


The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change (LCLUC) Through Analysis of Multi-scale and Multi-temporal Satellite Image Data

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NASA Interdisciplinary Research in Earth Science Program

The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change Through Analysis of Multi-scale and Multi-temporal Satellite Image Data

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University of California Santa Barbara

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University of Ghana Legon

SAN DIEGO STATE UNIVERSITY

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

UNIVERSITY OF GHANA




Presentation Objectives

Procedures and preliminary results of satellite-based land cover and land use (LCLU) mapping and change analyses

- Regional scale – Landsat ETM+/OLI
- Urban scale – Commercial high spatial resolution satellite data








NASA Project Overview

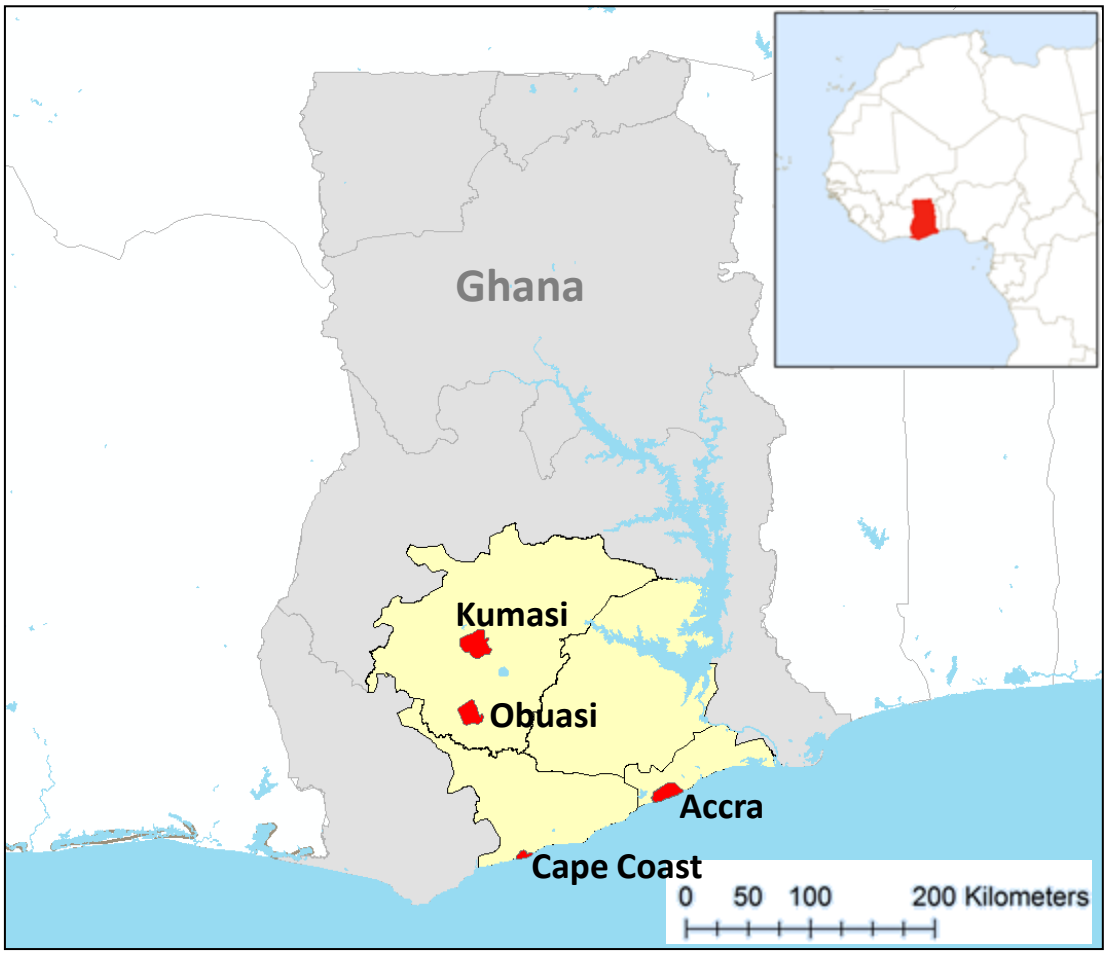
Drivers and impacts of land cover and land use change (LCLUC) in Ghana

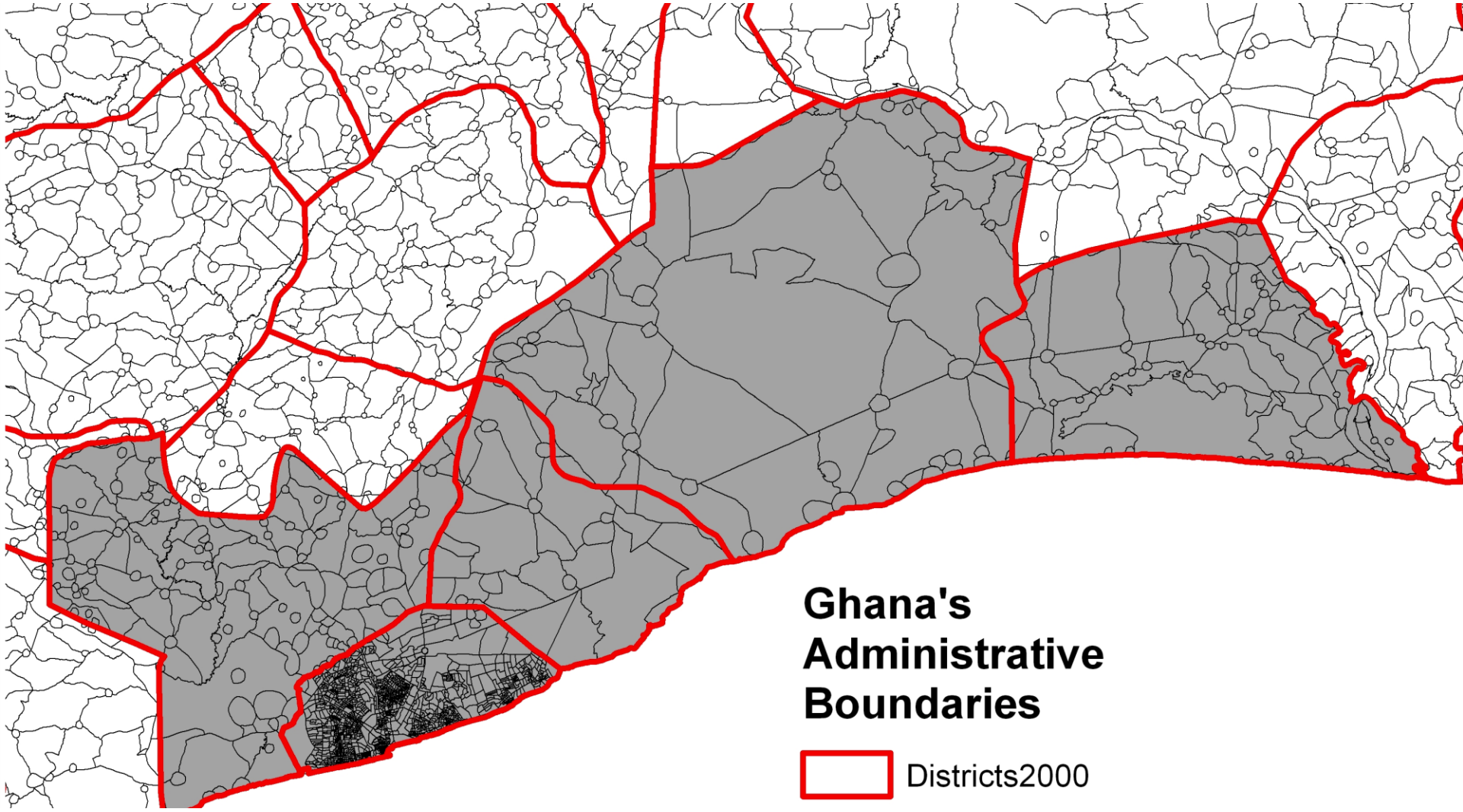
- Regional scale – rural to urban migration as a driver of LCLUC
- Urban scale – urban densification and expansion as an impact on people's quality of life

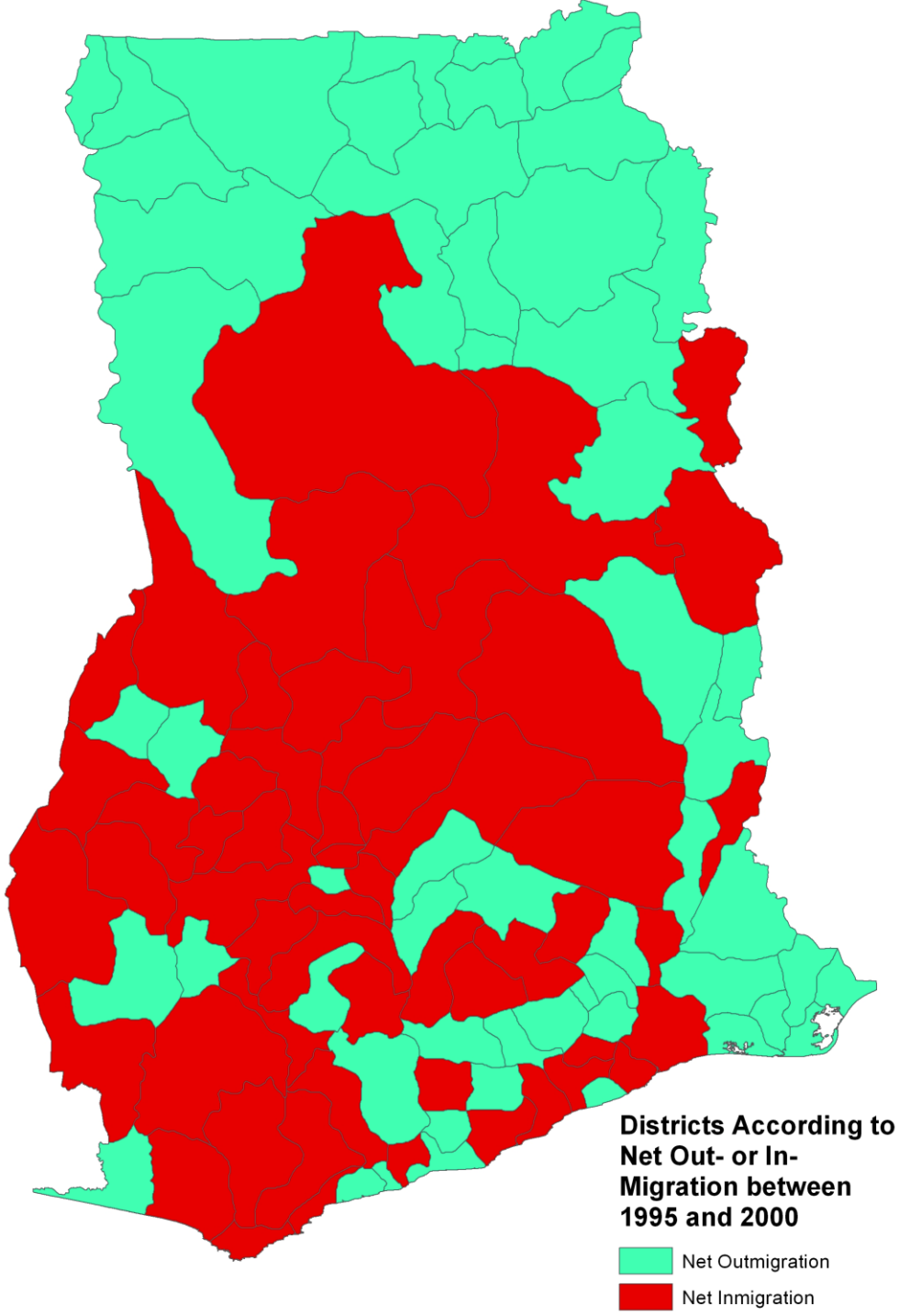




Study Areas: Regional & Urban




Ghana's
Administrative
Boundaries
Districts2000


Districts According to Net Out- or In-Migration between 1995 and 2000
Net Outmigration
Net Inmigration

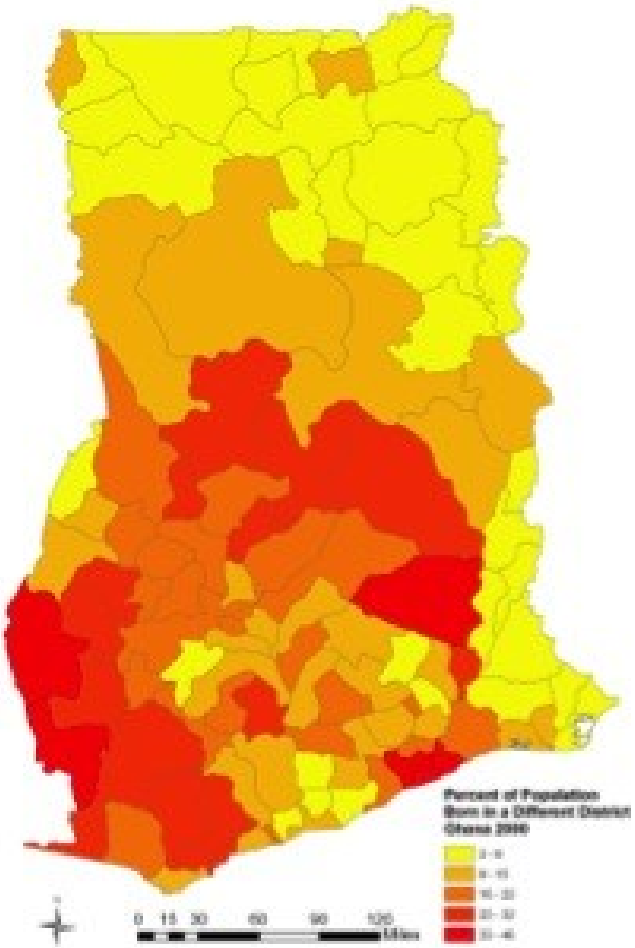
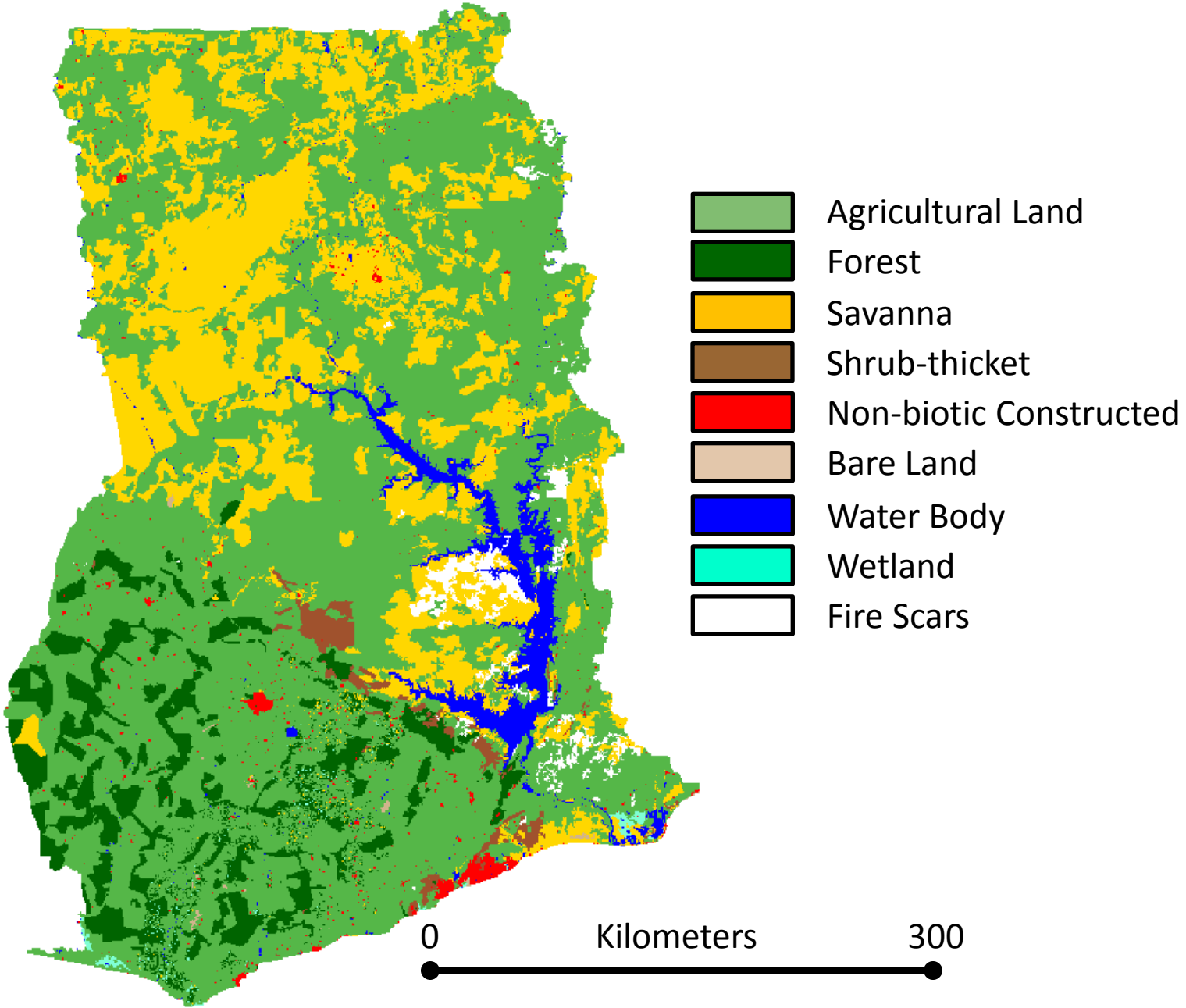


Figure 1. Percent Born in a Different District

Rural village

Dense urban settlement

CERSGIS Reference 2000 Land Cover/Land Use Map With MODIS IGBP Cloud-fill



Inter-regional LCLU classification scheme

(1) Forest

(2) Non-forest vegetation (open secondary forest, shrub thicket and savanna)

(3) Agriculture (mixed w/vegetation and commercial)

(4) Urban/built (city core, suburban, peri-urban, village)

Intra-urban LCLUC classification scheme

(1) Undeveloped

(2) Urban agriculture

(3) Urban Residential

(4) Urban Non-residential

Peri-urban residential development

Urban densification

Agribusiness expansion

Mixed agriculture and natural vegetation

New suburban residential




Challenges of Remote Sensing in Ghana

- Prevalent continuous cloud cover
  (Dec-Apr most cloud free; dry season)
- Partial clouds and cloud shadows
- Thick atmospheric optical properties on clear days (water vapor and aerosols)
- Wind borne dust – Harmattan effect: dusty West African trade wind in winter
- Minimal Landsat 5 Thematic Mapper coverage
- Landsat 7 ETM+ scan line corrector off 2003-13
- Most agriculture mixed with natural vegetation
- Soil and metal roofs contain iron oxides








Regional Scale LCLU Mapping and Change Identification

Single Date and Temporal Composites

Pete Coulter and Nick Ibanez








Objectives

- Identify, map, and quantify land cover and land use and change (LCLUC) within four populated regions of Ghana
- Regions of interest are:
  - Greater Accra
  - Central
  - Ashanti
  - Eastern
- c. 2000 and 2010 periods - corresponds to national census data
- Using Landsat data to the greatest extent possible (well registered, LEDAPS surface reflectance, high temporal resolution)





Interregional LCLU Mapping Process for Accra Path/Row

All Landsat TM/ETM+/OLI: 1986-2014
(in reflectance, LEDAPS processing)

↓

Scene selection: < 33% cloud/scene

↓

Mask cloud, cloud shadow, water, and SLC-off (fmask)

↓

Include derived image products:
ND21, ND31, ND43, ND45, ND47, stack stdev 123,457, 123457, additive local texture (3x3-11x11)

MODIS LCLU 2000 - 2010 →
ERS SAR 2000 - 2010 →

Single date image classification
"natural, ag, built"
(training on persistent LC features)

↓

LCLU map time series

↓

Discrete spatial-temporal filter

↓

Discrete LCLUC identifier

↓

Map of date and type of LCLUC
(2000, 2010, record length)

Radiometric normalization (PIF)

↓

Create c.2010 composite image set

↓

Classify 2002 and c.2010 composite/stack
(and possibly interim composites)

↓

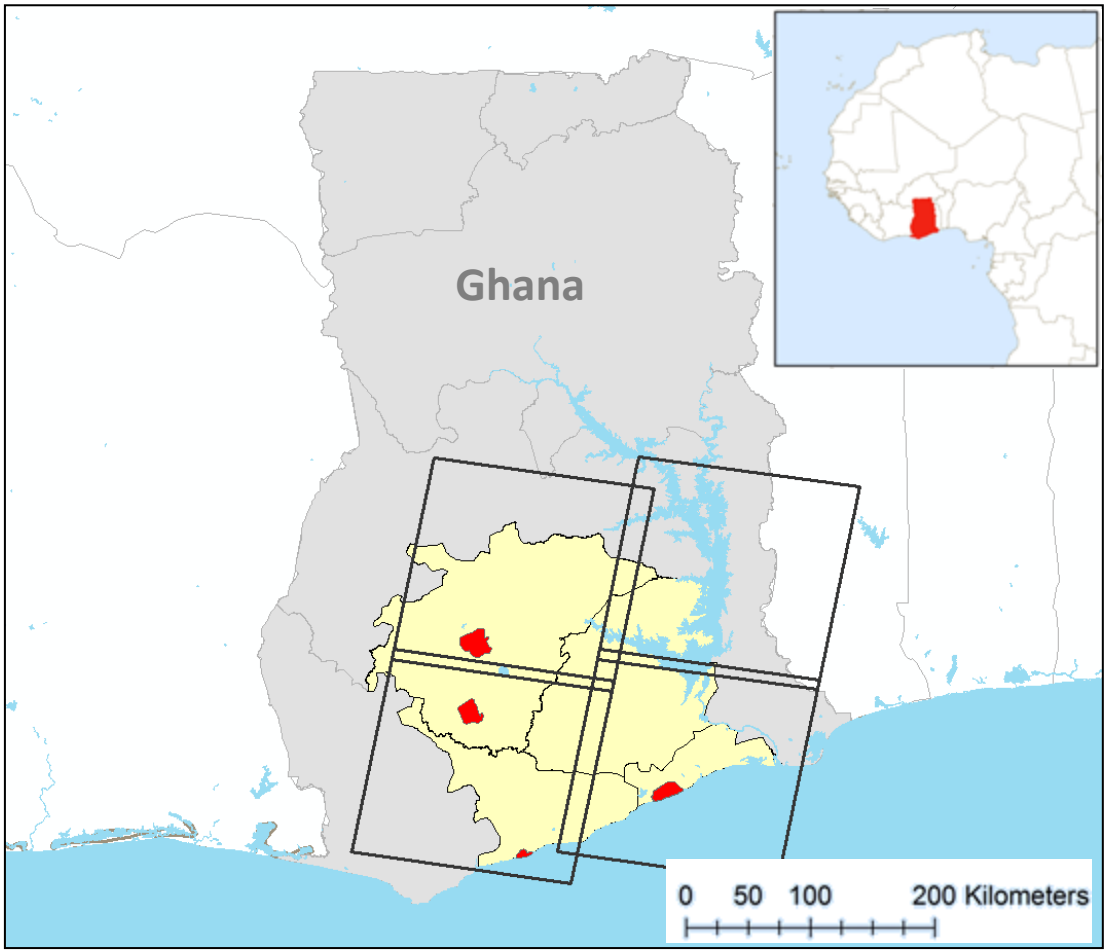
Discrete spatial filter

↓

Discrete LCLUC identifier

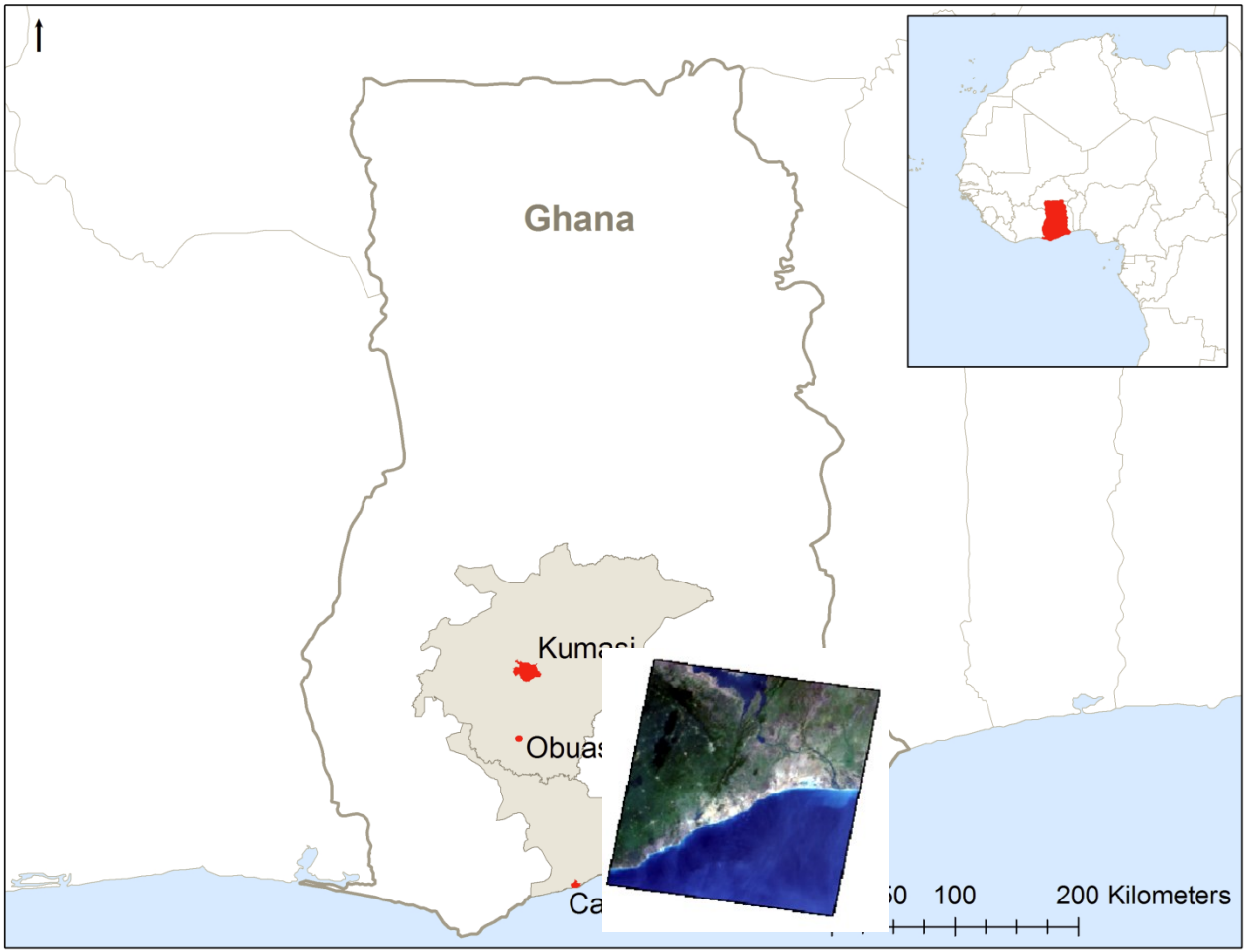
Map of date and type of LCLUC
(2000, 2010, record length)

