Natural Resource Change detection in Nigeria using NigeriaSat-2 and SPOT Earth Observation Satellites

By

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PRESENTATION OUTLINE

- Background
- Methodology & Results
  - Data Selection and Processing
  - Land cover change detection
  - Image change detection
- Conclusions

Background

INTRODUCTION

- Over the years, changes in Landcover resources in Nigeria are occurring at an accelerated rate, magnitude, and spatial extent.

- The Food and Agriculture Organization (FAO) reported that Nigeria lost approximately 410,000 hectares of forest annually between 2000 and 2010, translating to a deforestation rate of 3.5% annually.

- This decline is attributed mainly to logging, agricultural expansion (particularly subsistence farming), and firewood collection.

INTRODUCTION

- Monitoring these changes is essential for appropriate policy prescription.
- Given the large area coverage of Nigeria, earth observation satellite remains the optimum approach to monitor Landcover dynamics in Nigeria.
- The integration of a Nigerian Satellite (NigeriaSat-2) and a European Satellite (Airbus Satellite Pour l'Observation de la Terre -SPOT) was used to monitor Landcover dynamics in Nigeria.
- This presentation showcase the product of Earth Observation (EO) change detection work undertaken to ascertain the extent of broad land cover changes in Nigeria since 2012 and demonstrate the utility of high resolution images from NigeriaSat-2 (N2) and SPOT for rapid change identification.

Work Flow

Summary of Work Flow

- The following activities were implemented for the project:
  - Selection of a suitable set of N2 Time 0 (T0) and SPOT Time 1 (T1) image pairs
  - Preprocessing of the image data in readiness for change detection (Ortho-rectification, spatial harmonization, and radiometric co-registration).
  - Selection of land classification scheme.
  - Preparation of the land cover maps for T0 & T1
  - Comparison of T0 & T1 land cover maps to identify changes
  - Collation of quantitative land cover and land cover change statistics
  - Qualitative observations of the land cover change
  - Execution of image change detection (T0 image to T1 image)
  - Qualitative observations of the image change utility
  - Results summary

Selection of a suitable set of N2 Time 0 (T0) and SPOT Time 1 (T1) image pairs

- The data selection aimed to identify images suitable for change detection.
- This resulted in the definition of 50 AOIs across Nigeria.
- Each AOI was chosen from two pools of images:
  - N2 from 2012-2016,
  - SPOT imagery circa 2022.
  - The average time difference between the N2 and SPOT images is: 8 years, 8 months, 14 days.
- N2: 53 images: 2.5m pansharpened (2.5m Panchromatic, 5m Multispectral), 4 band, red, green, blue, Near-Infrared (NIR)
- SPOT: 60 images: 1.5m pansharpened (1.5m Panchromatic, 6m Multispectral), 4 band, red, green, blue, NIR
- The AOIs and images were selected against a range of selection criteria.

Selection of a suitable set of N2 Time 0 (T0) and SPOT Time 1 (T1) image pairs

Criteria for Selection of AOI

- **Cloud cover**: Identifying AOIs with low or no cloud cover in both N2 and SPOT imagery.
- **Image quality**: Avoiding images with band registration and radiometric calibration concerns.
- **Minimized Seasonality variability**: Aim to find pairs of N2 and SPOT imagery with matched seasonality.
- **Spatial distribution**: Image pairs are targeted to achieve an approximately even distribution across Nigeria. The objective is a sample that is statistically representative of the whole country.
- **Sample size**: A 10x10km (100km2) area was targeted for each sample.

Selection of a suitable set of N2 Time 0 (T0) and SPOT Time 1 (T1) image pairs

The distribution of the 50 (100km2) sample AOIs.

