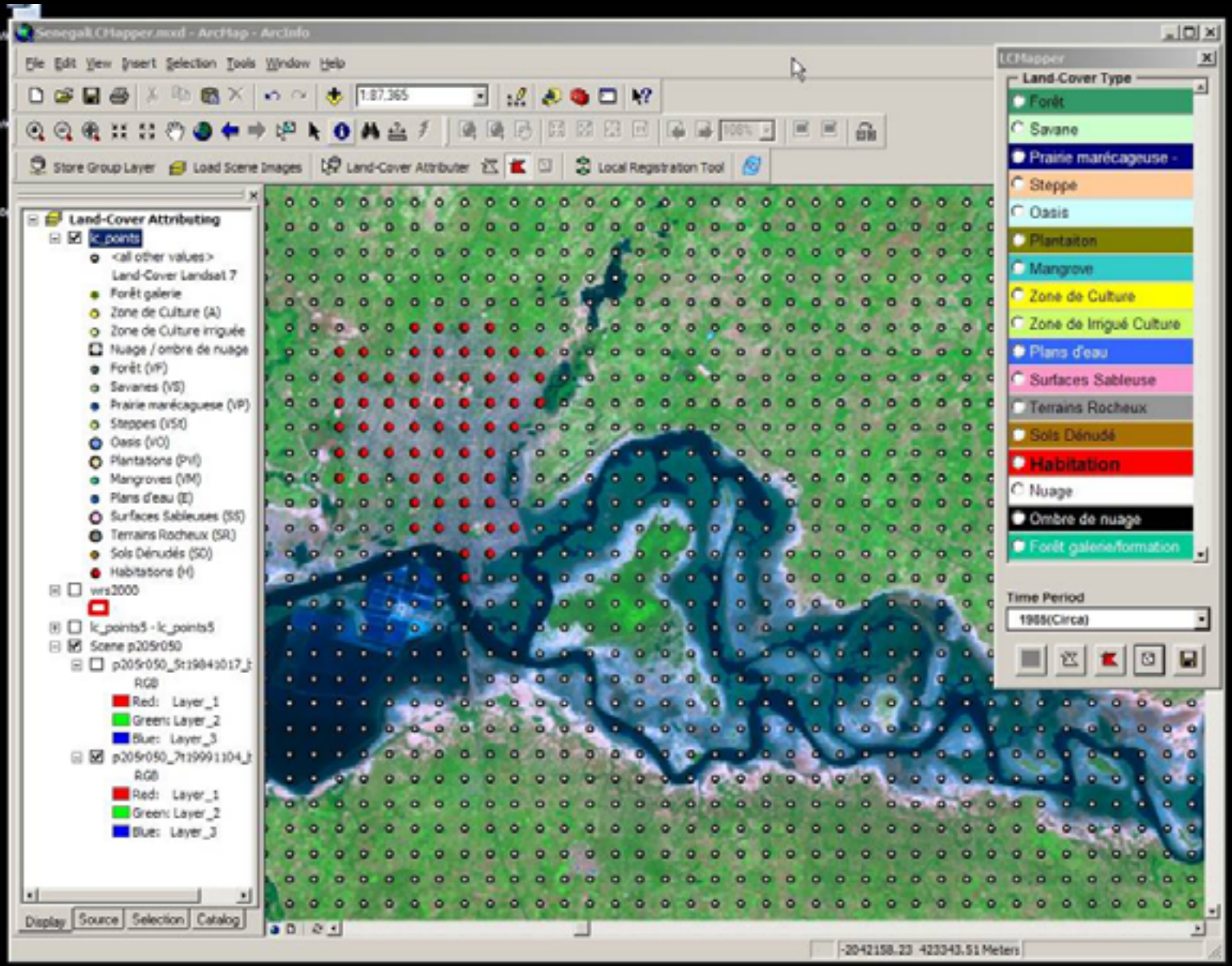
Attribute the dots (classify)



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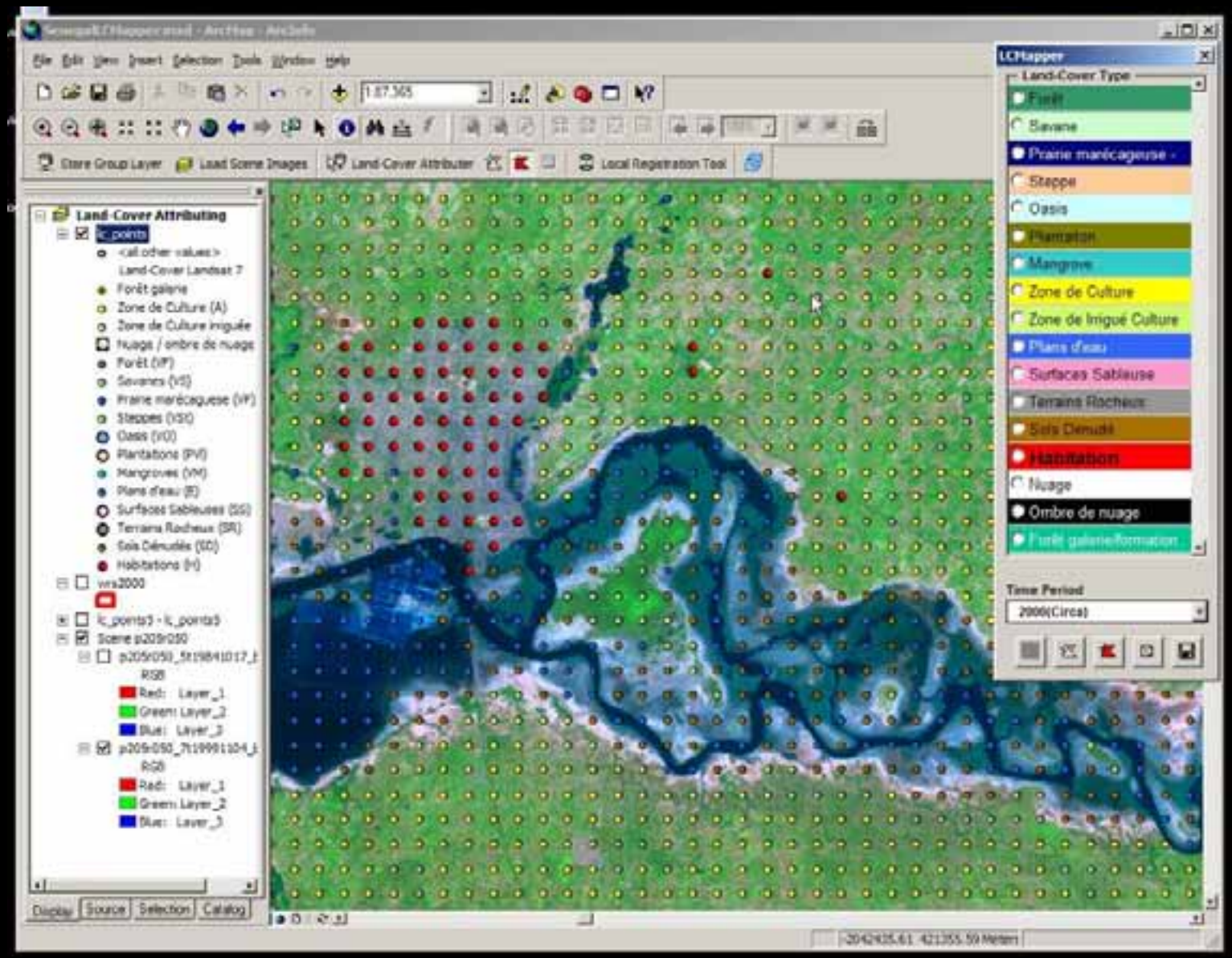
Complete dot grid classification



