



#### **Presentation Objectives**

 NASA IDS project progress report; emphasis on remote sensing — Stow

 Dissertation research findings; emphasis on demographic analysis – Benza-Fiocco (a new early-career investigator)

#### NASA Interdisciplinary Research in Earth Science (IDS) 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

Douglas Stow (PI), John Weeks (Co-PI), Pete Coulter (Project Manager), Li An (Co-Investigator) – San Diego State University

Ryan Engstrom (PI) – The George Washington University

David Lopez-Carr (Co-Investigator) -- University of California Santa Barbara

Samuel Agyei-Mensah and Foster Mensah (Collaborators) -- University of Ghana Legon









#### **Participating Students**

SDSU

**GWU** 

Doctoral (w/UCSB)

Magdalena Benza-Fiocco

Stephen Crook

**Sory Toure** 

Cindy Tsai

\_

Master's

Hsaio-Chien (Ace) Shih

Sean Taugher

Milo Vejraska

\_

<u>Undergraduate</u>

Nicholas Ibanez

Post-doc

Qin Yu

Master's

**Avery Sandborn** 

U. Ghana Legon

**Doctoral** 

Foster Mensah



# Doctoral Dissertations and Master's Thesis Associated with NASA IDS Project

#### **Doctoral Dissertations**

Benza-Fiocco, Magdalena (SDSU/UCSB) Degree of Urbanization and Population Dynamics: A Case Study in Sub-Saharan Africa Utilizing Remotely Sensed Imagery, John Weeks, Adviser, completed February 2014

Mensah, Foster (U. Ghana) Detailed Land Cover and Land Use Change Assessment of Accra, Ghana, 2000 – 2010.

Toure, Sory (SDSU/UCSB) Urban Land Use and Land Cover Change in Ghana: Connections to Demography, Health and Wealth, Doug Stow, Adviser, in progress.

#### Master's Theses

Sandborn, Avery (GWU), Quantifying Spatial Features of Built-Up Areas and Their Relationship to Quality of Life Indicators in Accra, Ghana, in progress.

Shih, Hsaio-Chien (SDSU), Identification of land cover and land use change based on discrete analyses of dense Landsat time series and spatial and temporal filtering, in progress.

Vejraska, Milo (SDSU) Image Metrics As Indicators of Socioeconomic and Demographic Characteristics in Slum Neighborhood of Accra, Ghana, John Weeks advisor, completed June 2013.



### **Project Progression**

- Nominal start: 01 August 2012
- Effective start: 01 November 2012
- Nominal end: 31 July 2015
- Likely end: 31 January 2016
- Nominal duration: 55%
- Effective duration: 40%
- Expenditures of total fund allocation: 45%

#### Manuscripts in Preparation (submissions by Aug. 2014)

Benza, M., Weeks, J., Stow, D., López-Carr, D. and Clarke, K. A, in preparation pattern based definition of the urban context using remote sensing and GIS: A case study in West Africa, *Remote Sensing of Environment*. In preparation.

Benza, M., Weeks, J., Stow, D., López-Carr, D. and Clarke, K. In preparation. Comparing a GIS based urban gradient to the census definition of urban spaces in Ghana, *Population, Space and Place*.

Engstrom, R., Burgdorfer, J., Grasser, J., Cheiryadat, A., Bright, E., Qin Y., and Bhaduri, B., in preparation. An Evaluation of a Remotely Sensed Methodology of Slum Mapping in Accra, Ghana, *Journal of Applied Geography*.

Engstrom, R., Ashcroft, E., and Rain, D., in preparation. Mapping spatial variability in Health and Wealth Indicators in Accra, Ghana, *International Journal of Remote Sensing*.

#### Manuscripts in Preparation (submissions by Aug. 2014) – cont.

Stow, D. H-C, Shih and L. Coulter, in preparation. Discrete Classification Approach to Land Cover and Land Use Change Identification Based on Landsat Image Time Series: Initial Results for a Ghanaian Study Area, *Remote Sensing Letters*.

Toure, S. and D. Stow, in preparation. Land Cover and Land Use Change Analysis Using Multi-Spatial Resolution Data and Object-Based Image Analysis, *Remote Sensing Letters*.

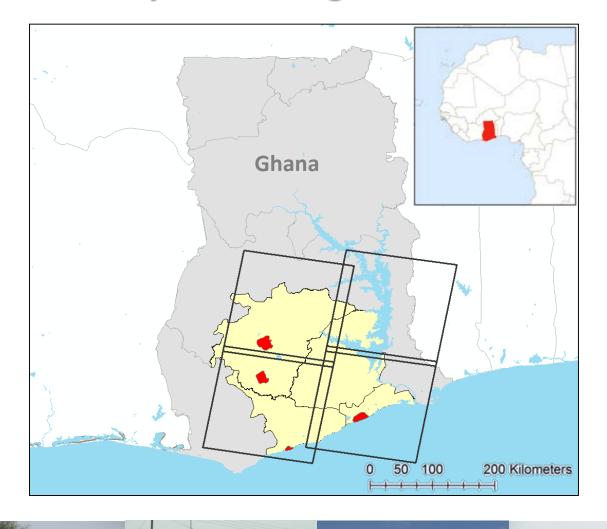
Taniguchi, K., D. Stow and S. Toure, in preparation. Potential of high spatial and temporal frequency satellite imagery for refining land cover and land use identifications of urban areas in Ghana, *Remote Sensing Letters*.

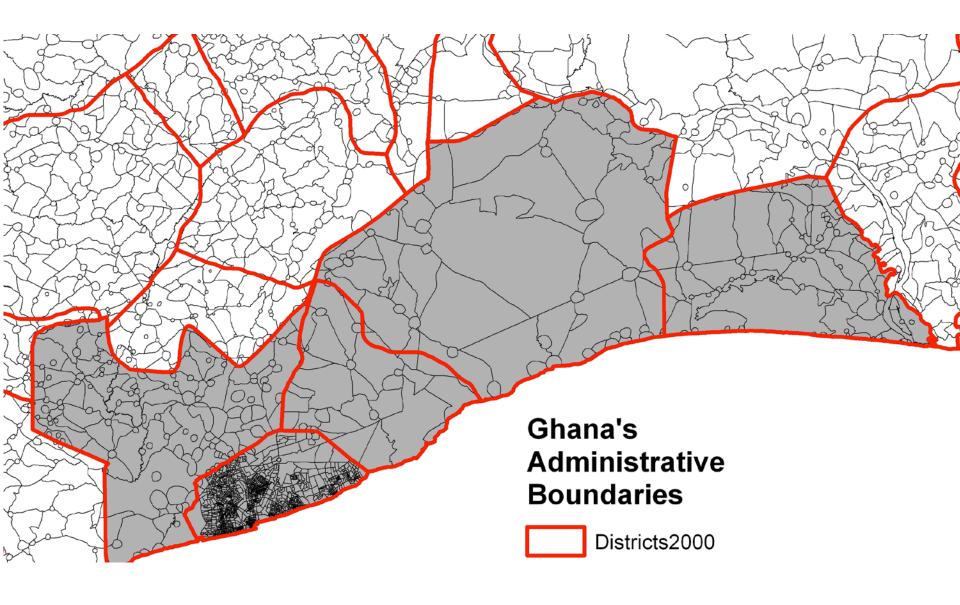
Vejraska, M., J. Weeks and D. Stow, in preparation. Satellite image metrics as indicators of socioeconomic and demographic characteristics in slum neighborhoods of Accra, Ghana, *Photogrammetric Engineering and Remote Sensing*.

## **Central Hypotheses**

- Inter-regional LCLUC in Ghana driven by rural-urban migration
- Demographic, health and environmental outcomes in Ghanaian cities strongly impacted by LCLUC

### **Study Areas: Regional & Urban**





Greater Accra region in gray Accra Metropolitan Area – dense enumeration area units

## Rural village



#### **Dense urban settlement**



### **Urban densification**



#### New suburban residential



### Peri-urban residential development



#### Commercial agricultural expansion





#### **Geo-tagged Ground Reference Imagery**

- Supported by Foster Mensah,
   University of Ghana
- Conducted January-February 2014
- Emphasis on location and land cover characteristics of new built development



#### **Challenges of Remote Sensing in Ghana**

- Prevalent continuous cloud cover (May Dec)
- Partial clouds and cloud shadows (Jan Apr most cloud free; dry season)
- Atmospherically thick 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
- Confusion between impervious and soil cover

### Mixed agriculture and natural vegetation





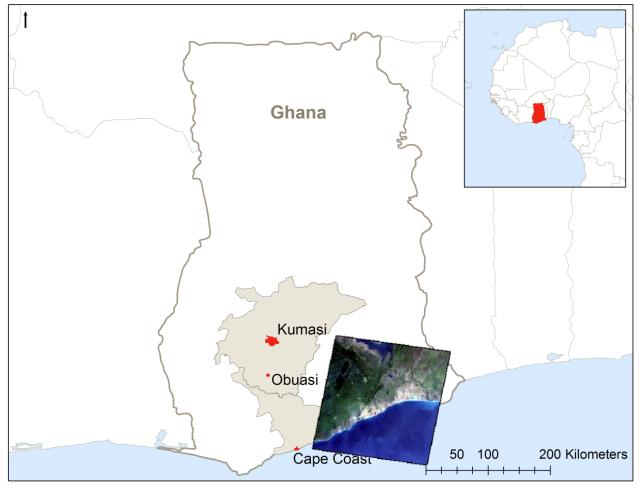
# Benefits and Challenges of Demographic and Health Research in Ghana