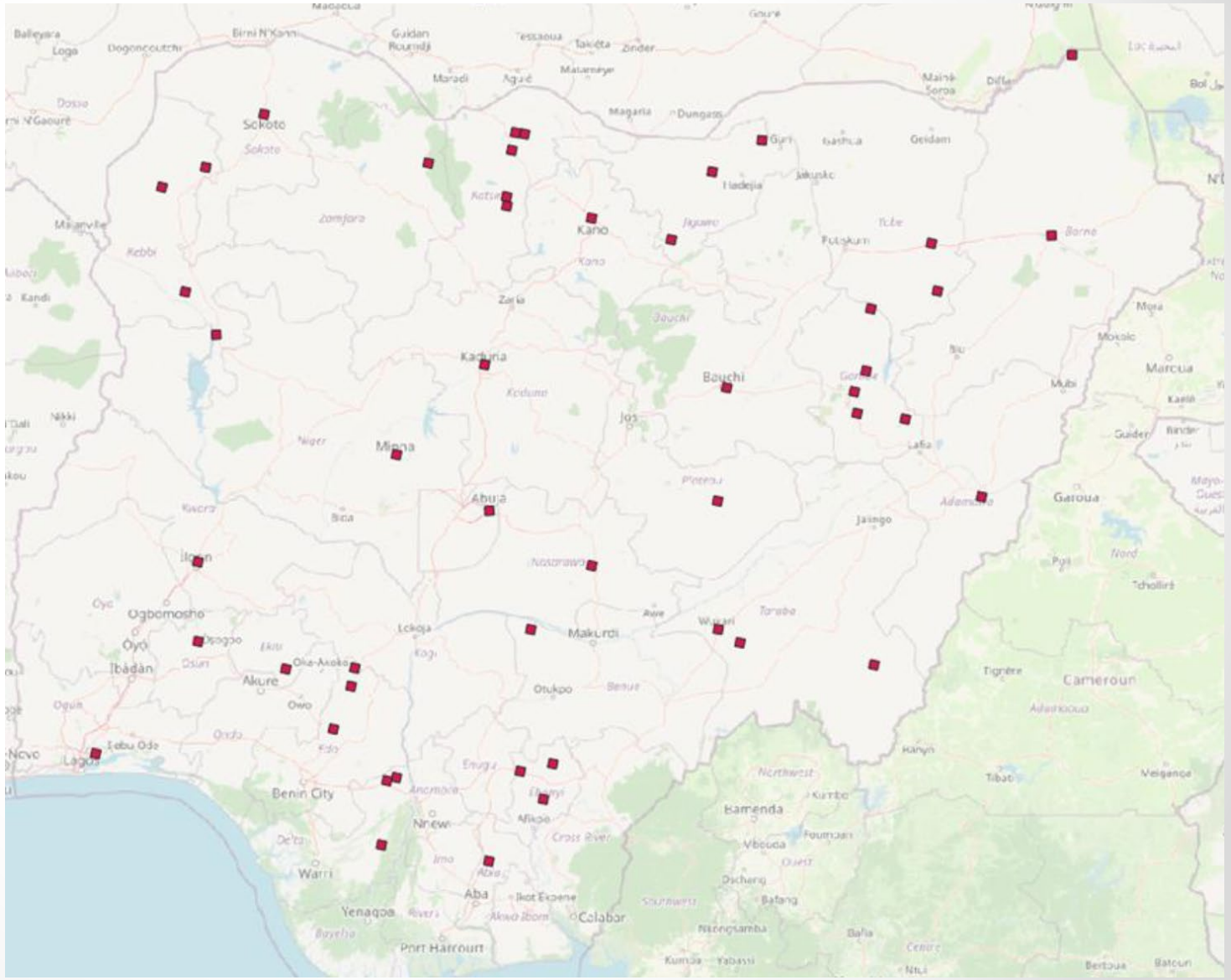


Image Preprocessing

- Orthorectification
- Spatial Resolution Harmonization of N2 and SPOT
  - Resampling SPOT spatial resolution from 1.5m to 2.5m
    : Bilinear resample to 2.5m
  - 3x3 average filter

Land cover change detection Processes

- The land cover change detection workflow is based on a two-stage process :
- Stage 1: A classification model is developed separately for both SPOT and N2, using a machine learning classifier and bespoke reference data.
- This model is used to generate probability predictions for each image, which are subsequently used as the inputs to an object-based classification.
- This approach combines the benefits of both machine learning and object-based classification methods, and is well suited to complex and heterogeneous landscapes.