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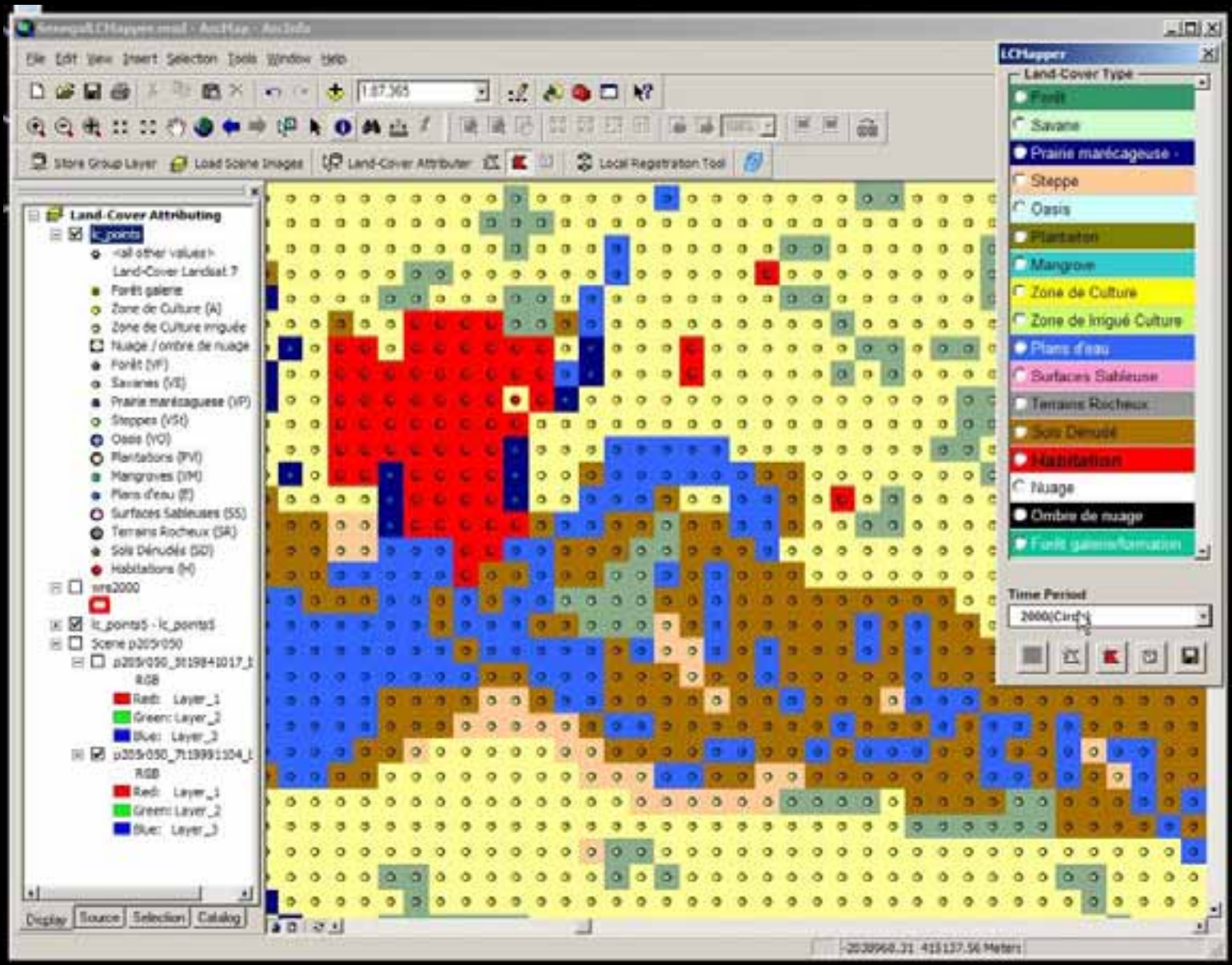
Convert dot grid to raster format