- Decadal demographic census 2000 and 2010
- Census "geography" for 2010 decadal census not yet released
- Multiple DHS and WHS for selected enumeration areas
- Relatively stable and safe environment
- Complex land ownership and development policy between national and tribal governments
- Residential building a slow process
- Technology leader in West Africa



# Inter-regional Scale LCLU Mapping and Change Identification

#### **Greater Accra Landsat Footprint (193/056)**

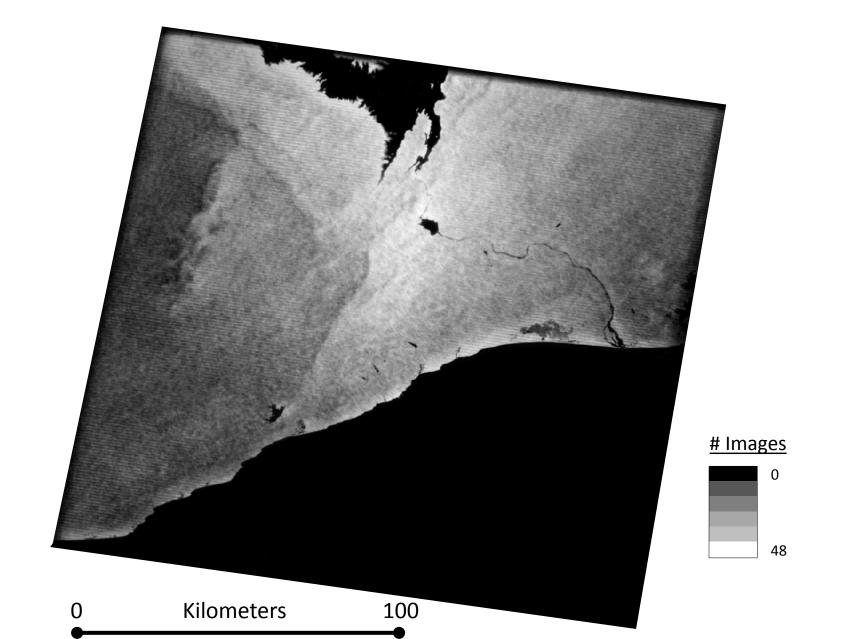




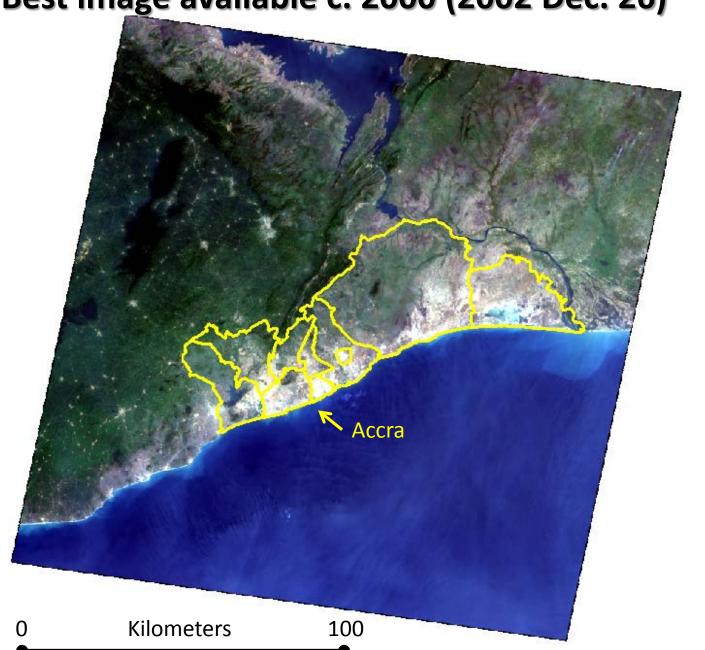
#### **Inter-regional LCLU and LCLUC Mapping Process**

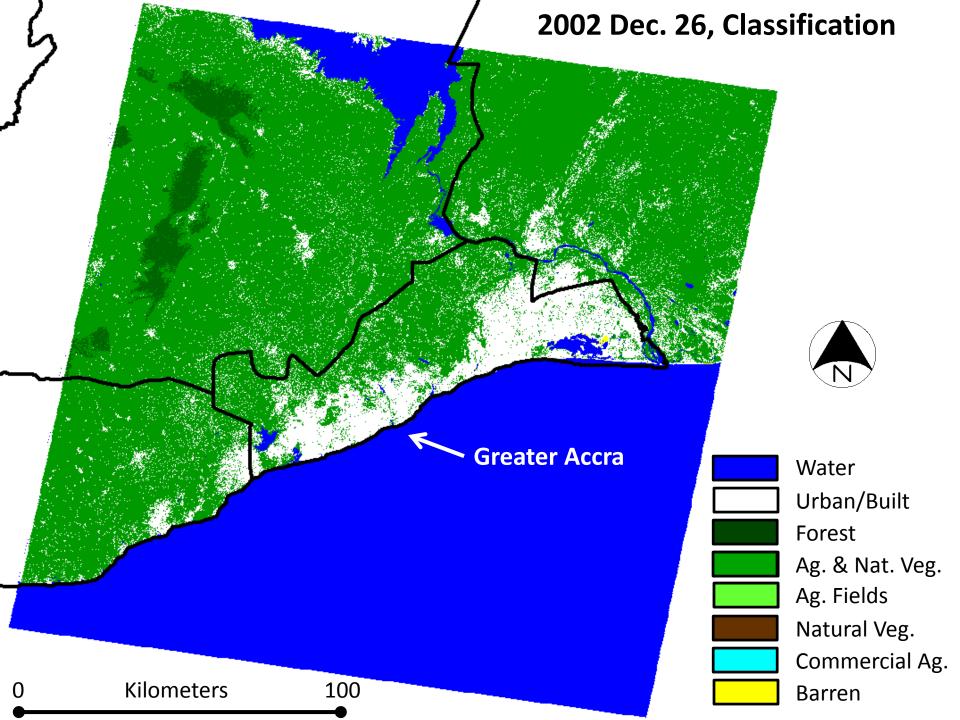
All Landsat TM/ETM+/OLI: 1986-2014 (surface reflectance, LEDAPS processing) Scene selection: < 33-50% cloud/scene Mask cloud, cloud shadow, water, and SLC-off (fmask) Include derived image products: ND21, ND31, ND43, ND45, ND47, stack stdev 123, 457, 123457, additive local texture (3x3-11x11) Create c.2000 and c.2010 composites (max. value for NDVI, ND23, stack stdev 123) Classify c.2000 LCLU: 2002, c.2000 urban, c.2000 RADAR urban (cloud free) (composite) (ERS SAR) c.2000 to c.2010 change detection and updating (NDVI for urban change) Discrete spatial filter and manual editing Maps of LCLU and LCLUC (2000, 2010, 2000-2010)

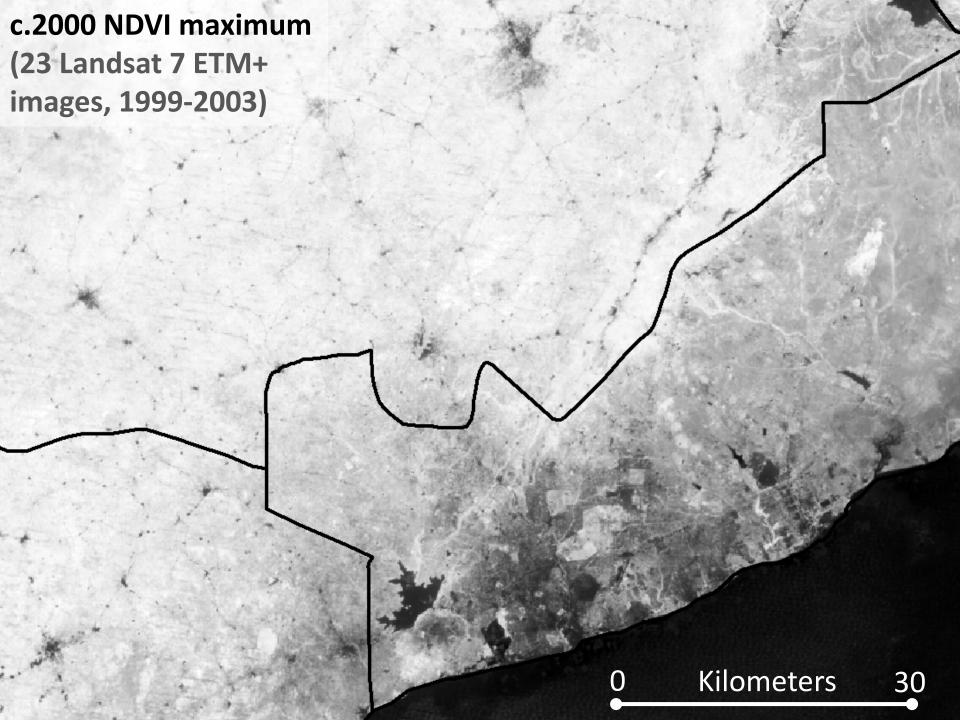
Regional Landsat Data:
Usable data frequency -- 48 images 1999-2013 < 33% cloud