Study Areas: Regional & Urban



Greater Accra Landsat Footprint (193/056)

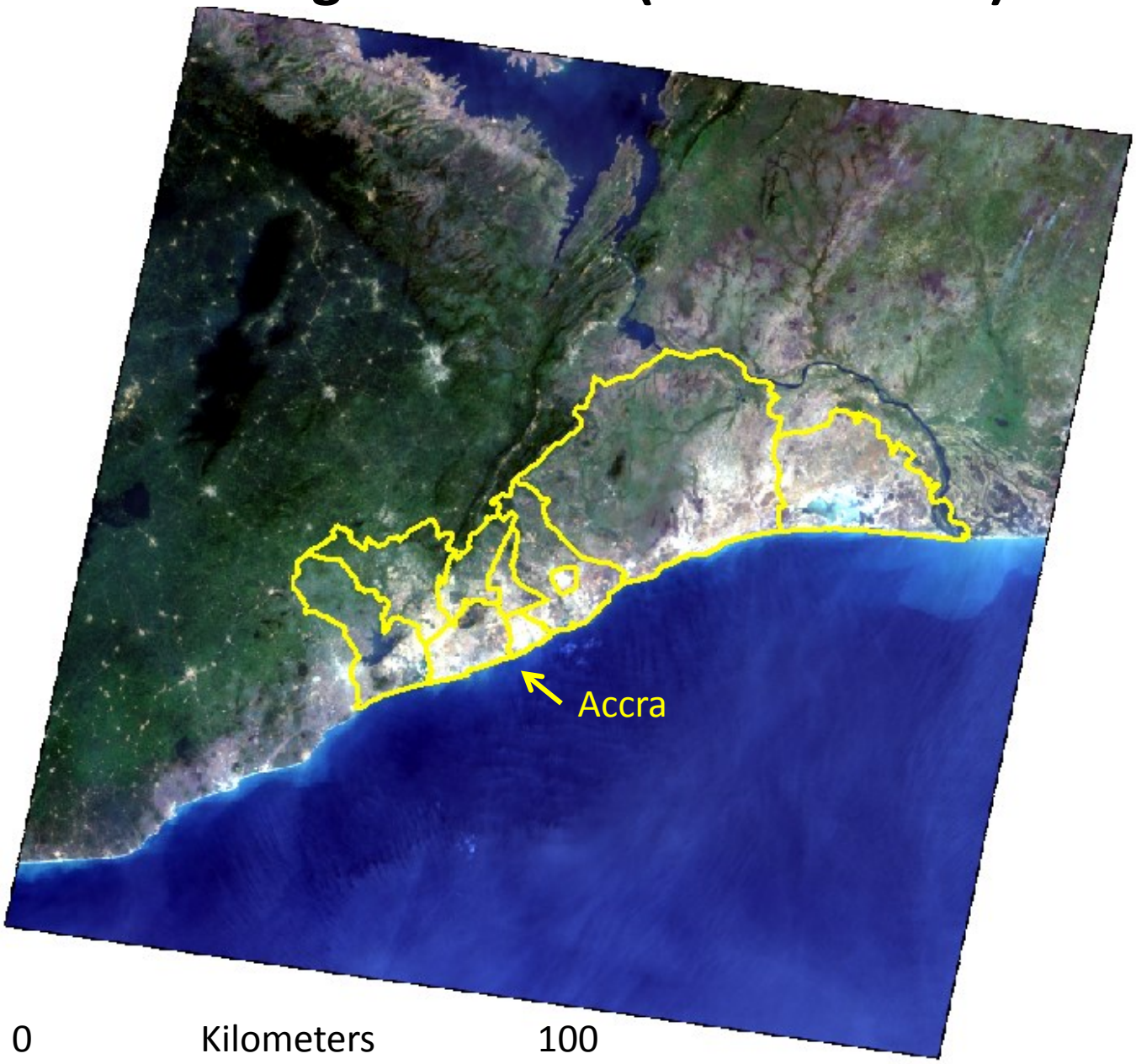


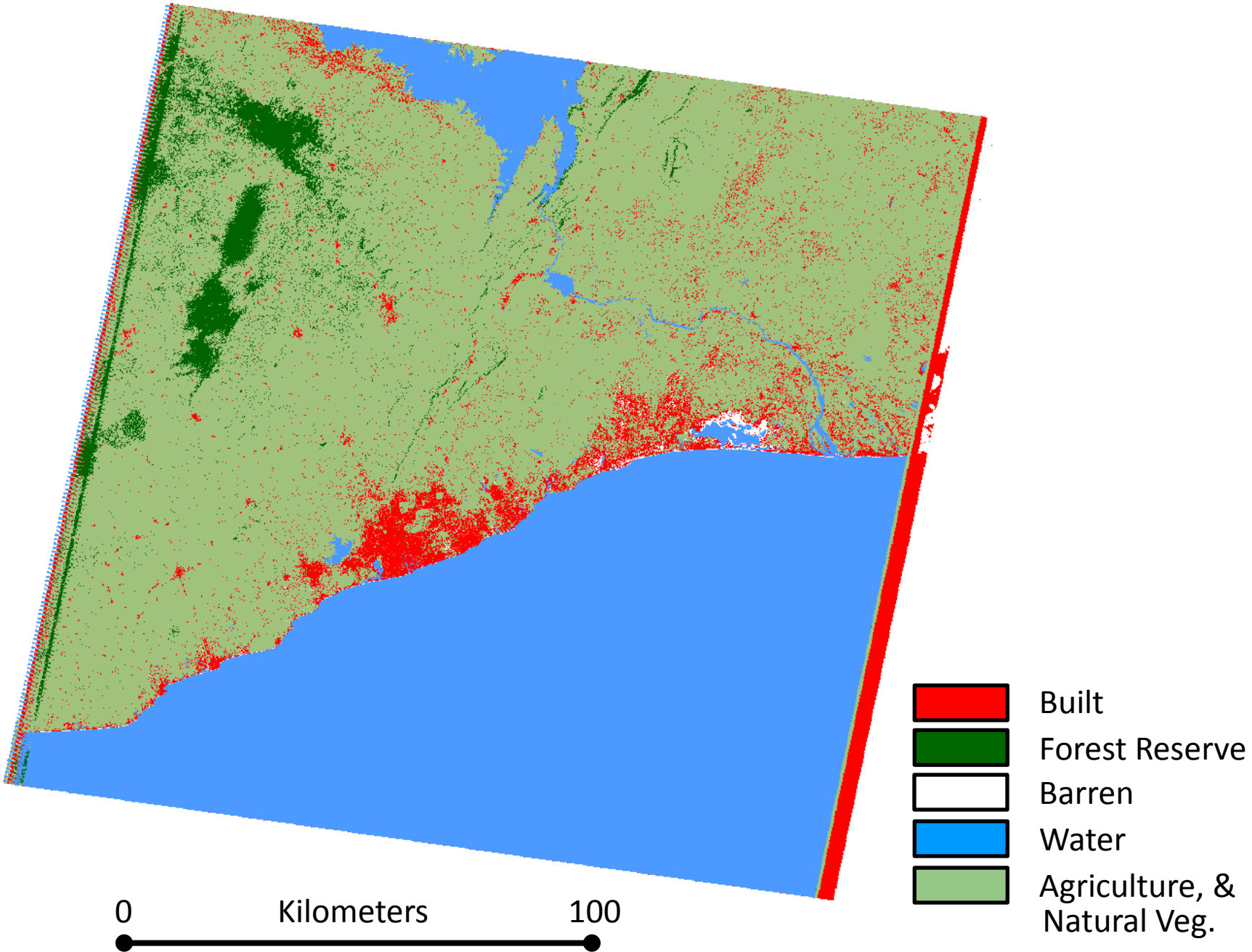




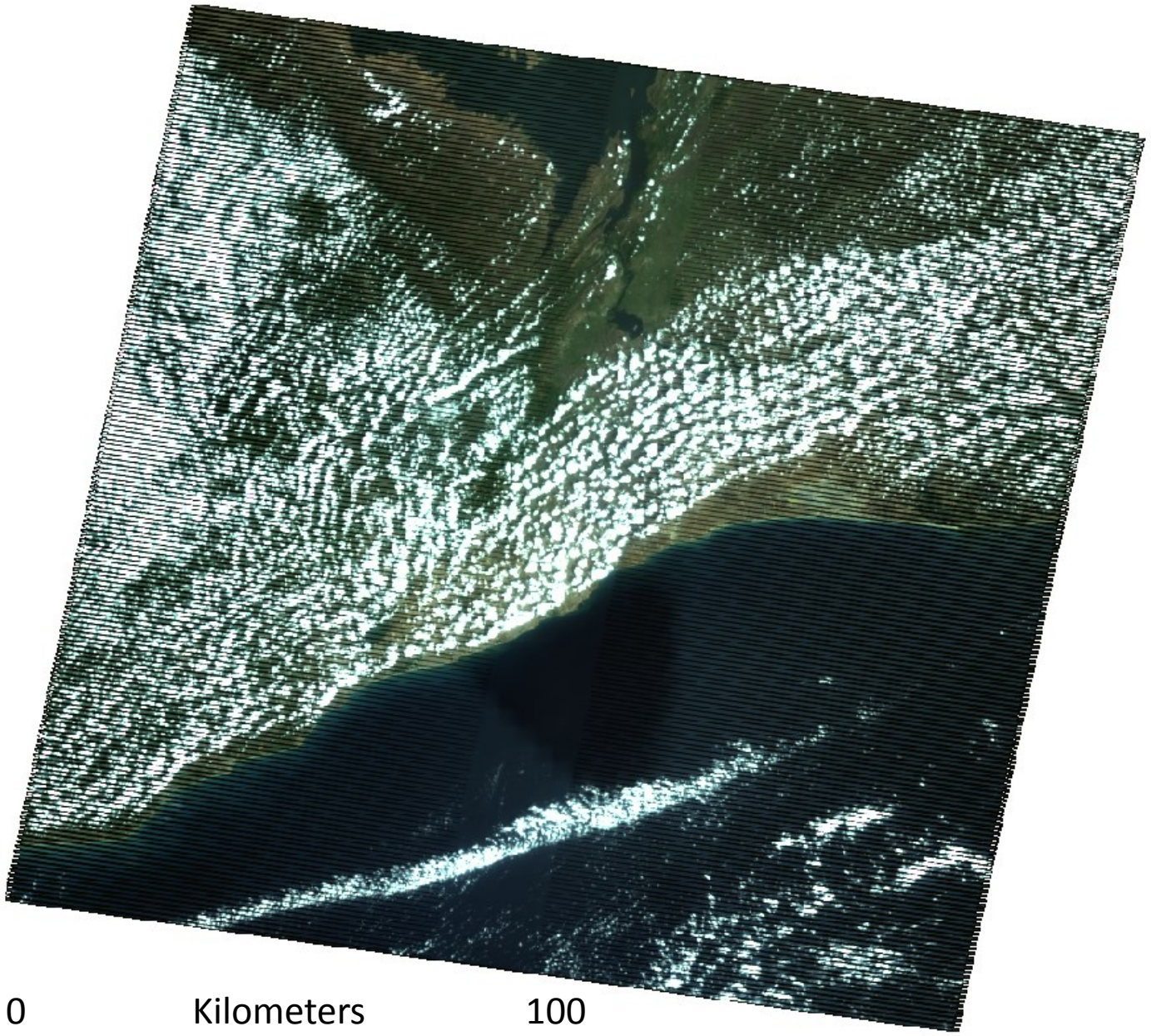
Regional Landsat Data: Greater Accra
Best image available (2002 Dec. 26)



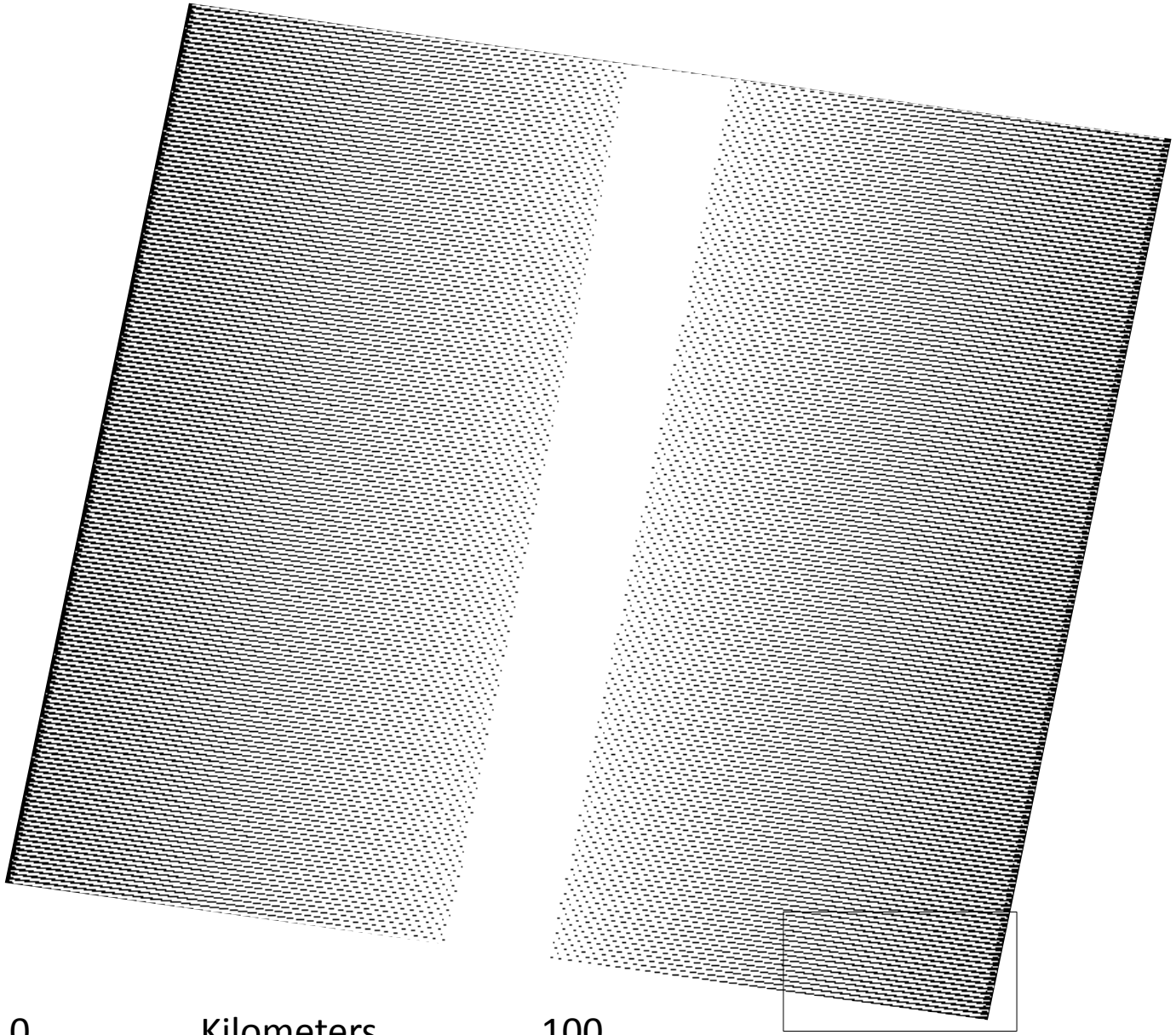
2002 Draft Image Classification Product



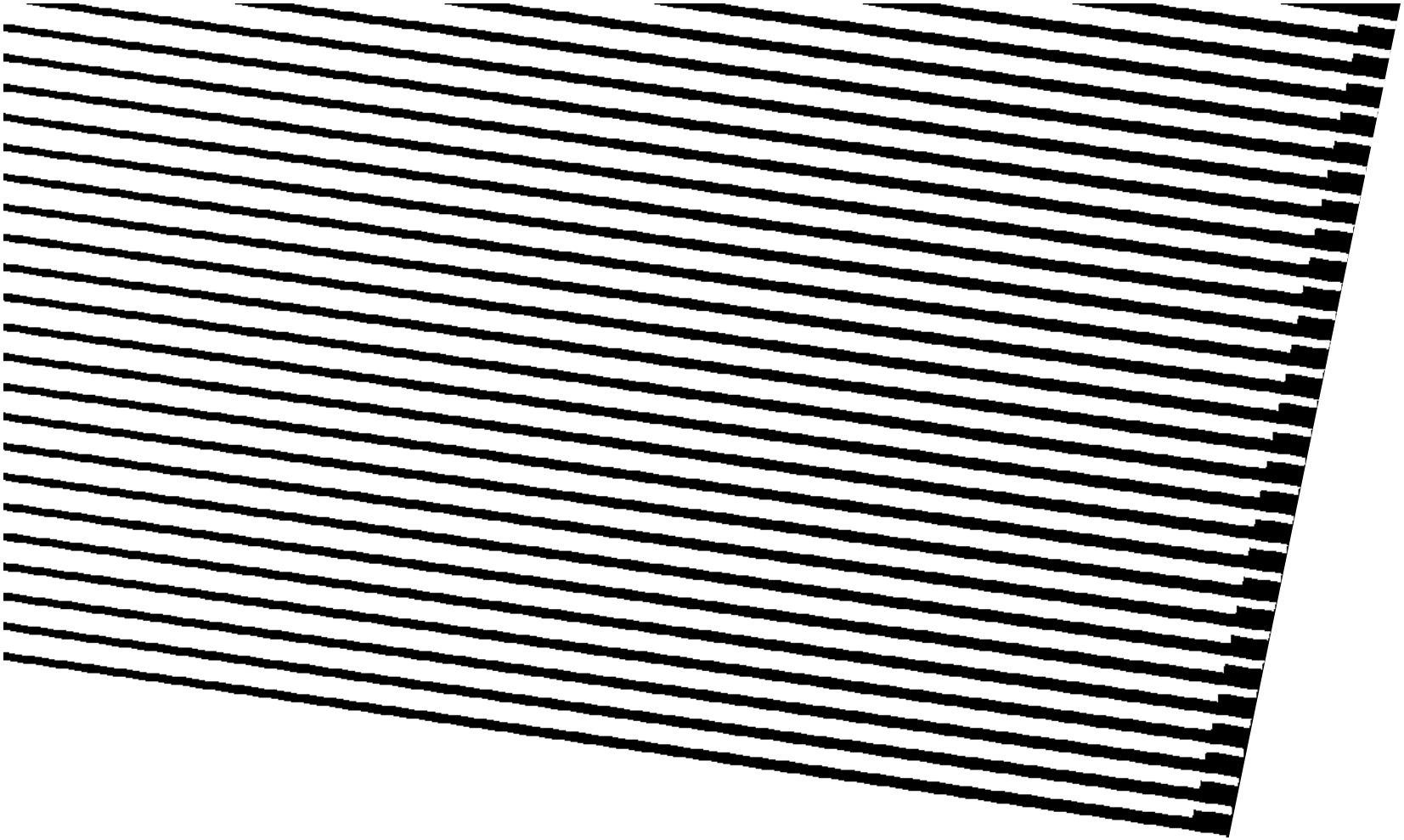
2010 Regional Landsat Data:
Typical image with cloud cover & SCL-off issues



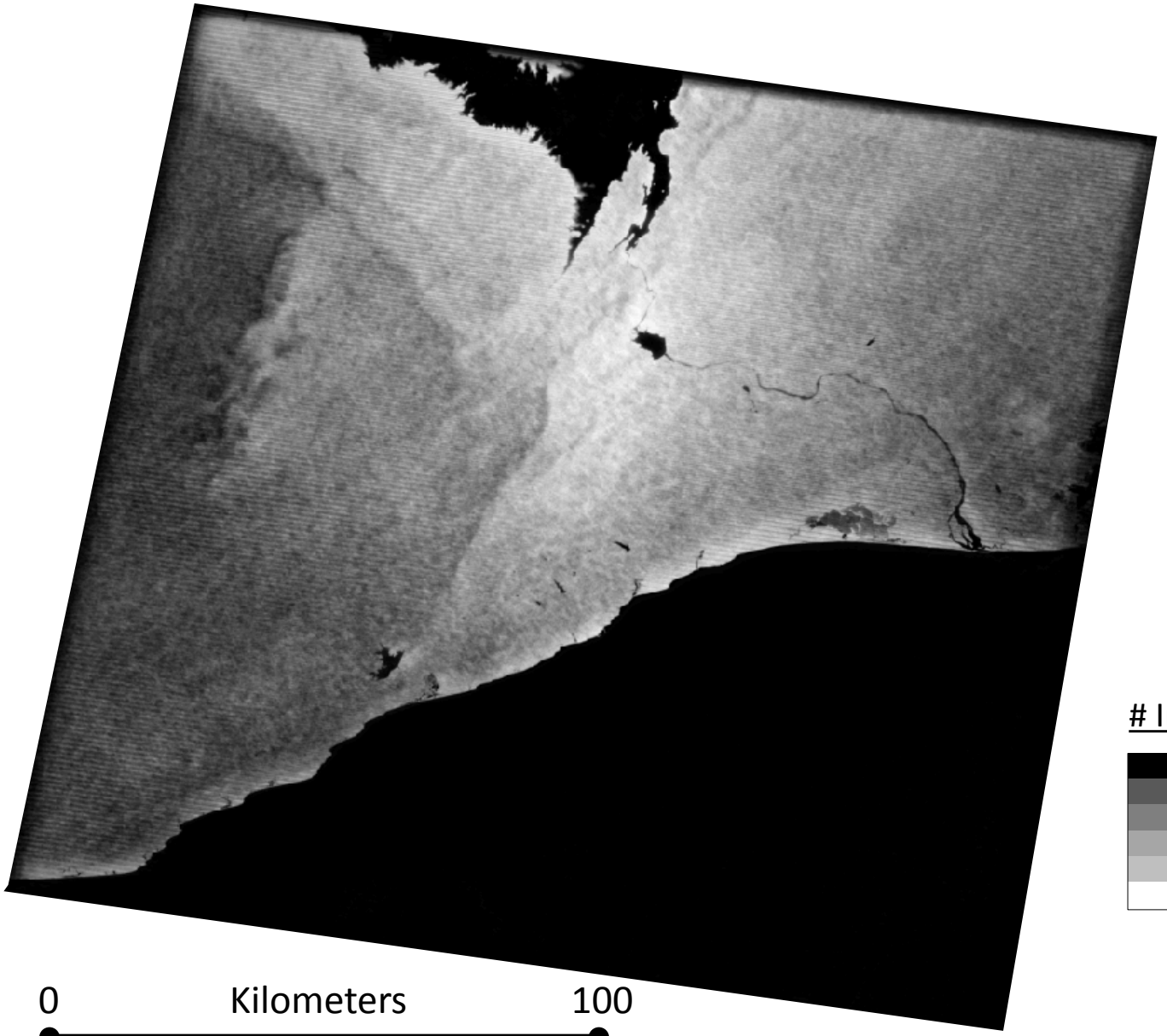
Regional Landsat Data:
SCL-off Data Gaps



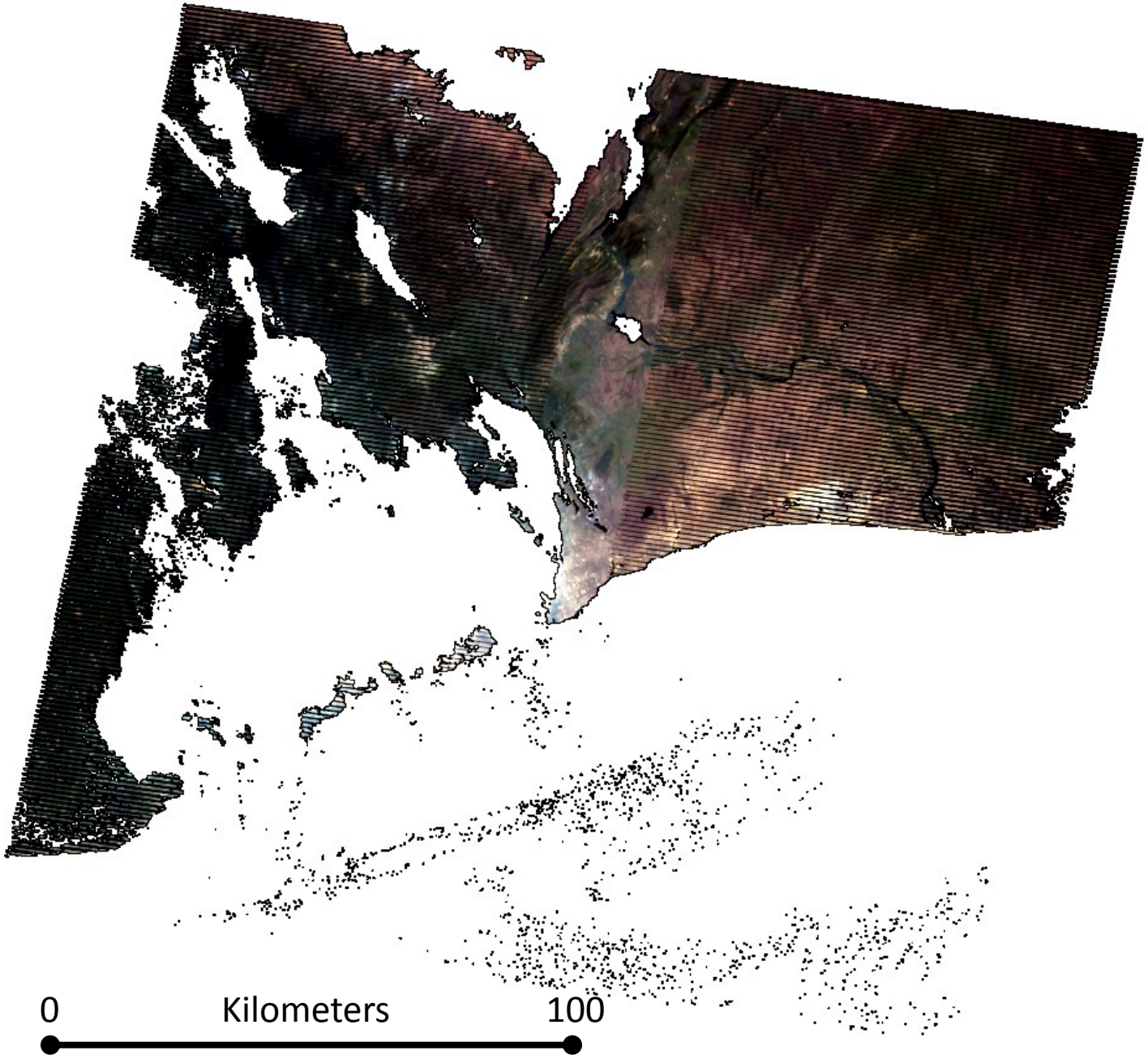
Regional Landsat Data:
SCL-off Data Gaps



