



Examination of the Nigerian Extractive Industry's impact on Agriculture in Kaduna State, Nigeria, Using a Spatial-Temporal Analysis of MODIS NDVI Data

Christopher M. Parrett

Pennsylvania State University

Masters of Geographic Information Systems

Advisor: Dr. Brian King, PSU

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Outline

- Task and Purpose/Goals
- Hypothesis
- Phenology
- MODIS NDVI
- Kaduna State
 - Agriculture
 - Extractive Industry
- Analysis Process
- Spatial-Temporal Analysis
- Results
- Conclusion



This Presentation's Goal: Get Feedback from Peers and Experts.



Task and Purpose/Goals

Developing the Agricultural sector is essential to Nigeria's long term socio-economic stability - USAID Strategy 2010-2013

Hypothesis: Expansion of extractive industries result in transformations in land-use from a vegetated land-cover to an impervious surfaces/ non-vegetated land-cover class which has a negative impact on agricultural productivity.

- **Goal #1: Develop a method of monitoring large areas for changes in land-cover**
 - Identify areas of probable de-vegetation over a time-span
 - Develop method to tip/cue analysis to assess impacted areas both spatially and temporally
 - Develop a confidence level to qualify area of change
- **Goal #2: Implement method using only ESRI ArcGIS & Python Toolsets**
 - Working on budget; Limited bandwidth and processing power
 - Utilize ESRI's evolving image processing capabilities
 - Leverage Python and open source packages
- **Goal #3: Examine the extractive industry's impact on agricultural**
 - Focus on Kaduna State – has both petroleum, industry, and extractive activities
 - Confirm/deny direct effect of extractive industry's expansion on agricultural industry
 - Identify any secondary issues arising from the focus on extractives





MODIS NDVI

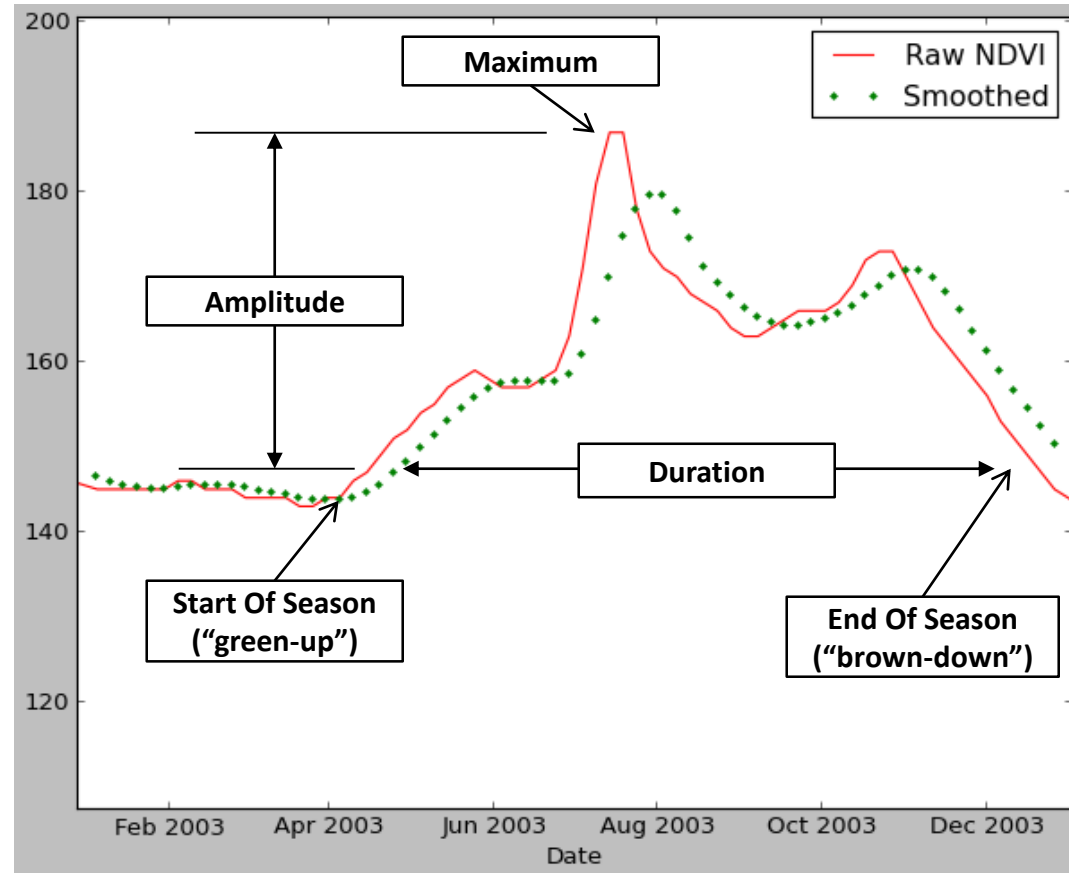
- Moderate Resolution Imaging Spectroradiometer (MODIS)
 - 2x Orbital Platforms: Aqua & Terra
 - Multi-Spectral (0.405-14.385 μm)
 - Large swath-width (~ 2330 km)
 - Resolution: 250m/500m/1000m
- Normalized Difference Vegetation Index (NDVI)
 - Indicator of biomass/vegetative health
 - Based on digital brightness values
 - Susceptible to many factors
 - Qualitative versus quantitative
- MODIS 13Q1
 - Large data - CY2001 alone was ~ 8.0 GB)
 - Data quality a challenge – would require significant processing
 - Processing in ArcGIS would not be feasible
- eMODIS NDVI from USGS
 - Cleaner and user friendly data
 - Continental scale via USGS
 - Larger than MOD13Q1 (~ 1.6 GB)
 - Require image processing (cloud masks, image acquisition times)
- eMODIS FEWS composites
 - Pre-smoothed 10-day composites
 - Smaller data subsets available via bulk FTP
 - Normalized data based on historical mean

$$NDVI = \frac{NIR - RED}{NIR + RED}$$



Phenology

- Study of vegetation growth cycles
- Particular attention to senescence
 - Growth of new foliage, fruits, flowers
 - Deterioration of leaves, fruits, flowers
- Plants experience different phenological patterns
 - Annual versus perennial
 - Deciduous versus Evergreen
 - Seasonal phases
- Use of remote sensing expands focus from individual plant to large areas/biomes
 - Can define seasonal parameters
 - Can indicate health of biome

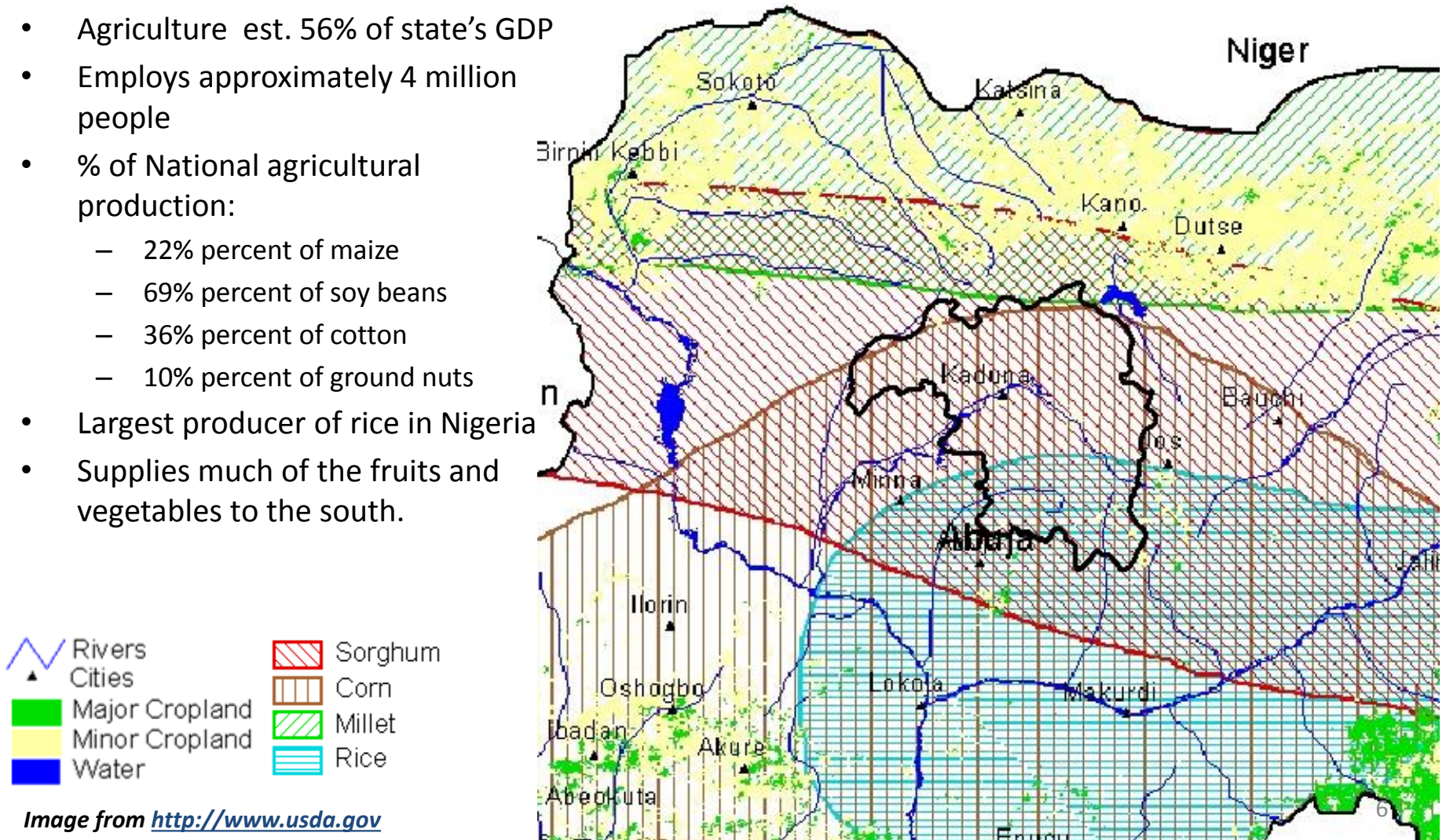




Kaduna State - Agriculture

- Agriculture est. 56% of state's GDP
- Employs approximately 4 million people
- % of National agricultural production:
 - 22% percent of maize
 - 69% percent of soy beans
 - 36% percent of cotton
 - 10% percent of ground nuts
- Largest producer of rice in Nigeria
- Supplies much of the fruits and vegetables to the south.

Crop Zones of Nigeria





Kaduna State - Extractive Industries

- **Nigeria Nationalized Industry in 1977**
 - Federal government holds all mineral rights
 - Small percentage of native population employed; labor traditionally imported
 - Government corruption and lack of reforms
- **Majority is Oil/Natural Gas**
 - Petroleum #1 Export (98% Exports 2000)
 - Bulk of resource concentrated in South
 - Environmental and ecological dangers
 - Recent investments to capture Natural Gas
- **Under-developed solid mineral sector**
 - Large deposits of Uranium, Gold, Tantalum-Niobium, Lead, Zinc, Coal
 - Attempts to re-energize and develop large scale mining could effect agriculture