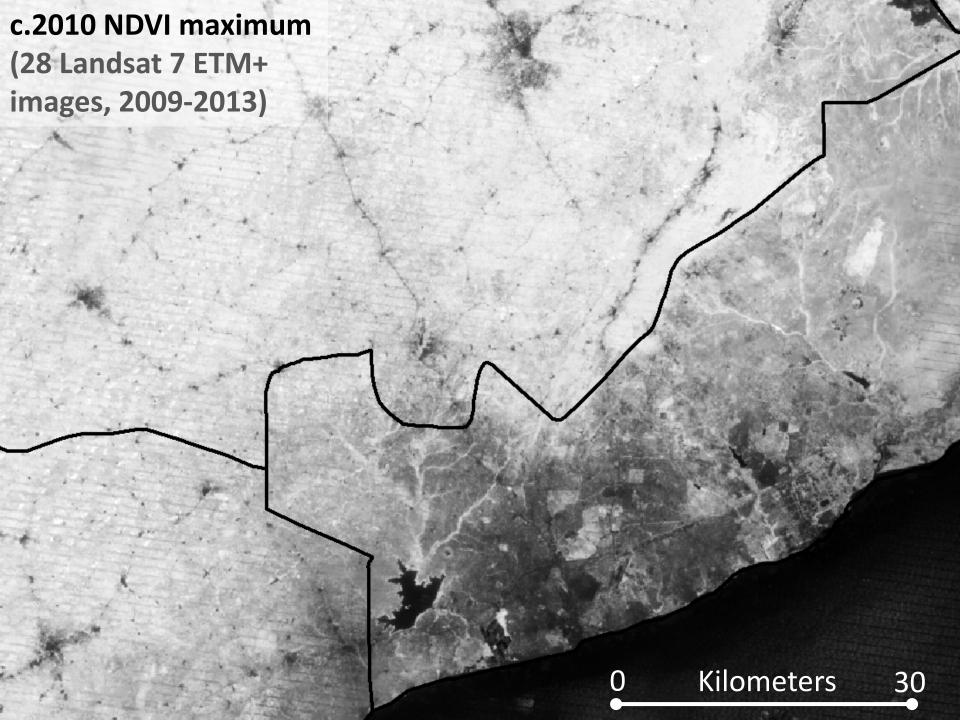


Regional Landsat Data: Greater Accra Best image available c. 2000 (2002 Dec. 26)

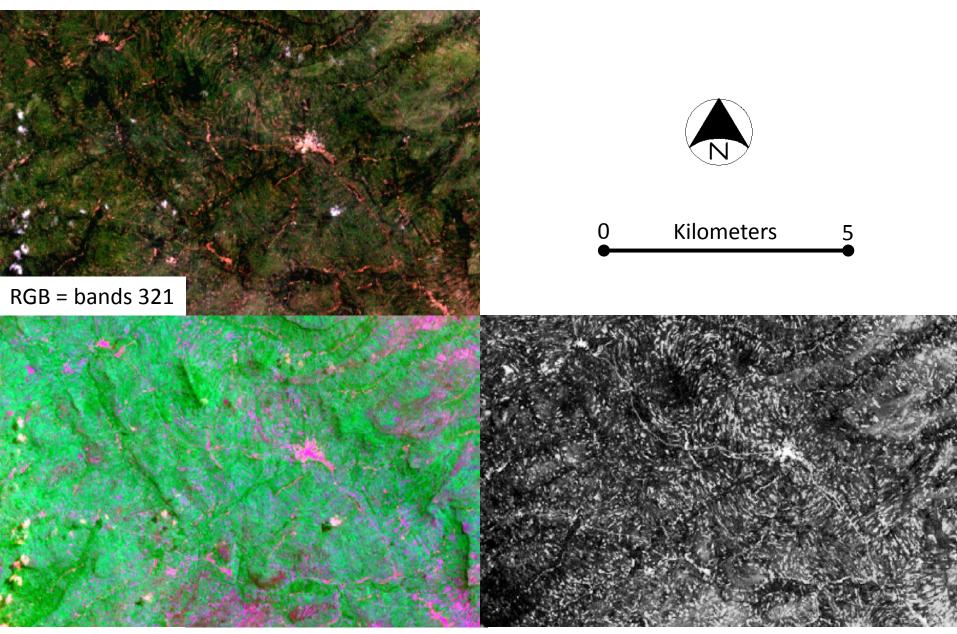






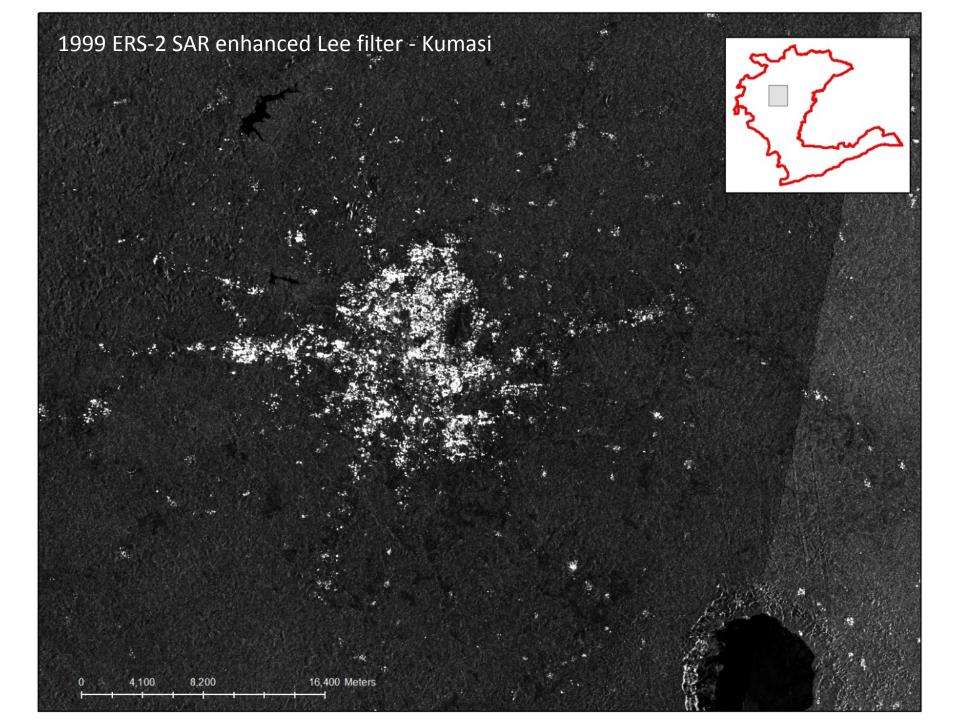


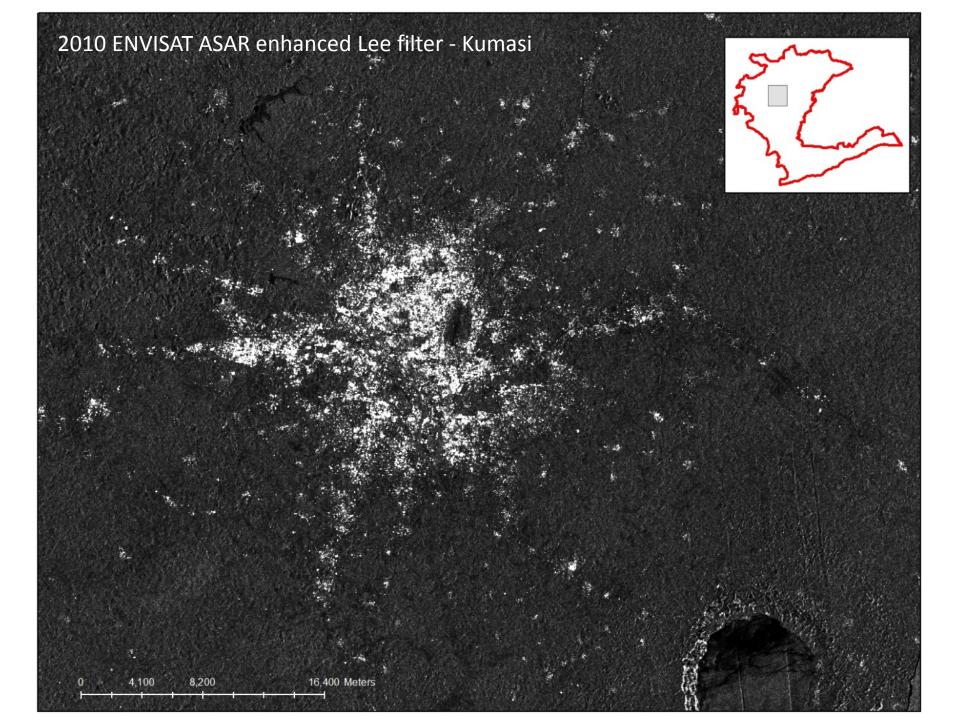
#### **Identifying and Mapping Agriculture Fields (Landsat 7 ETM+)**