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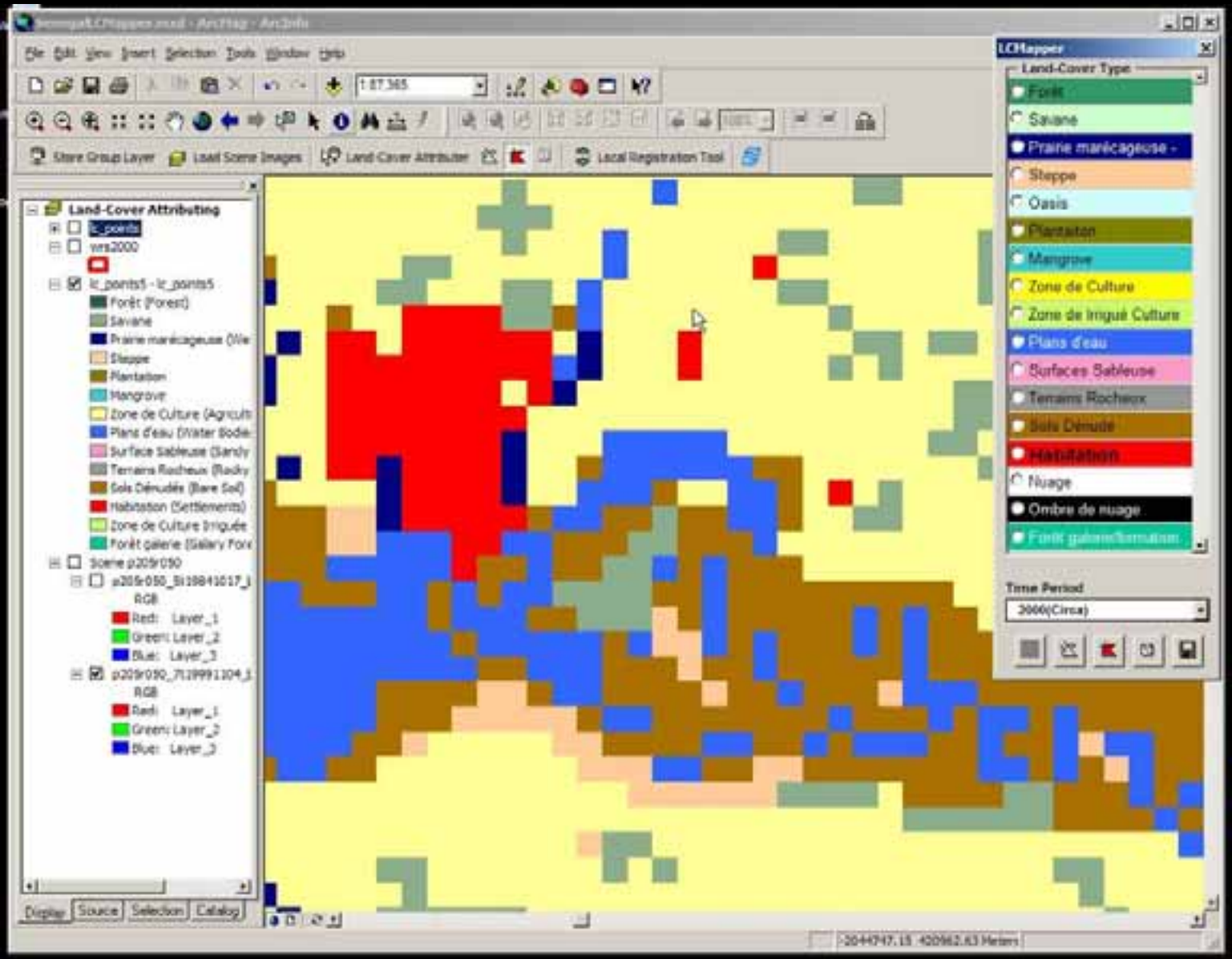
Rasterized dot grids



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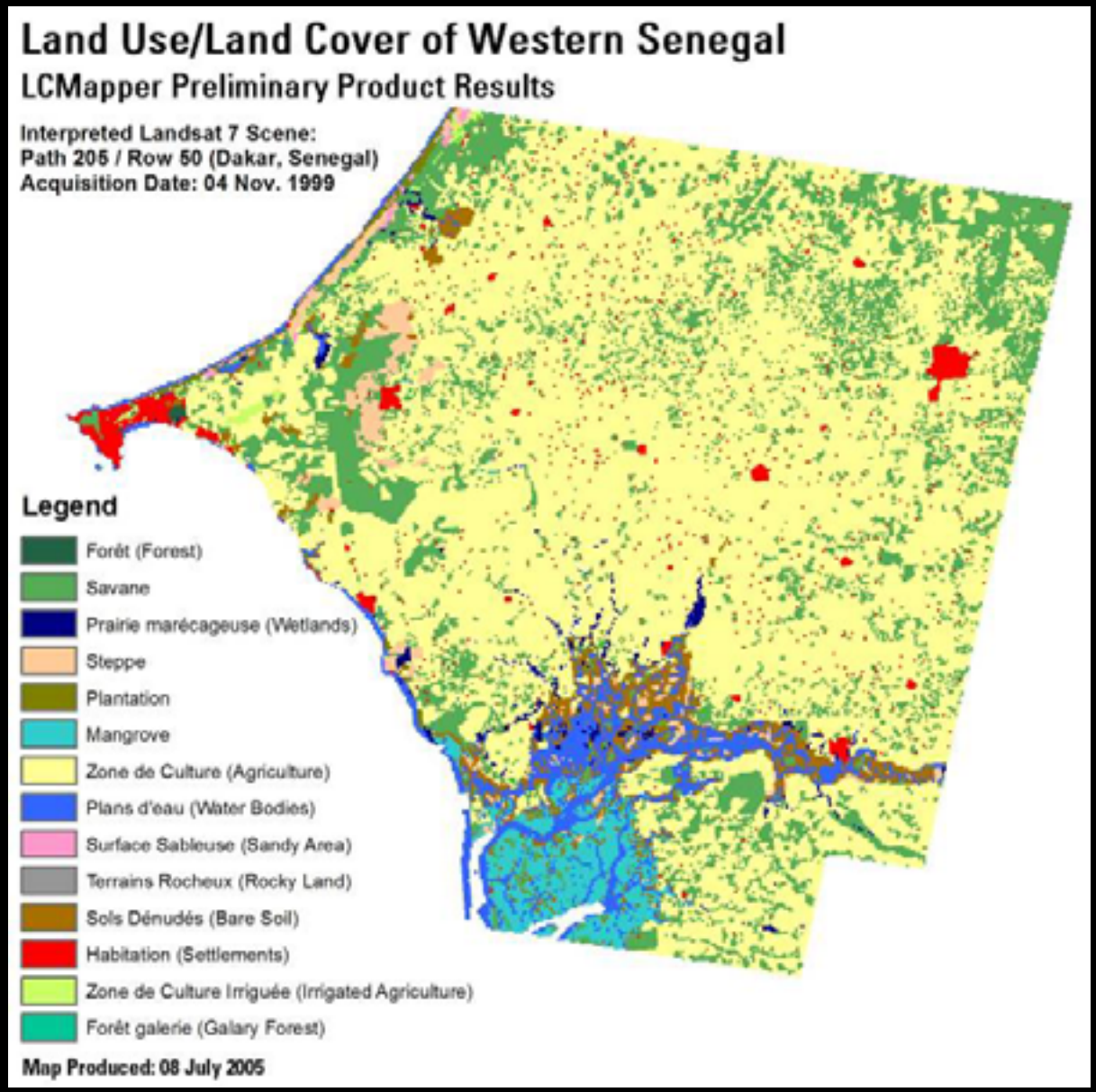
Completed RLCM Raster Map