Land cover change detection Processes

- Stage 2: For the land cover mapping, the image processing and probability analysis was undertaken in Python using the following libraries :
  - Rasterio for image processing,
  - Numpy for array manipulation, and
  - Sklearn for machine learning and modelling.
- The object classification was executed in Trimble eCognition, a proprietary analysis software

Land cover change detection Processes

Land cover class description

Land Cover Class	Relevant IPCC Class(es)	Notes
Forest	Forest Land	Includes all woody vegetation (trees and shrubs) with a crown identifiable in the N2 imagery
Vegetation	Cropland Grassland	Includes all other vegetation not covered by forest – no woody vegetation
Urban	Settlements	Includes buildings (residential, industrial and commercial), roads and paved areas
Water	Water/Wetland	Seasonal and permanent water bodies could not be separated based on a single image
Bare land	Other Land	Non-vegetated land that is not anthropogenic. Not included in the land cover probability mapping stage.

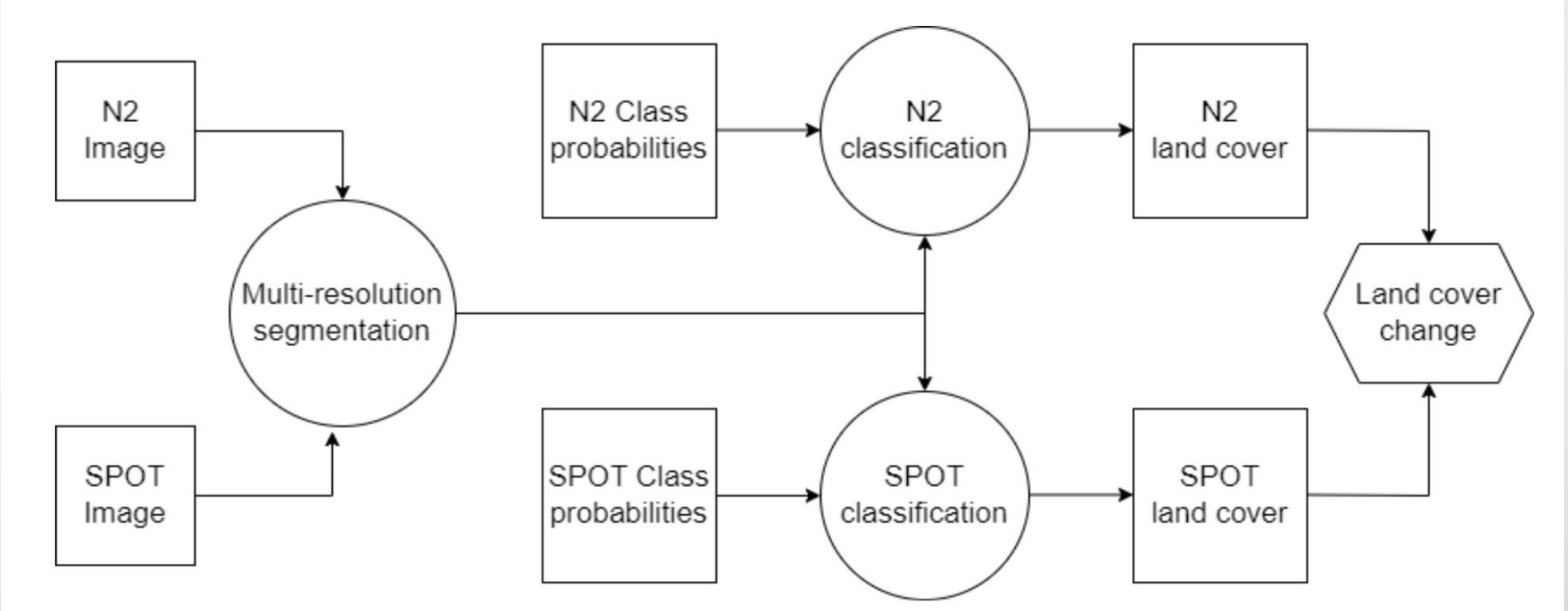
Land cover change detection Processes

Reference data collection

- The Reference data used to train and validate land cover models was collected through visual interpretation of the N2 and SPOT images.
- Polygon Geometries were digitised corresponding to the land cover schema using standard best practices for training data collection (e.g. avoiding edge pixels, ensuring homogeneous and compact objects).
- To ensure the same reference dataset could be used for both periods, N2 and SPOT images were inspected simultaneously and areas where no changes were apparent were digitised.
- Samples were collected from across all 50 AOIs.