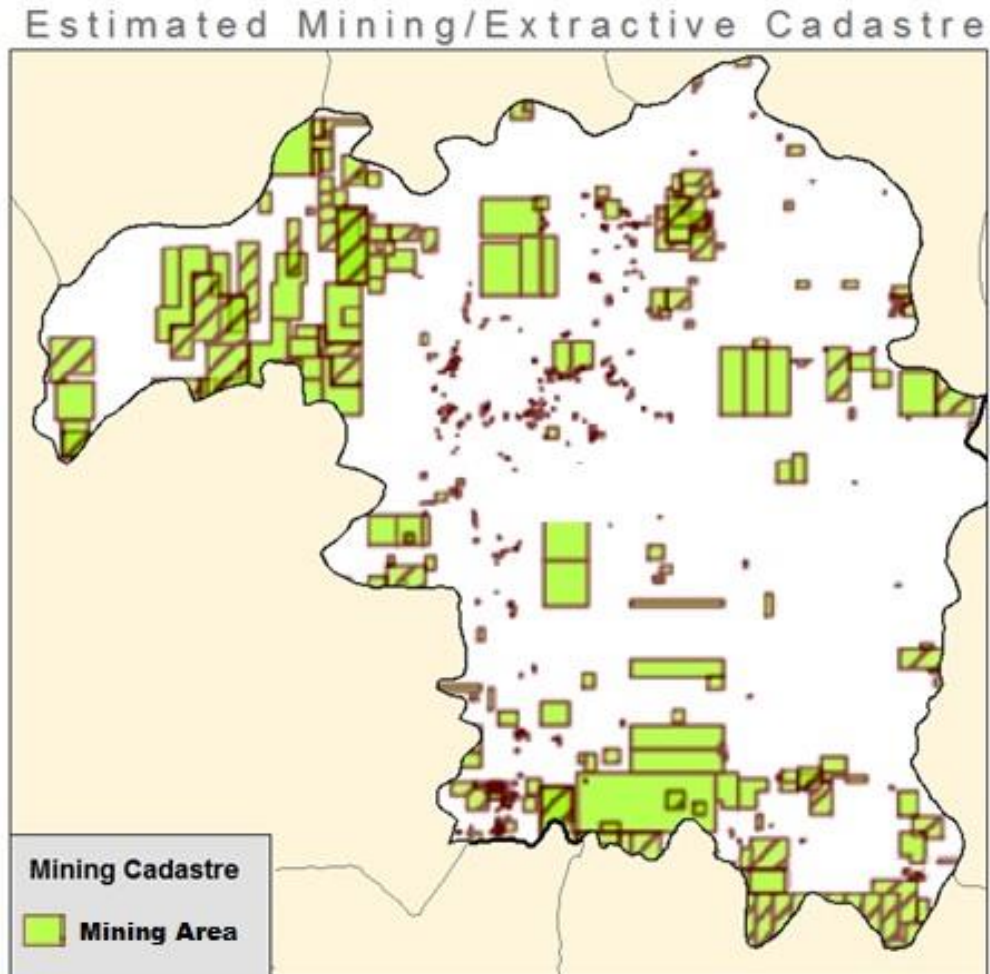
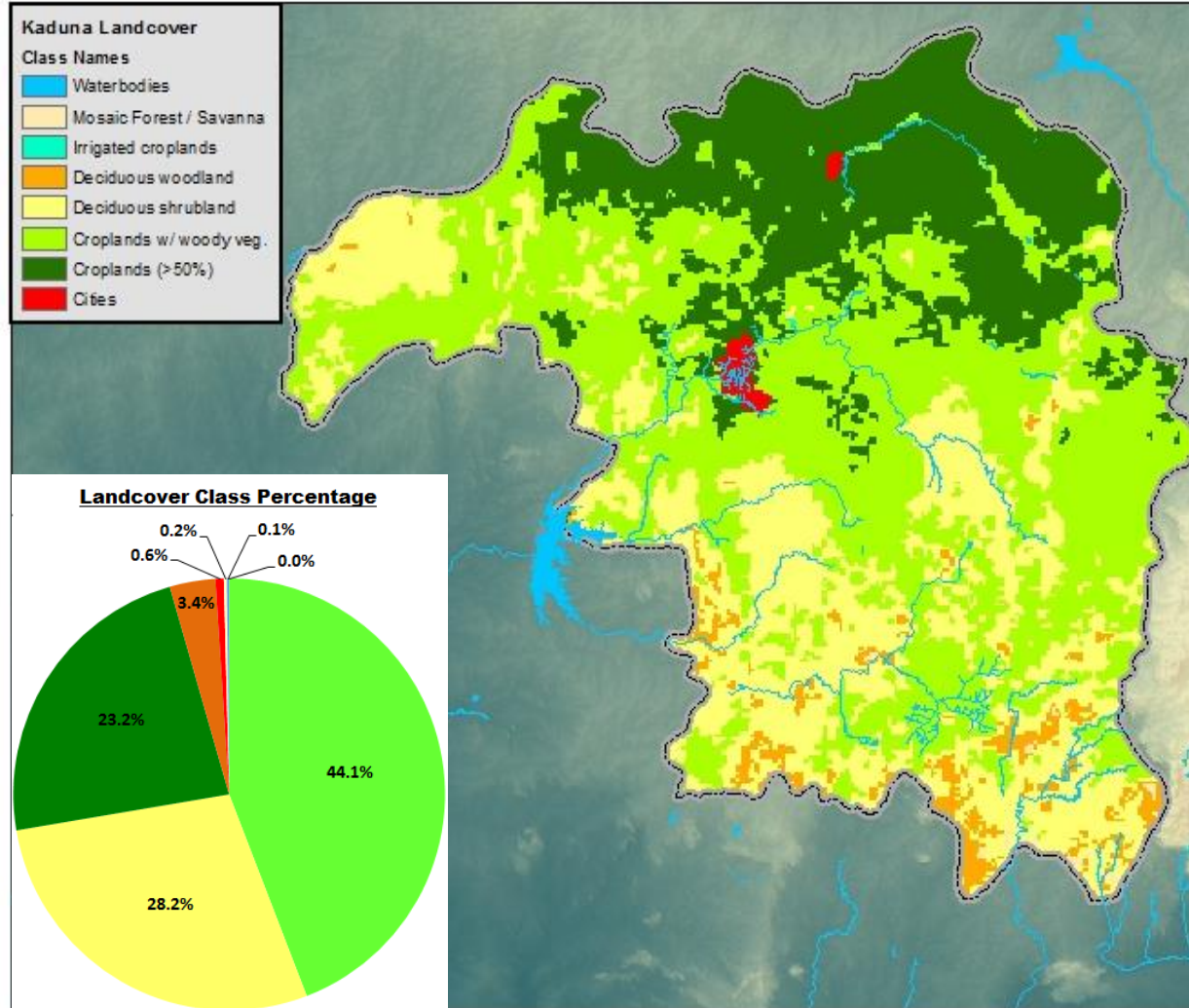


Image derived from the Nigerian Mining Cadastre Office
<http://miningcadastre.gov.ng/>



Kaduna State – Study Area

- Majority of croplands are in the North-East
- Most vegetation is classified as deciduous
- Phenology will likely follow rainy-season, complicating discrimination from croplands
- Impermeable surfaces are small fraction of LCLU
- Any increase in impermeable surface should be easier to locate and identify
- Assuming that mining areas in NW are more likely to affect agriculture than those in South



Used European Commissions Global Land Cover 2000

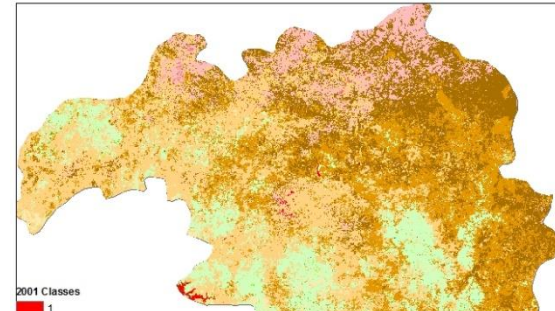
<http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php>



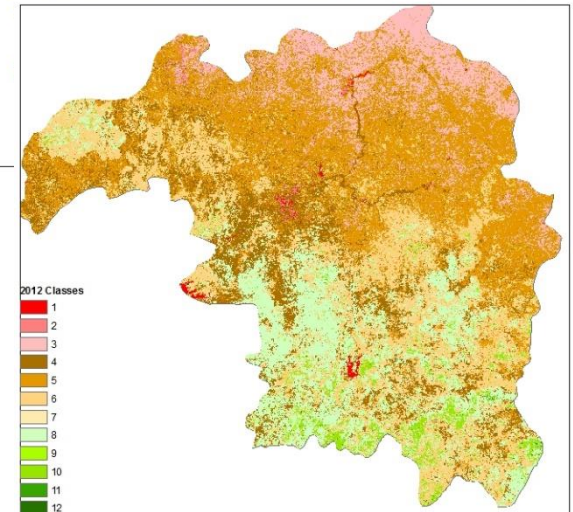
Analysis Process

- Seasonal Decomposition
 - Moving Weighted Average
 - Calculate Seasonal Factor
 - Calculate Random Factor (not used)
- Data-Stacking
 - 72-band composites, 10-day bands
- Iterative Self-Organizing Data Analysis Technique (ISODATA) Clustering
- Maximum Likelihood Classification
 - Chose 12 classes, minimum class size of 120 pixels

NDVI Classifications - 2001



NDVI Classifications - 2012

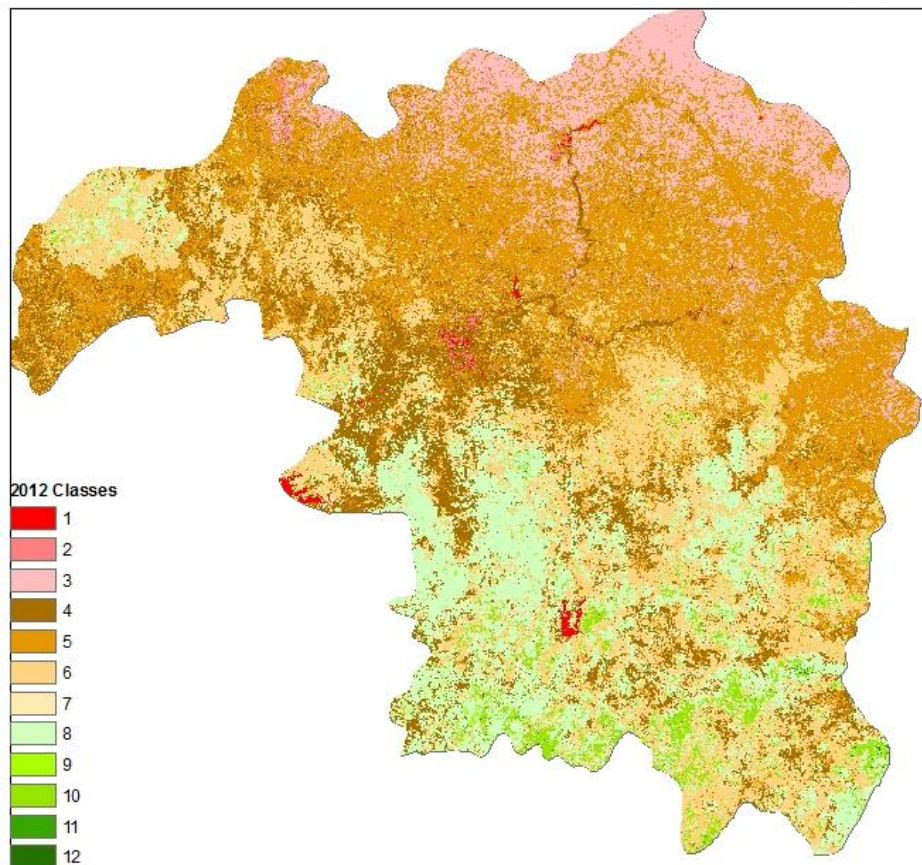
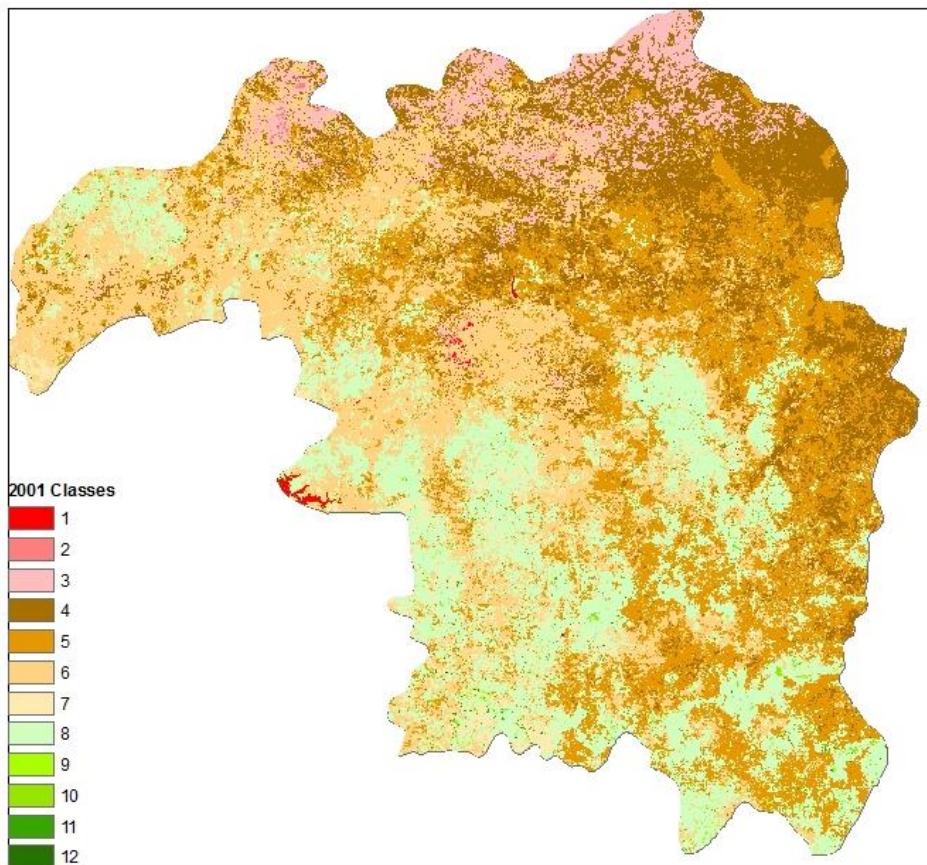




Analysis Process

NDVI Classifications - 2001

NDVI Classifications - 2012



2001 eMODIS Composite
ESRI ISO Cluster Unsupervised
Classification (12 Classes)