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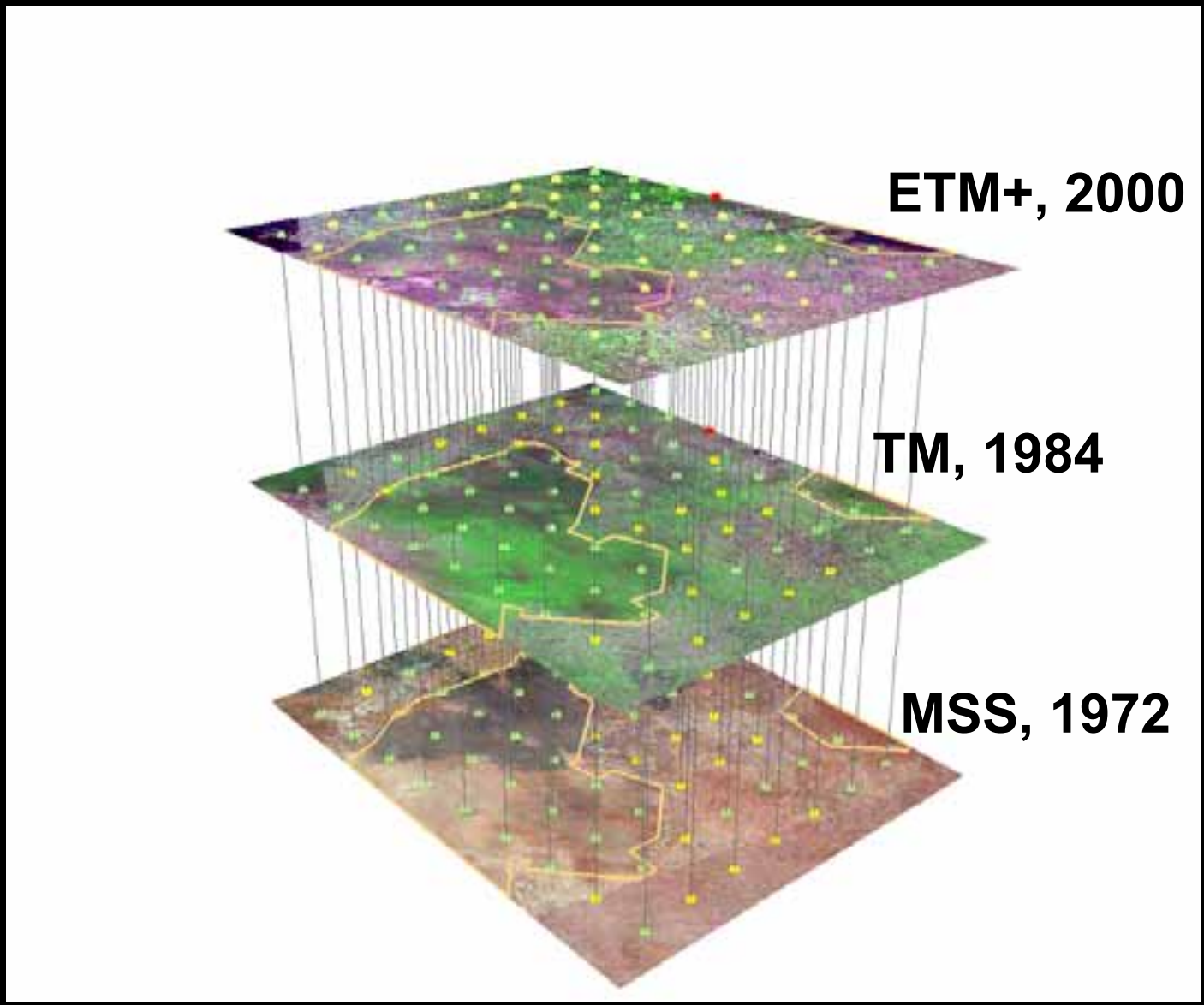
Time-Series Mapping with the RLCM