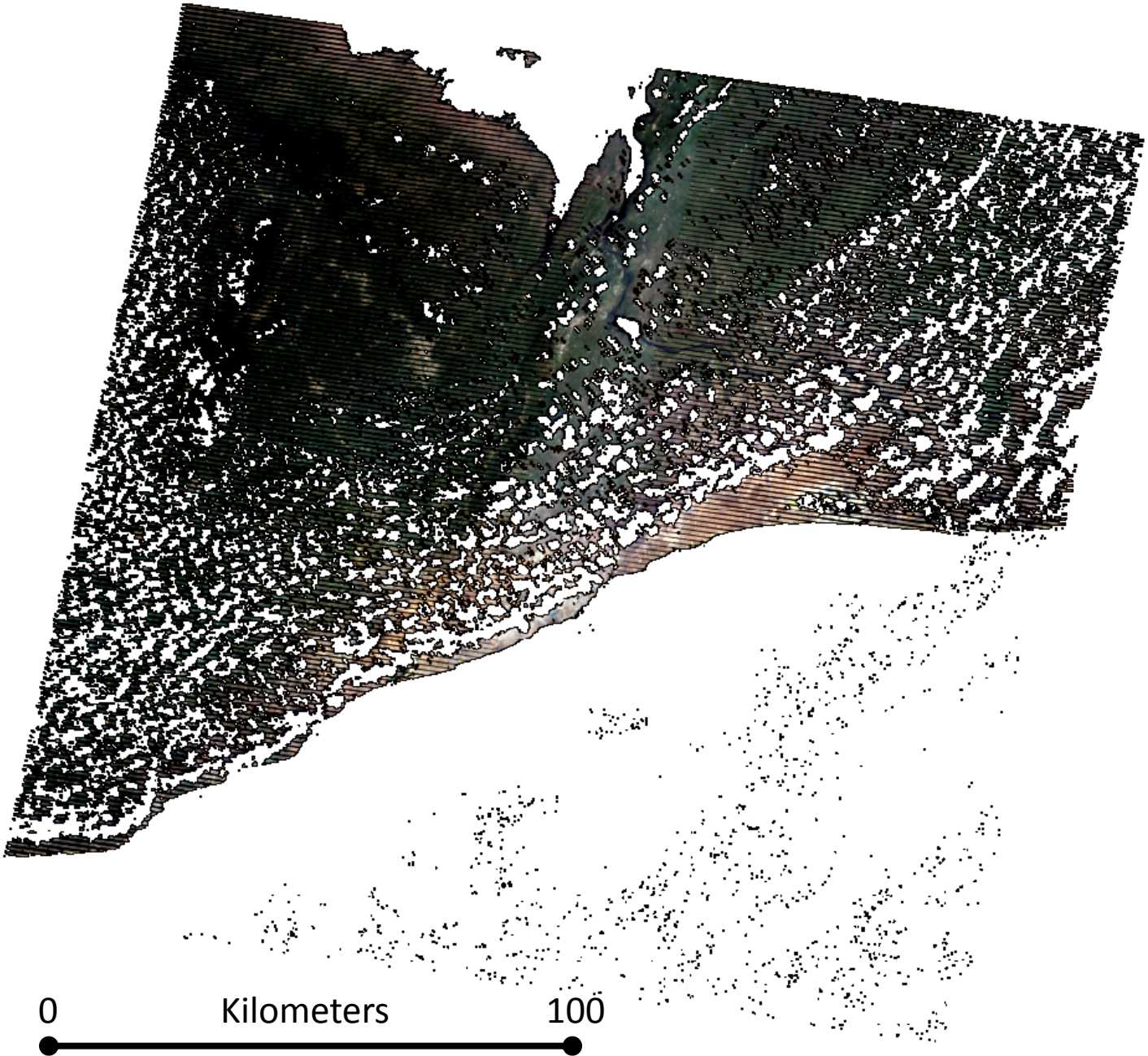
Regional Landsat Data:
Usable data frequency -- 48 images 1999-2013 < 33% cloud



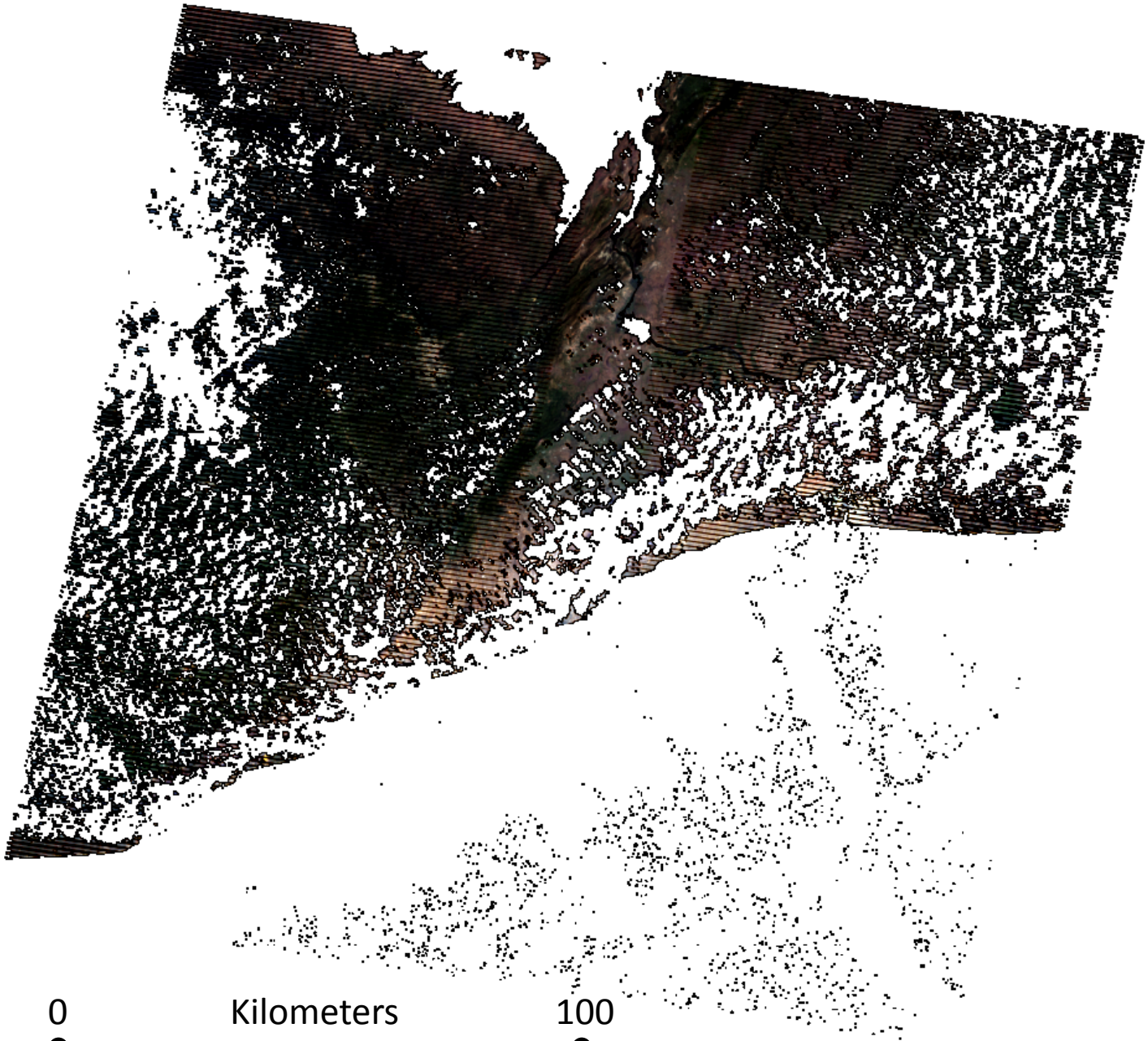
c.2010 Landsat 7 ETM+, 2009 011 (Jan 11)



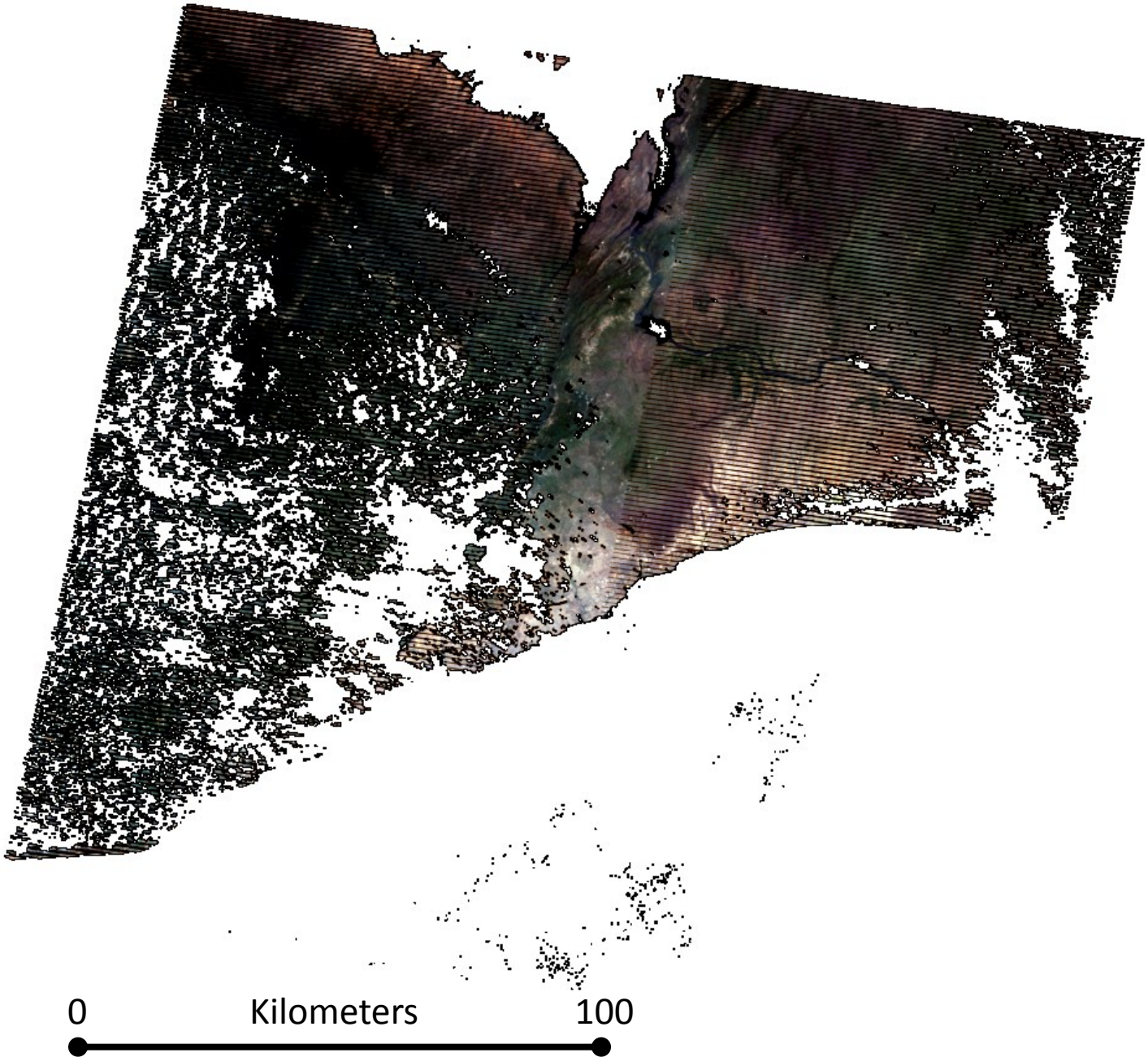
c.2010 Landsat 7 ETM+, 2009 331 (Nov 27)



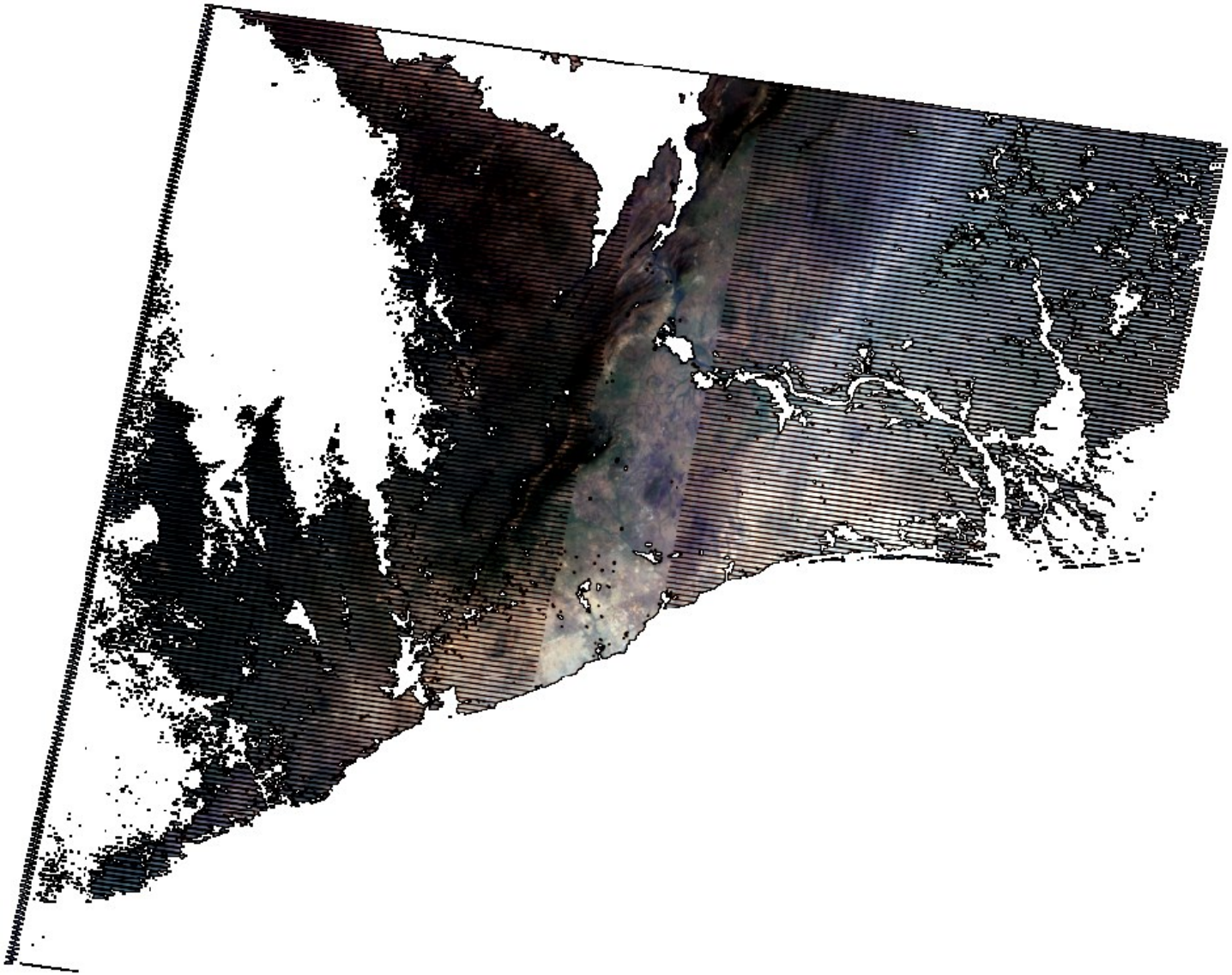
c.2010 Landsat 7 ETM+, 2009 363 (Dec 29)



c.2010 Landsat 7 ETM+, 2010 030 (Jan 30)

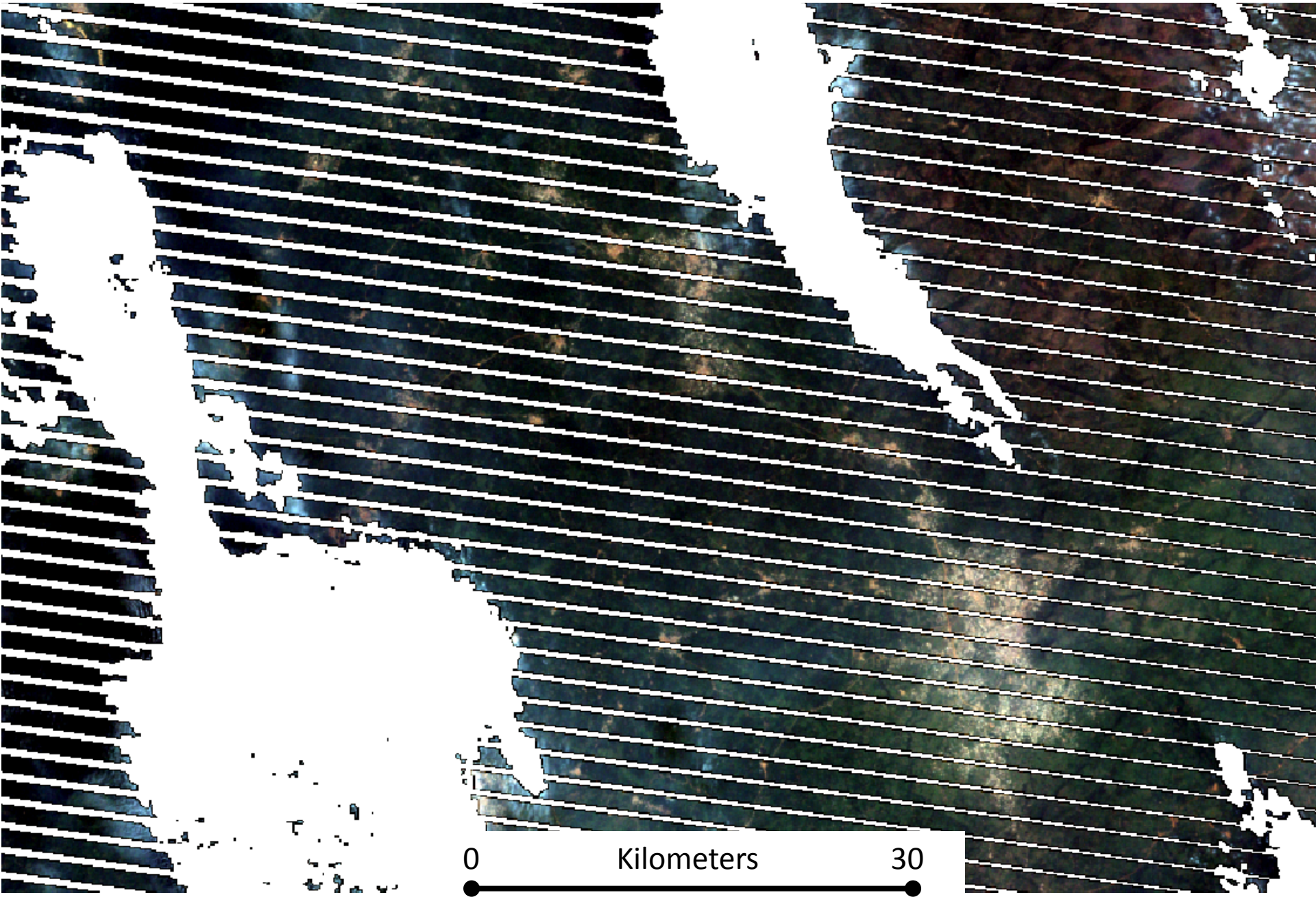


c.2010 Landsat 7 ETM+, 2011 017 (Jan 17)

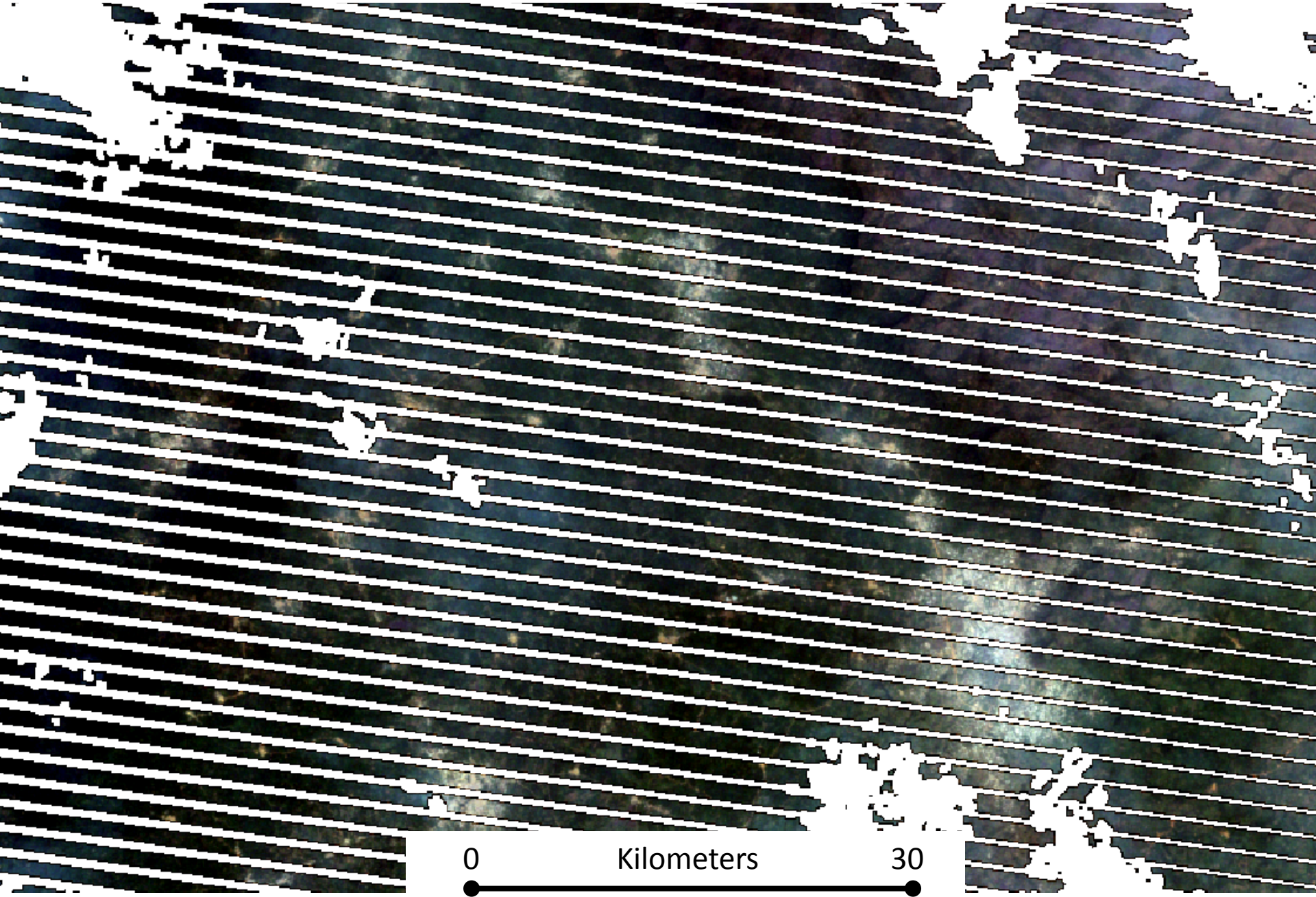


0 Kilometers 100

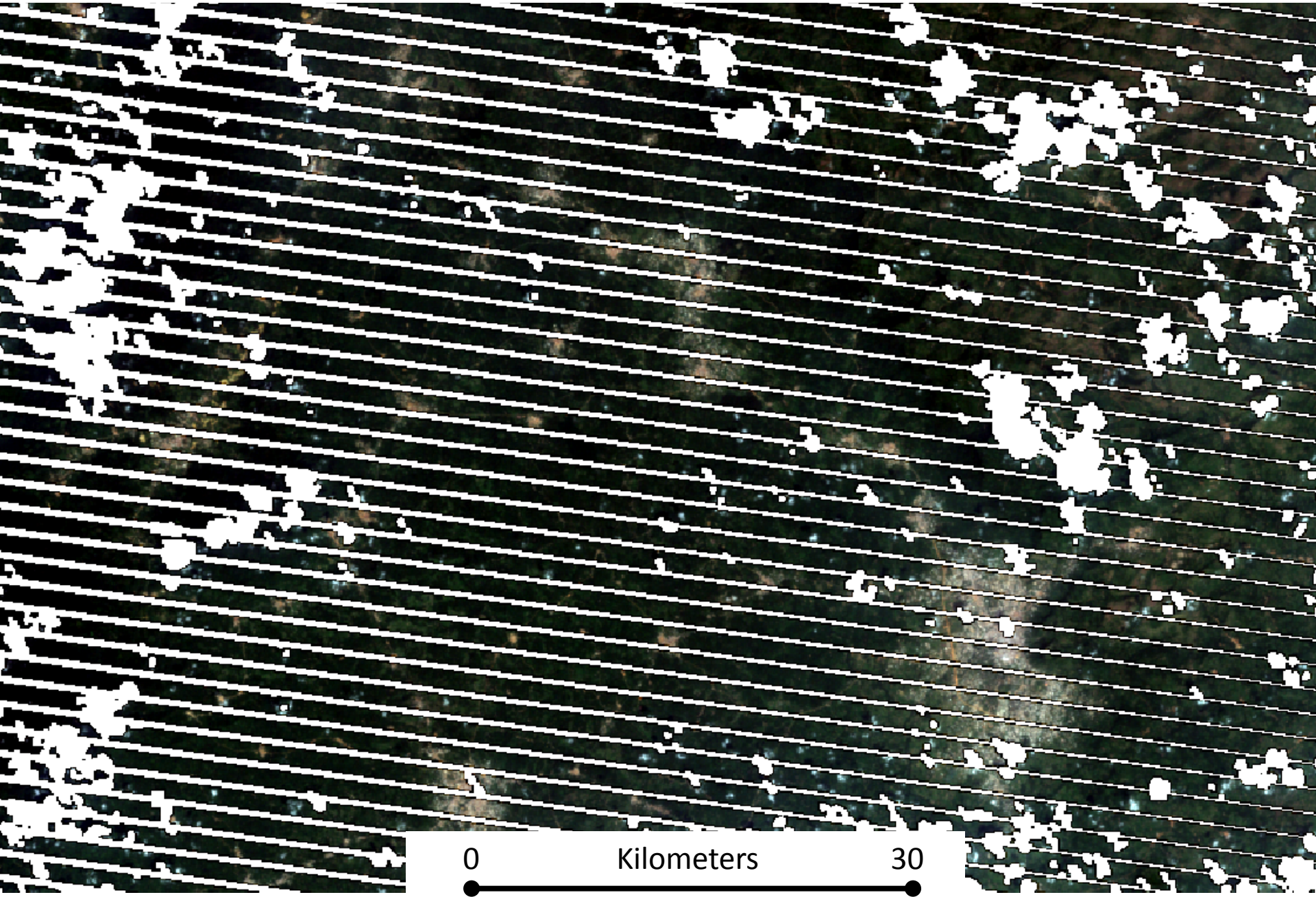
c.2010 Landsat 7 ETM+, 2009 011 (Jan 11)