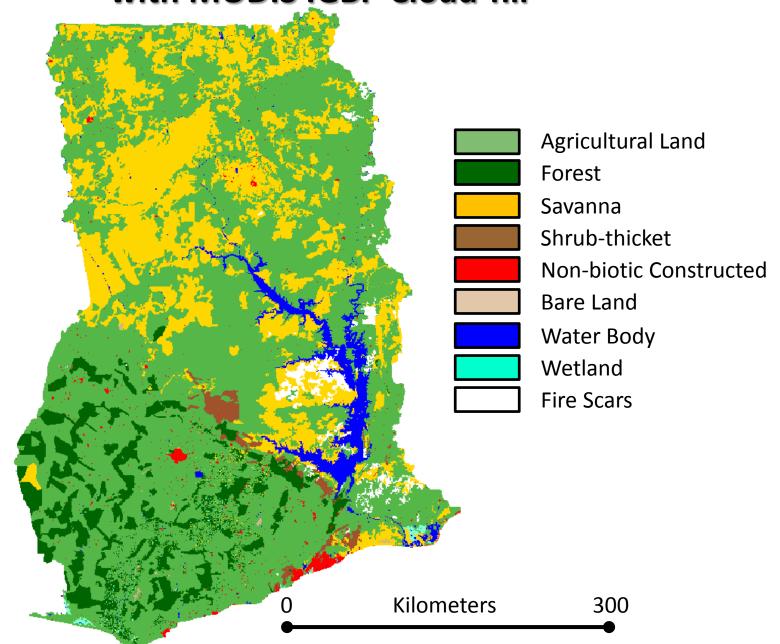
RGB = bands 345

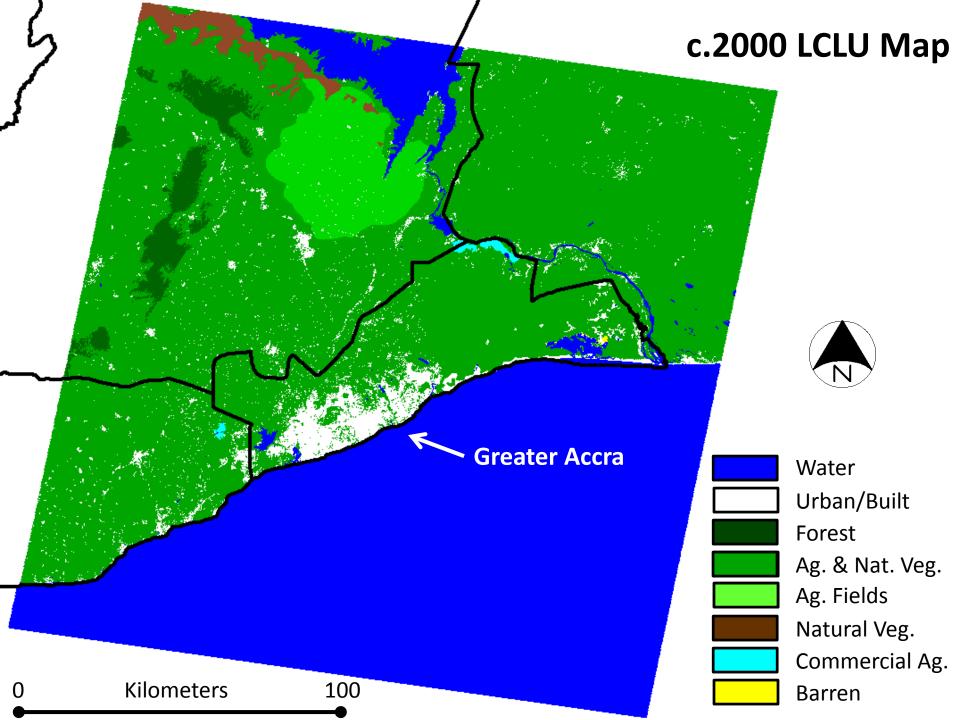
Grayscale = Std. Dev. of ETM+ reflective bands

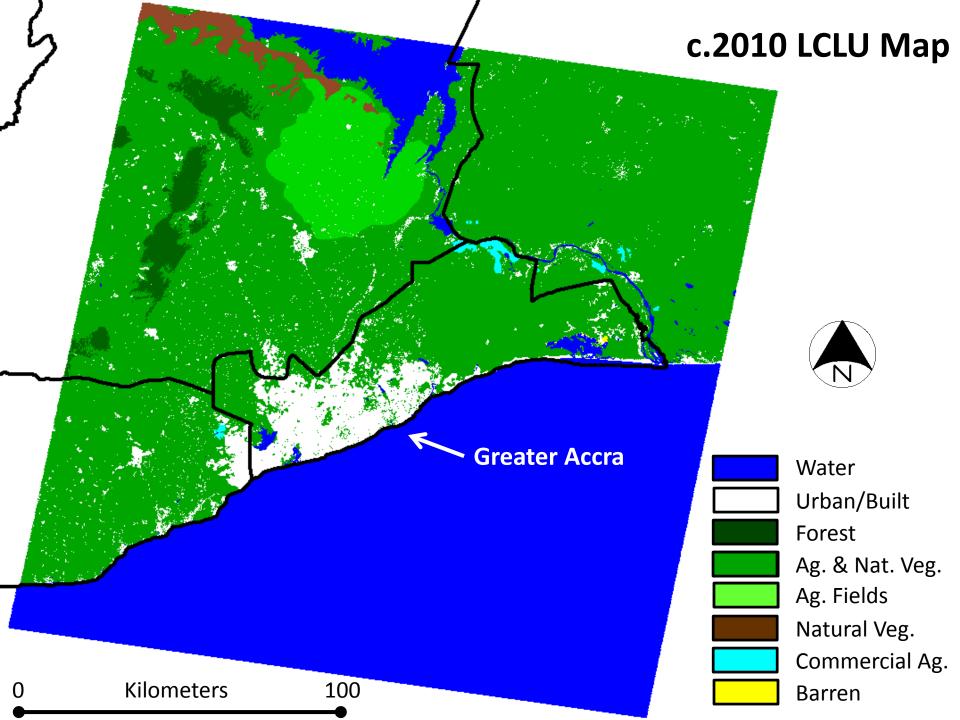


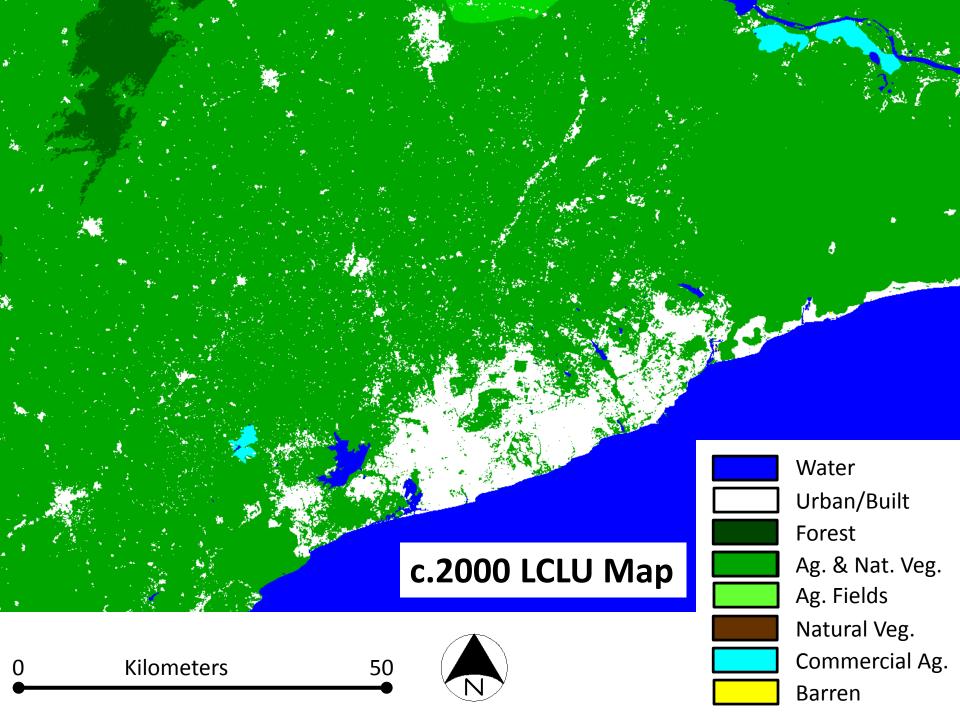


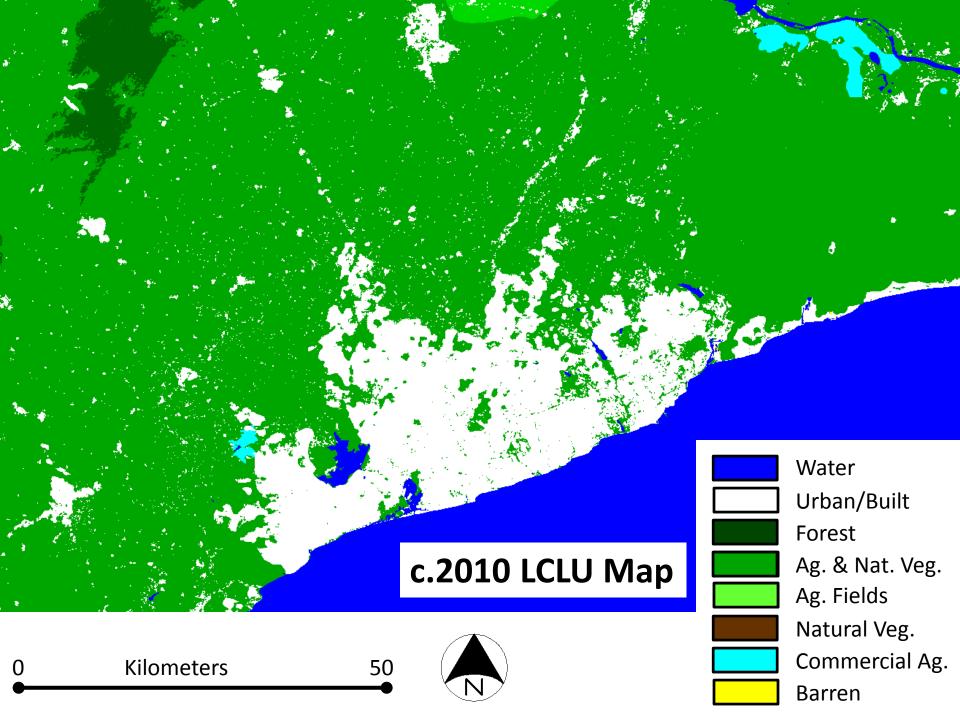
# CERSGIS Reference 2000 Land Cover/Land Use Map with MODIS IGBP Cloud-fill