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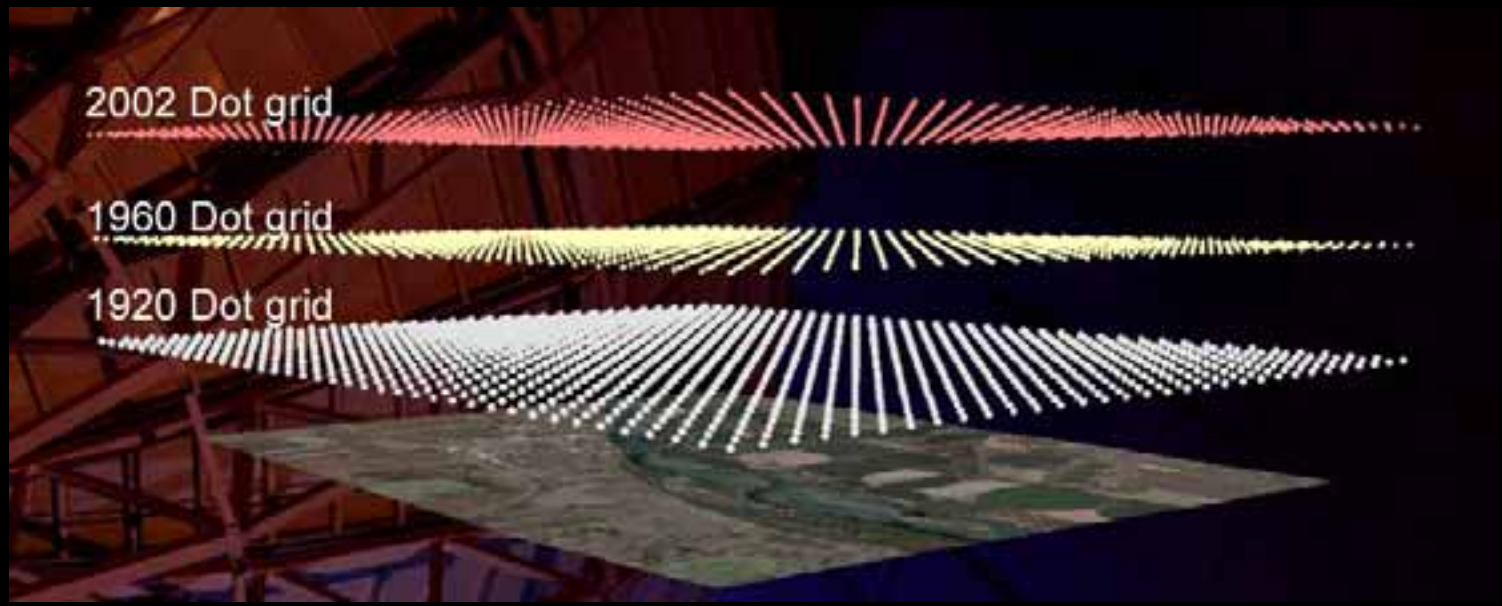
A Desktop Version of the RLCM that runs with ArcGIS 9.x can be downloaded from:

http://edcintl.cr.usgs.gov/rlcm/index.php

Presentation documents are also available:

http://edcintl.cr.usgs.gov/rlcm/promotional_products.php



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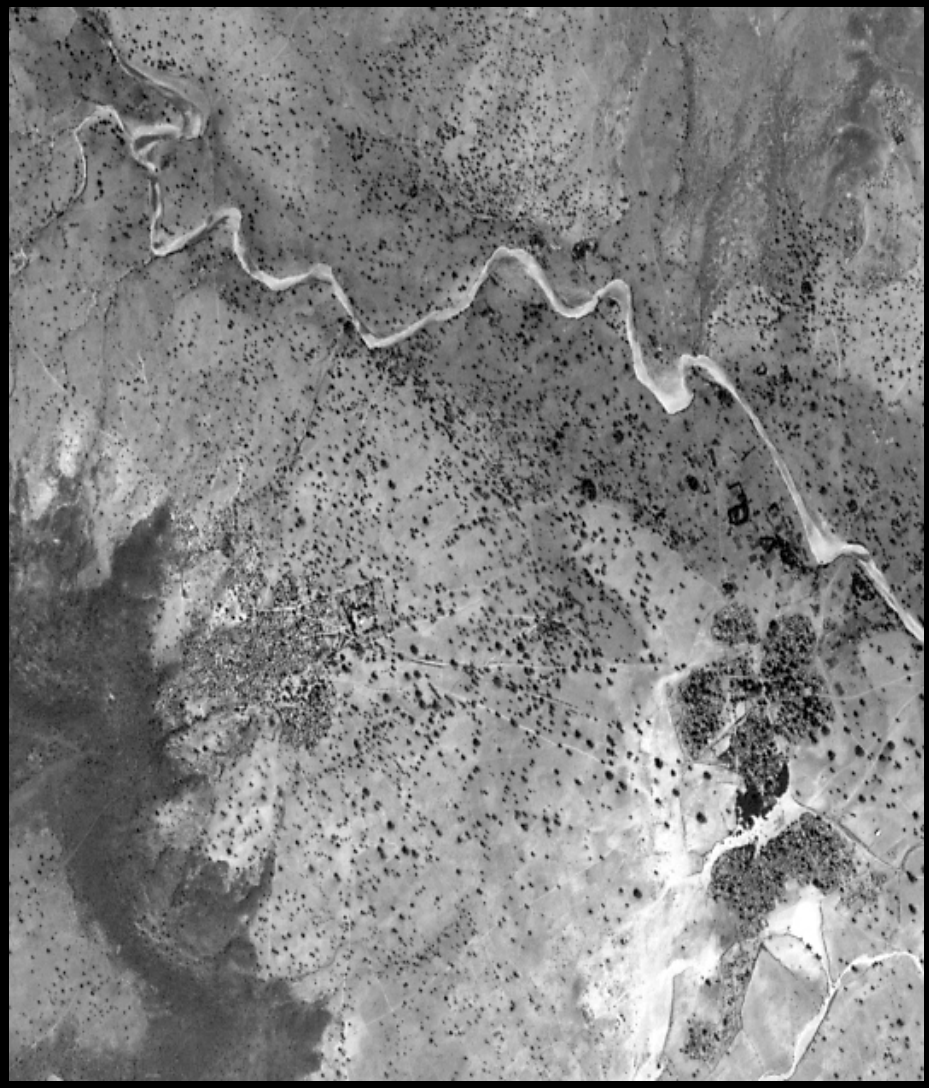
Tree Cover at Galma, Niger:
Which is the earlier photograph?