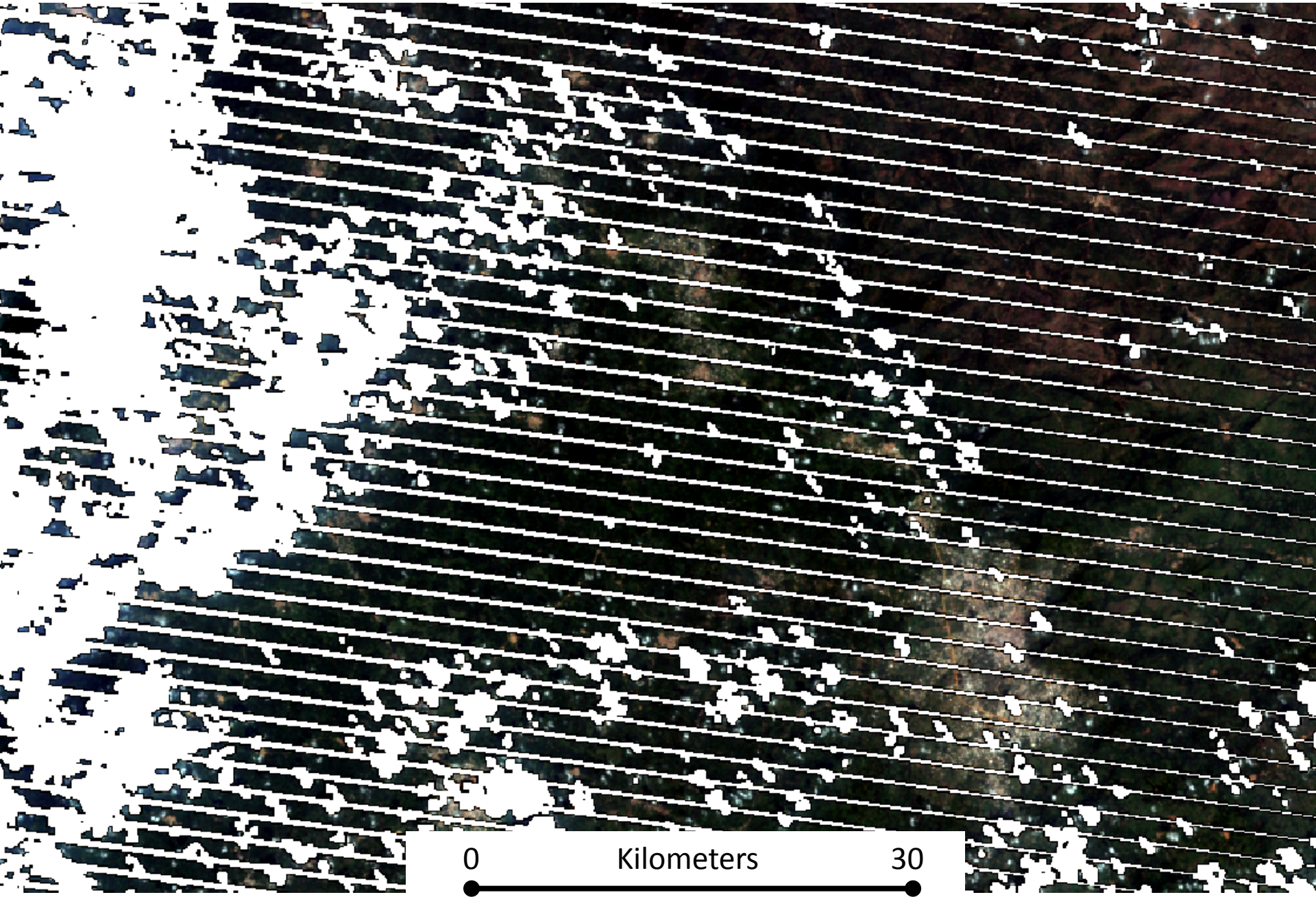
c.2010 Landsat 7 ETM+, 2009 027 (Jan 27)



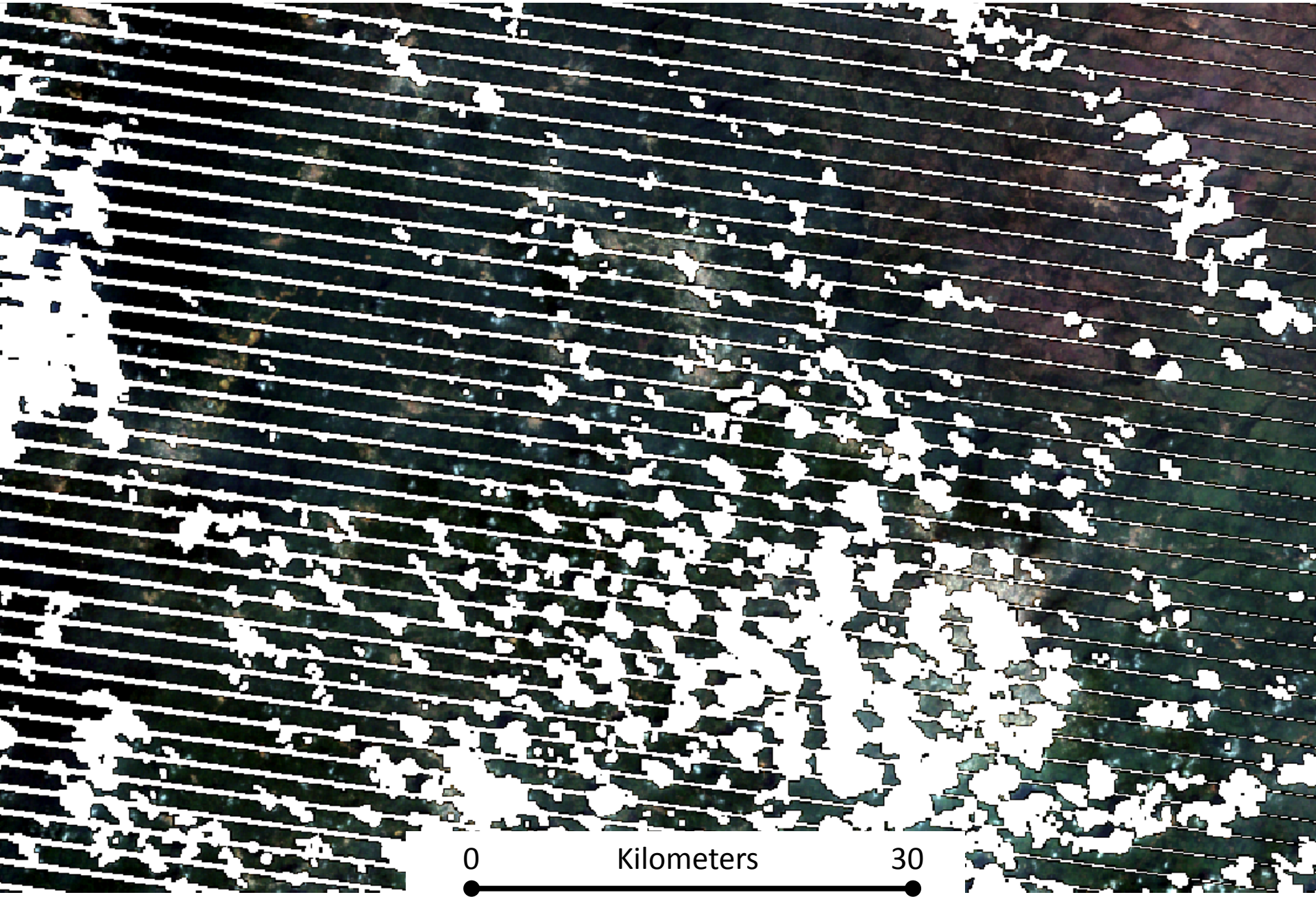
c.2010 Landsat 7 ETM+, 2009 331 (Nov 27)



c.2010 Landsat 7 ETM+, 2009 363 (Dec 29)



c.2010 Landsat 7 ETM+, 2010 030 (Jan 30)






Creating Temporal Composites (c. 2010 Landsat)

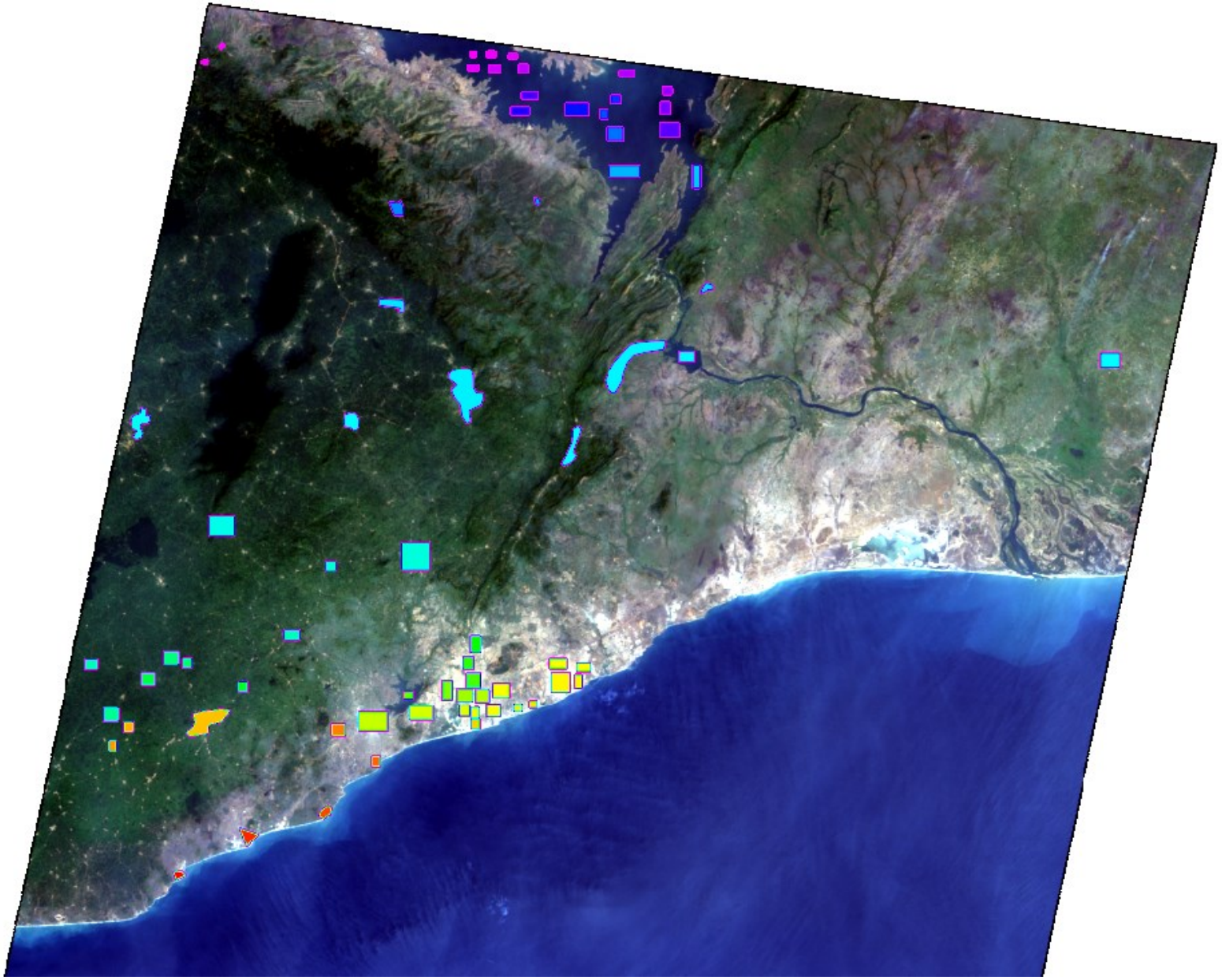
- LEDAPS surface reflectance products are not sufficiently radiometricallynormalized to create composite image sets; + seasonality effects
- Custom radiometric normalization is required
- Bright (urban) and dark (water) training sites were used as pseudo-invariant features (PIF) for radiometric normalization
- Following normalization, composites were created



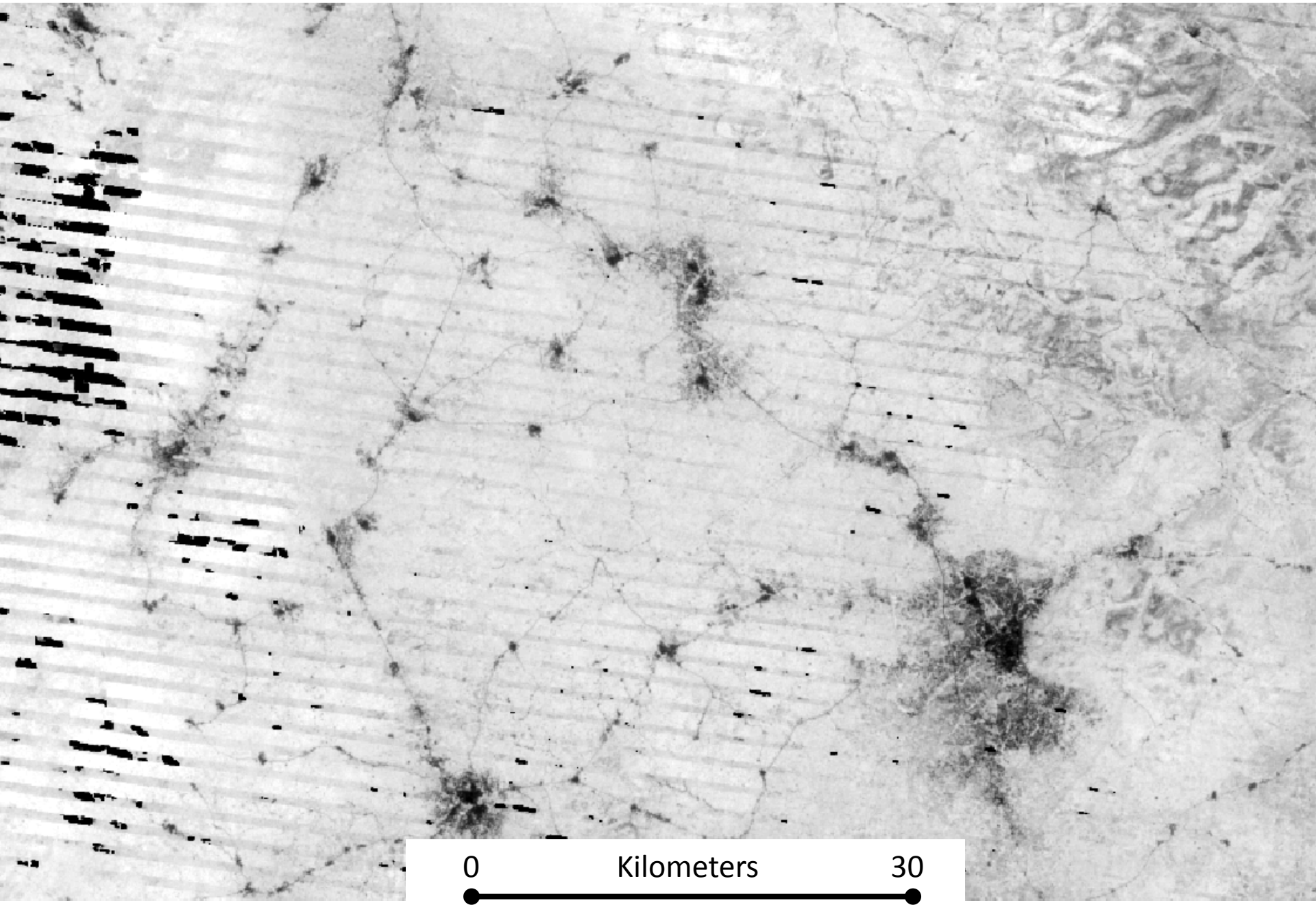


Radiometric Normalization: 2002 as Reference

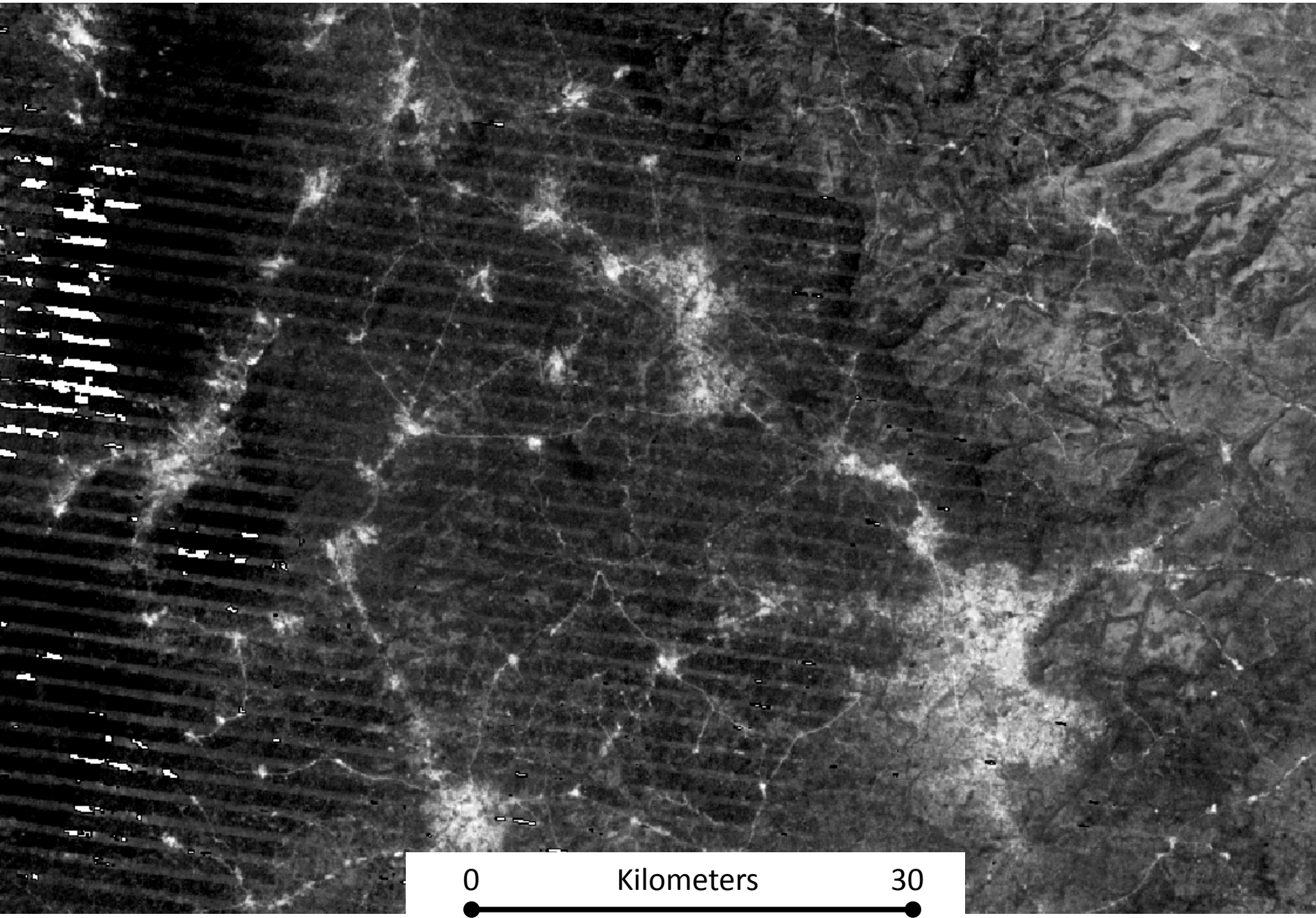
Radiometric Normalization: Water/Urban Targets



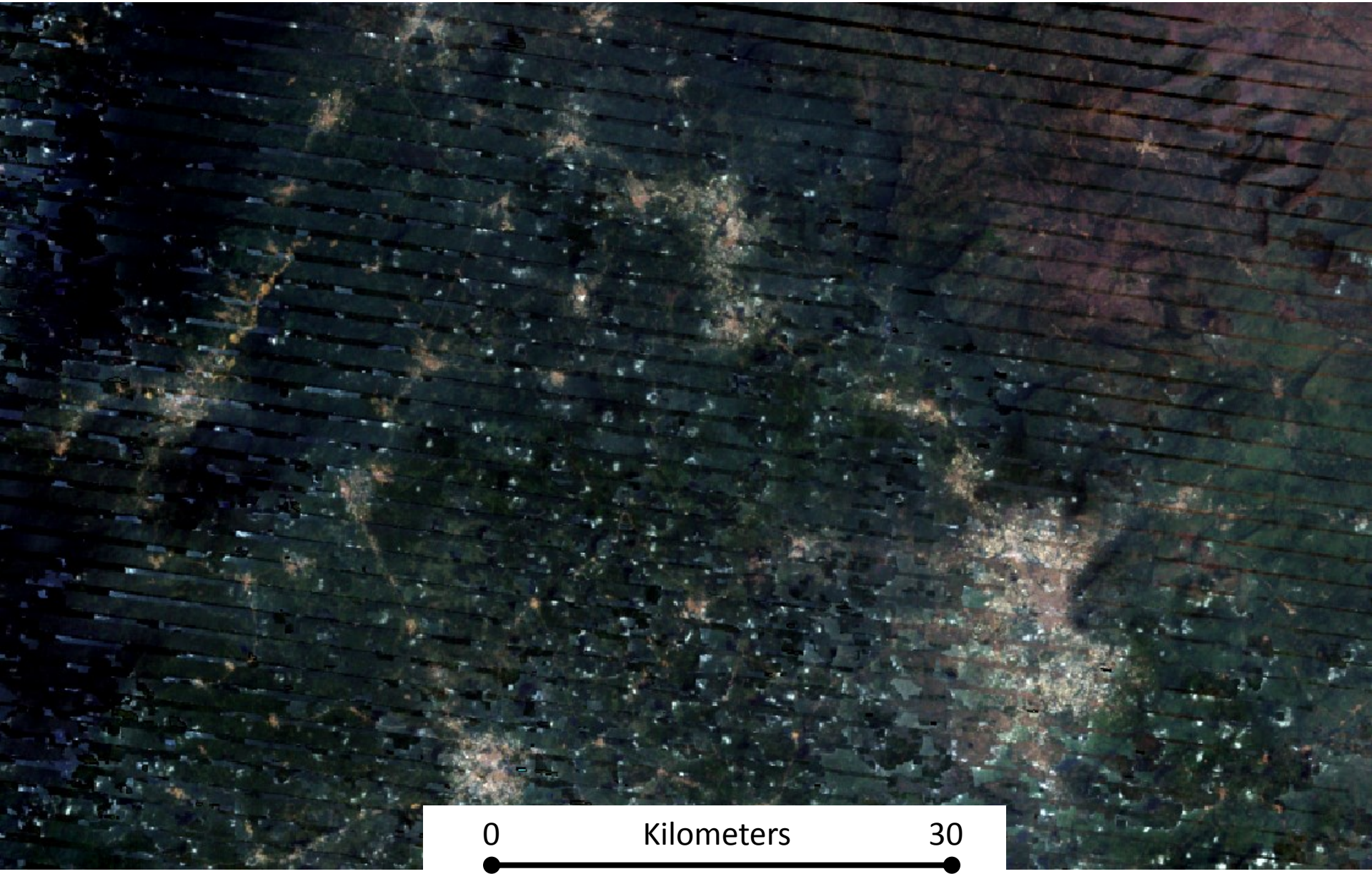
c.2010 Landsat 7 ETM+, NDVI Stack Max (9 images)



Landsat 7 ETM+, Red-Blue Normalized Diff. Stack Max (9 images)



c.2010 Landsat 7 ETM+, Temporal Composite RGB (filled based on date priority, contains artifacts)






Preliminary Results

- Derived image products (e.g., normalized difference products) aid classification of features of interest
- c. 2010 imagery is heavily affected by cloud cover and SLC-off issues
- Substantial manual editing of image classification products is likely to be required








Regional Scale Mapping and Change Detection

LCLUC Analysis w/ Discrete Class Temporal Sequences

Ace Shih

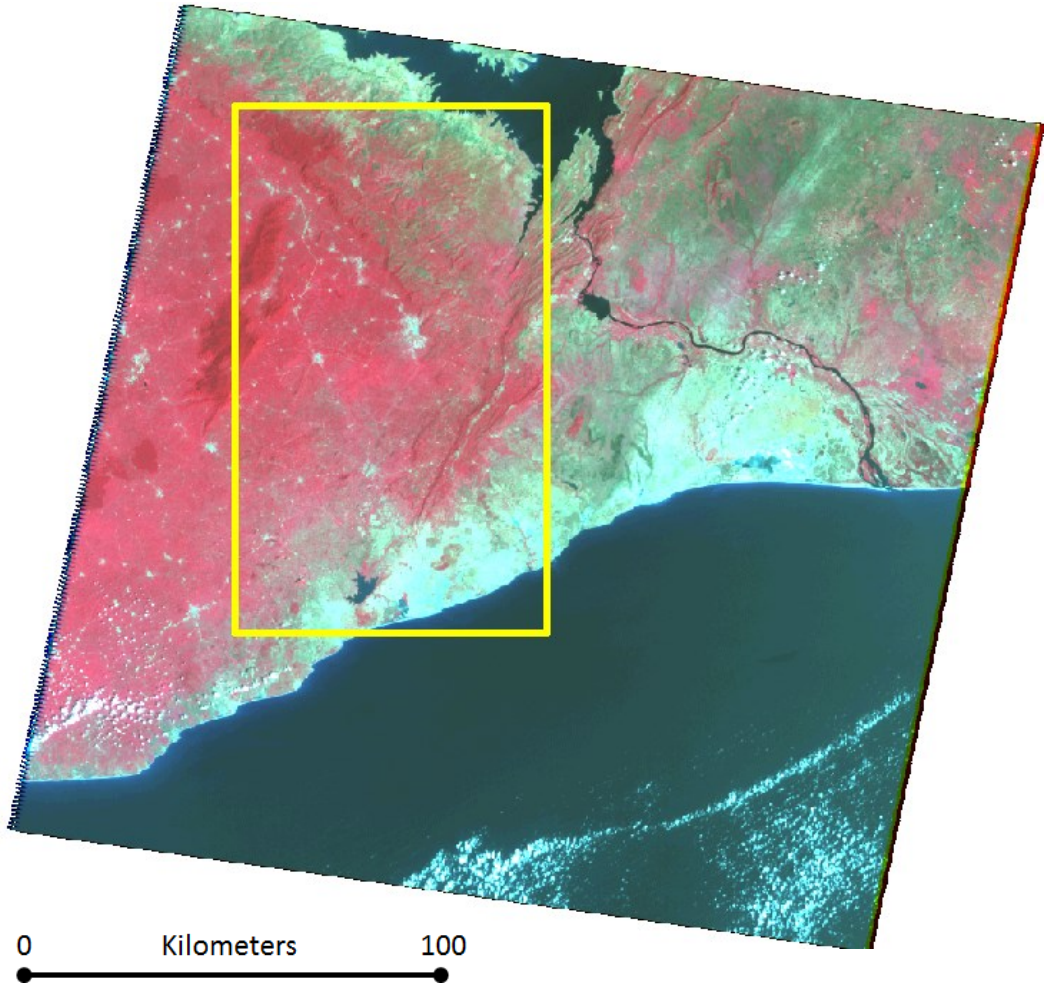




Problem and Objective

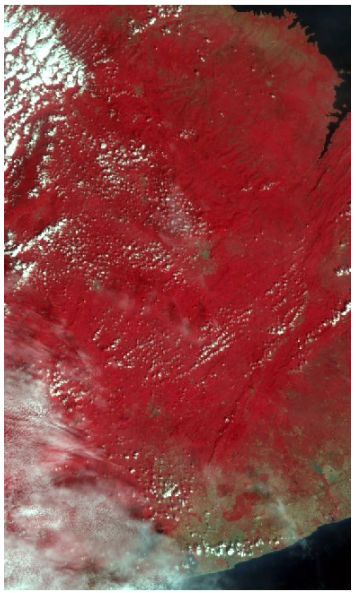
- Dense multi-temporal stacks of processed Landsat TM/ETM+/OLI data are readily available for LCLUC analyses
- Most studies of dense stacks analyze temporal trajectories of continuous value image derivatives (e.g. spectral indices)
- Discrete class time series is another approach
- Clouds, shadows, haze and ETM+ SLC-off create no data/no class pixels
- Objective 1: Hindcast 2000 and 2010 based on 2002 and 2013 image classification results
- Objective 2: Determine the timing and type of LCULC within a decadal time series of Landsat data using a discrete class time series approach with spatial and temporal filtering