Land cover change detection Processes

Model for the Change Analytics



Land cover change detection Processes

Model for the Change Analytics

		Forest	Urban	Vegetation	Water	Bareland
Abuja	T0	8.09%	63.81%	21.71%	0.71%	5.69%
	T1	27.48%	64.23%	3.54%	0.56%	4.19%
	Change	19.40%	0.42%	-18.17%	-0.15%	-1.50%
Akpafa	T0	65.12%	2.00%	32.10%	0.00%	0.76%
	T1	58.78%	4.32%	34.90%	0.00%	1.99%
	Change	-6.34%	2.32%	2.81%	0.00%	1.23%
Akwukwu-Igbo	T0	16.18%	6.48%	77.34%	0.00%	0.00%
	T1	15.31%	5.43%	79.26%	0.00%	0.00%
	Change	-0.88%	-1.05%	1.93%	0.00%	0.00%
Bauchi	T0	0.24%	21.56%	77.88%	0.07%	0.25%
	T1	5.68%	33.88%	60.38%	0.03%	0.03%
	Change	5.44%	12.31%	-17.51%	-0.03%	-0.22%
Besse	T0	1.87%	9.45%	87.42%	0.20%	1.06%
	T1	14.19%	12.57%	71.70%	0.54%	1.00%
	Change	12.32%	3.12%	-15.72%	0.34%	-0.06%

Land cover change detection

Land cover map results

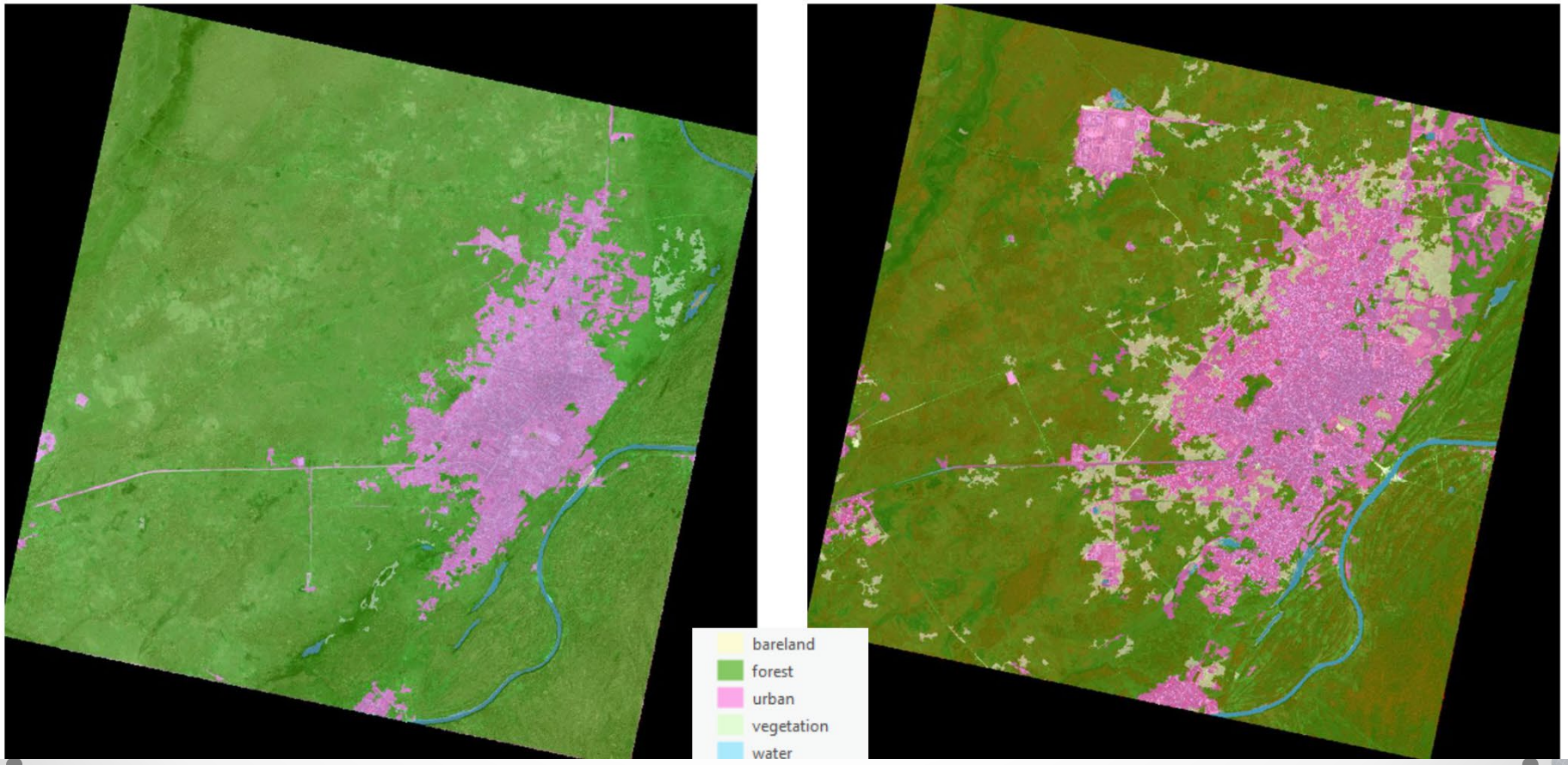
Summary of Land Cover Change Detection Results