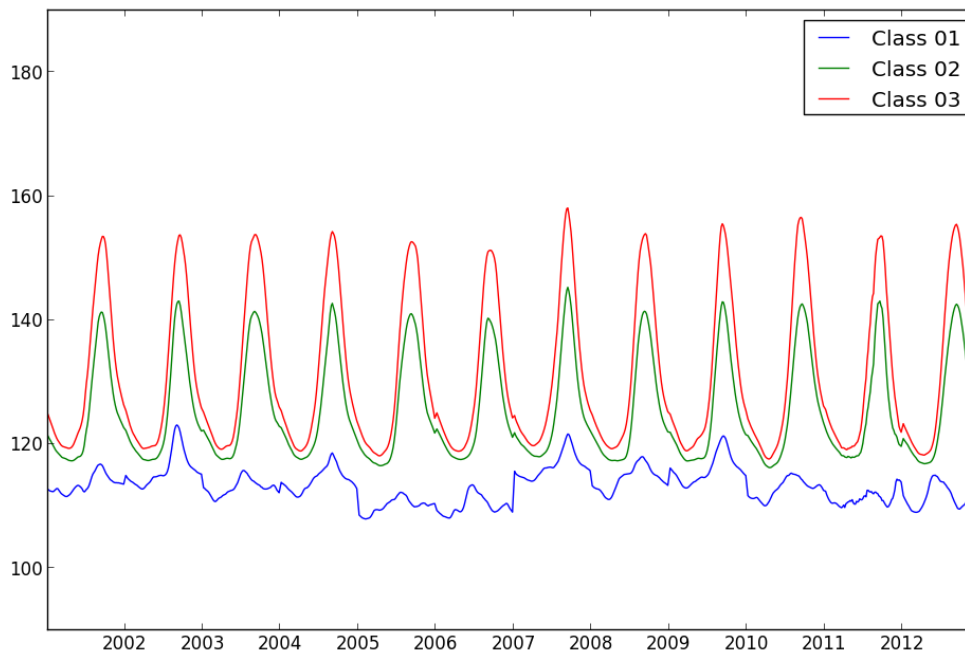
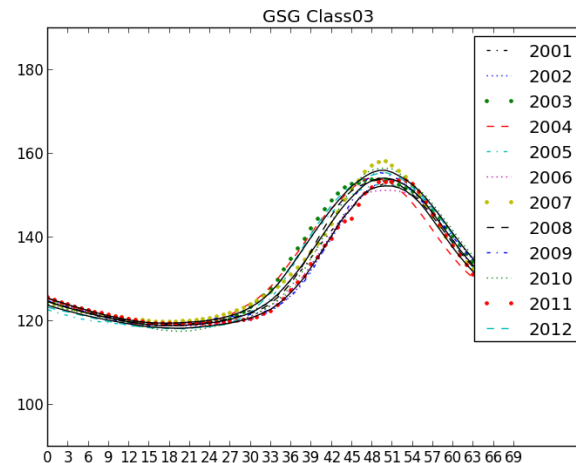
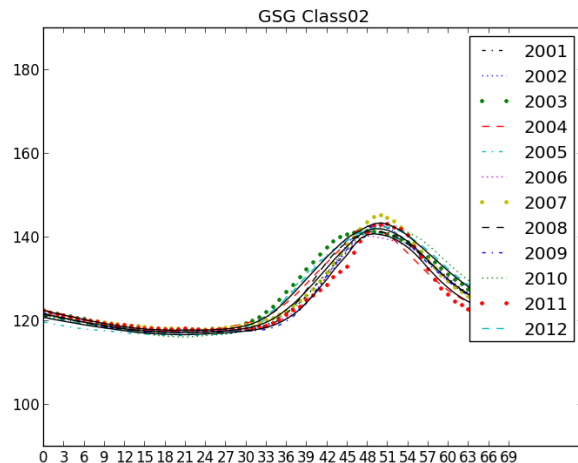
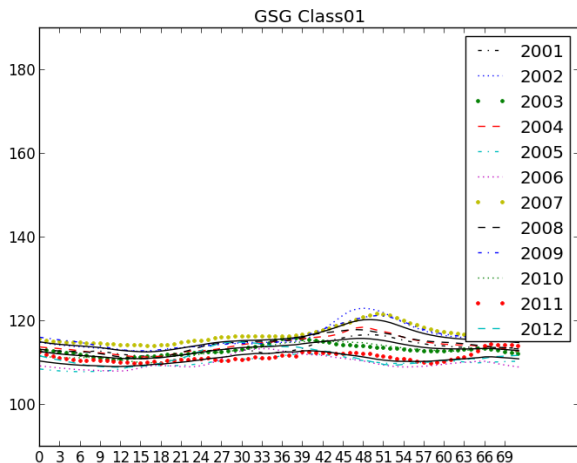


2012 eMODIS Composite
ESRI ISO Cluster Unsupervised
Classification (12 Classes)



Temporal Signature Analysis

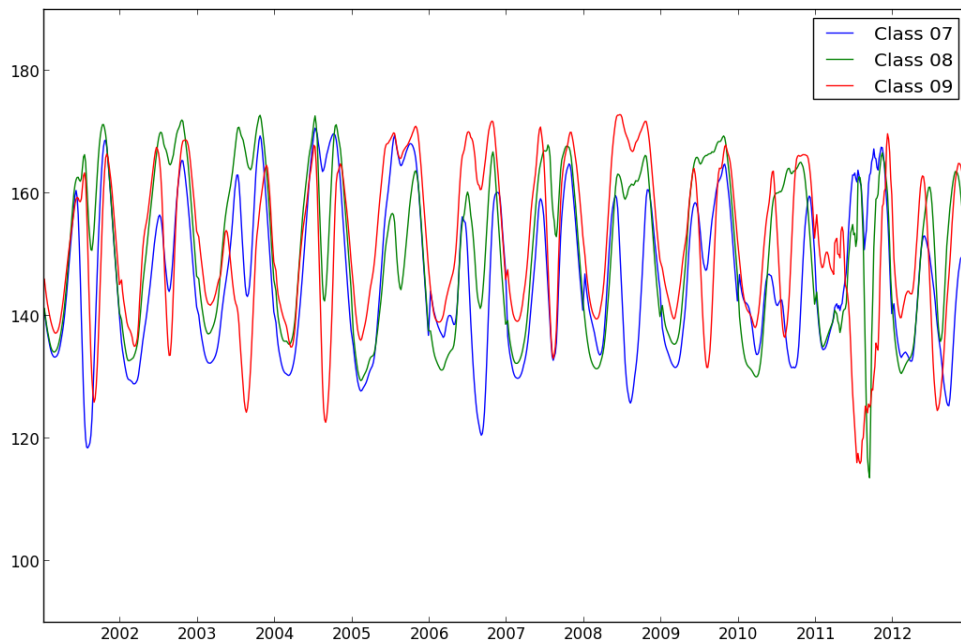
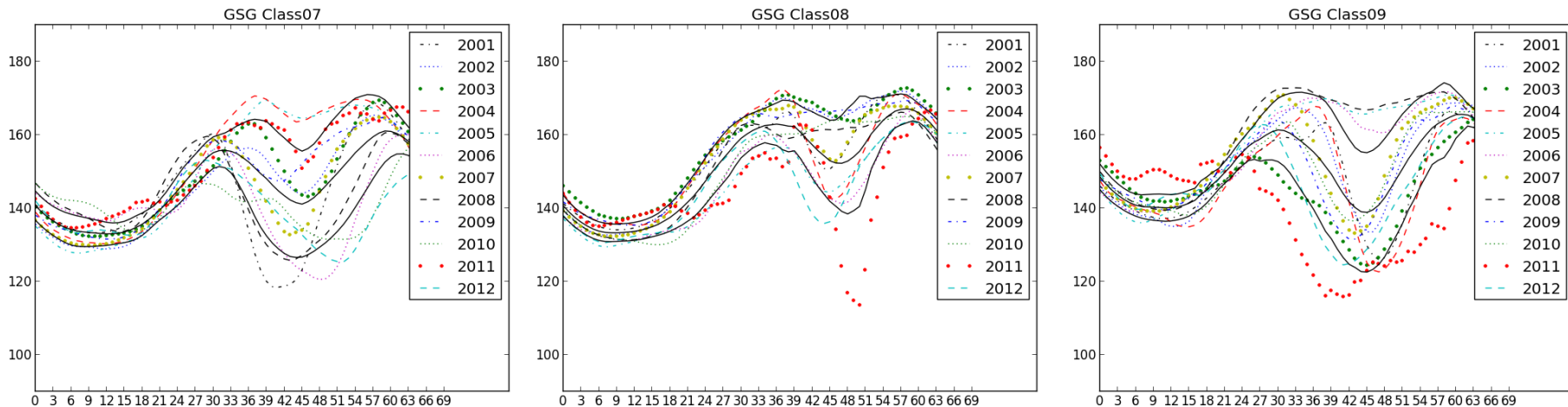
Consistent





Temporal Signature Analysis

Inconsistent





Spatial-Temporal Method

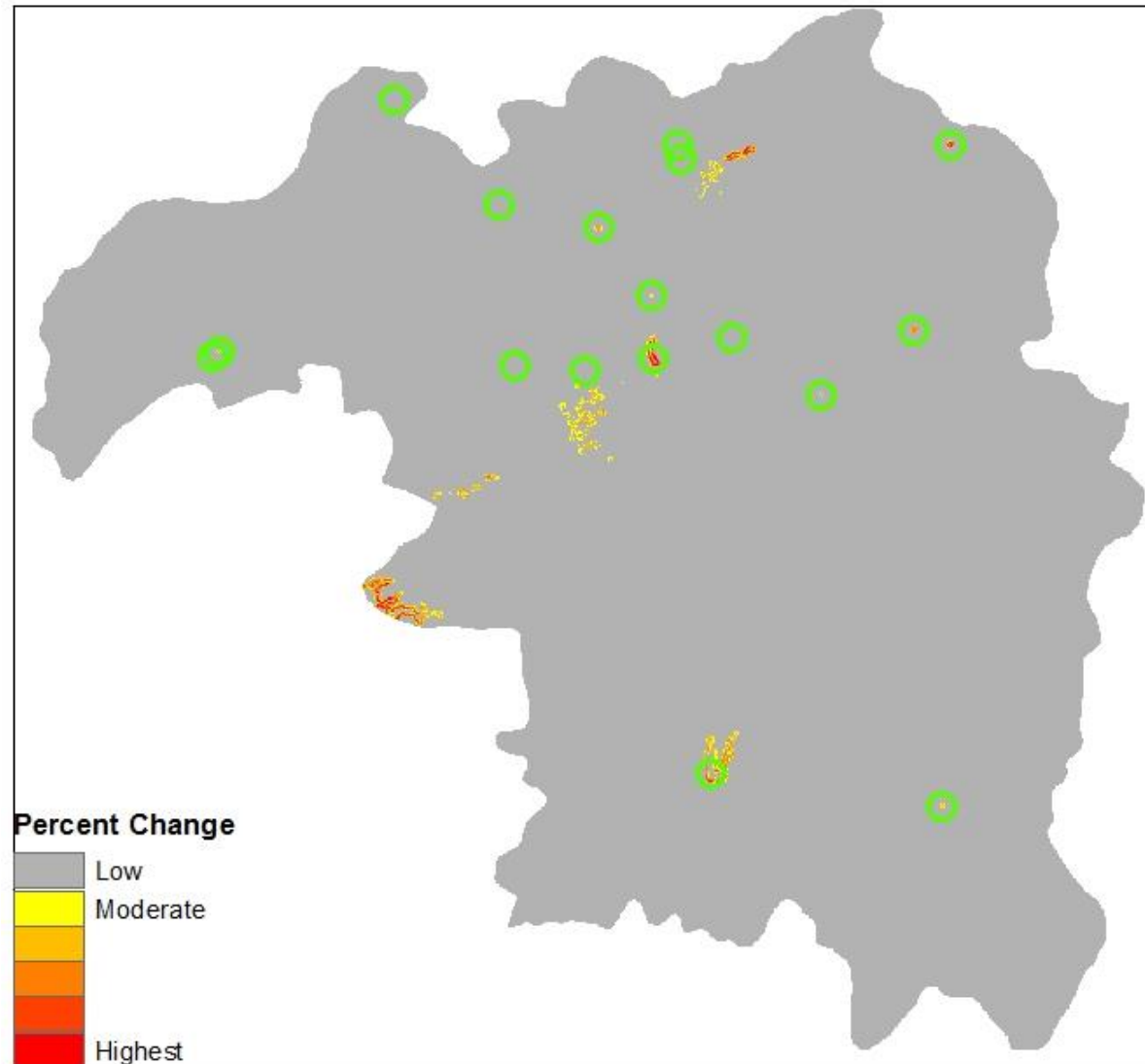
NDVI Classification Changes

- Reclassify each class file to focus on stable classes
- Calculate differences from year to year