Study area



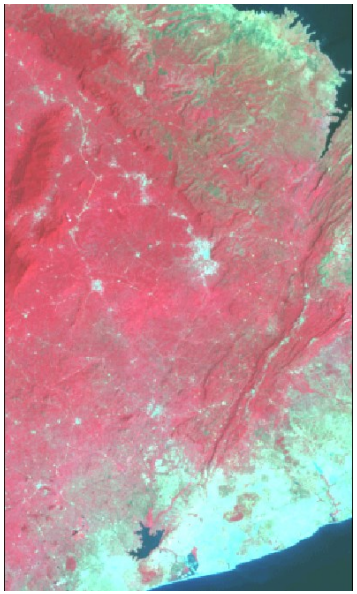
Study area

115.8km

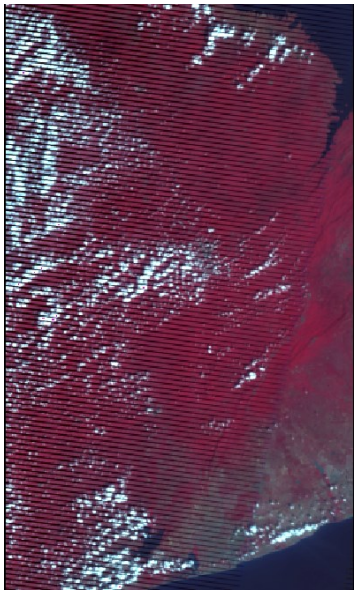


68.5km

30 Nov 2002
(2002344)



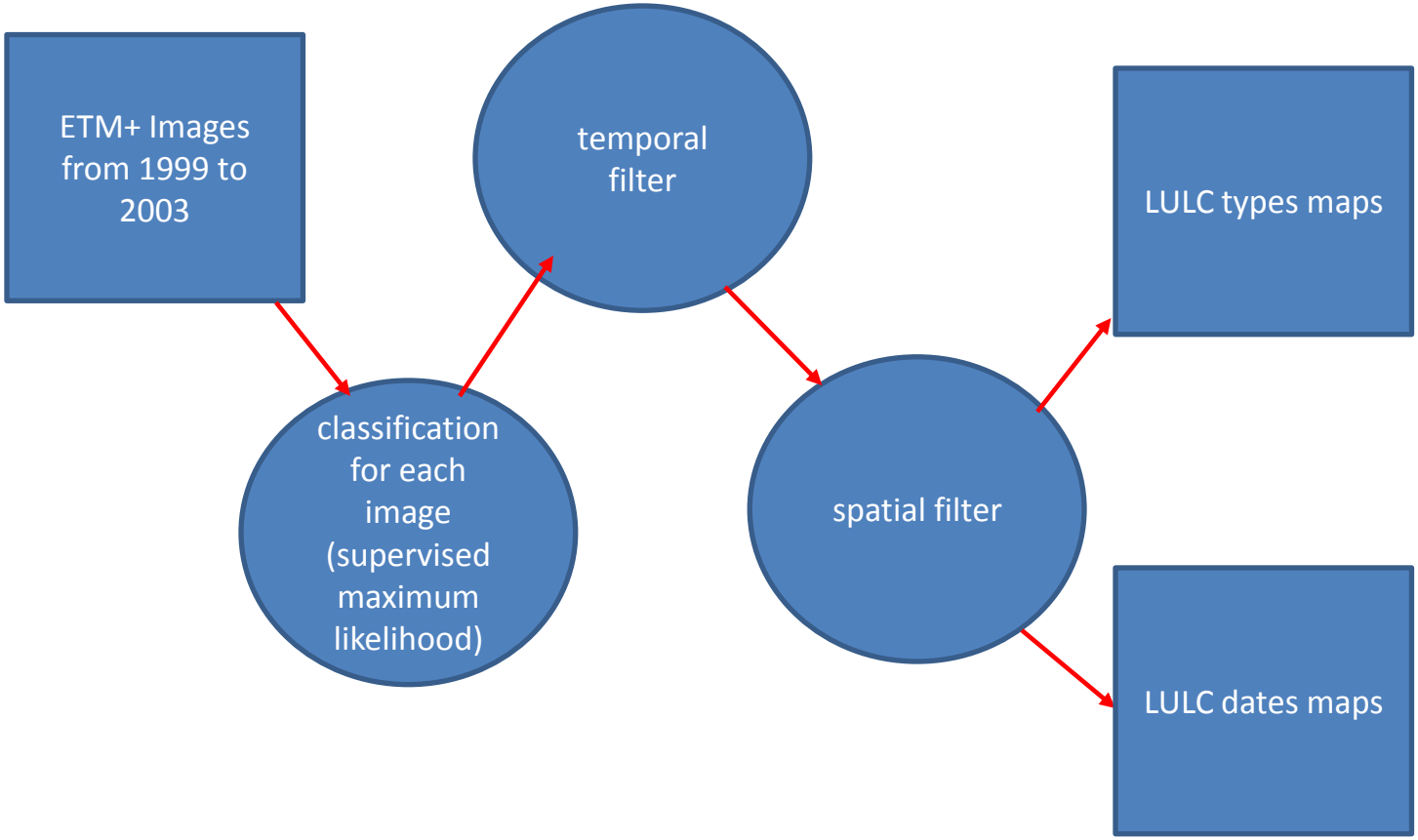
12 Feb 2003
(2003043)



13 Dec 2003
(2003347)




Process Flow










Training Approach

- Persistent LCLU features throughout record length
- Urban at beginning of period
- Forest at end of period
- Agriculture at beginning and end of period







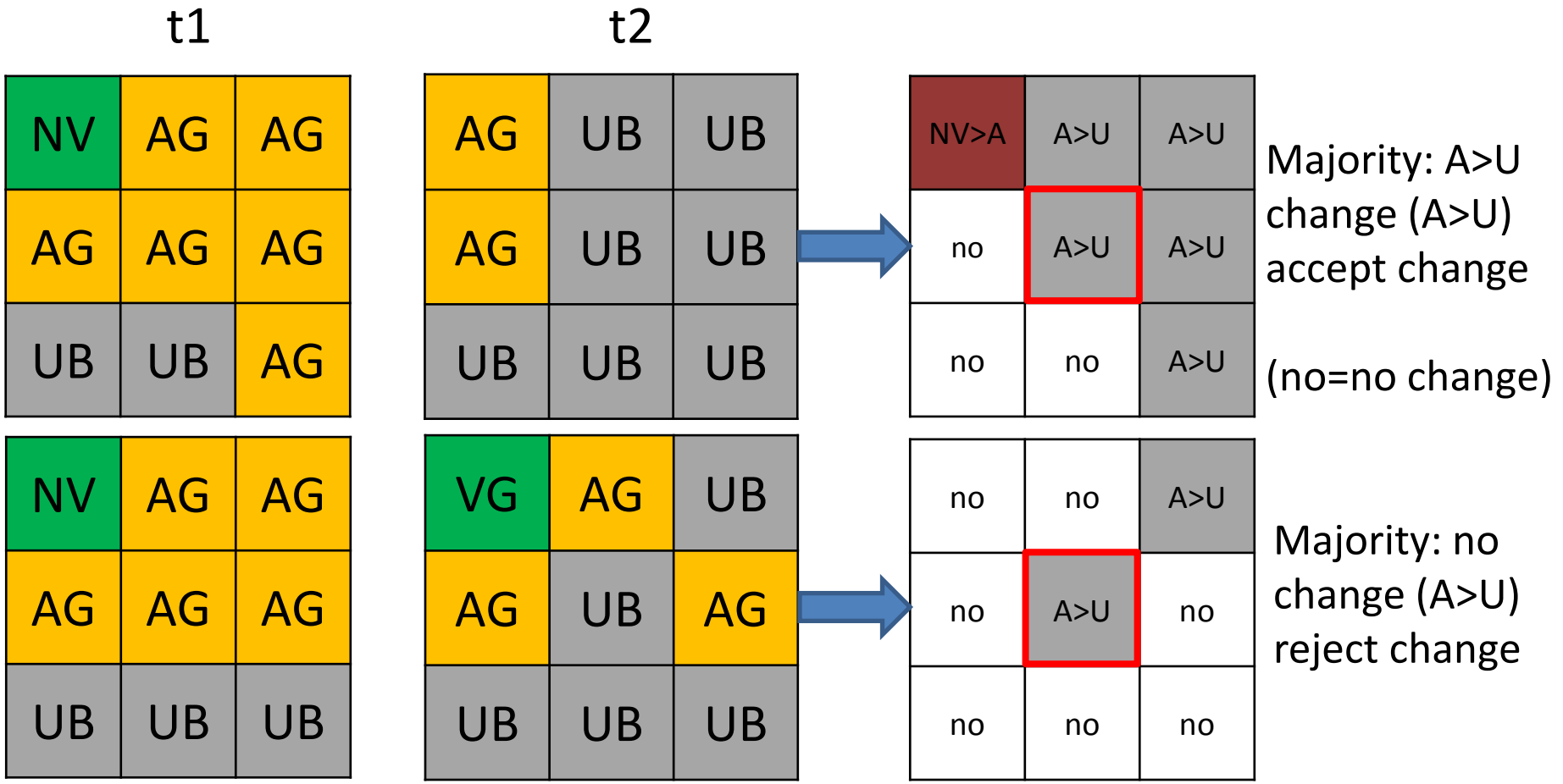

Temporal filter

	t	t+1	t+2	t+3	t	t+1	t+2	t+3
(a)	UB	ND	UB	UB	UB	UB	UB	UB
(b)	AG	AG	UB	AG	AG	AG	AG	AG
(c)	UB	UB	UB	NV	UB	UB	UB	UB
(d)	AG	AG	UB	UB	AG	AG	UB	UB



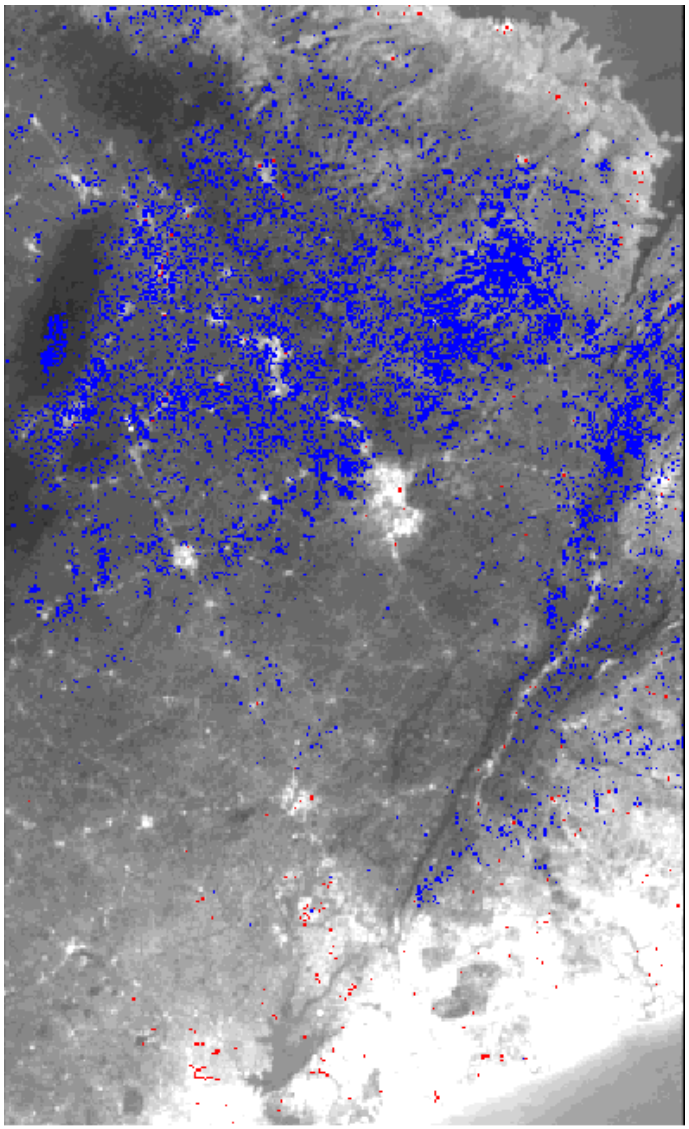


Change map spatial filter: focal majority



LCLU Change Map

20 km



legend	
	NV change to AG
	Non-urban change to urban
Gray scale	No change

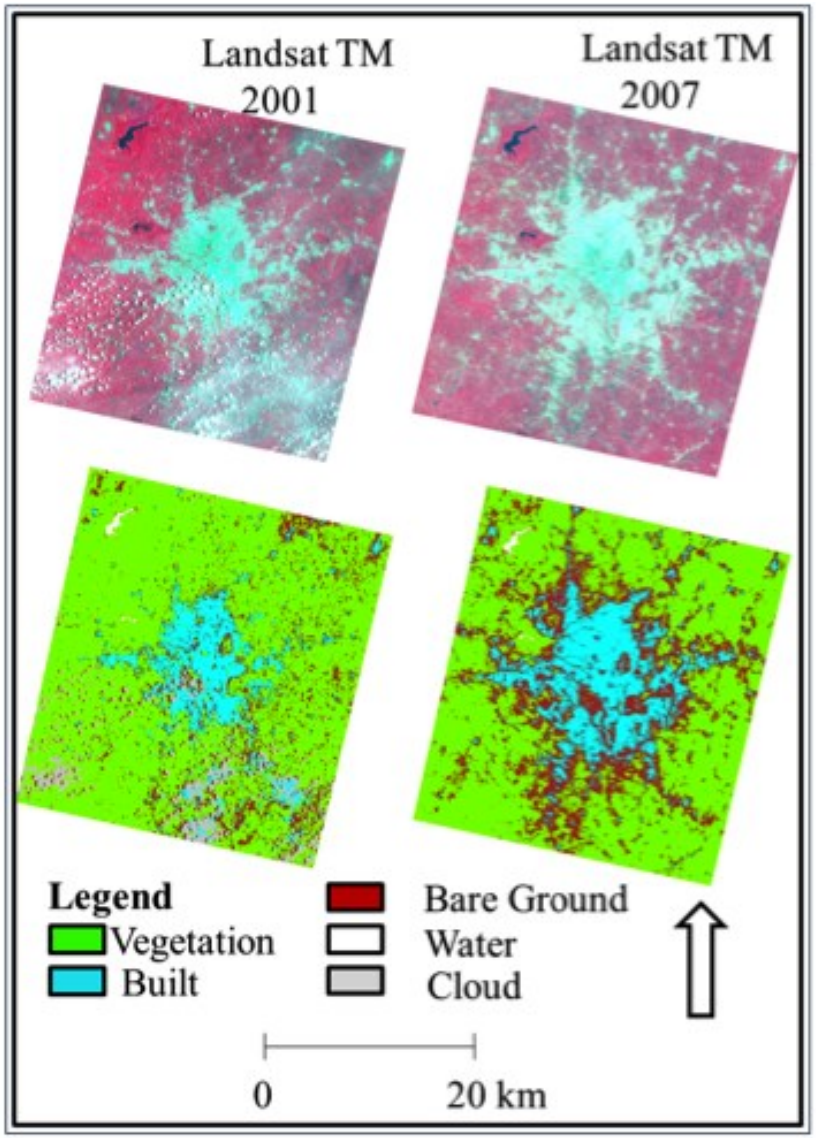
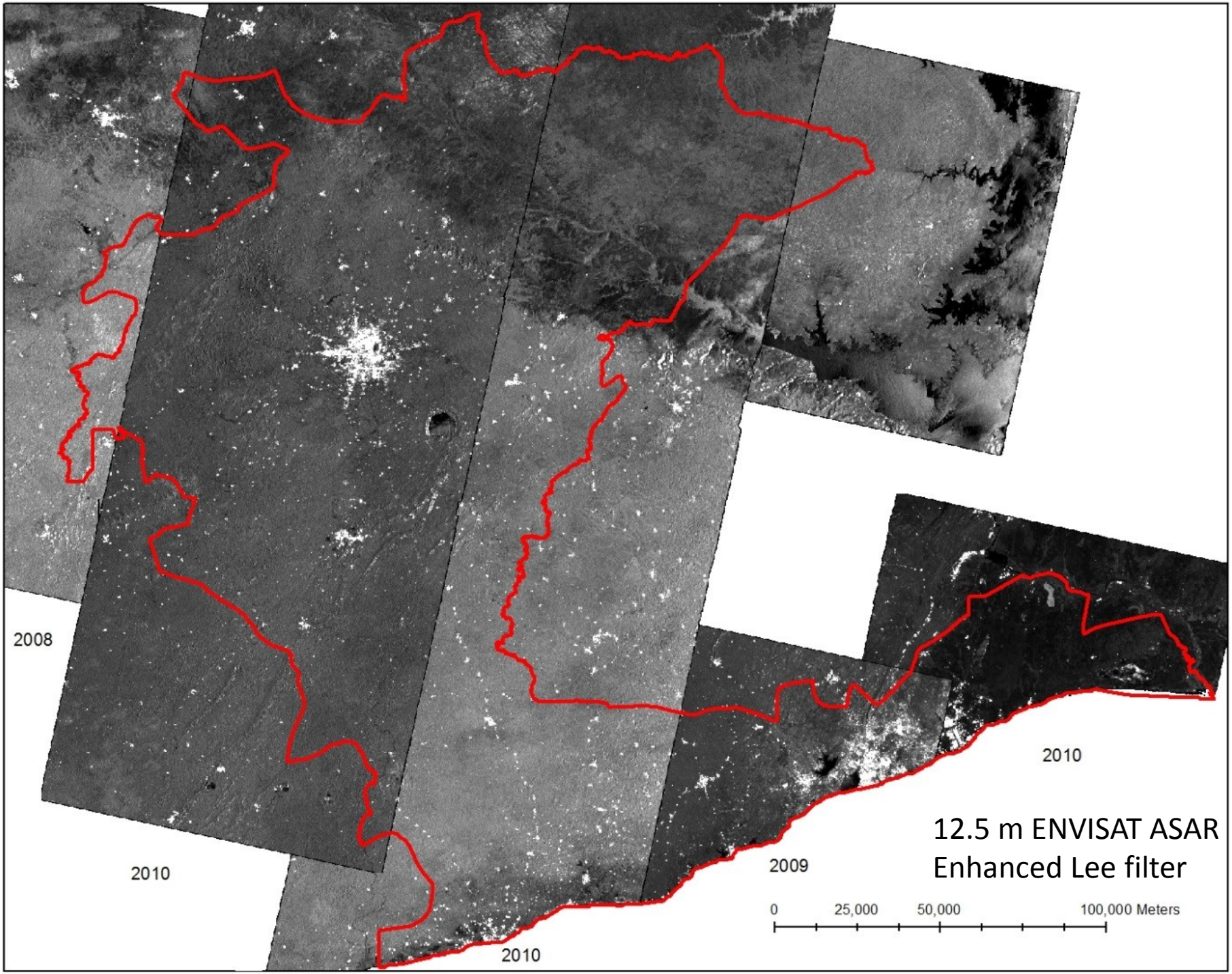
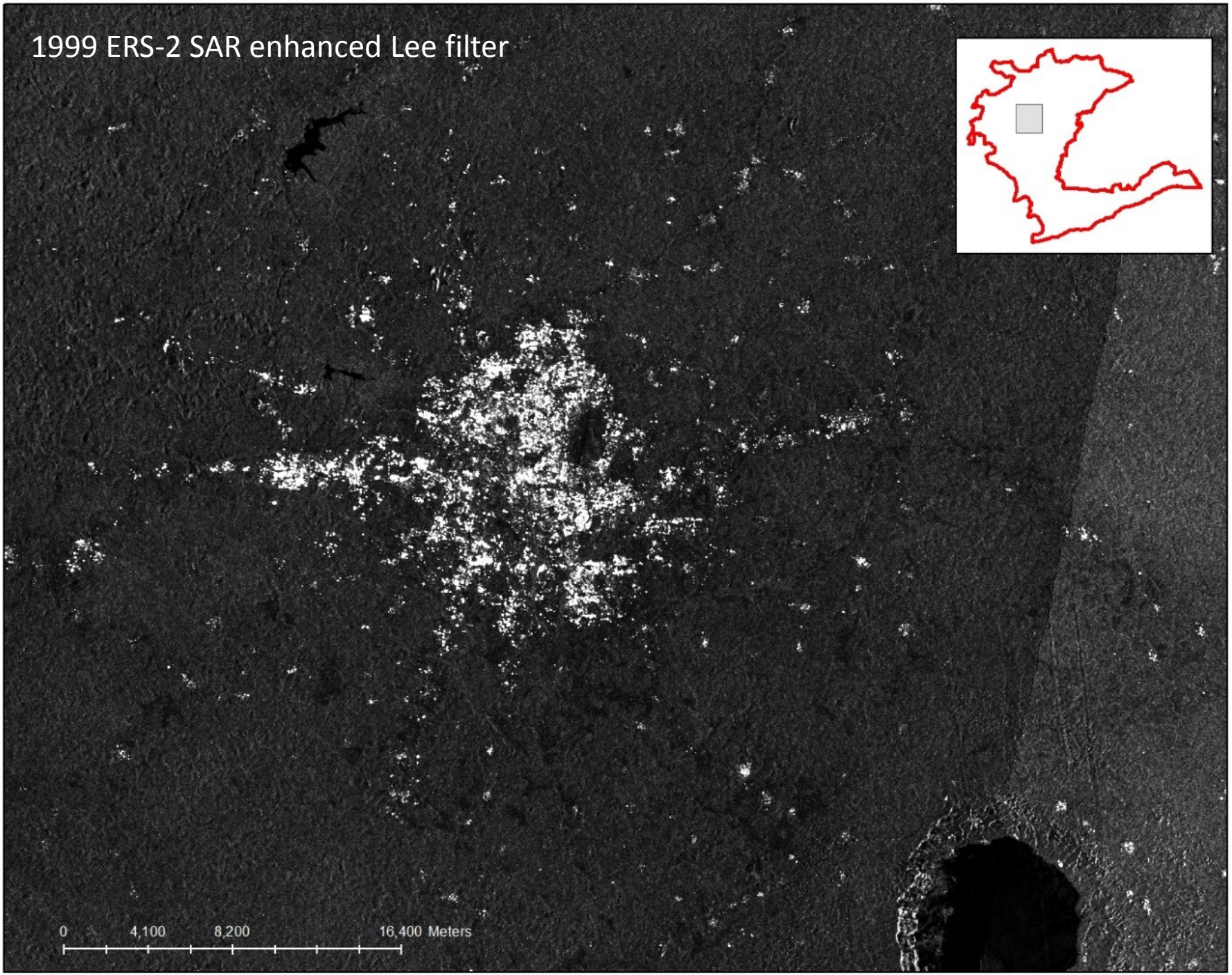
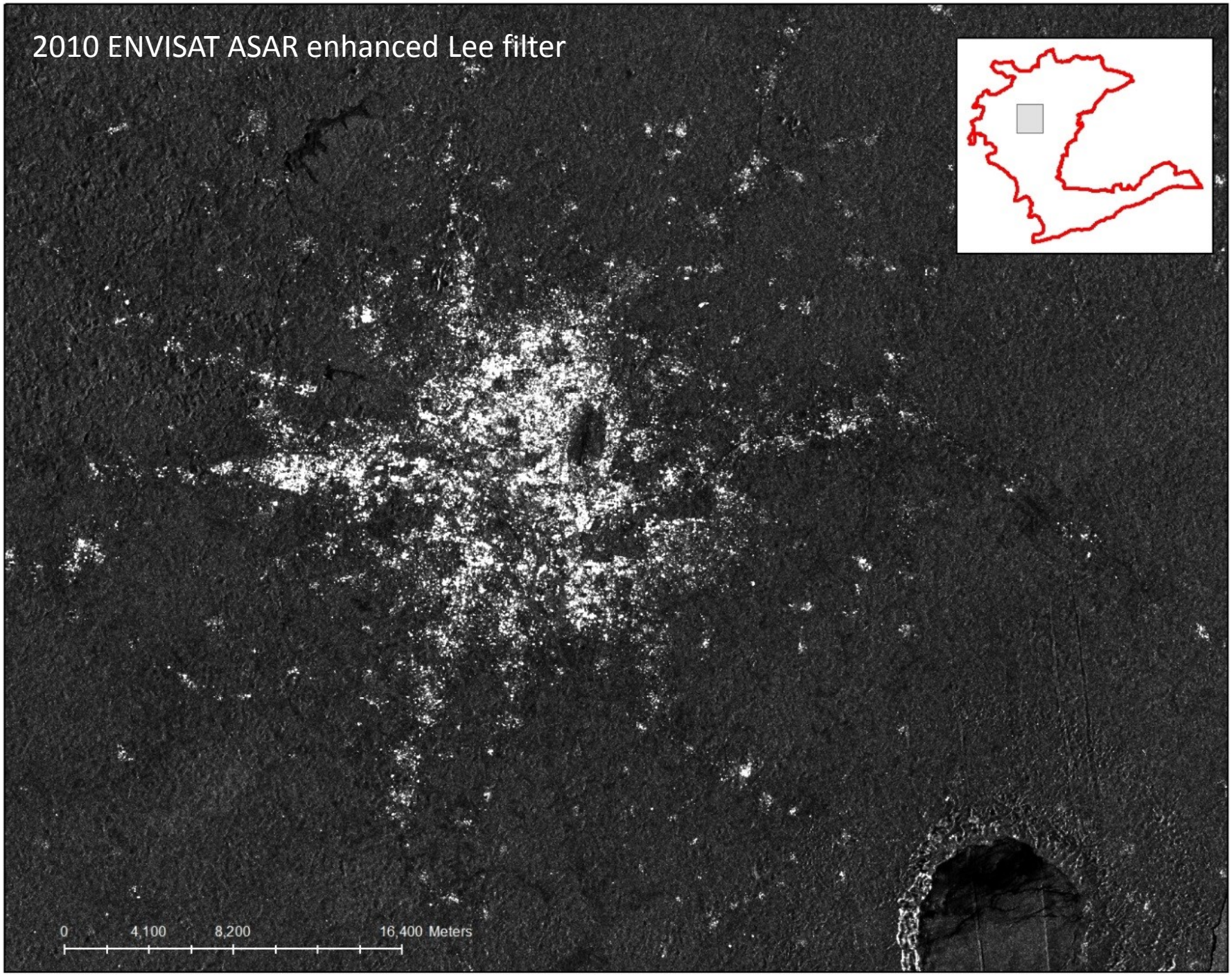


Figure 4. Preliminary evaluation of LCLUC for greater Kumasi area between 2001 and 2007 based on classification of Landsat ETM+ data. "Built" land cover increased substantially particularly in northern and eastern Kumasi, where high spatial resolution satellite image data are available for more detailed analyses.