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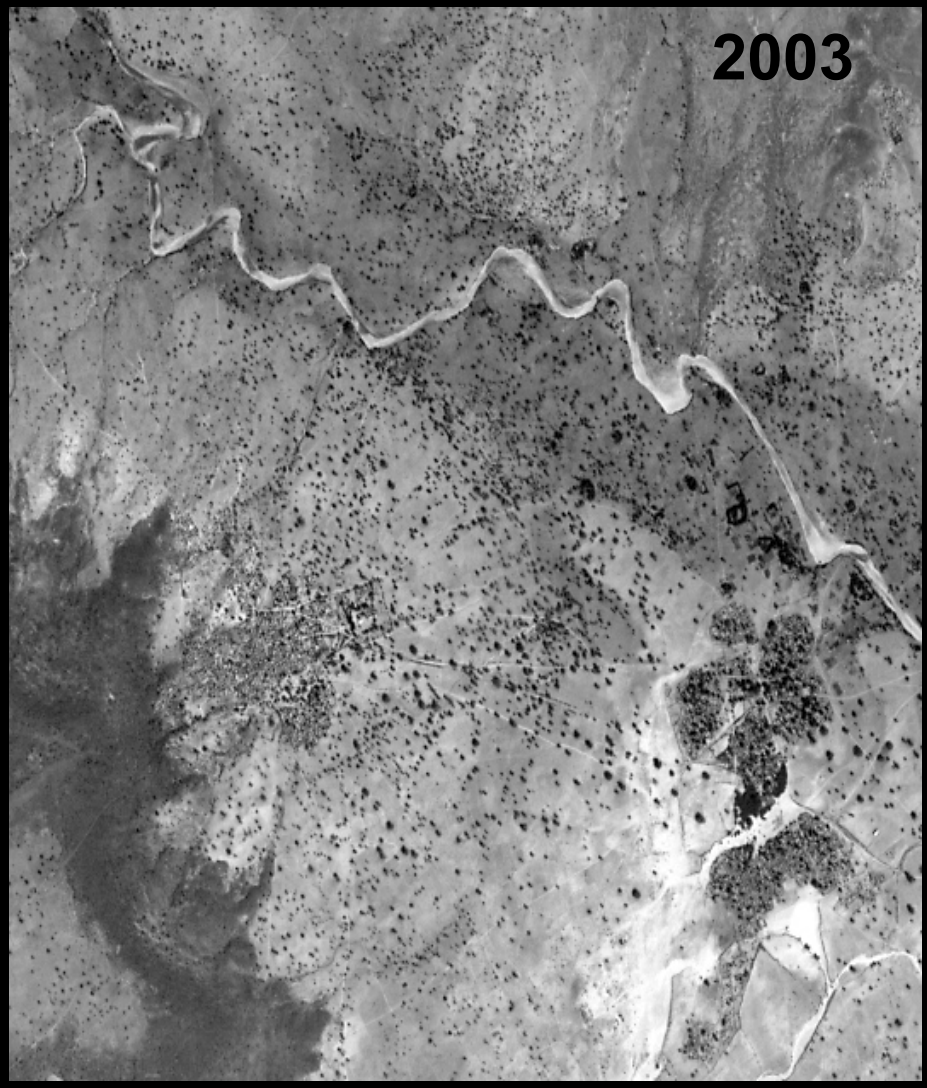
4. Local Successes in Natural Resource Management: Tree Cover at Galma, Niger:



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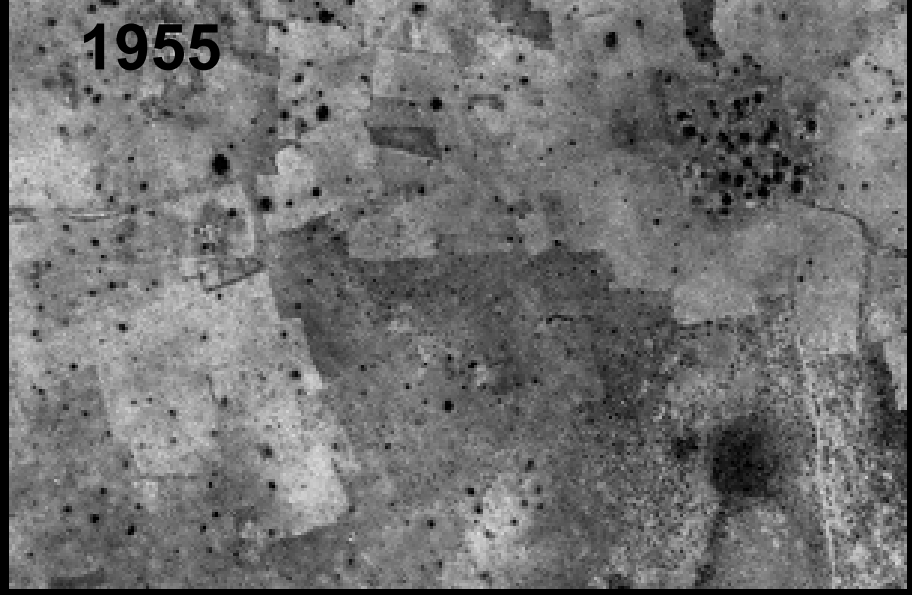
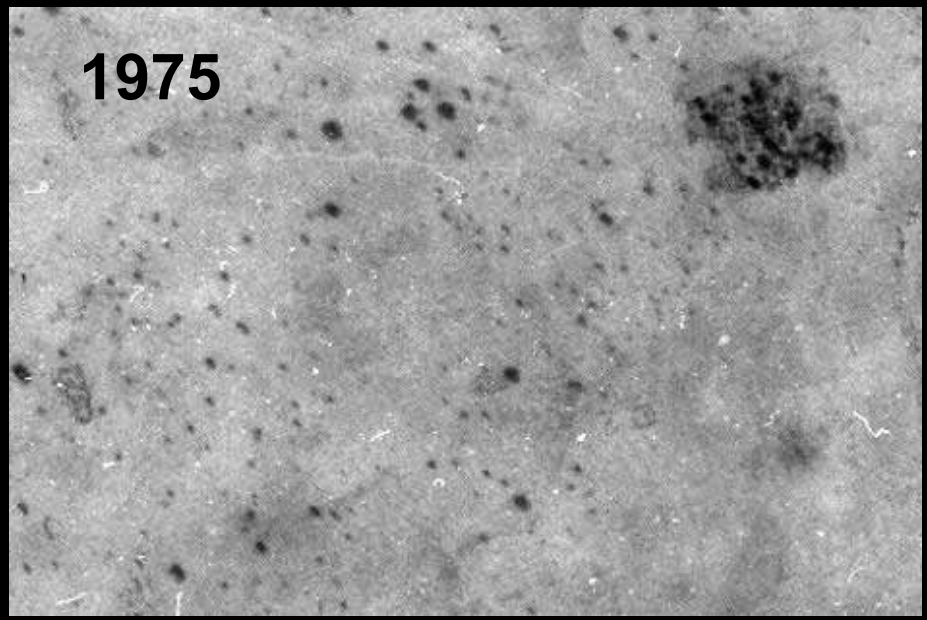
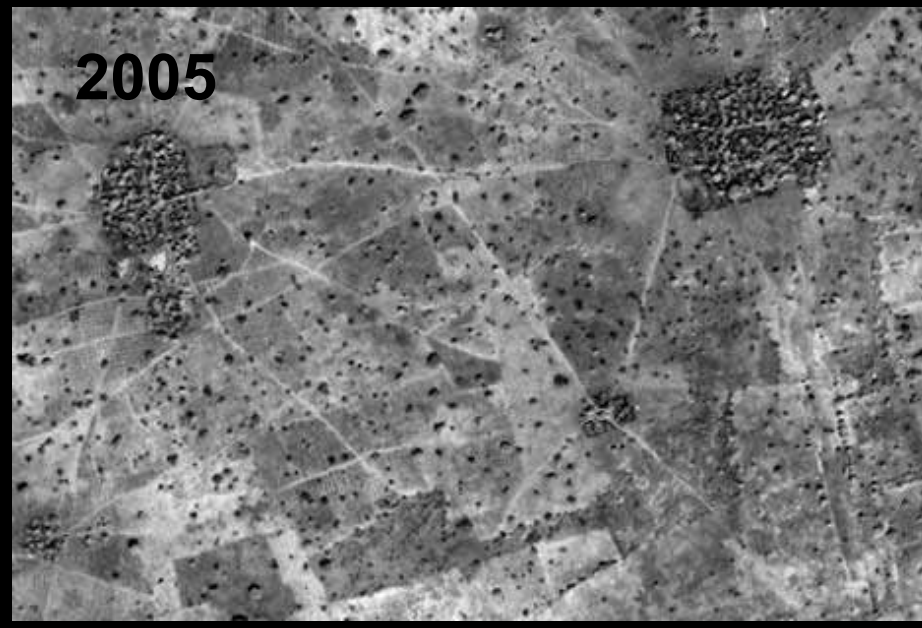