$$\sum_{k=2}^n \left(\frac{C_k(C_k - C_{k-1})}{2} \right) e^{1/k}$$

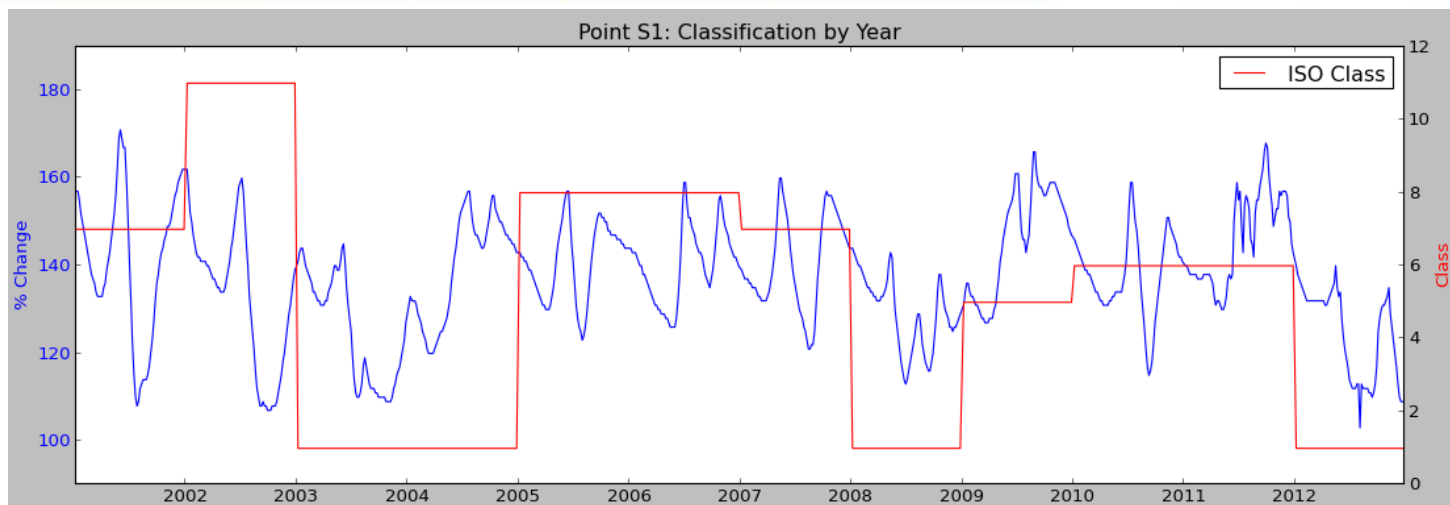
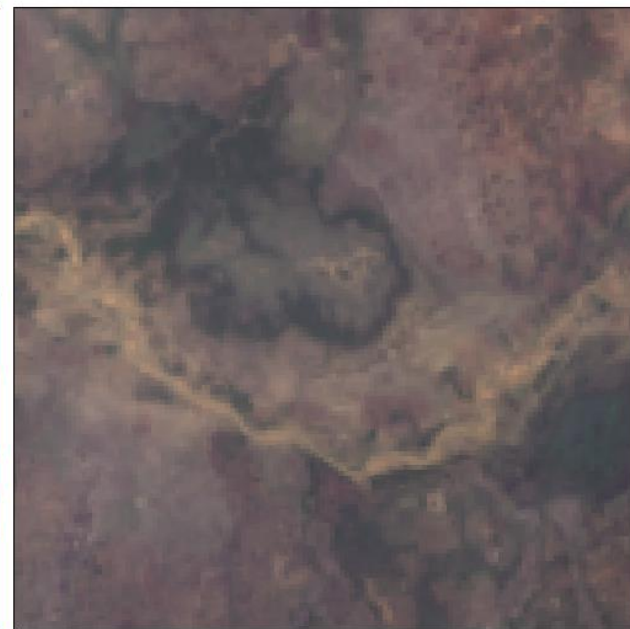
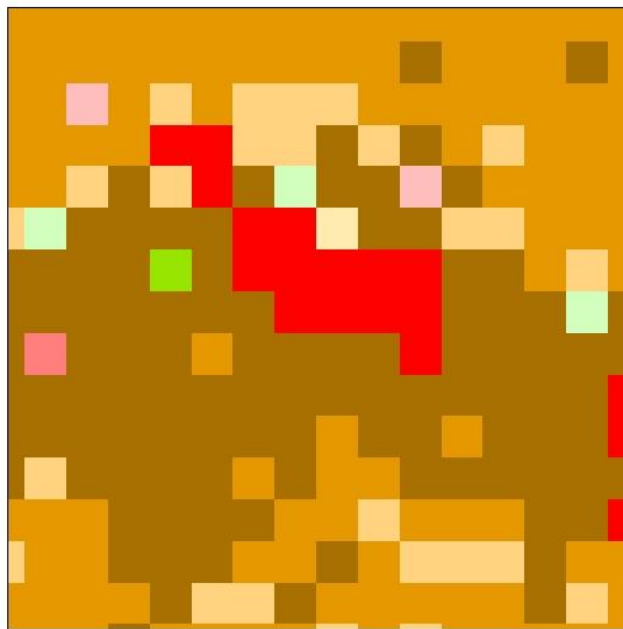
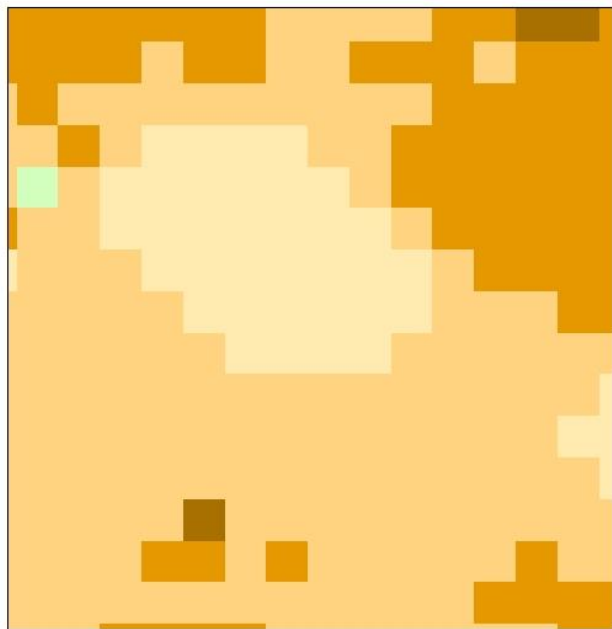
- Slope to detect peaks
- Select moderate slope and reclassify*
- Convert to polygons
- Calculate centroid points*
- Feature datasets used to reduce false alarms*
- Export to KML
- Verify points against historical imagery via GoogleEarth*

* *Indicates manual process*



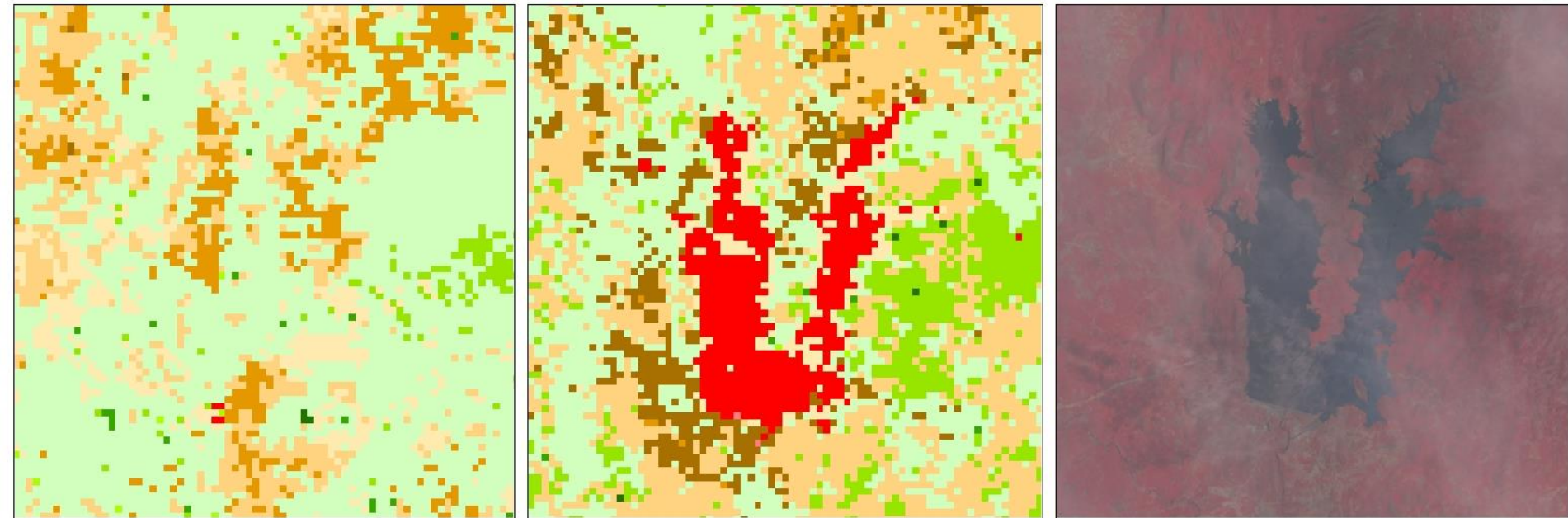


False Positives





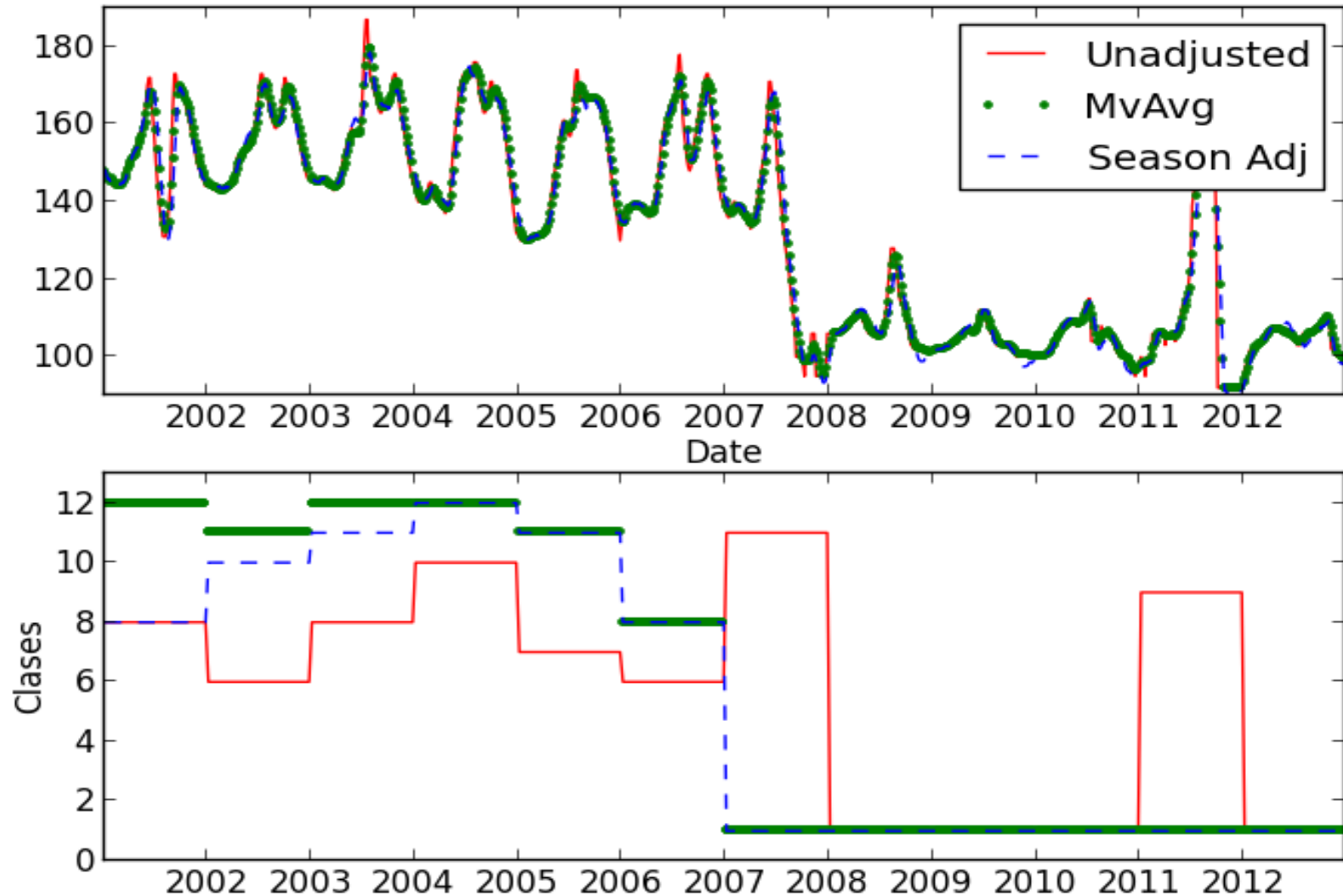
Positive Result





Confirmed Change

Sample Number 04





Results

- **Process identified 86 areas of potential changes**

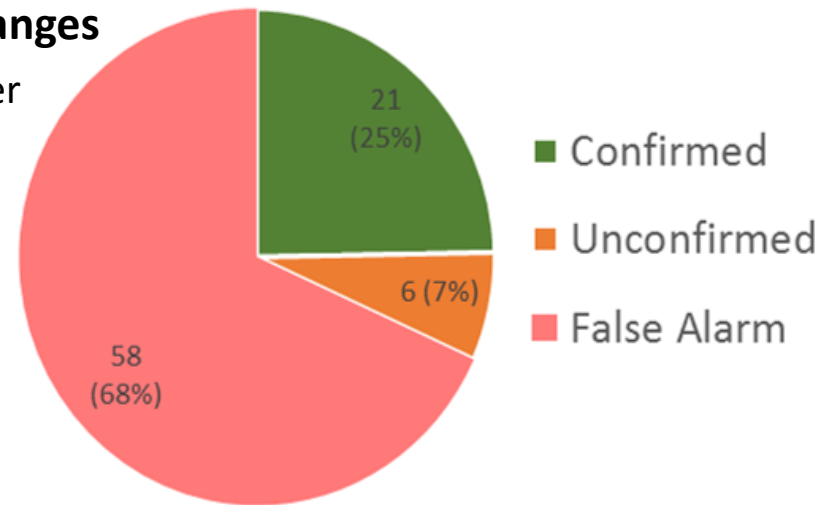
- High-false Alarm rate mostly caused by water
- Some observations could not be confirmed
- Bulk of confirmed changes cause by urban expansion and/or increased agriculture

- **Process was practical**

- Computationally inexpensive
 - Process & Data within capabilities
 - Python, NumPy, SciPy, and Pandas were critical
- FEWS provided eMODIS NDVI data were easy to work and reliable
- May not scale to large, diverse areas

- **Process has potential applications, but many challenges**

- Can identify sustained areas of decreased vegetation both spatially and temporally
- Quick and inexpensive method to monitor large areas of land
- Reliability in highly complex environments is uncertain; Not able to identify land-use
- Future model improvements could incorporate surface temperature and precipitation





Conclusion

- **Minimal evidence of extractive industry related land-cover changes**
 - No/little significant change between 2001-2012
 - Changes could have been filtered out
 - Changes could be too small or unobservable (mines)
- **Agricultural output in Nigeria actually increased between 2001-2011**
 - Noticeable increase in water management
 - Population growth could be fueling increase
 - Per capita production index is still much lower than other countries
- **ArcGIS not *the* best tool for spatial-temporal analysis... but it worked**
 - Spatial Analyst is a great toolset, but results are often not intuitive
 - Multiple python scripts required to connect outputs and access spatial-temporal data
 - High-disk serialization required
 - ISO Cluster Maximum Likelihood Classification toolset required supplementary tools to examine signatures



Questions?