2008
2010
2010
2009
2010
12.5 m ENVISAT ASAR
Enhanced Lee filter
0
25,000
50,000
100,000 Meters


1999 ERS-2 SAR enhanced Lee filter
0
4,100
8,200
16,400 Meters


2010 ENVISAT ASAR enhanced Lee filter
0
4,100
8,200
16,400 Meters




Urban Scale

High Spatial Resolution Mapping of LCLU and Change in Accra

Sory Toure








Objectives

- Generate LCLU maps for c.2000 and c. 2010
- Generate LCLU change maps between 2000 and 2010





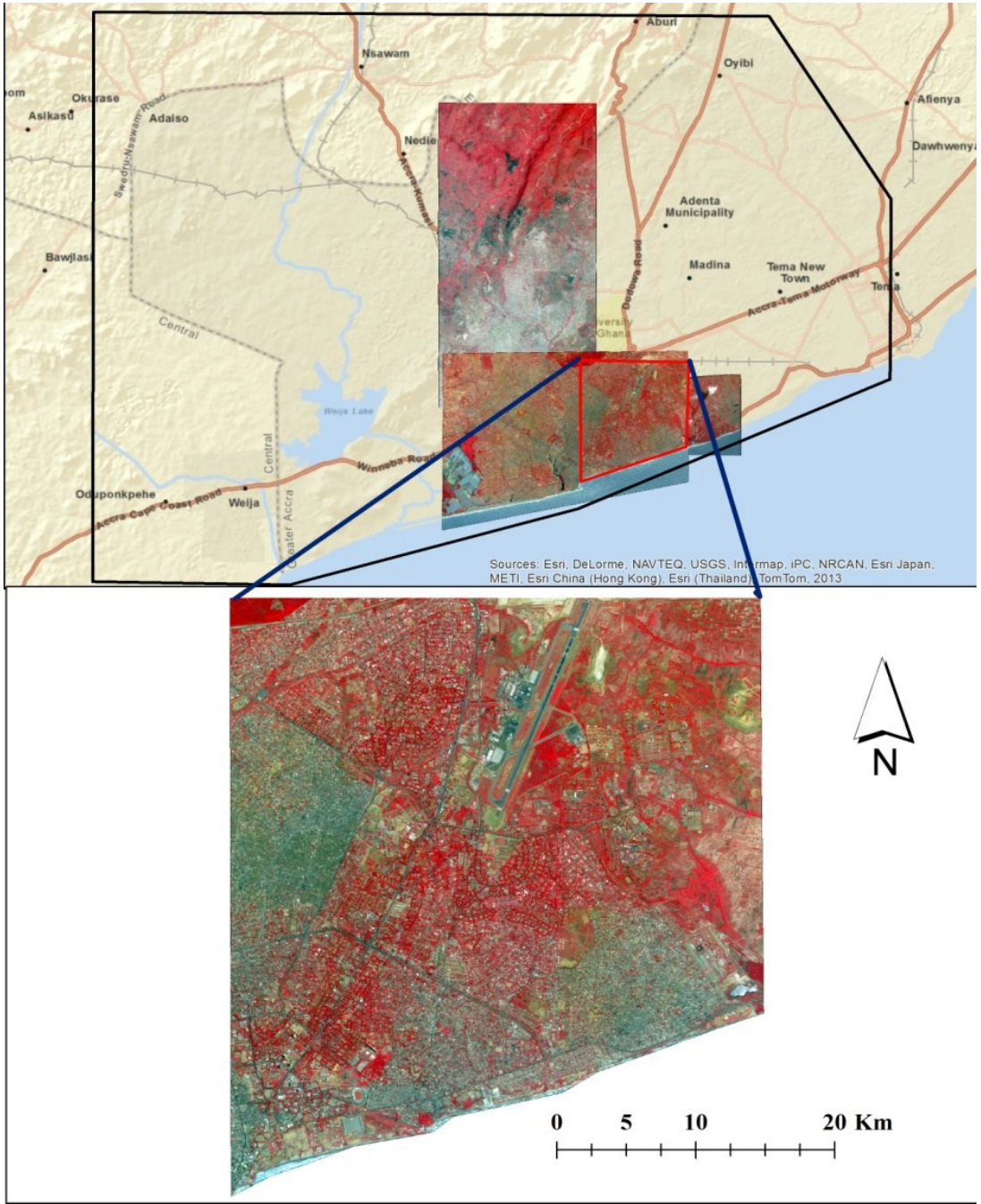
Data

High Res. Data Composite c. 2000:

- Ikonos 02/10/2000
- Ikonos 05/22/2002
- QuickBird 04/12/2002

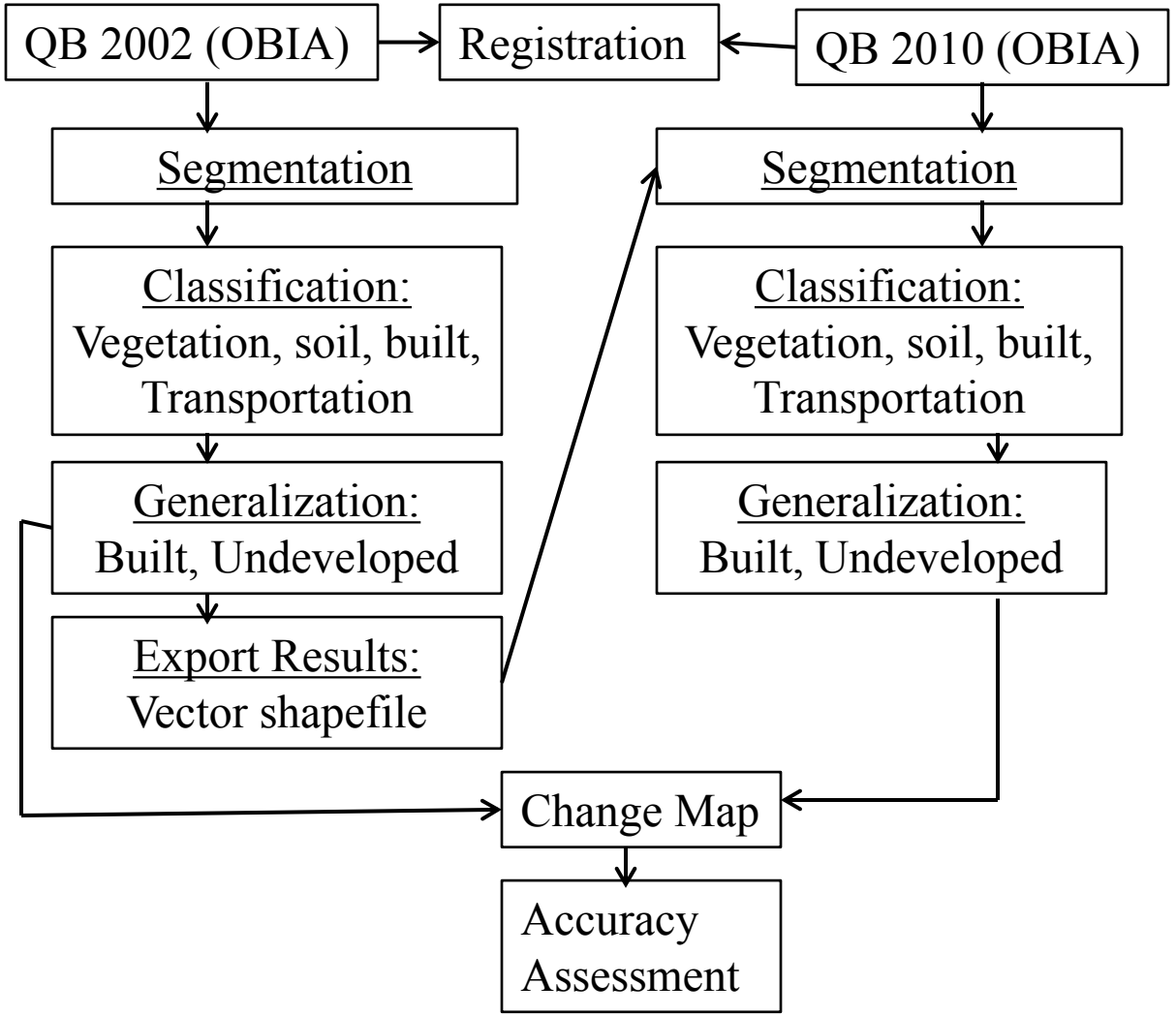
Study area:

- QuickBird 04/12/2002
- QuickBird 01/12/2010






Methods


QB 2002 (OBIA)
Registration
QB 2010 (OBIA)
Segmentation
Segmentation
Classification:
Vegetation, soil, built,
Transportation
Classification:
Vegetation, soil, built,
Transportation
Generalization:
Built, Undeveloped
Generalization:
Built, Undeveloped
Export Results:
Vector shapefile
Change Map
Accuracy
Assessment








QuickBird 2002 Analysis

- **Segmentation:**
  - Multi-resolution segmentation
  - 4 layers inputs (VNIR)
  - Scale parameter 10
  - Shape = 0.1
  - Compactness = 0.5
- **Classification:**
  - NDVI >= 0.21, Vegetation
  - Soil, Built, Transportation classification feature inputs:
    - Mean red, blue, green, NIR
    - Std dev. neighbor pixels
    - Green Band texture 11 x 11; 9 x 9
    - NIR Band texture 11 x 11
    - NDVI
  - Features chosen through feature space optimization tool
- **Generalization:**
  - Built: Built + Transportation
  - Undeveloped: Soil + Vegetation







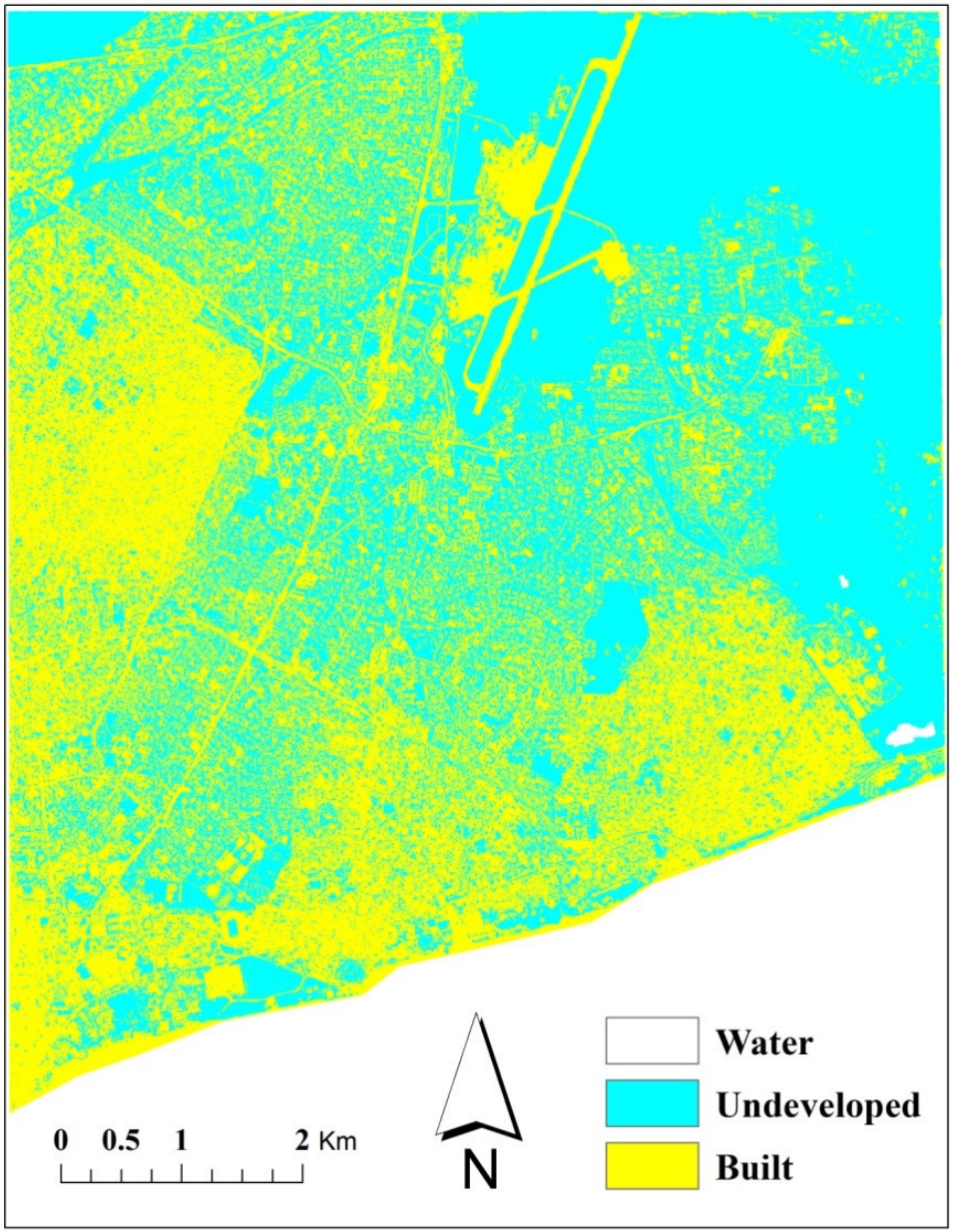

QuickBird 2010 Analysis

- **Segmentation:**
  - Chessboard segmentation
  - 2002 segmentation result as Thematic layer
  - Replicated similar segmentation in both dataset
- **Classification:**
  - NDVI >= 0.18, Vegetation
  - Soil, Built, Transportation classification feature inputs:
    - Mean red, blue, green, NIR
    - Neighborhood StdDev.
    - Green Band texture 11 x 11; 9 x 9
    - NIR Band texture 11 x 11
    - NDVI
  - Features chosen through feature space optimization tool
- **Generalization:**
  - Built: Built + Transportation
  - Undeveloped: Soil + Vegetation

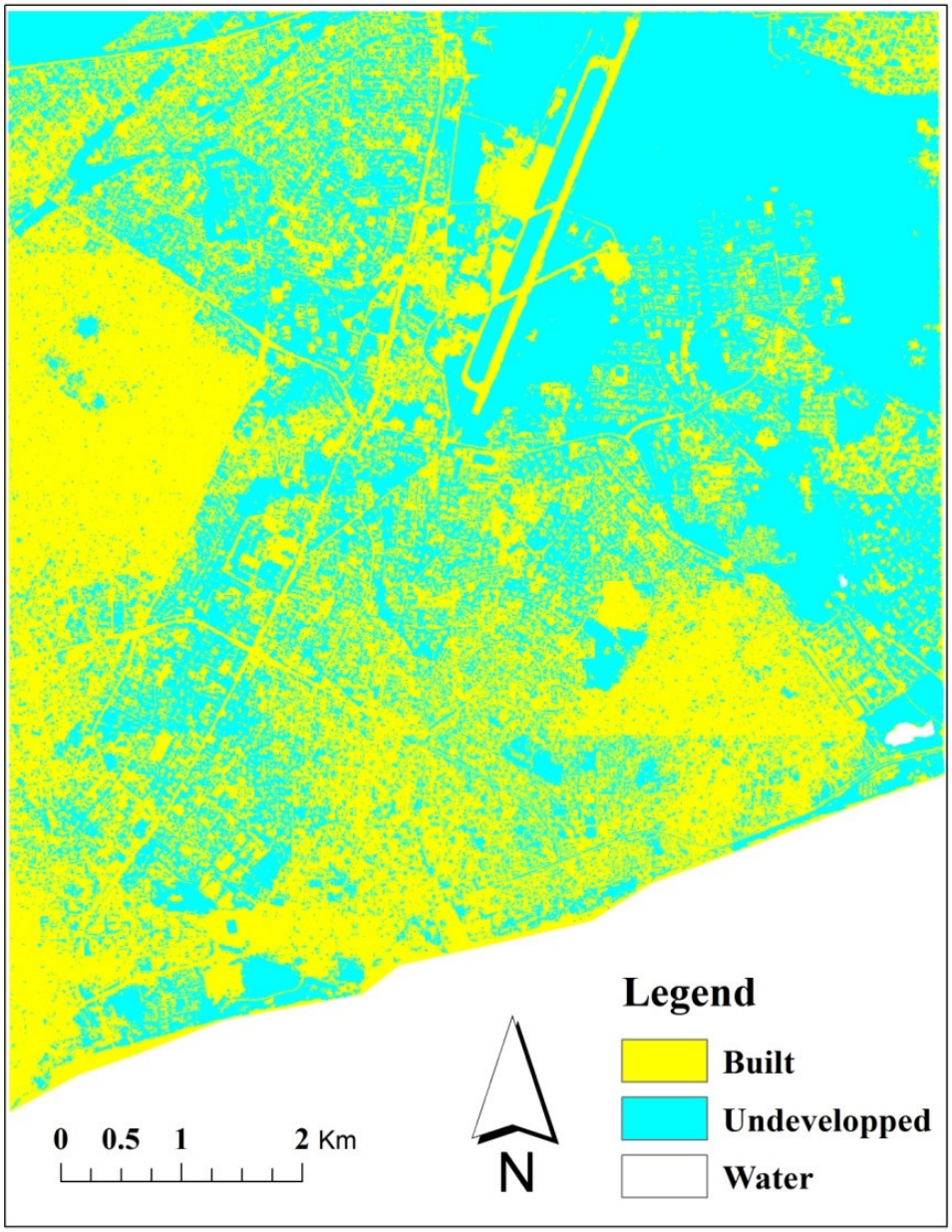




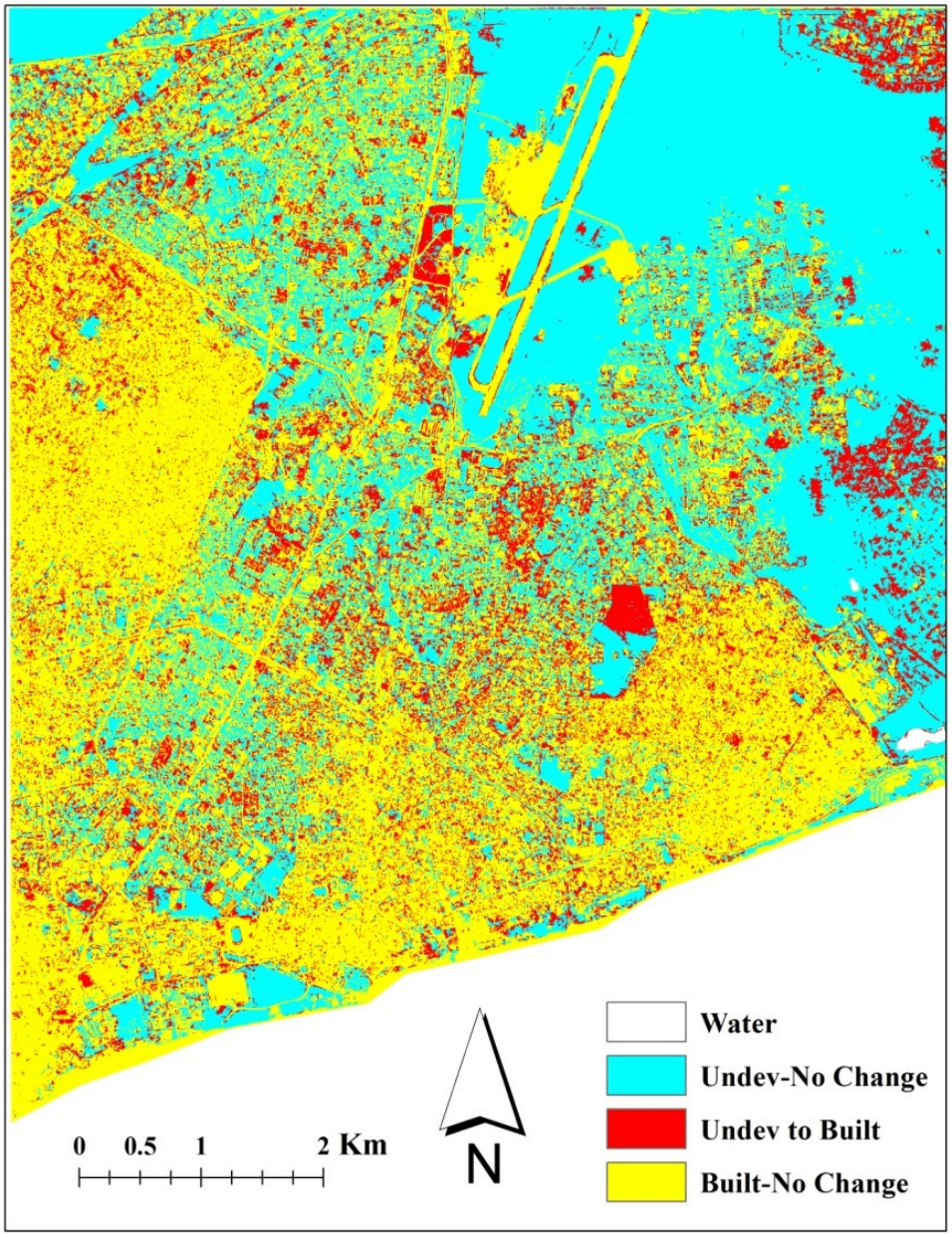
QuickBird 2002 Classification



QuickBird 2010 Classification



2002-2010 LCLUC Map



Results

	Undev. To Built	Built-No Change	Undev-No Change	**Total**
Undev. To Built	7	1	3	11
Built-No Change	0	24	5	29
Undev-No Change	0	2	20	22
Total	7	27	28	62

n = 62

Overall Accuracy: 82.26%




Preliminary Results

- Most new developments are residential, except near the airport and CBD
- Issues in separating between built and soil classes
- Texture features improve classification accuracy
- Manual editing performed to reduce misclassification in all three maps
- Next steps: Improve and expand classification scheme to Res., Non Res., Ag., and Undeveloped








Urban Scale

LCLUC – bi-temporal vs. multi-temporal classification

Kris Taniguchi








Objectives

- Map changes in Vegetation-Impervious-Soil (V-I-S) in Accra, Ghana with a time sequence of high spatial resolution multispectral satellite images using a post-classification approach and spatial/temporal filters; improvement over bi-temporal approach?

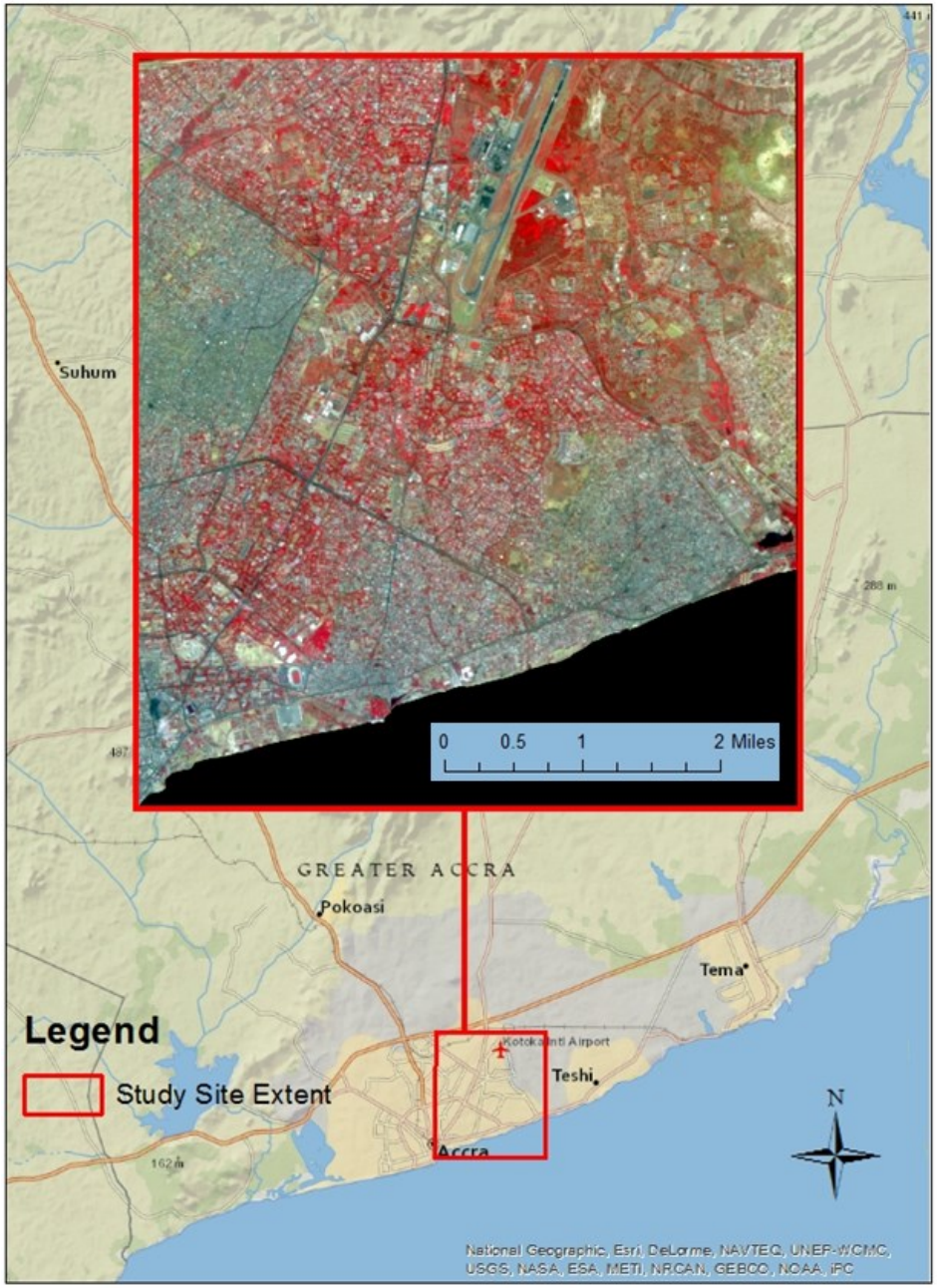
- Determine appropriate spatial unit size for examining urban expansion and densification (on going research not reported here)





Study Area

Common area of five available high spatial resolution, mostly cloud-free images between 2002 and 2010