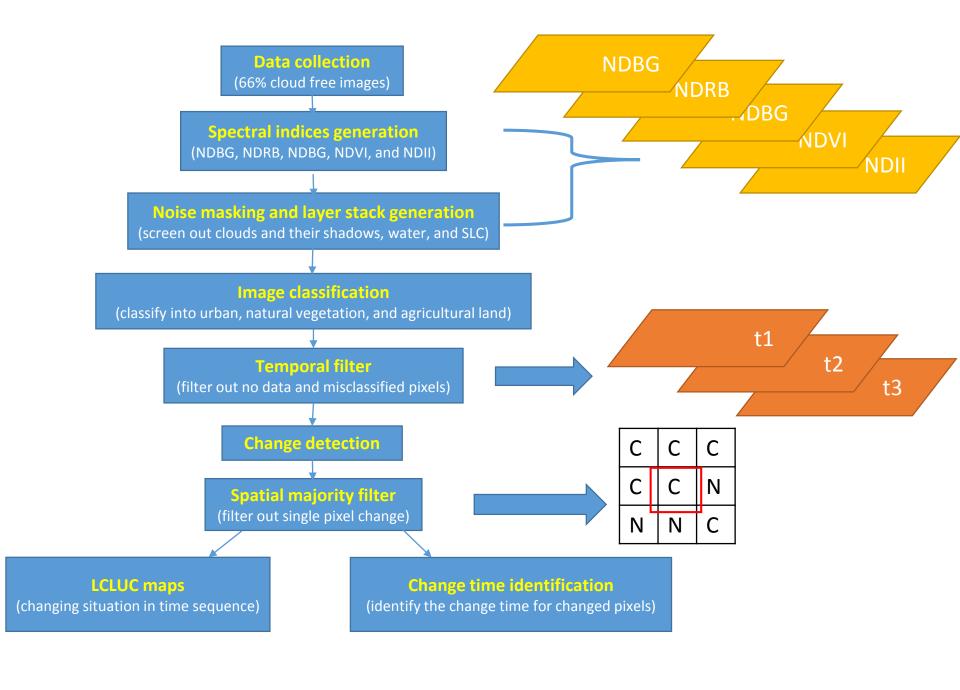


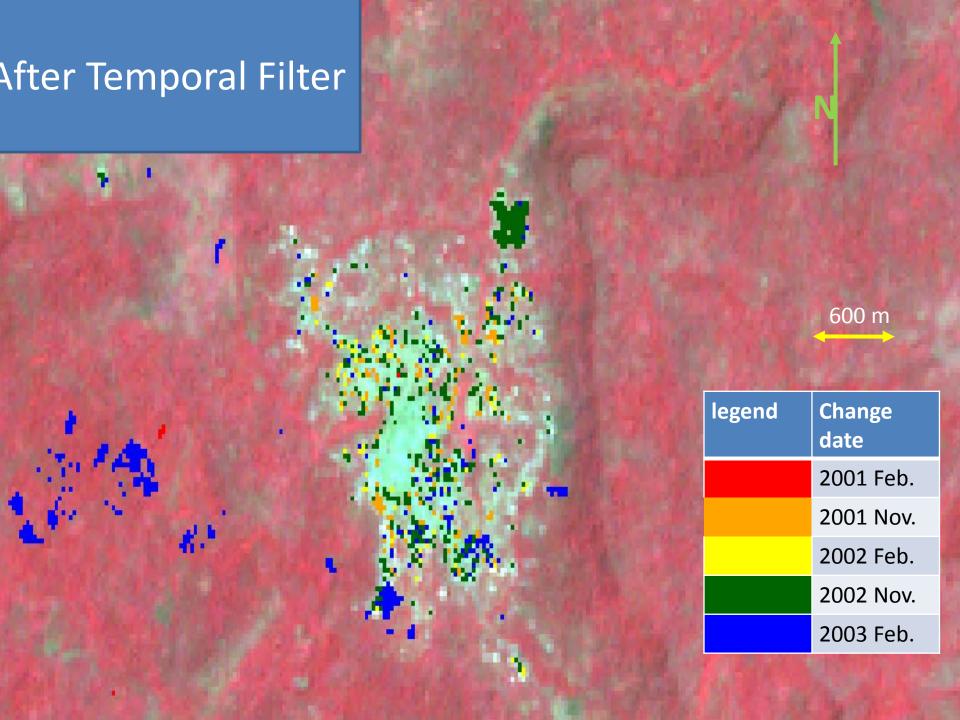








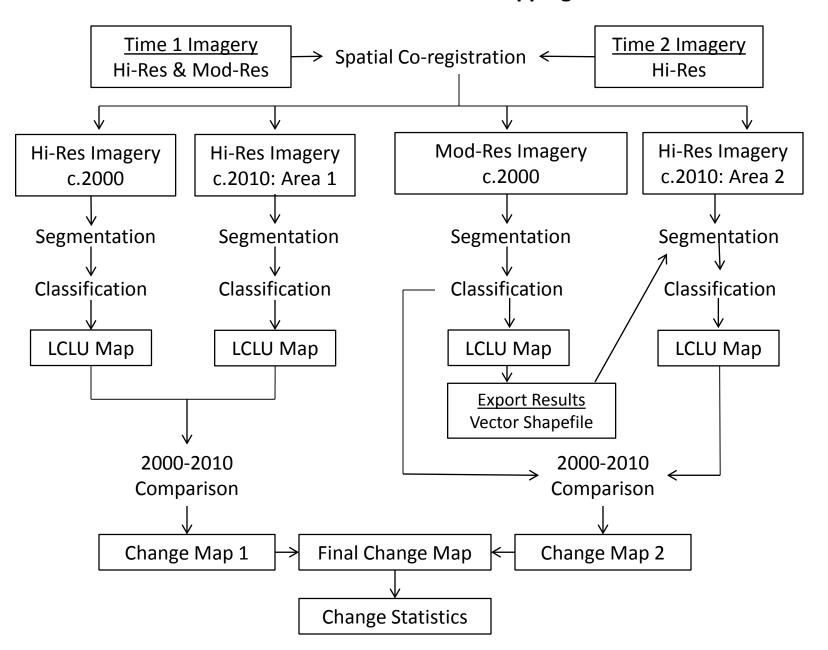




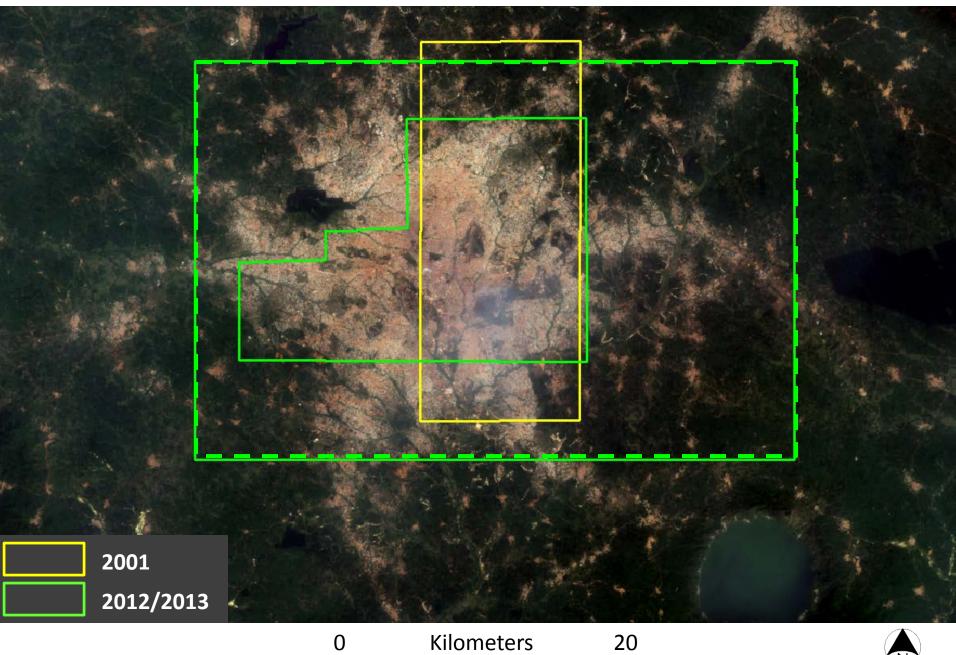


Intra-urban Scale Mapping
of LCLU and Change for Accra,
Cape Coast, Kumasi and Obuasi
with High Spatial Resolution
Satellite Imagery