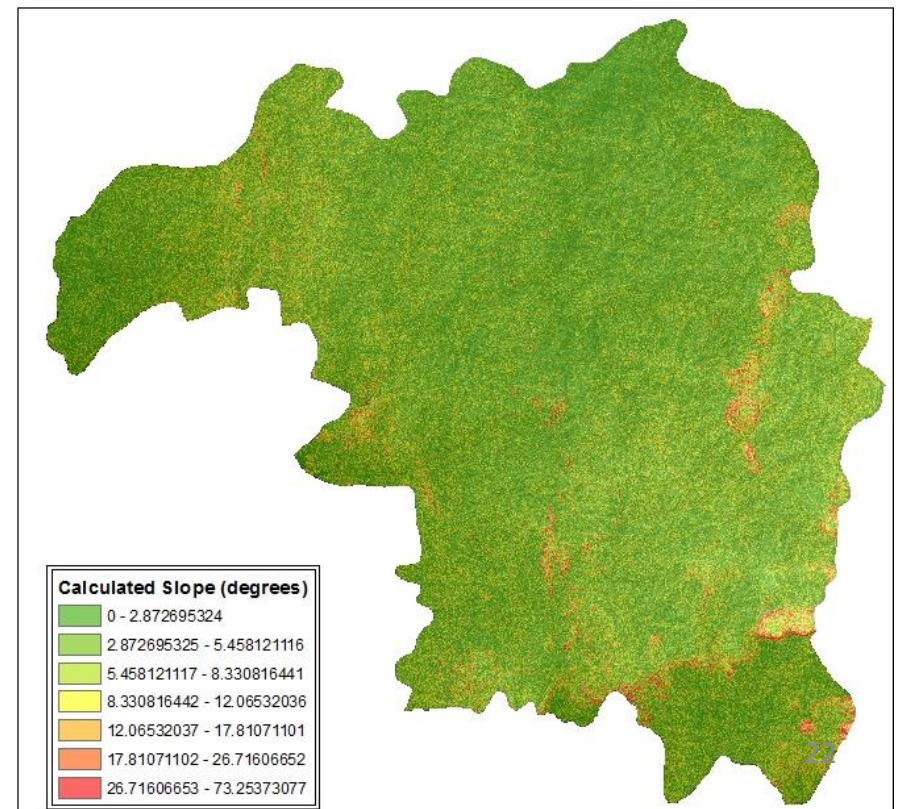
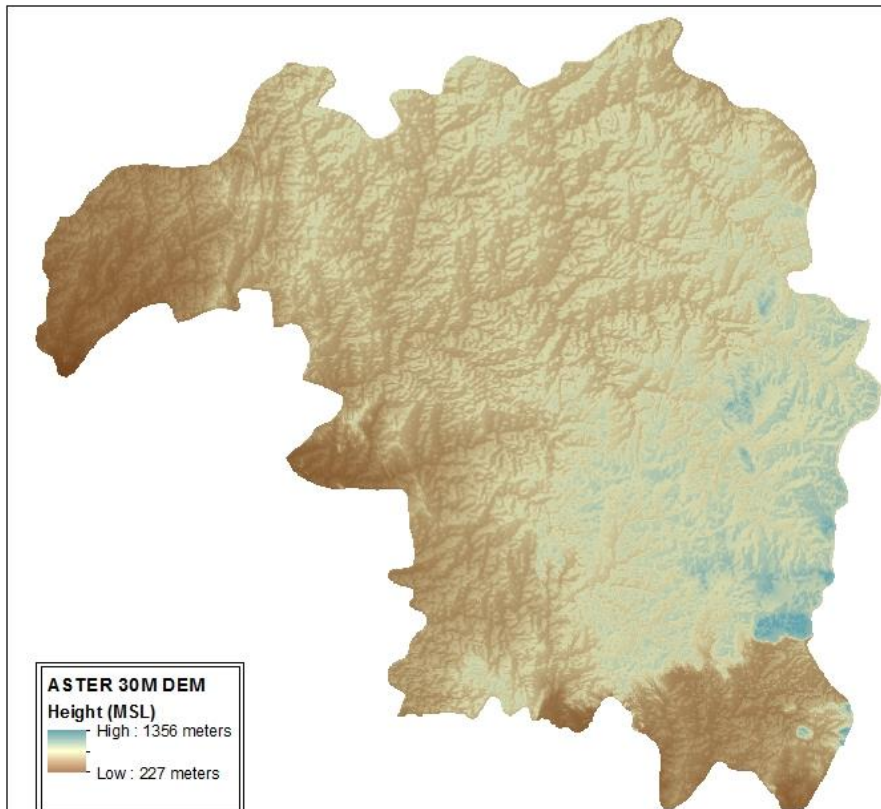
BACK-UP / DELETED



Kaduna State

Physical Geography

- Approximately 46,053 sq. km: ~5% total land area of Nigeria
- Majors rivers: Kaduna, Kogum, Gurara, Matsirga, and Galma
- Generally mild terrain, with areas of plateaus and ridges
- Central location and good transportation network of roads & rail



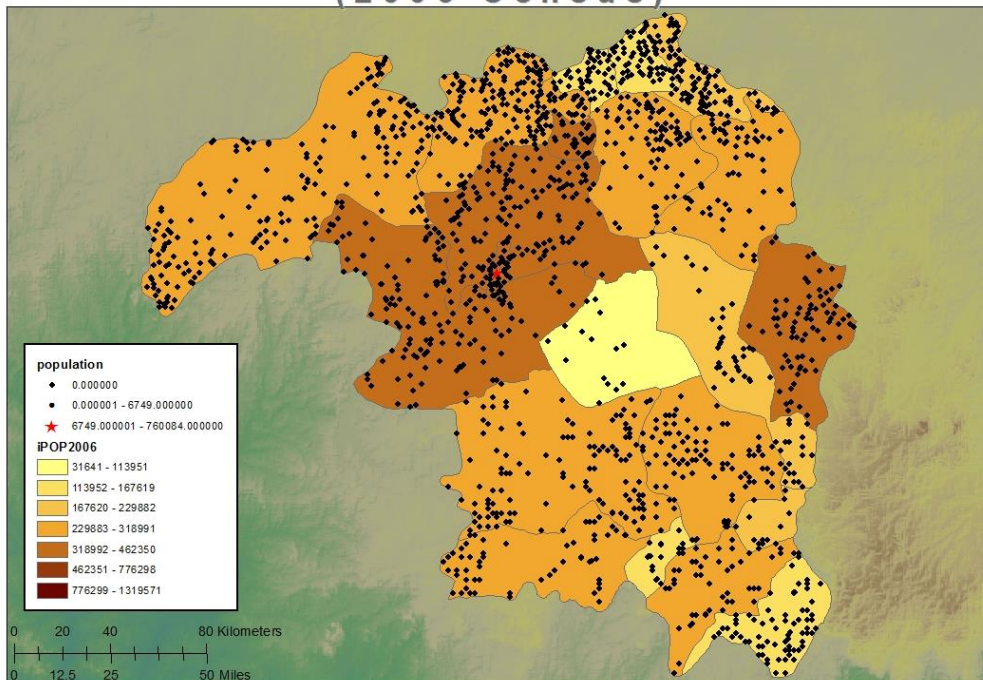


Kaduna State

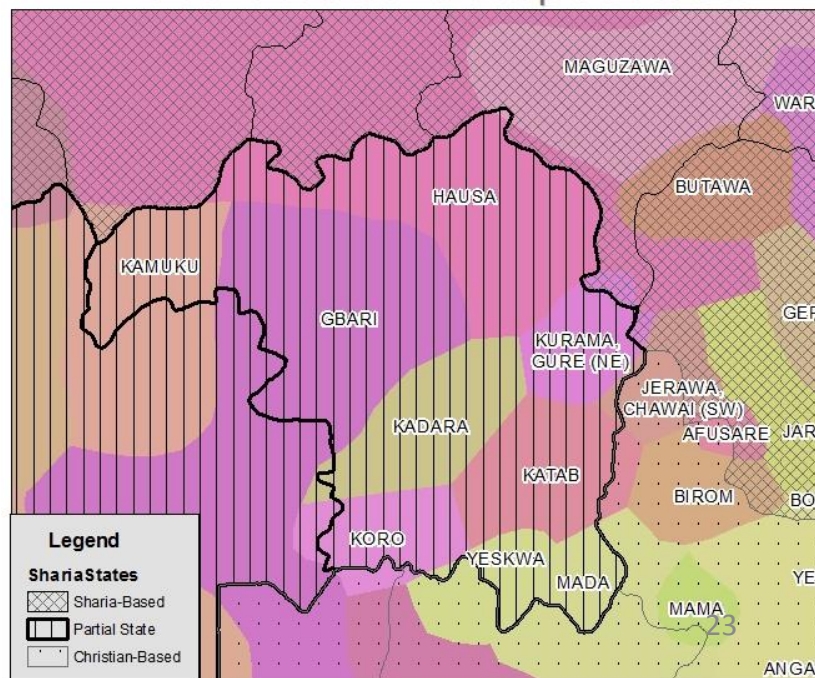
Human Geography

- Population: 6,113,503 (2006), projected 7,474,000 in 2013 (3.18% growth)
- Ranks 3rd in population and population density
- Diverse tribal composition; large Muslim population in the North
- Partial Sharia law exists; historical violence between Christians & Muslims

Kaduna State Estimated Population (2006 Census)



Sharia States in Nigeria vs. Tribal Composition



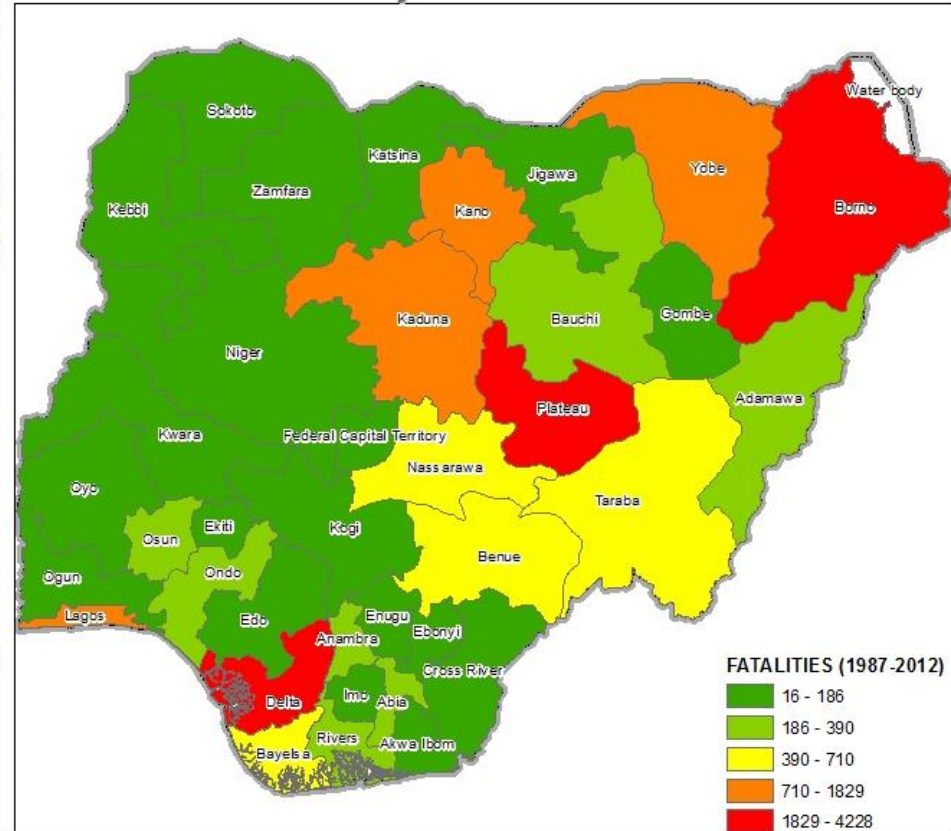
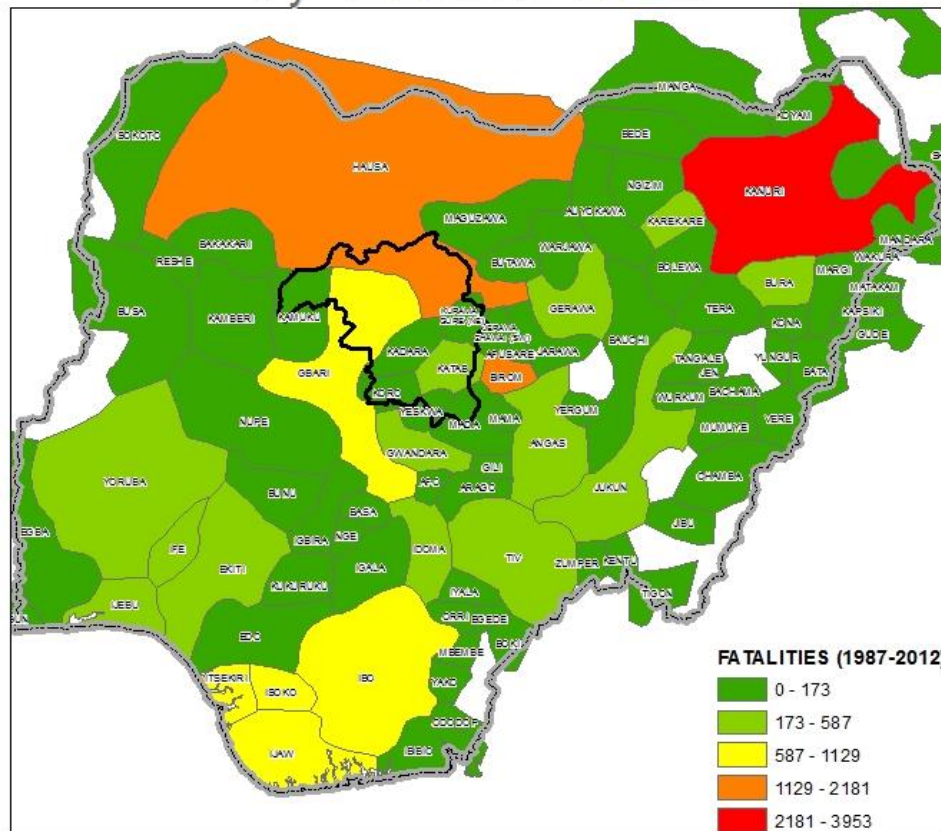