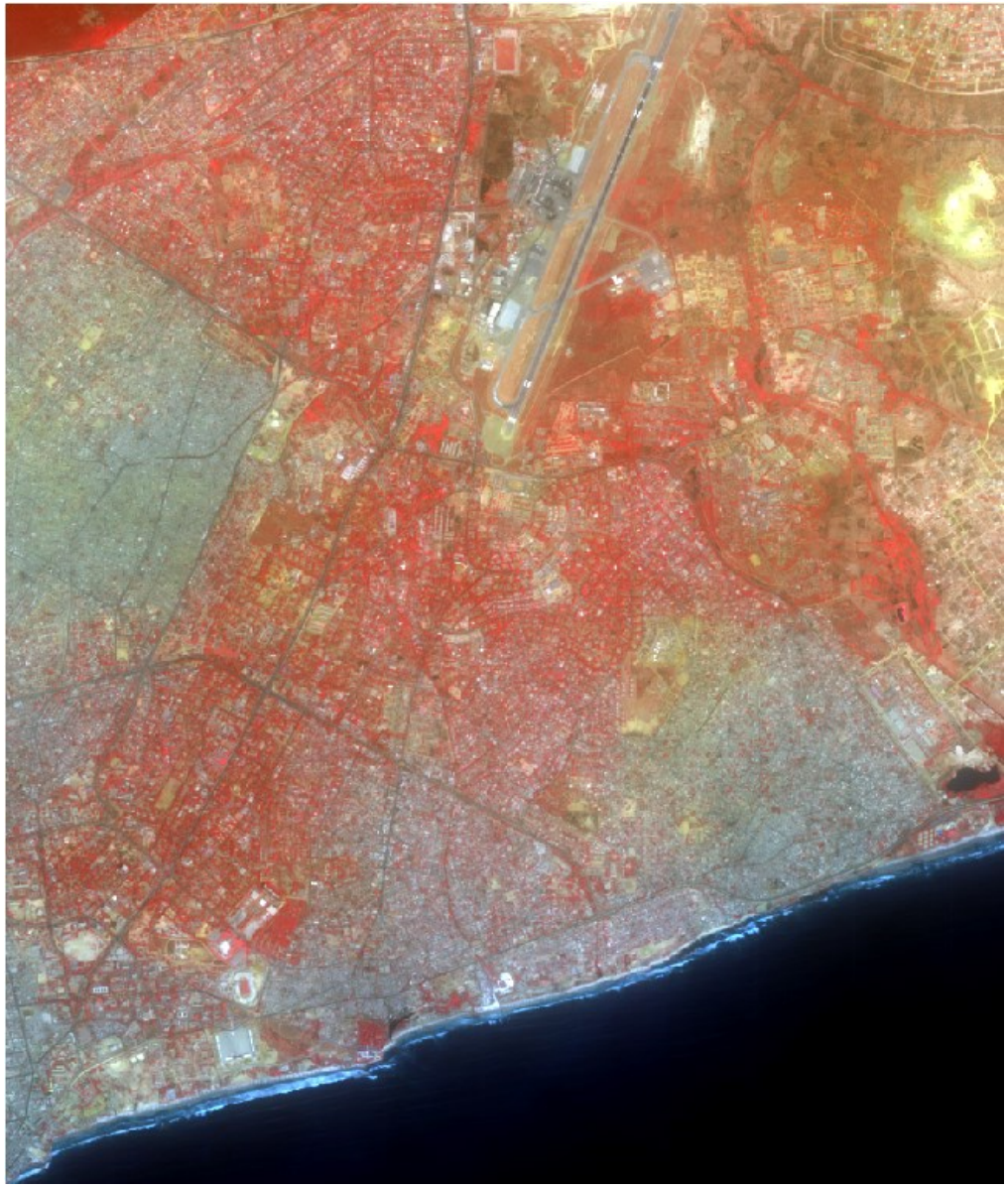


Data

Quickbird MS imagery: April 2002

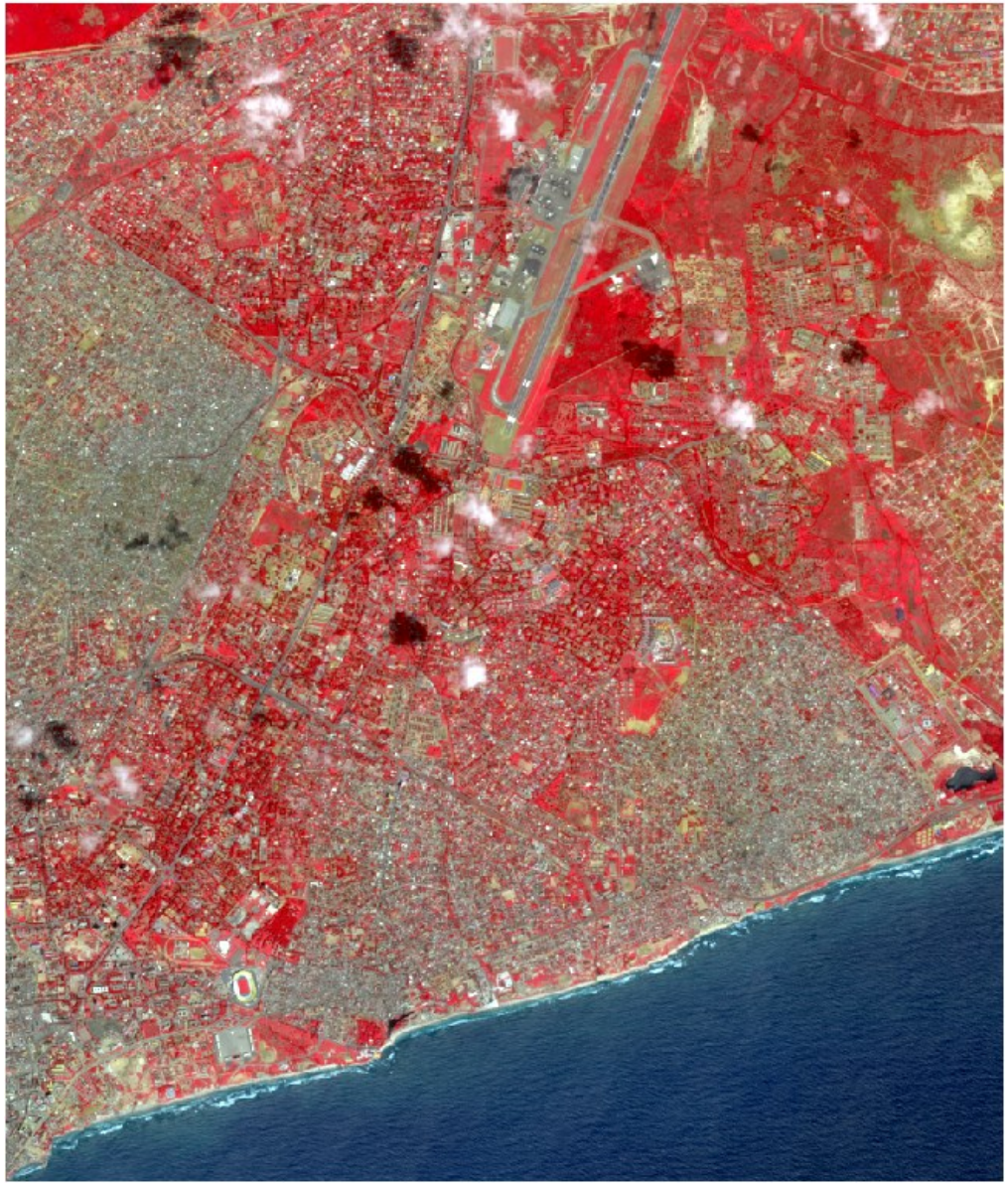
Data

Quickbird MS imagery: January 2007



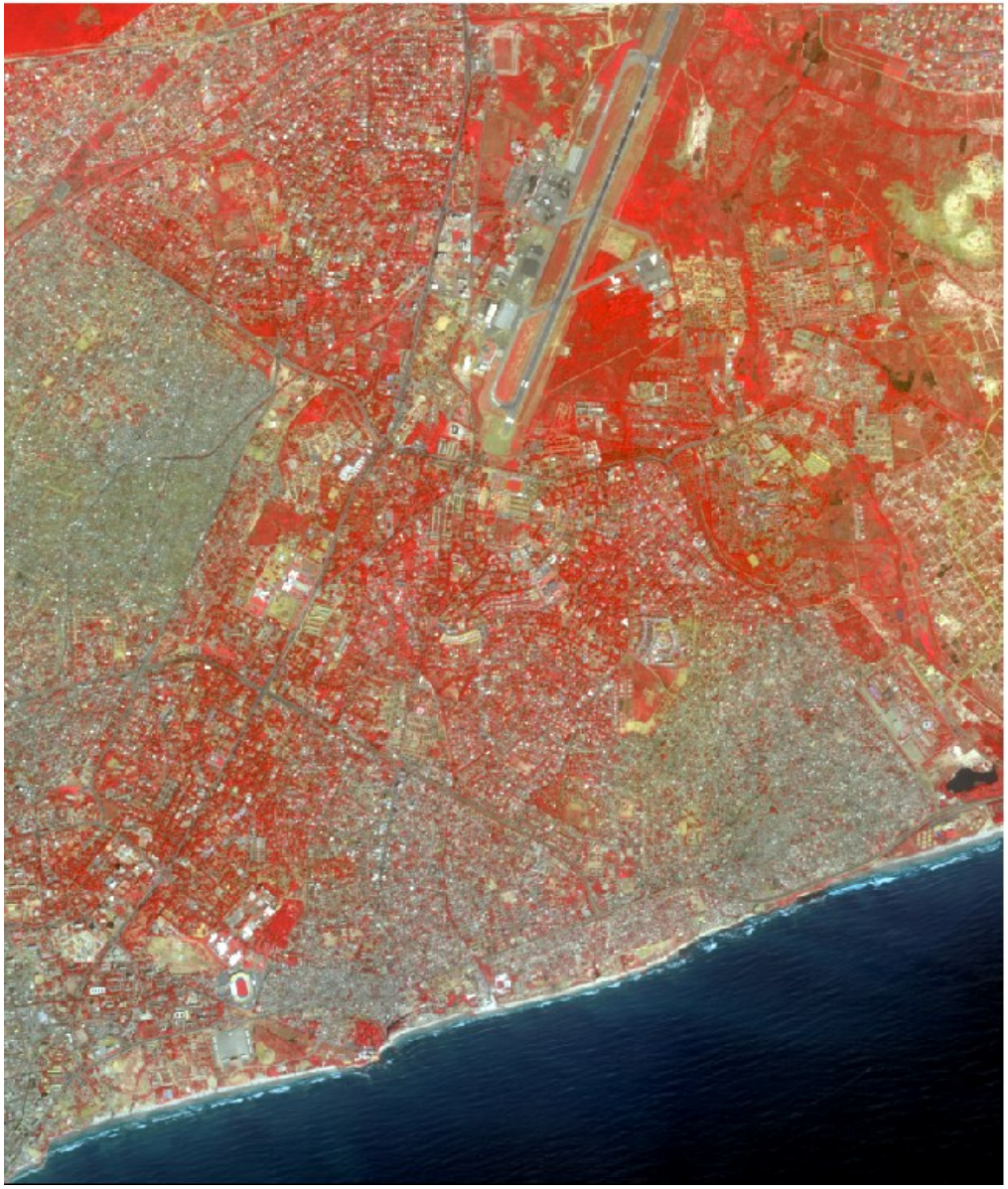
Data

Quickbird MS imagery: November 2007



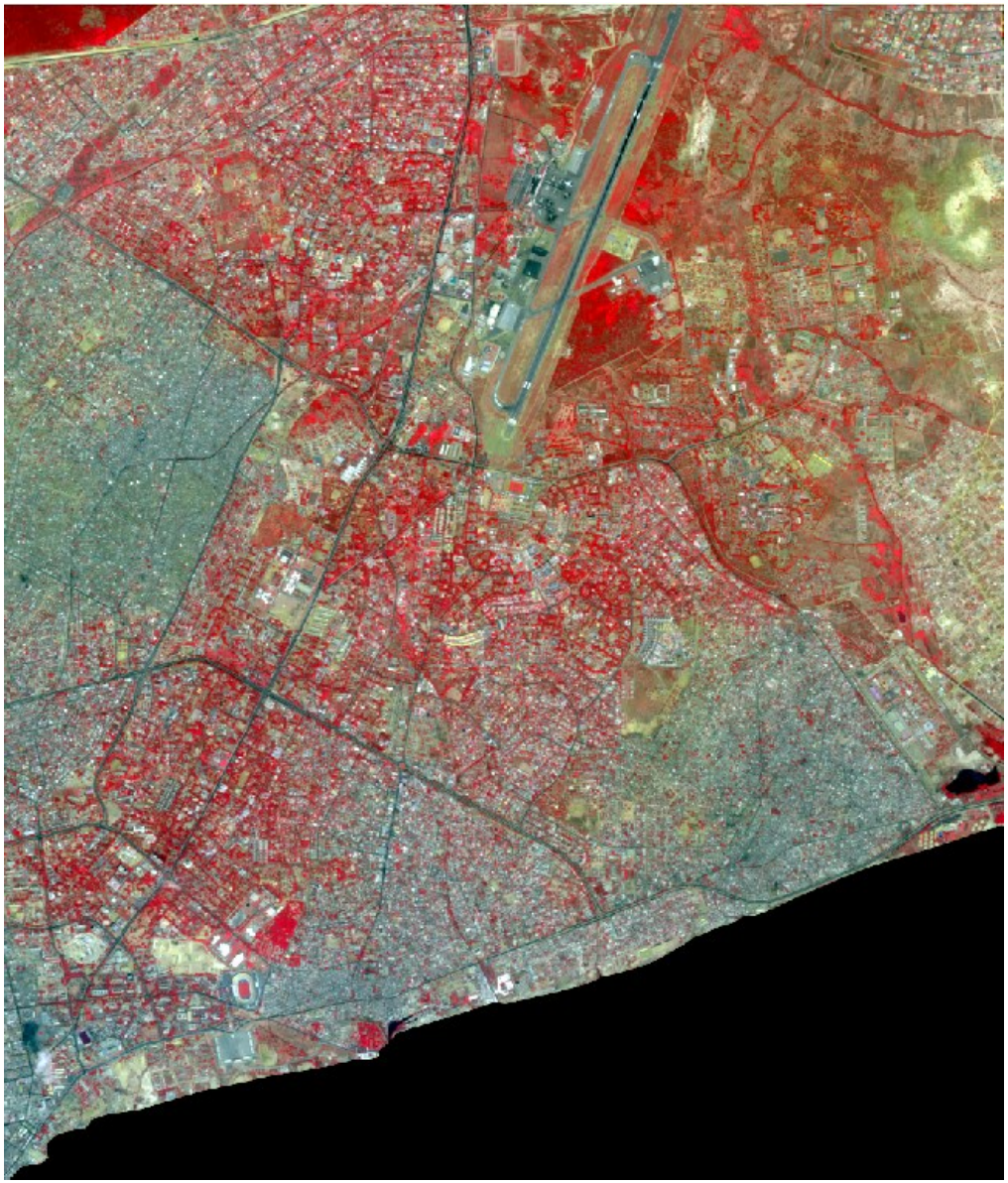
Data

Quickbird MS imagery: January 2009



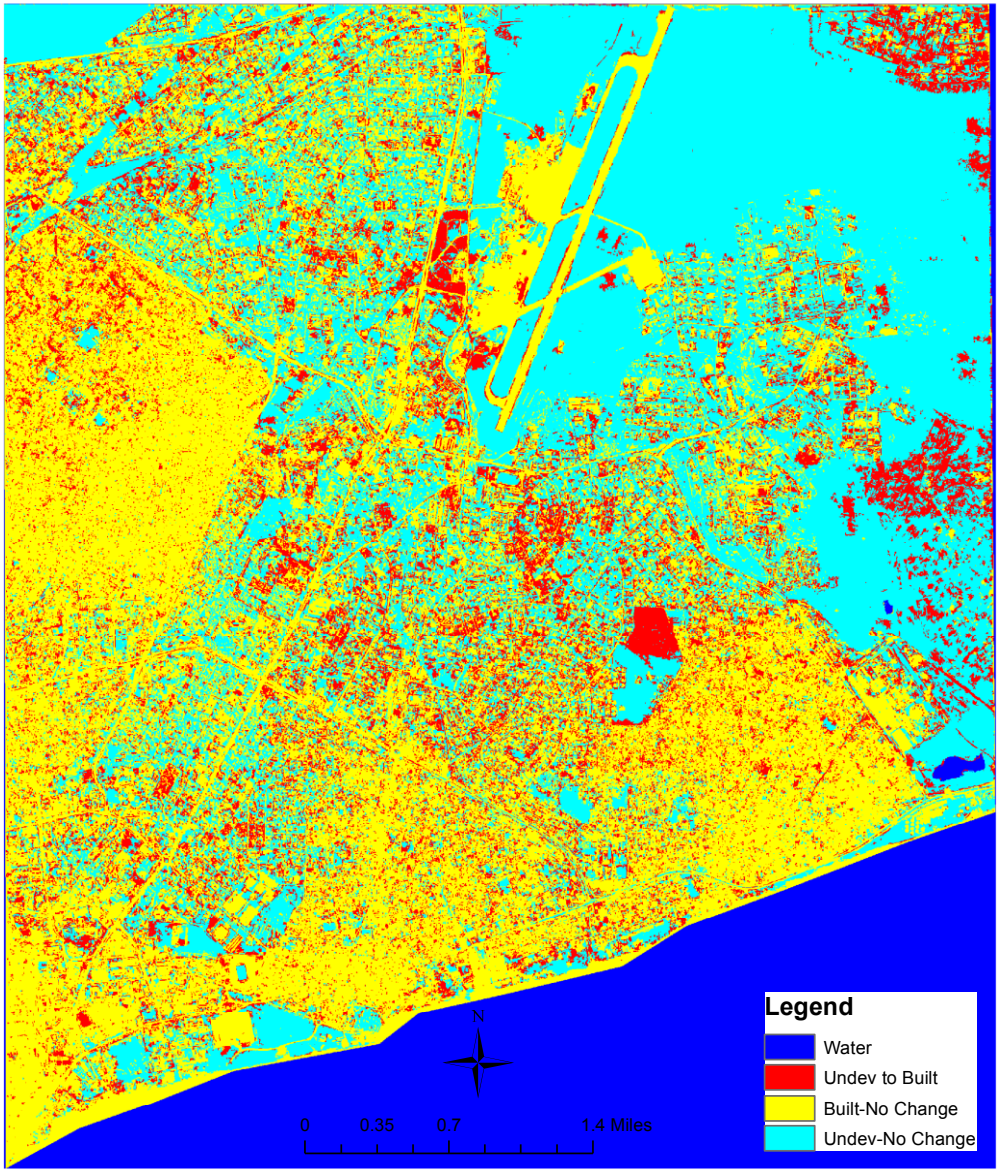
Data

Quickbird MS imagery: January 2010



Reference Data

2002 to 2010 LCLUC map based on OBIA and manual editing





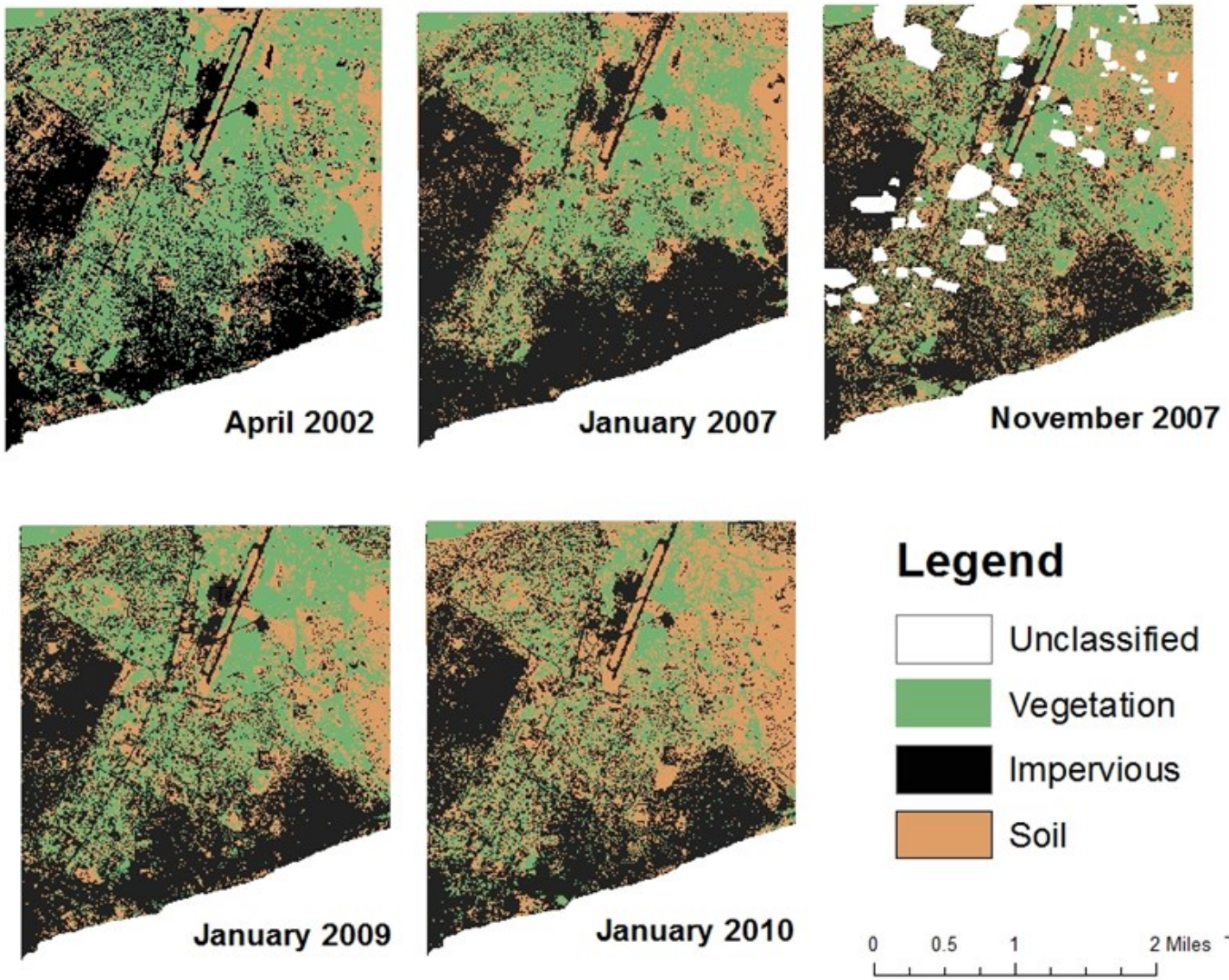

Methods

- Data Preparation:
  - Mask clouds/shadows
- Supervised classification on all 5 dates
- Spatial Filtering:
  - 3x3 focal majority and categorical aggregation using a 5x5 grid cell
- Temporal Filtering
  - Created rules for temporal filtering of the 4 "late" years (2007 to 2010)
    - If Vegetation in 2010, it is Vegetation
    - If Soil at time 1 (2007), apply majority filter
    - If Impervious at time 1, it is Impervious

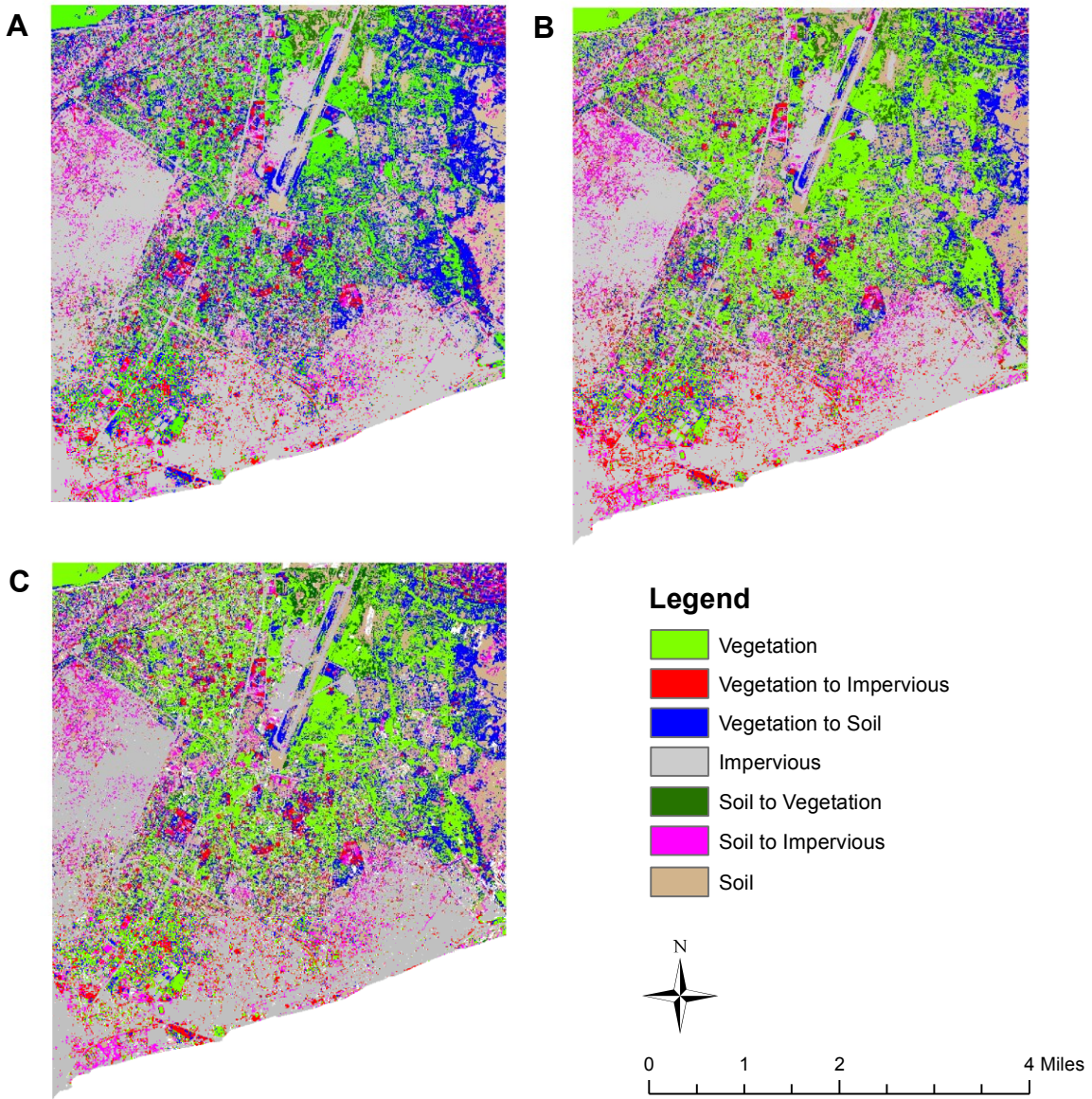




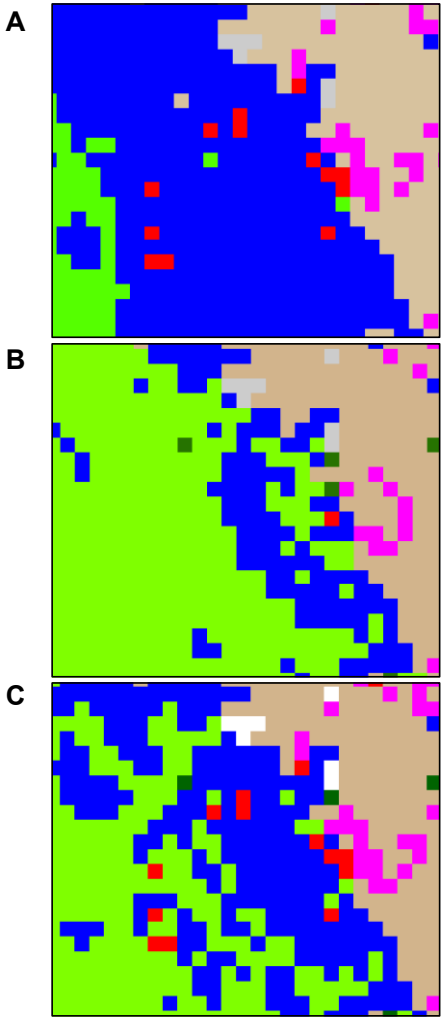
VIS maps after spatial and temporal filters

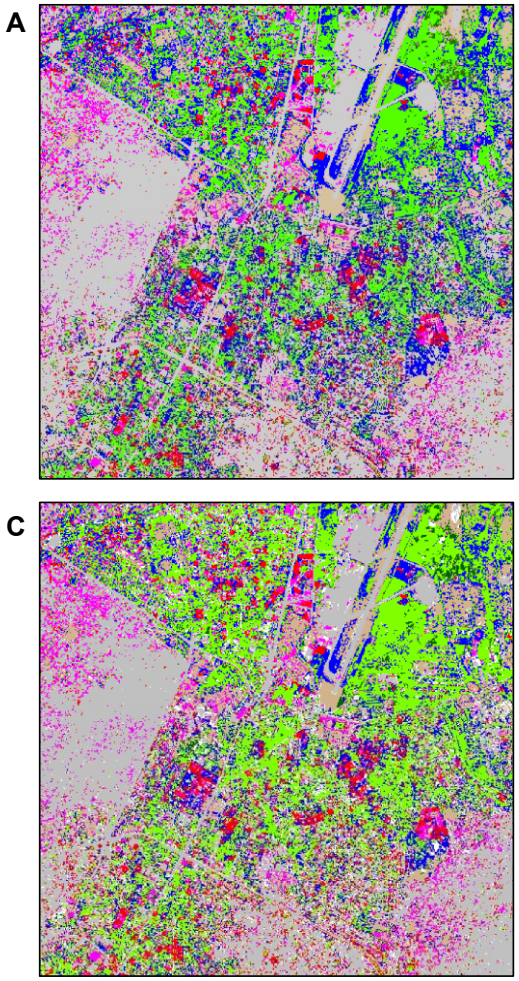


Change Maps: A) 2002 to 2010, B) 2002 to temporal majority filter C) 2002 to temporal filter with conditional rules



Zoom of change maps





A) 2002 to 2010, B) 2002 to temporal majority filter C) 2002 to temporal filter with conditional rules

2010 \ 2002	Veg	Impervious	Soil
Veg	41%	4%	10%
Impervious	14%	82%	25%
Soil	45%	14%	65%

Temporal Majority Filter:

Late Period \ 2002	Veg	Impervious	Soil
Veg	56%	3%	14%
Impervious	15%	87%	26%
Soil	29%	9%	60%

Temporal Filter with Conditional Rules:

Late Period \ 2002	Veg	Impervious	Soil
Veg	52%	5%	13%
Impervious	16%	85%	27%
Soil	32%	10%	60%

Reference Data:

2010 \ 2002	Undeveloped	Built
Undeveloped	40%	0%*
Built	15%	45%




Discussion/Conclusion

Temporal filter with conditional rules helped reduce the vegetation phenology changes in the urban areas *and* was able to capture vegetation reduction in the peri-urban areas compared to the temporal majority filter








Urban Scale

Moderate and High Spatial Resolution Mapping of LCLUC Change in Accra

Sory Toure








Future Research

1999 – 2014 Landsat time series for date and type of LCLUC

Incorporate Landsat 8 OLI data

LCLU mapping Kumasi, Obuasi and Cape Coast

Statistical analysis and agent based modeling of demographic and health variables vs. LCLU/C








Thank you !!