#### **Intra-urban LCLU and LCLUC Mapping Process**

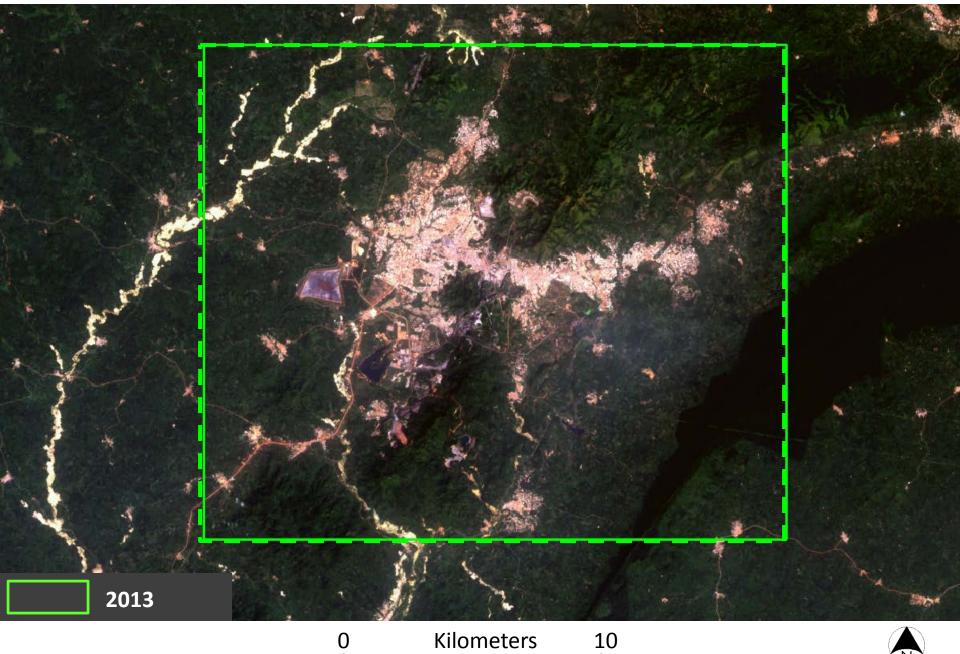


## Kumasi



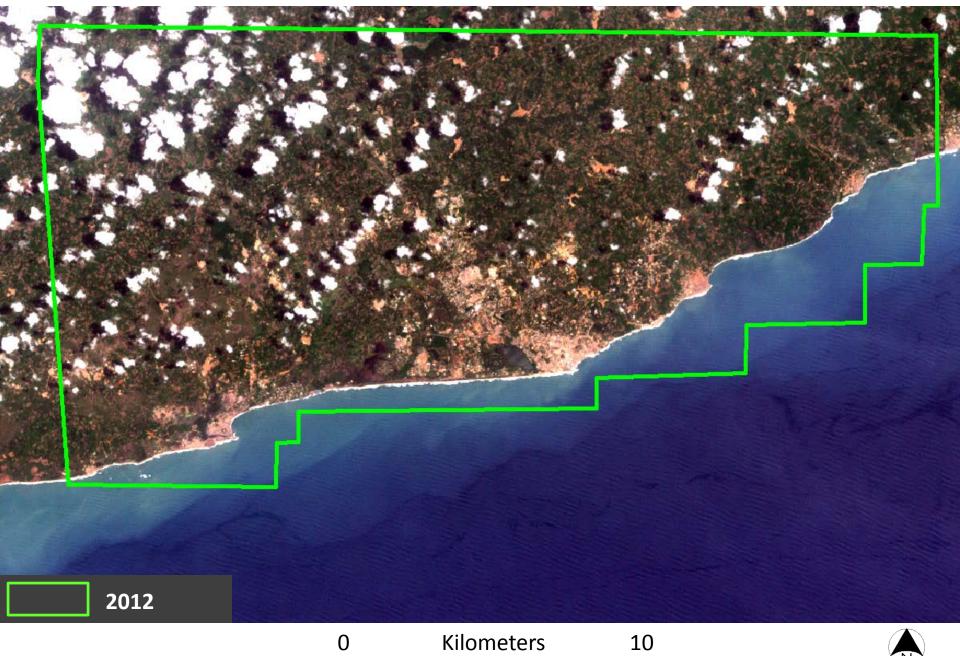


## Obuasi



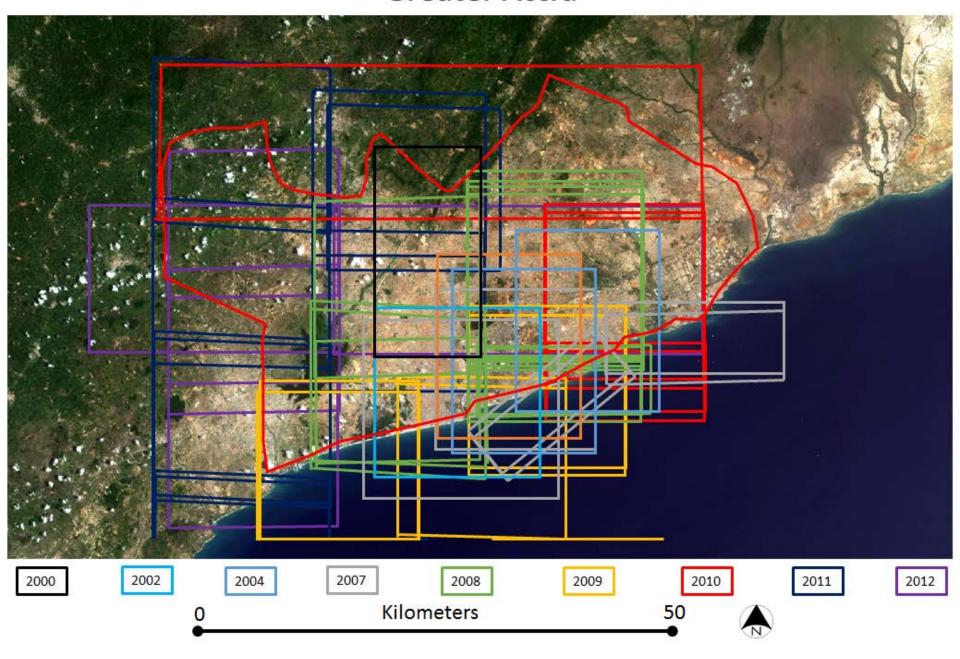


# **Cape Coast**





#### **Greater Accra**



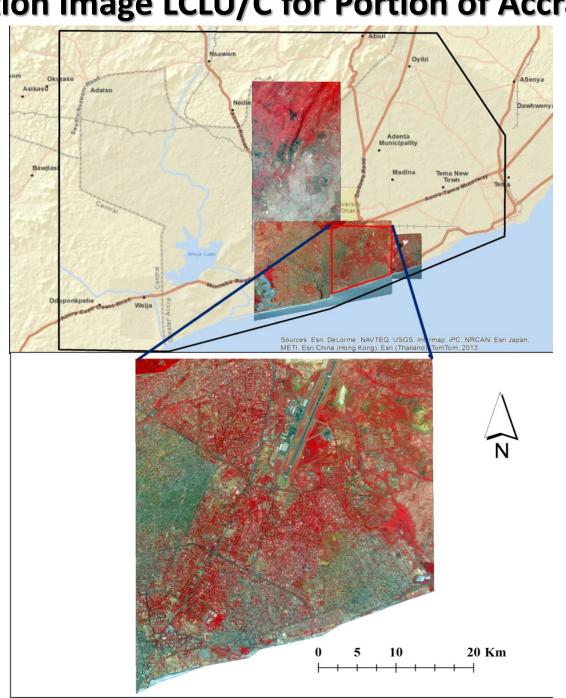
## High Spatial Resolution Image LCLU/C for Portion of Accra

High Res. Data Composite c. 2000:

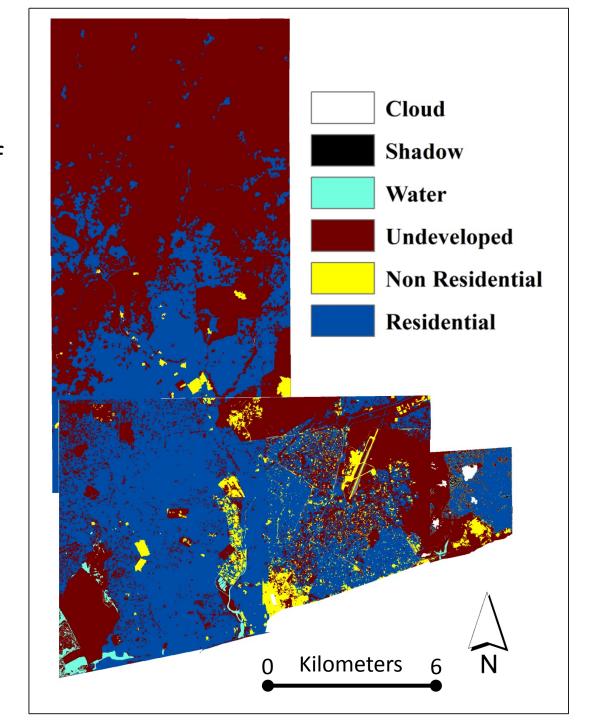
- Ikonos02/10/2000
- Ikonos05/22/2002
- QuickBird 04/12/2002