Tree Cover Trends Southwest of Zinder





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Approximate area of re-greening in Niger (green polygon)

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Drought in the 1970s and 1980s …

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What induced farmers to protect and manage on-farm natural regeneration?

- The environmental (drought) and economic crisis of the 1970s and 80s
- The increasing population pressure on natural resources
- A perceived change in ownership of trees since the mid-1980s
- The multiple benefits generated by on-farm trees

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Improved soil fertility and
an increase in fodder production
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Less time required for collection of firewood

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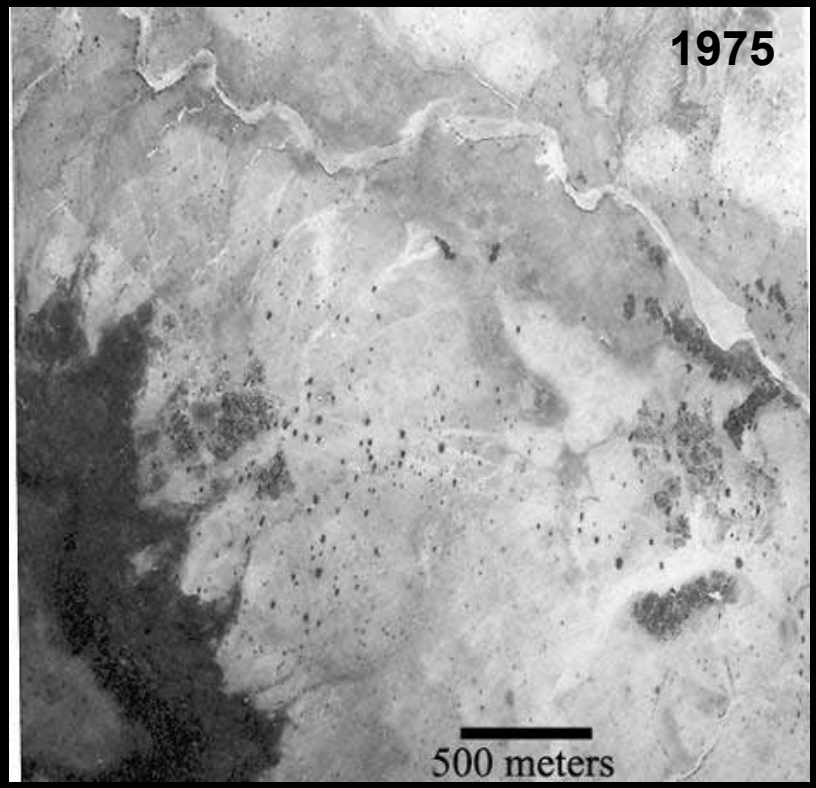
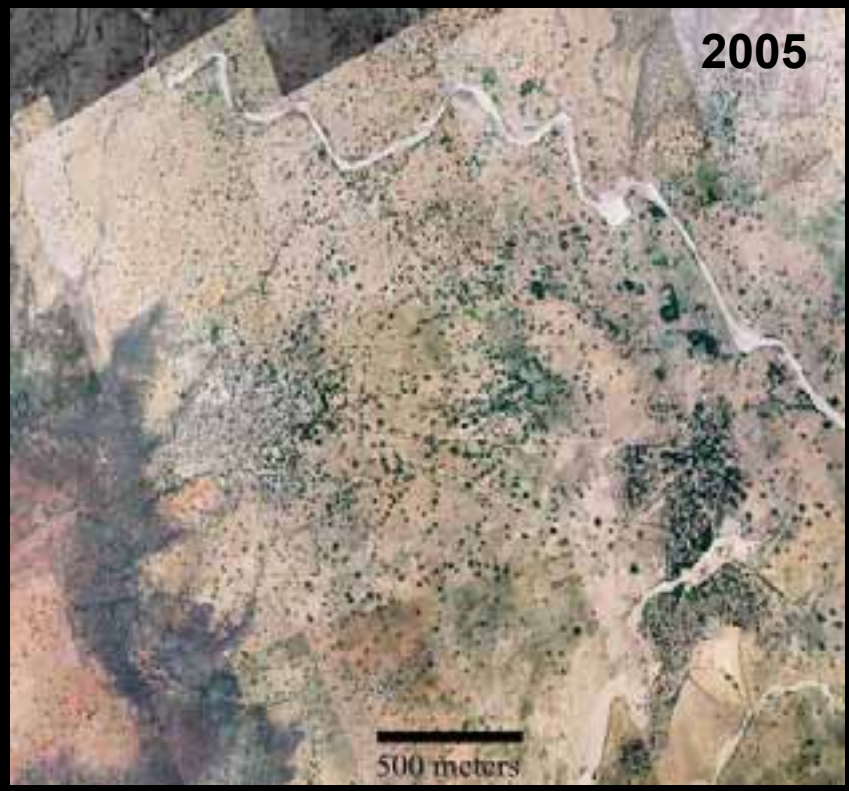
Quantifying Tree Cover Trends at Galma, Niger