Reported Violence

1987-2012

Reported Violence Fatalities by Ethnic Area

Reported Violence Fatalities by State

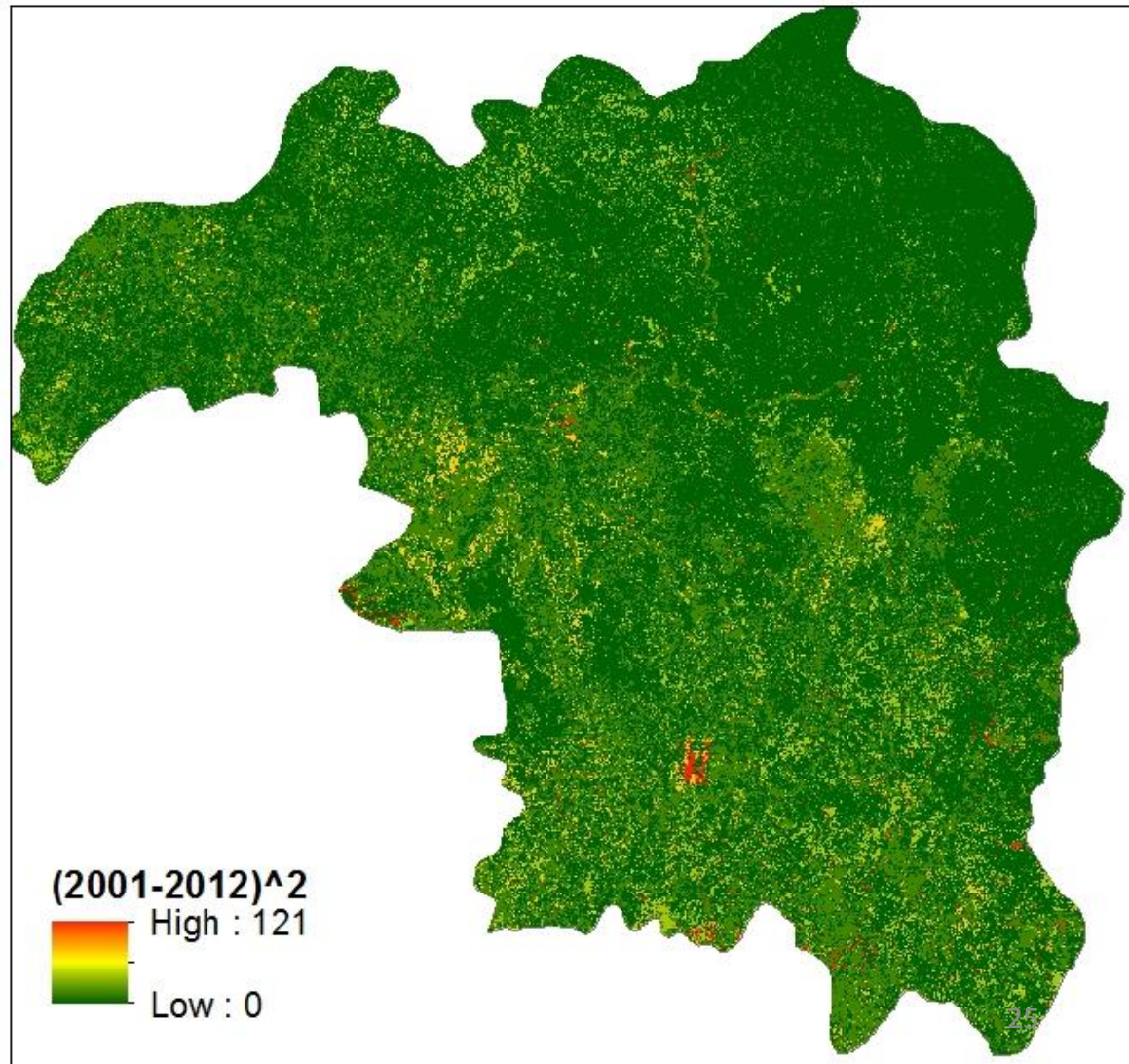




Simple Class Subtraction

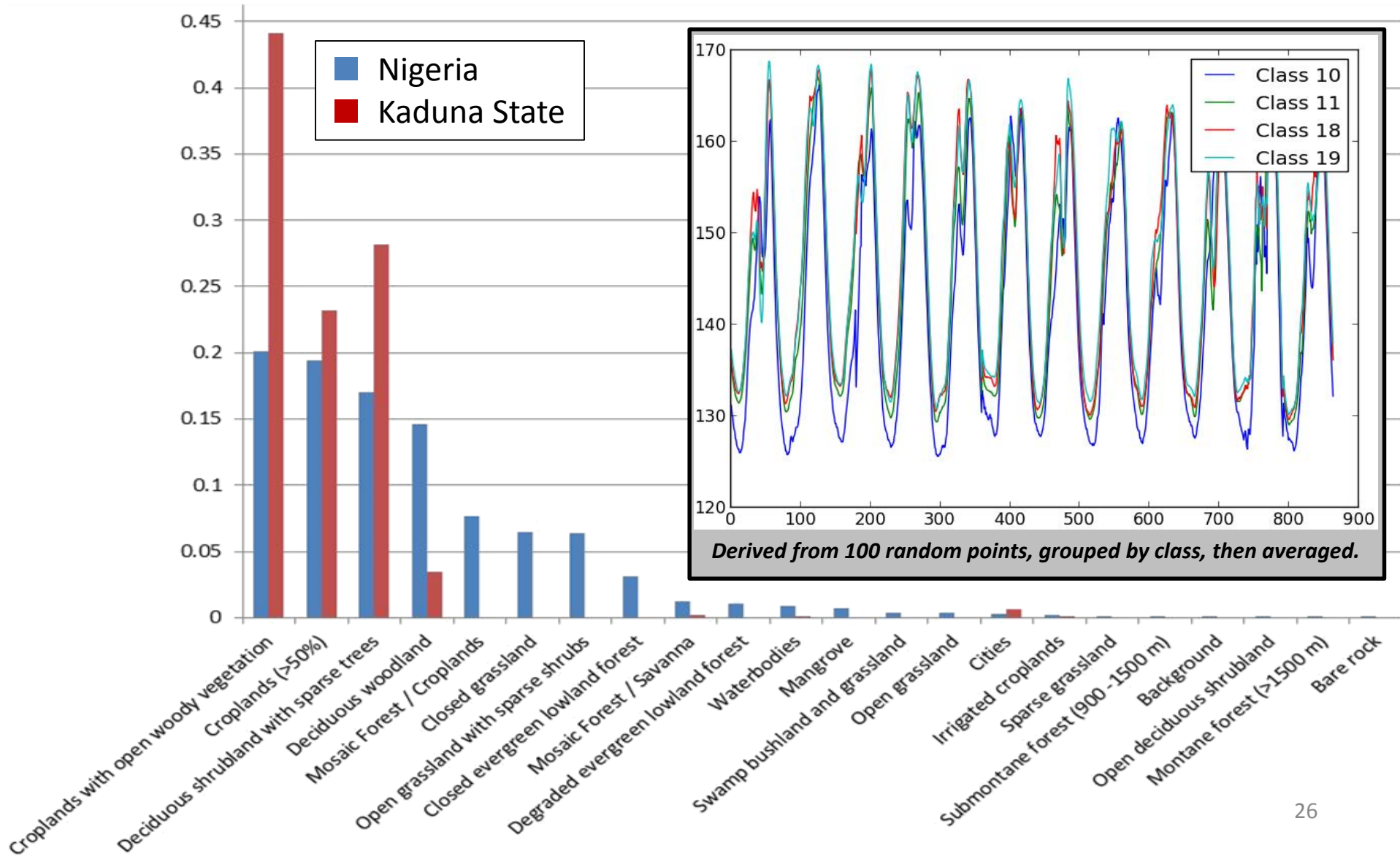
NDVI Classification Changes

- Simple subtraction of 2012 from 2001 Class Raster
 - Showed large changes
 - Very noisy
 - Difficult to quantify two snap-shots
 - Based on fluctuations in classification schemes, unreliable
 - Changes could not be narrowed down to a distinct time



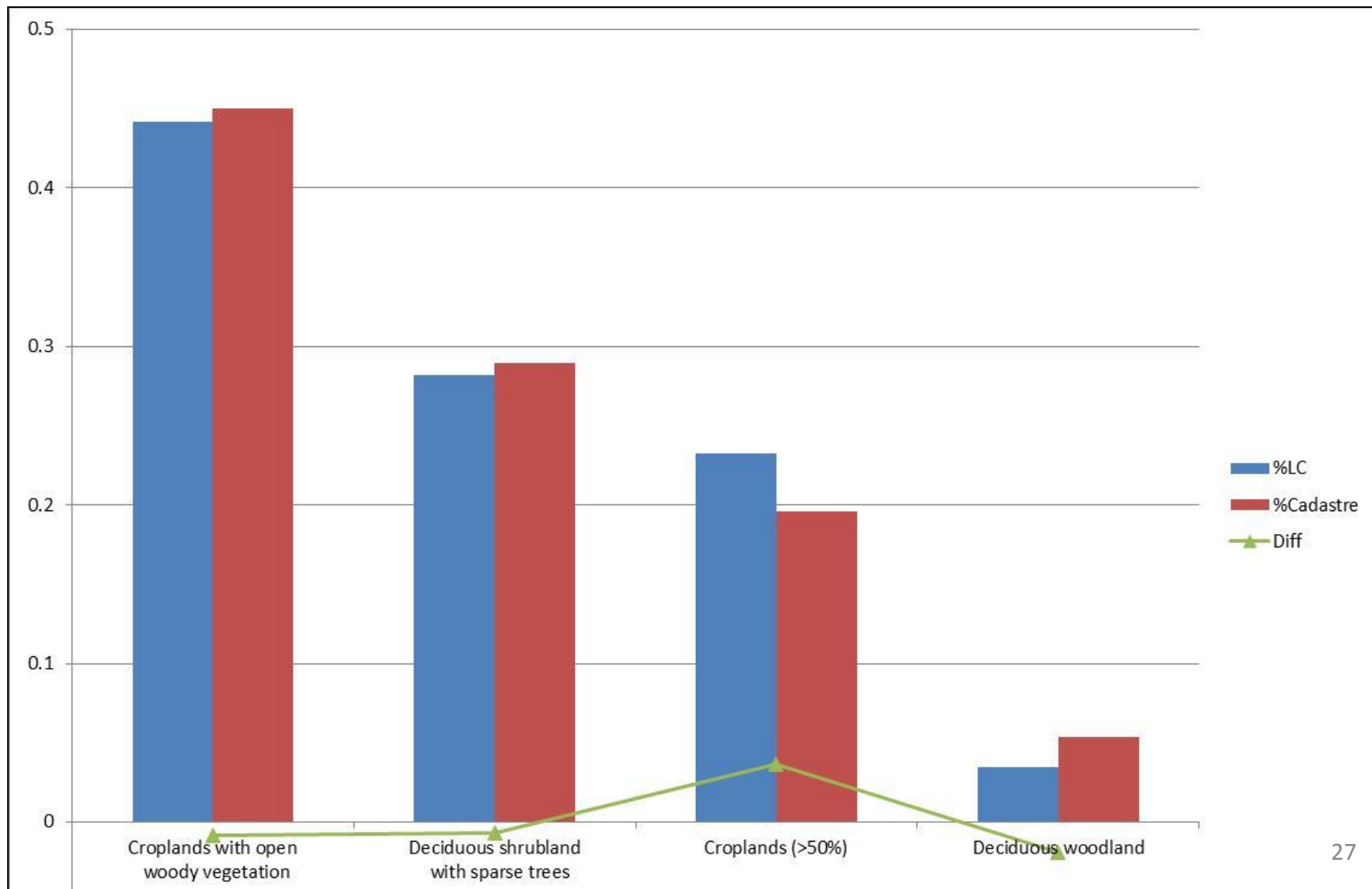


Land-Cover Classification





Potential Area Impacts on Agricultural





Literature References

(2 of 2)