#### Multitemporal set:

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



c.2000 LCLU Classification for Portion of Accra



# 2002 to 2010 LCLUC Map Based on OBIA and Manual Editing

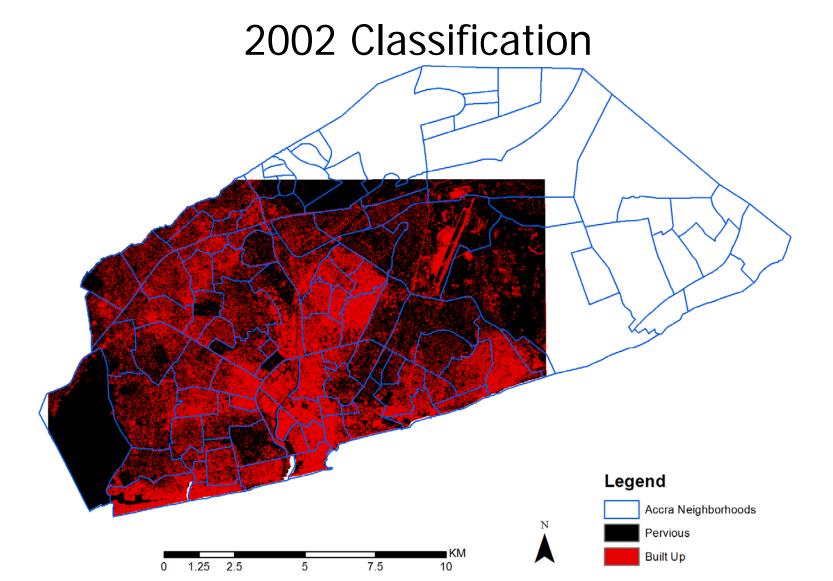
# Intra-urban LCLUC Identification Research Professor Ryan Engstrom

#### **Decision trees**

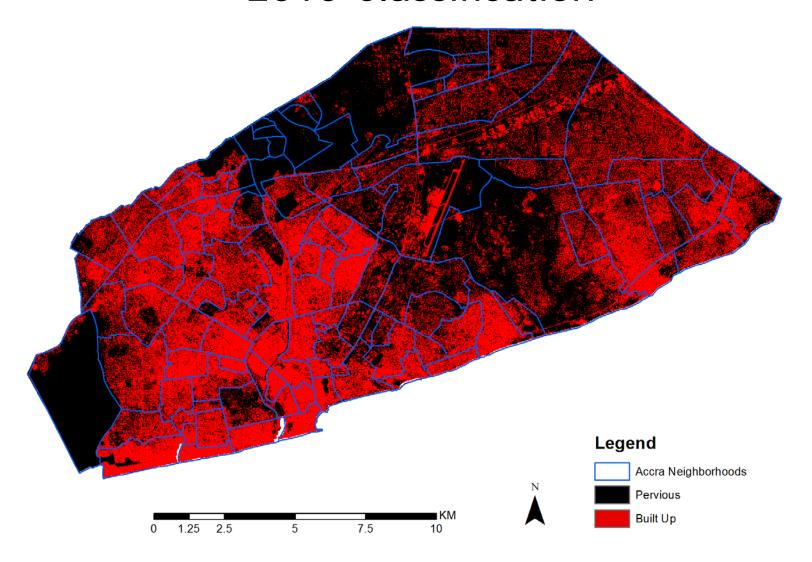
- Binary-built-up versus pervious
  - 2002 & 2010 QuickBird multispectral
  - Mapping at the EA and FMV Neighborhood

#### Formal vs Informal housing

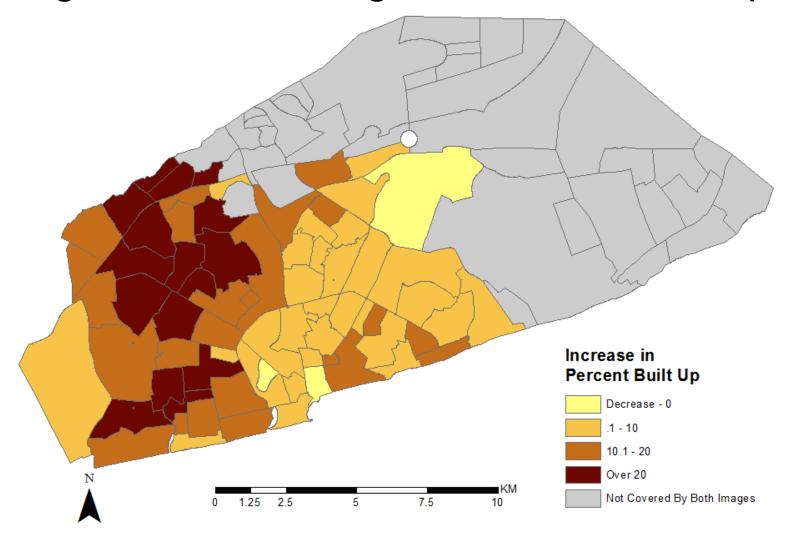
- Image Features, testing a new open source software
  - Pantex, histogram oriented gradients, line support regions, probabilistic Hough transform, local binary patterns, structural feature set textures and other "neighborhood" features
  - Creates inputs to decision tree classifiers to classify formal vs informal settlement
  - Testing on SPOT 2003, Panchromatic image

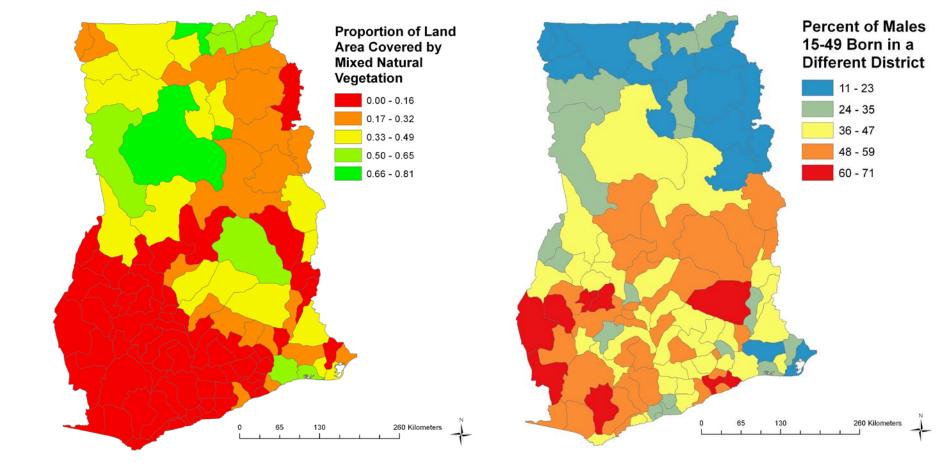


## 2010 Classification



# Neighborhood Change in Percent Built-up





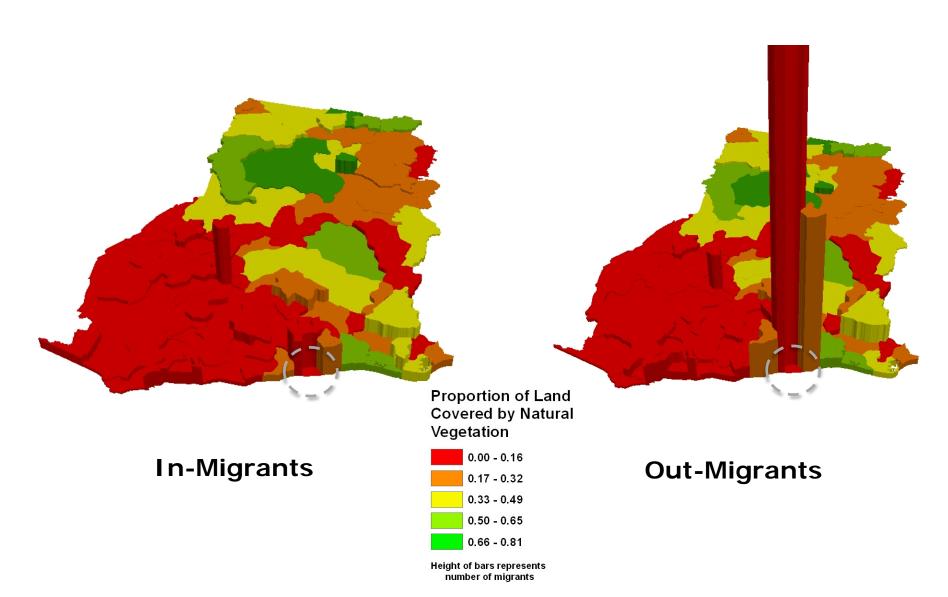
Using Born in Another Region as the dependent variable and land cover classes as predictor variables:

 $R^2 = .332$  with Natural Vegetation

(Beta = -.766; p=.000) and Mixed Agriculture/Vegetation

(Beta = -.547; p=.000) as the significant predictors

# Migrants into and out of Accra between 1995 and 2000 were predominantly inter-urban migrants



Research Design for Demographic and Health Analyses

### Professors John Week and David Lopez-Carr

#### **Two-level Multinomial Regression**

**Dependent Variable**: Migration (defined as no migration (baseline), rural migration, and urban migration)

**Independent Variables:** (available at the household and district level (aggregated):

Population variables: e.g., household size age and structure (WHSA and DHS)