- 4 Trees/ha
- 2.9 tons woody biomass/ha
- 1.4 tons C in woody biomass/ha
- 3 tree species/ha

- 22 Trees/ha
- 16 tons woody biomass/ha
- 7.2 tons C in woody biomass/ha
- 6 tree species/ha

(based on field plots, March 2007)





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The scale of farmer-managed re-greening in Niger

- Scale of on-farm regeneration: at least 5 million ha in 20 years (average of 250.000 ha/year)
- 5 million ha x 40 trees/ha = 200 million trees
- By comparison: number of trees planted by projects in Niger: about 60 million, of which about half survive

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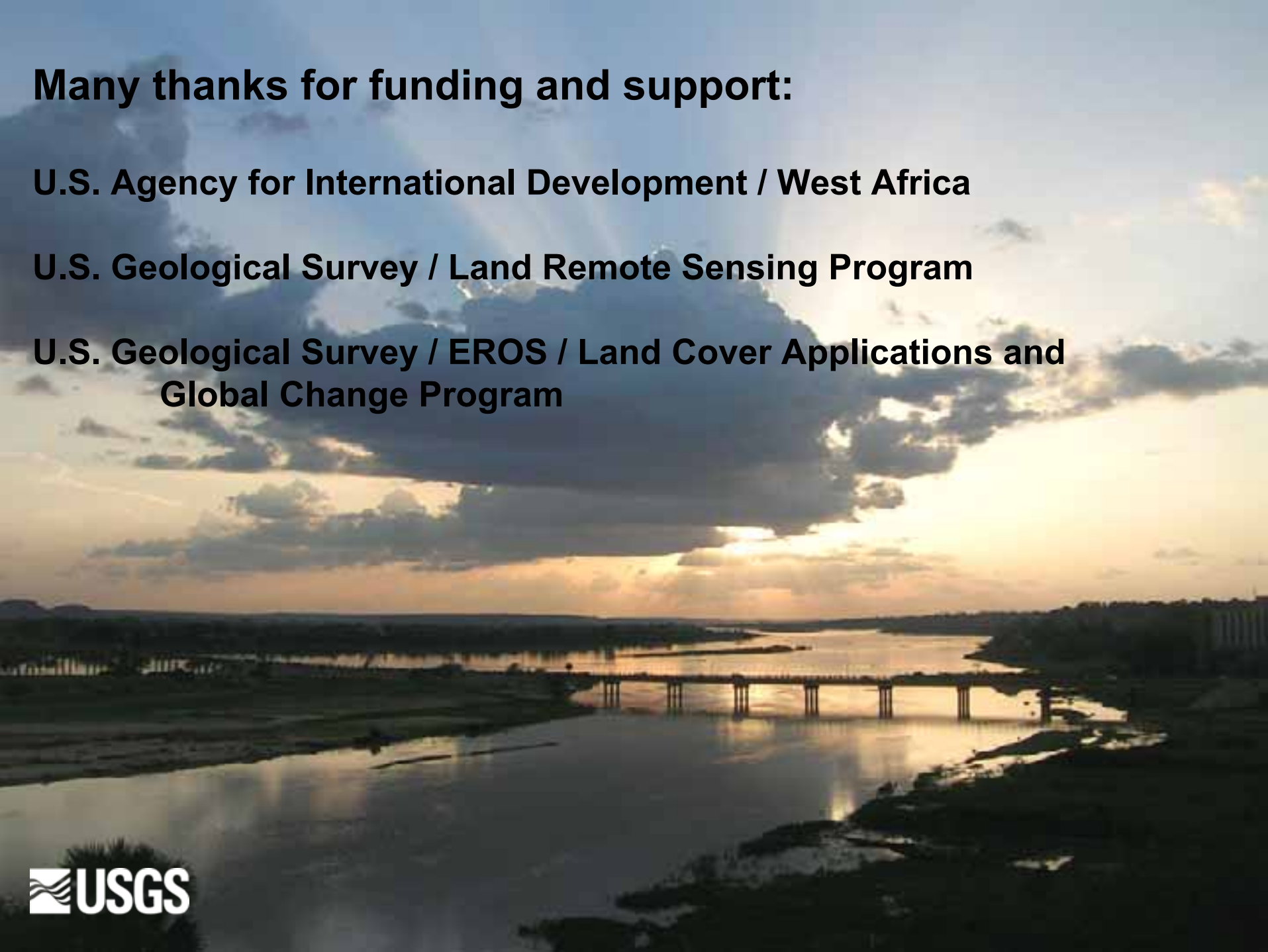
Many grass-root successes in on-farm re-greening remain to be uncovered in the Sahel



Many thanks for funding and support:

U.S. Agency for International Development / West Africa

U.S. Geological Survey / Land Remote Sensing Program

U.S. Geological Survey / EROS / Land Cover Applications and Global Change Program

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