Questions ??







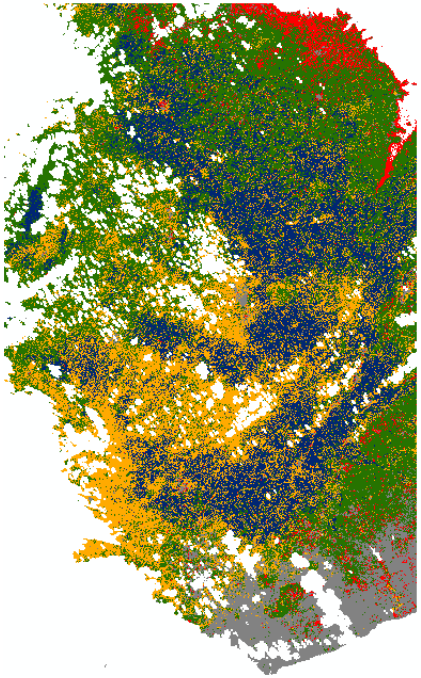

Methods

- Classification: supervised maximum likelihood
- Training data: persistent features through record length; urban at beginning; forest at end; agriculture at beginning and end
- Temporal filter: consider the previous and next dates of LULC maps to fill in no data pixels and filter illogical or erroneous change
- Spatial filter: applied to change map and considers each pixel's surrounding LULC, eliminating salt and pepper effect in change map

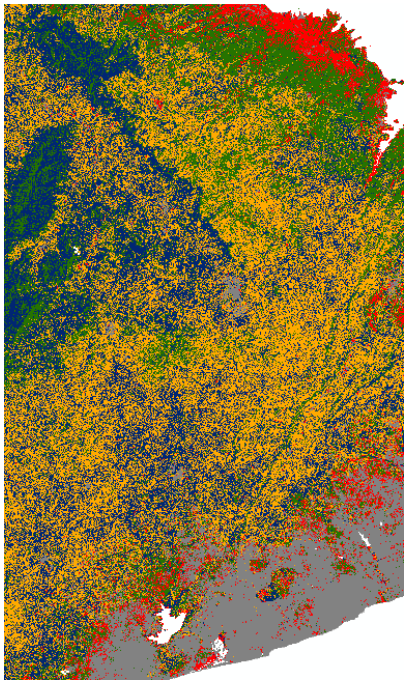




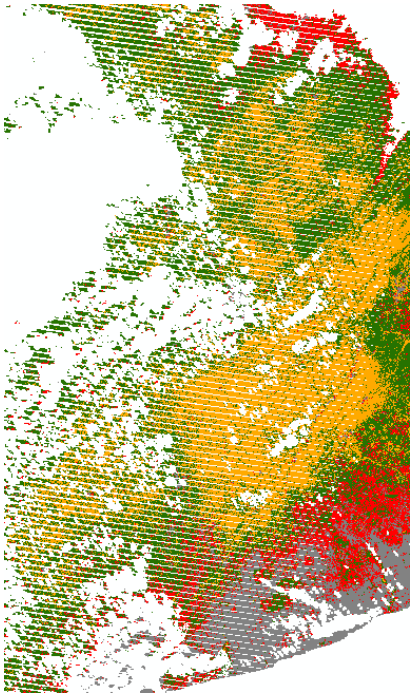
Before temporal filter



30 Nov 2002
(2002344)



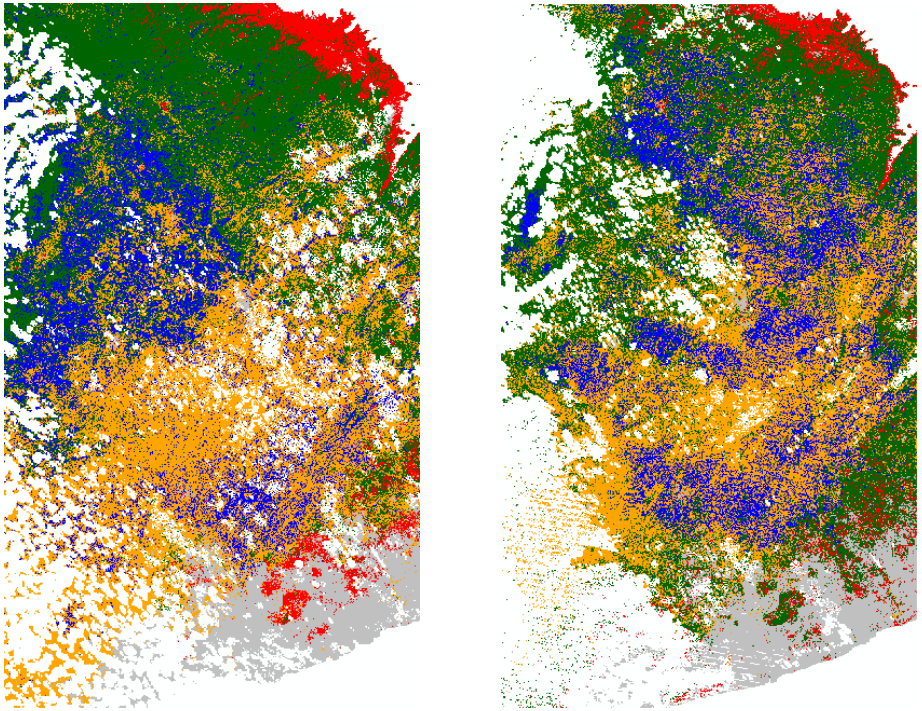
12 Feb 2003
(2003043)



13 Dec 2003
(2003347)

legend	
	UB
	NV
	Pure AG
	Mixed AG
	Fire scar or barren
	No data

After temporal filter

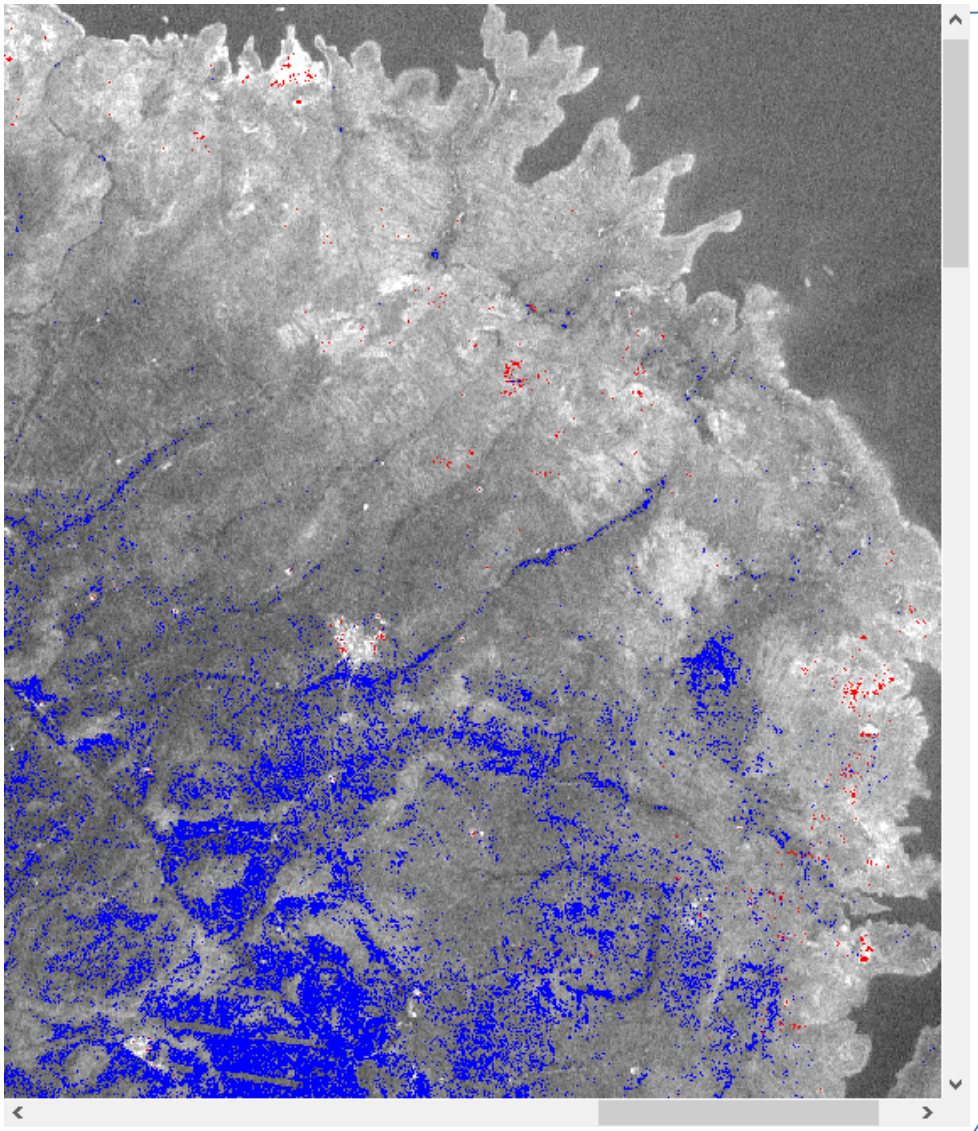


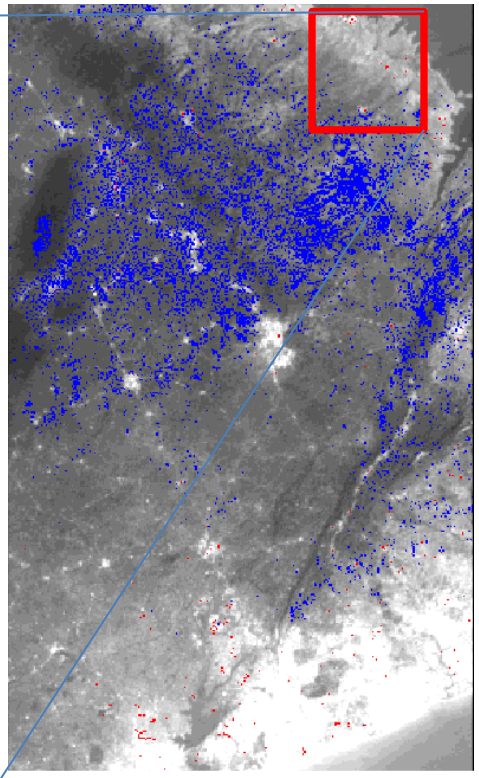
30 Nov 2002
(2002344)

12 Feb 2003
(2003043)

legend	
	UB
	NV
	Pure AG
	Mixed AG
	Fire scar or barren
	No data

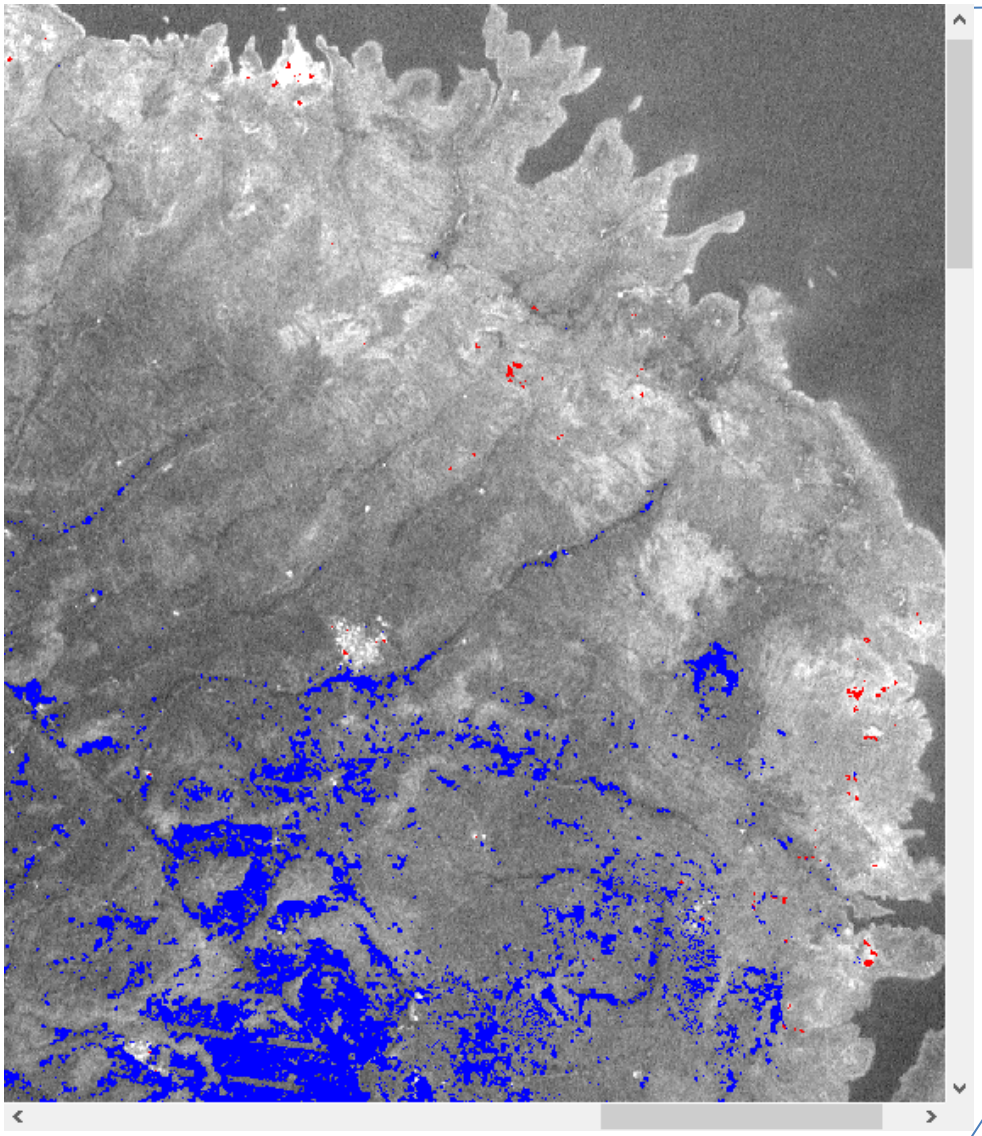
Before Spatial Filter

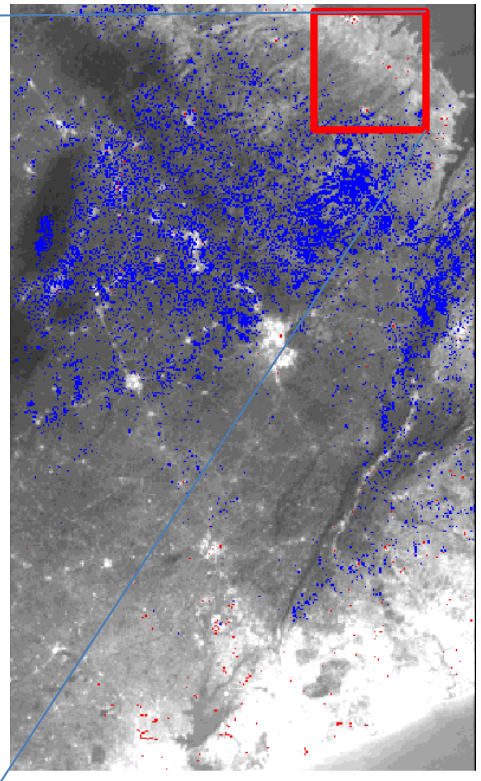




legend	
	NV change to AG
	Everything else change to urban
Gray scale	No change

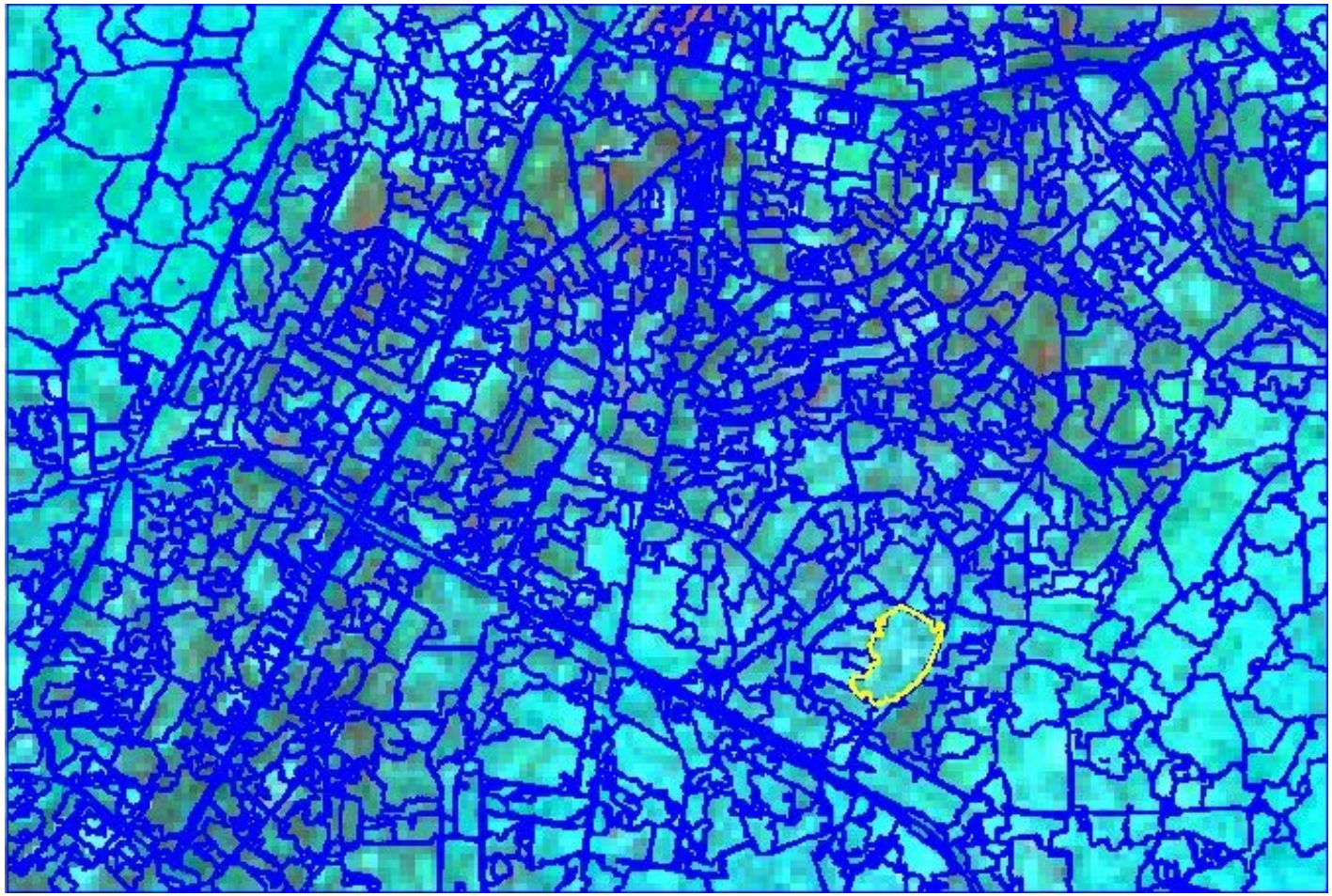
After spatial filter





legend	
	NV change to AG
	Non-urban to urban
Gray scale	No change

Mapping Unit Overlaid on Landsat





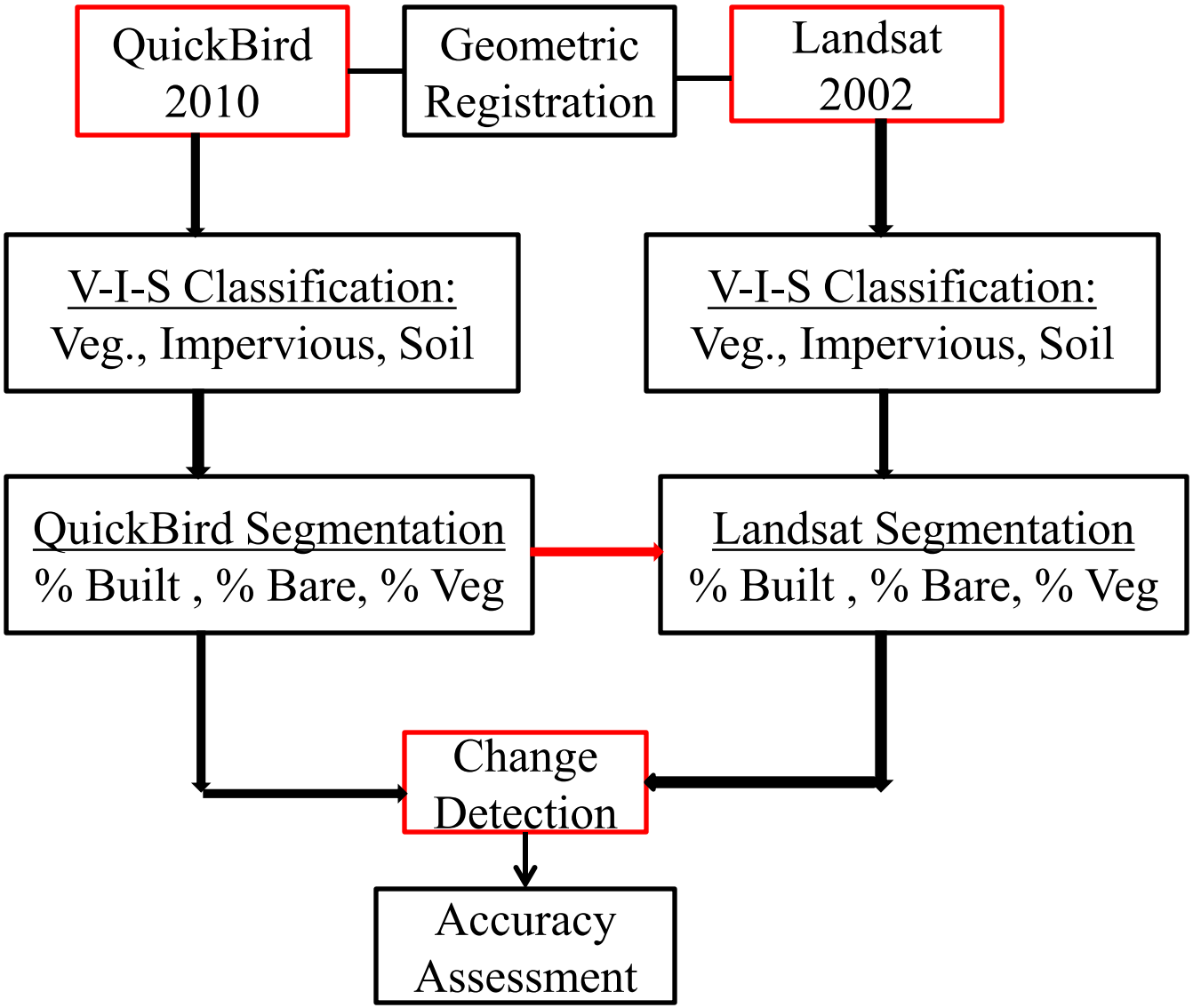

LCLUC Analysis

- **Built–No Change:**
  - Objects classified as built in 2002 and 2010
- **Undeveloped-No Change:**
  - Objects classified as Undeveloped in 2002 and 2010
- **Undeveloped to Built:**
  - Objects classified as Undeveloped in 2002 and Built 2010
- **Water:**
  - Masked manually





Methods


QuickBird 2010
Geometric Registration
Landsat 2002
V-I-S Classification: Veg., Impervious, Soil
V-I-S Classification: Veg., Impervious, Soil
QuickBird Segmentation % Built , % Bare, % Veg
Landsat Segmentation % Built , % Bare, % Veg
Change Detection
Accuracy Assessment