Health variables: e.g., a rich array of communicable and degenerative diseases (and related factors such as diet) can be examined with available data (WHSA and DHS)

Socioeconomic Variables: income, employment, literacy, highest schooling achieved

#### Land Change:

district (second-level) measures of land use, land cover, and land consolidation at the municipal level (remote sensing data)

#### Land Consolidation Research

#### Professor David Lopez-Carr

### **Specific Hypothesis**

Rapid increase in land consolidation, driven by international investments and measured remotely by a signature pattern shift from mottled mixed land use small farms to large monocropped industrial plantations is a key independent driver of urbanization vis a vis rural farm labor displacement

## **Agent Based Modeling**

#### Prof. Li An and PhD student Stephen Crook

- Integrates multi-scale and multidisciplinary data
- Characterizes system dynamics, feedbacks, emergent properties over time and space
- For Accra and Kumasi simulate effect of individual/household actions and decisions and LCLUC on health:
  - Parameterization of individual and household decisions/actions based on census and survey data -- e.g. child mortality, fertility, marriage timing, migration, mortality
  - Empirically linked to LCLUC
  - Interactions between agents and the environment play out over time, affecting each other
  - Allows scenario exploration: how changes in certain variables affect LCLUC and health -- e.g., Experimentally increasing fertility may cause a increase urban density, decreasing health (which may then lead to ultimately increasing mortality and/or migration)
- Model implementation with Repast: advanced, open source modeling software



# **Charcoal production**



# Examining fertility throughout an urban gradient

Magdalena Benza<sup>1</sup> and John Weeks<sup>2</sup>
Department of Geography

<sup>1</sup> San Diego State University and UC Santa Barbara

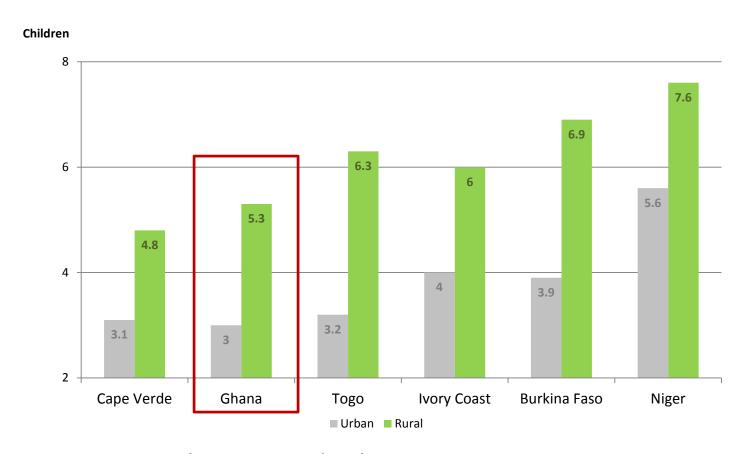
<sup>2</sup> San Diego State University

## An urban world

 Rapid urban growth combined with poverty is creating diverse urban contexts in West Africa

 These urban contexts are linked to diverse lifestyles that generate a wide range of reproductive behaviors

#### **Urban and rural total fertility rates in West Africa 1998**



DHS STATcompiler: Accessed online on January 2014

# What is an urban place?

- Urban definitions:
  - Niger: Capital city, capitals of the

departments and districts
Even though definitions vary widely they
- Senegal: Agglomerations of 10 000 or more
all assume that there are significant

differences between rural and urban - Ghana: any settlement with a population of places and their population

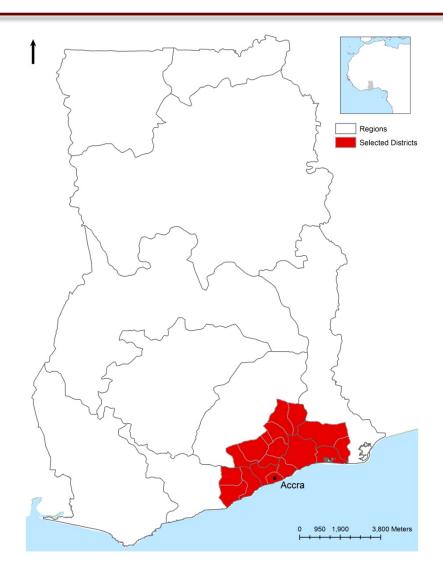


# Research questions

o Does a pattern-based definition of urban context capture the diversity of urban landscapes?

o Is there a connection between fertility levels and urban context?

# Study Area



# Data

- o Landsat 7 ETM+ from December 2002 path 193 row 56
- o ERS-2/SAR 3 orbits from 1998, 1999 and 2000
- o 2000 Ghana population and housing census

Individual and household data aggregated to towns and then aggregated to a 450 m uniform grid cell

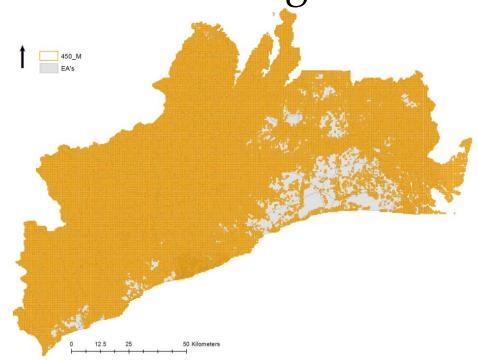
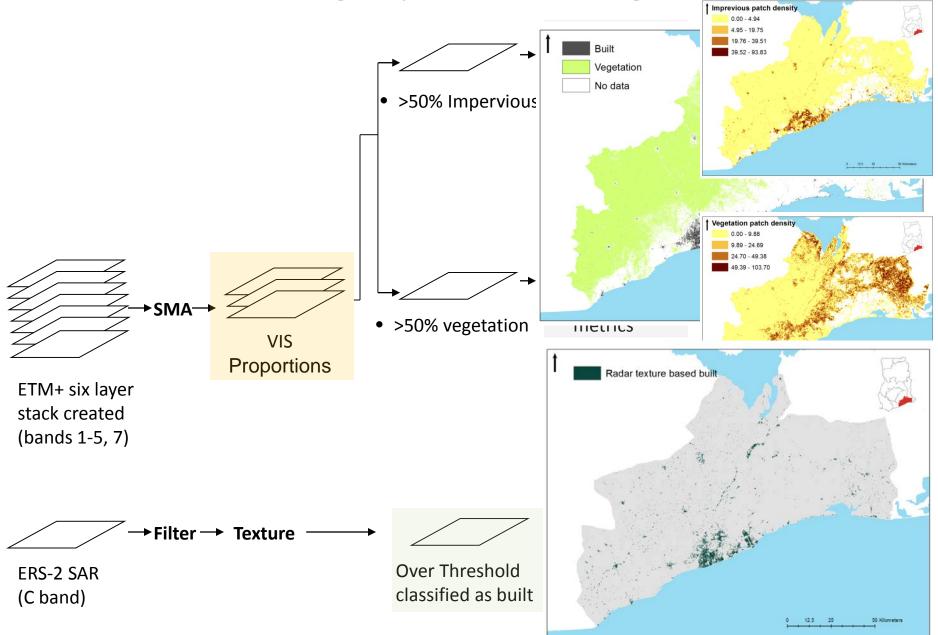
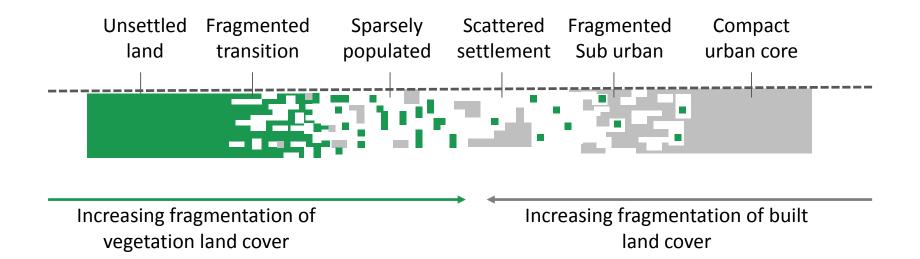


Image processing



## Urban context definition



# Fertility and urban context

OLS	WCoefficients for urban Context variables	R <sup>2</sup> :0.348	urban
	Compact urban	-0.056**	erest
contr	Fragmented large urban patches	-0.105***	
1.	C. Dense and dispersed small urban patches	-0.058***	old
2.	C Fragmented sub-urban	-0.053***	
3.	C Scattered settlements	-0.028*	
	Sparsely populated	-0.023.	
	Fragmented transition	0.017.	
	magnaentea0.05etttær0.01, ***p<0.001	-0.019	

# Fertility and Urban context: spatial filter

Coefficients for urban Context variables	R <sup>2</sup> :0.406
Compact urban	-0.057***
Fragmented large urban patches	-0.095***
Dense and dispersed small urban patches	-0.054***
Fragmented sub-urban	-0.046**
Scattered settlements	-0.016
Sparsely populated	-0.011
Fragmented transition	0.04**
Fpagmentpd0u05ettlep<0.01, ***p<0.001	0.007

# Conclusions

- Pattern based characterization of the urban context expands on the classic rural/urban definition of space
- Benneit slass from the description of the least least the description of the least least least the least lea
- o **Weattreass**eas in the countryside where fertility levels are above average