1. Murtala Chindo (2011). **An Extensive Analysis of Mining in Nigeria Using a GIS**. *Journal of Geography and Geology Vol. 3, No. 1* pgs. 145-159
2. Ross S. Lunetta, Joseph F. Knight, J. Ediriwickrema, John G. Lyon, L. Dorsey Worthy (2006). **Land-cover change detection using multi-temporal MODIS NDVI data**. *Remote Sensing of Environment 105* pgs142–154
3. William L. Stefanova, Maik Netzband (2005). **Assessment of ASTER land cover and MODIS NDVI data at multiple scales for ecological characterization of an arid urban center**. *Remote Sensing of Environment 99* pgs 31 – 43
4. Louisa J.M. Jansen, Antonio Di Gregorio (2002). **Parametric land cover and land-use classifications as tools for environmental change detection**. *Agriculture, Ecosystems and Environment 91* pgs 89–100
5. A. Gobin, P. Campling, J. Feyen (2002). **Logistic modeling to derive agricultural land use determinants: a case study from southeastern Nigeria**. *Agriculture, Ecosystems and Environment 89* pgs213–228
6. Souleymane Pare, Ulf So ¨nderberg, Mats Sandewall, Jean Marie Ouadba (2008). **Land use analysis from spatial and field data capture in southern Burkina Faso, West Africa**. *Agriculture, Ecosystems and Environment 127* pgs 277–285
7. Ademola K. Braimoh, Takashi Onishi (2007). **Spatial determinants of urban land use change in Lagos, Nigeria**. *Land Use Policy 24* pgs. 502–515
8. K. Lyncha, T. Binns and E. Olofin (2001). **Urban agriculture under threat: The Land Security Question in Kano, Nigeria**. *Cities. Vol. 18, No. 3*, pp. 159–171
9. 2010 Annual Statistical Bulletin, Nigerian National Petroleum Corporation (<http://www.nnpcgroup.com>)
10. Oil and Gas in Africa, African Development Bank and the African Union, July 29, 2009
11. A. A. Ammani, A. K. Ja’afaru, J. A. Aliyu and A. I. Arab (2012). **Climate Change and Maize Production: Empirical Evidence from Kaduna State, Nigeria** *Journal of Agricultural Extension Vol. 16 (1), June 2012*, pp



Data Providers

Spatial Data Holdings

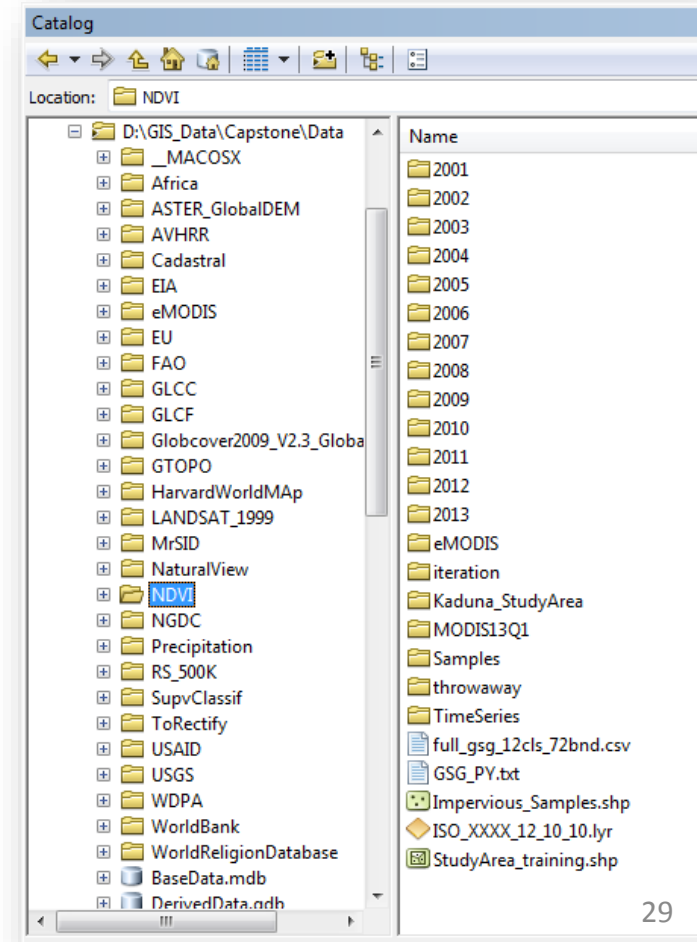
- US Geologic Survey (**USGS**): MODIS, Landsat 7/ETM+, Landsat 8/OLI-TIRS, GTOPO30, ASTER
- National Geographic Data Center (**NGDC**): DMSP, VIIRS, Flare Reporting
- U.N. Food and Agriculture Organization (**FAO**): LCLU
- European Commission: Joint Research Center (EU/JRC): LCLU
- Open Street Maps (**OSM**): Infrastructure, places, physical features
- Natural Earth Data: Foundational Data
- CRU

Supporting Data (Map Holdings and Statistical Data)

- U.S. Energy Information Administration
- U.S. Agency for International Development
- U.S. Department of Agriculture
- NASA Socioeconomic Data and Applications Center (SEDAC)
- World Bank Data
- UN FAO STAT
- UN Environmental Program (UNEP)
- International Monetary Fund
- University of Texas, Department of Geography

Online Support

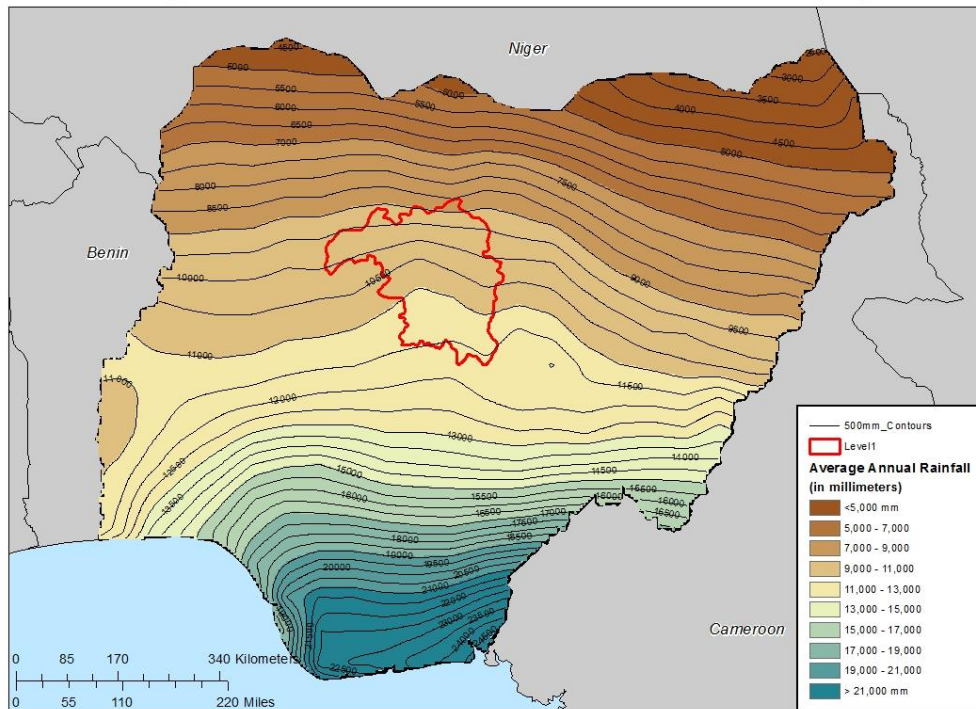
- ArcGIS Online
- Google Maps
- Harvard Africa Map
- WikiMapia.org



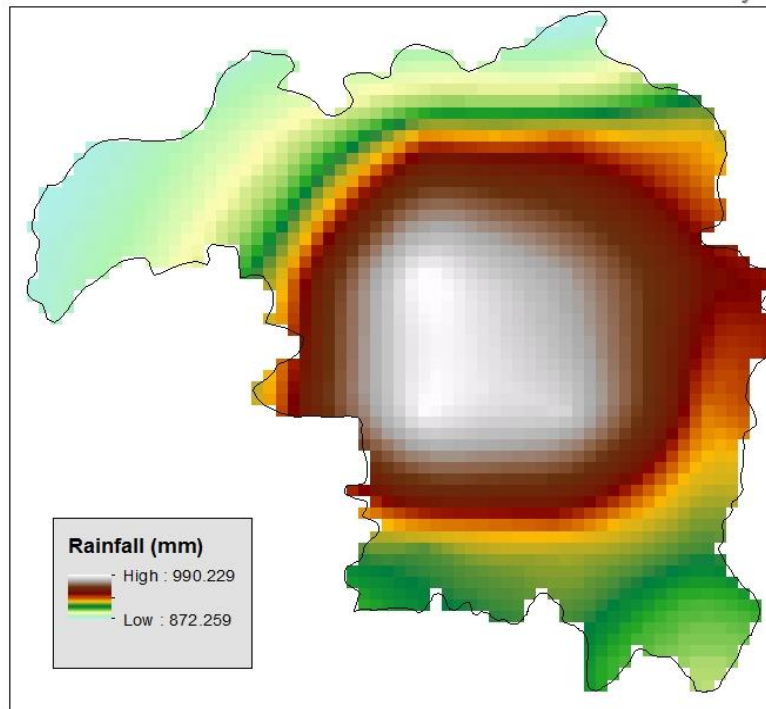


Estimated Precipitation

Average Annual Rainfall Across Nigeria



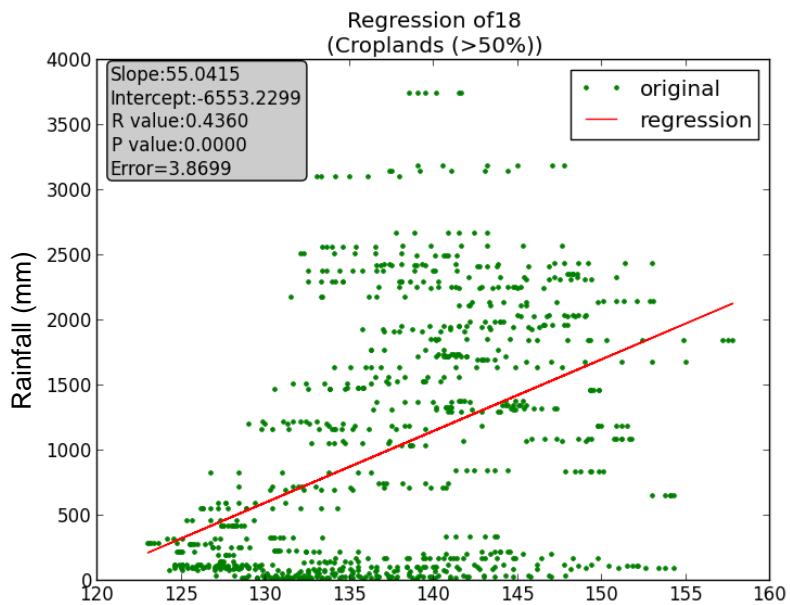
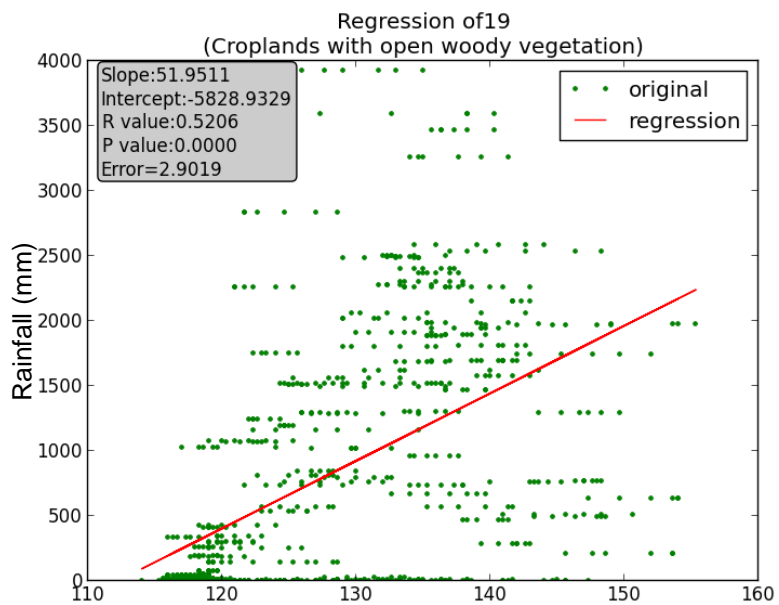
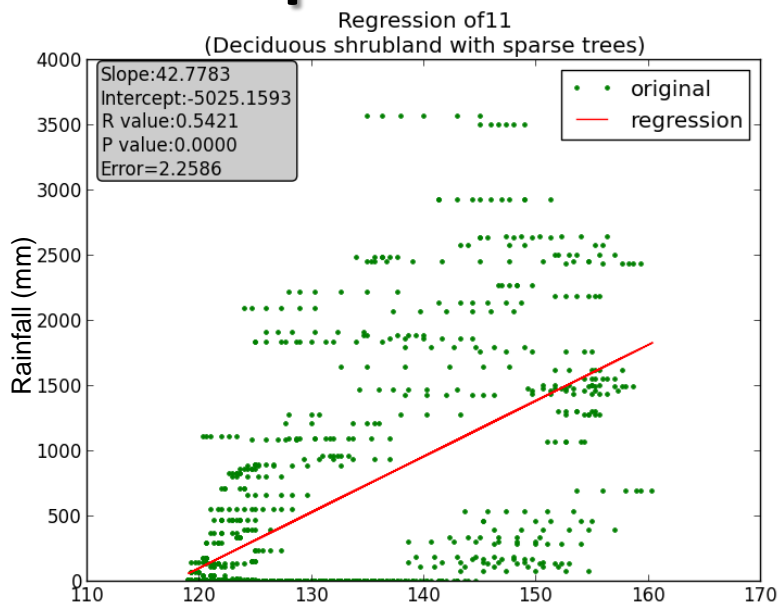
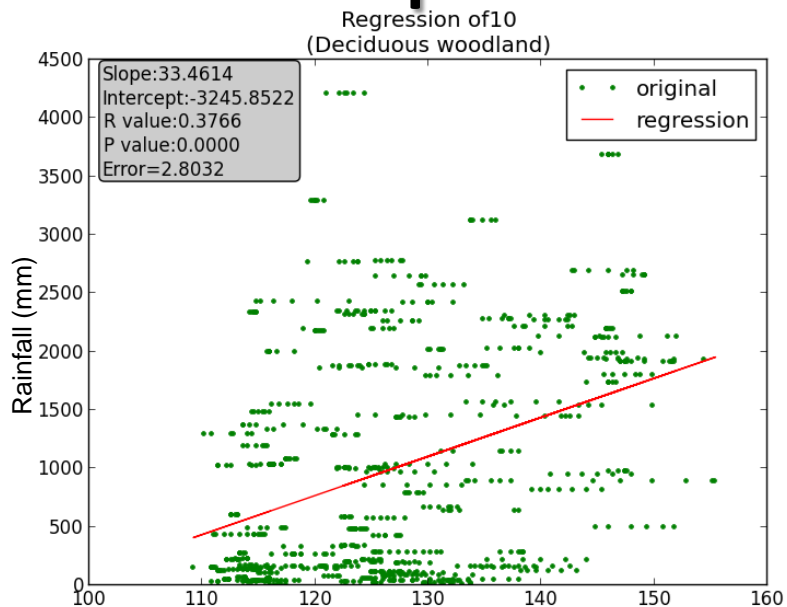
Annual Estimated Rainfall Variability



- Tropical continental climate
- Rainy season from May-Oct
- Farmers usually plant maize, soy, other



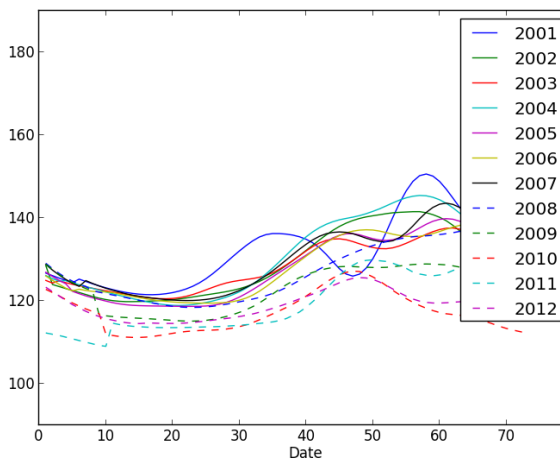
Response to Precipitation



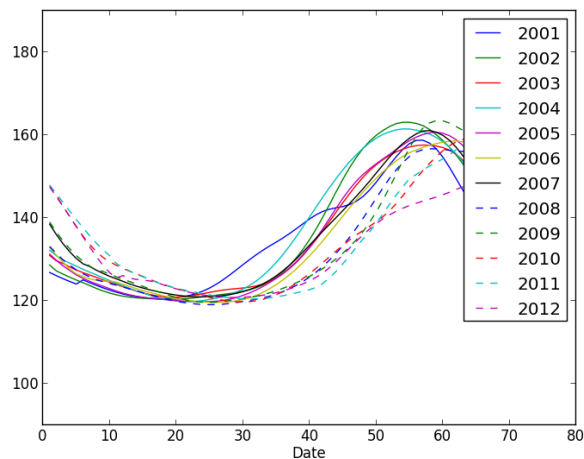


Moving Average Classes

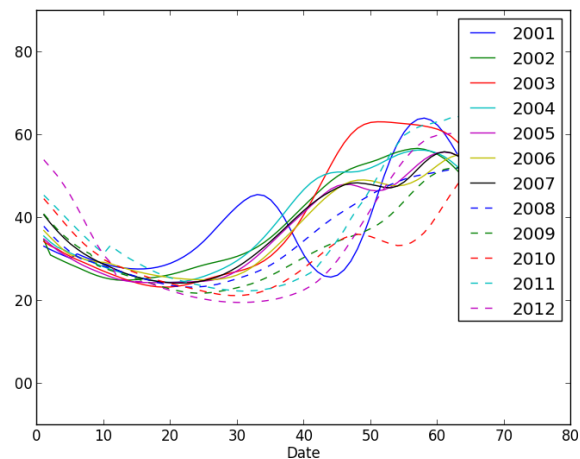
Class 01



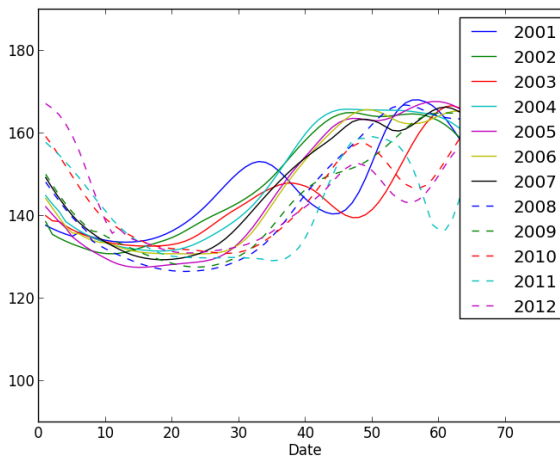
Class 02



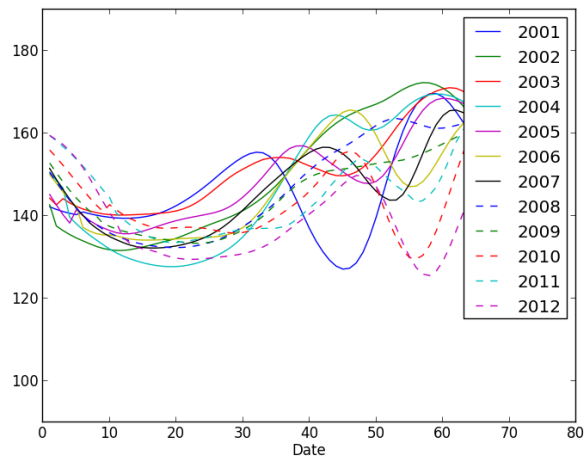
Class 03



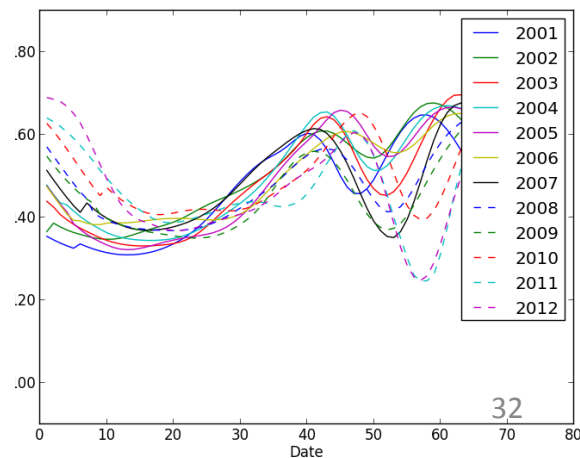
Class 07



Class 08



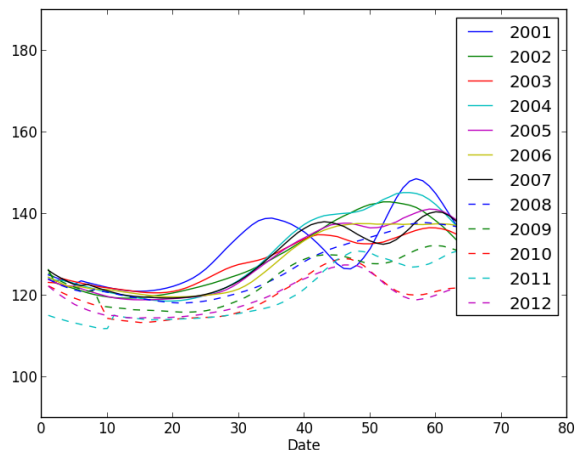
Class 09



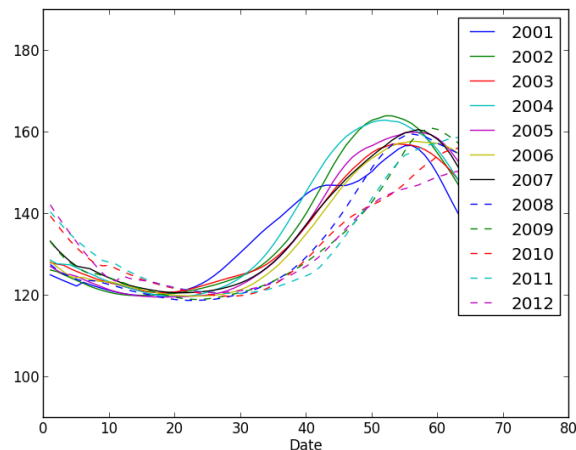


Seasonally Adjusted Classes

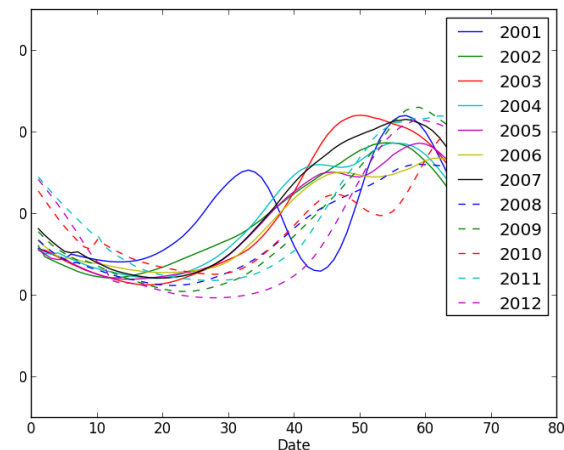
Class 01



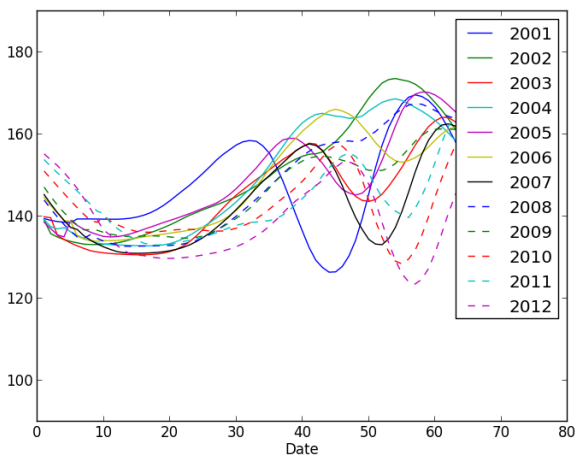
Class 02



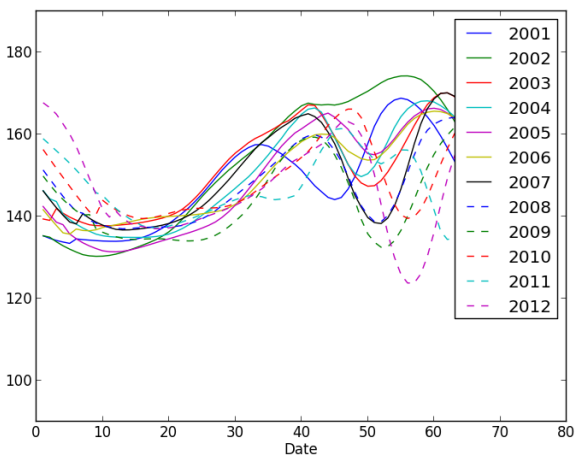
Class 03



Class 08



Class 09



Class 10