T0 Forest	T0 Urban	T0 Vegetation	T0 Water	T0 Bareland
14.30%	16.17%	66.12%	1.04%	2.38%
T1 Forest	**T1 Urban**	**T1 Vegetation**	**T1 Water**	**T1 Bareland**
13.53%	20.11%	60.73%	1.43%	4.19%
T0 - T1 Change				
-0.76%	3.94%	-5.39%	0.39%	1.82%

Land cover change detection

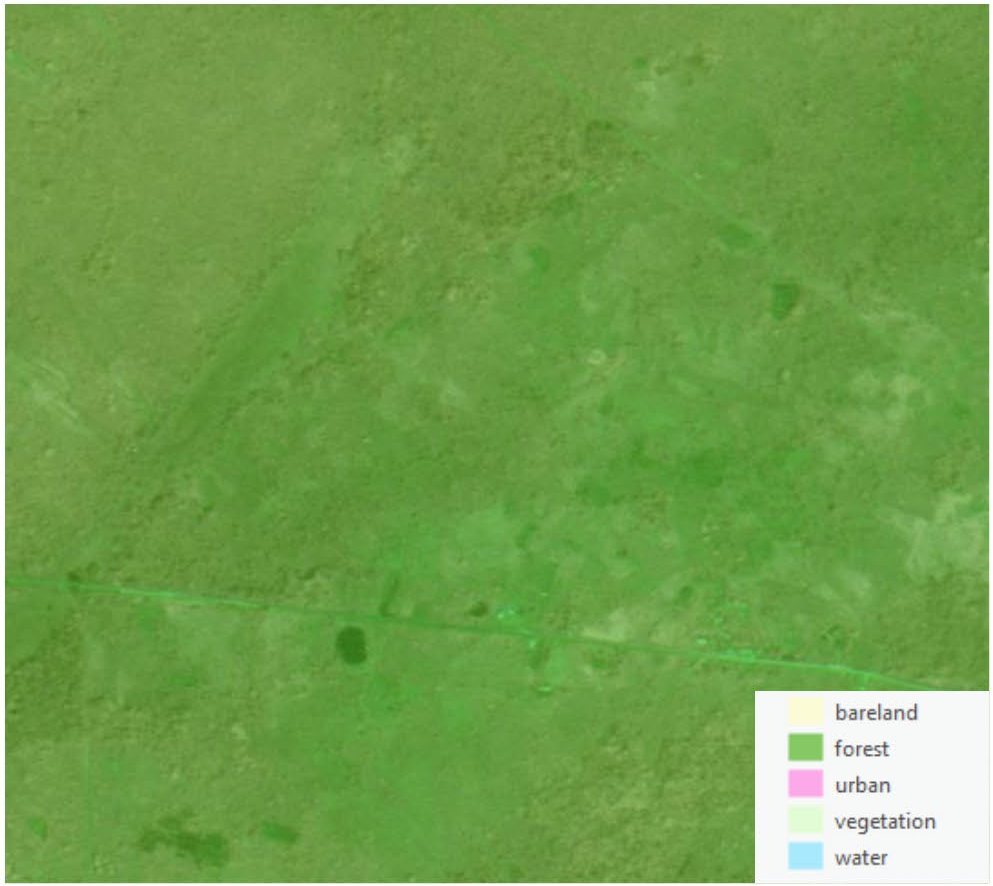
Land cover map results

Land Cover Change Detection Results - Kwale



Land cover change detection

Land Cover Change Detection Results - Kwale

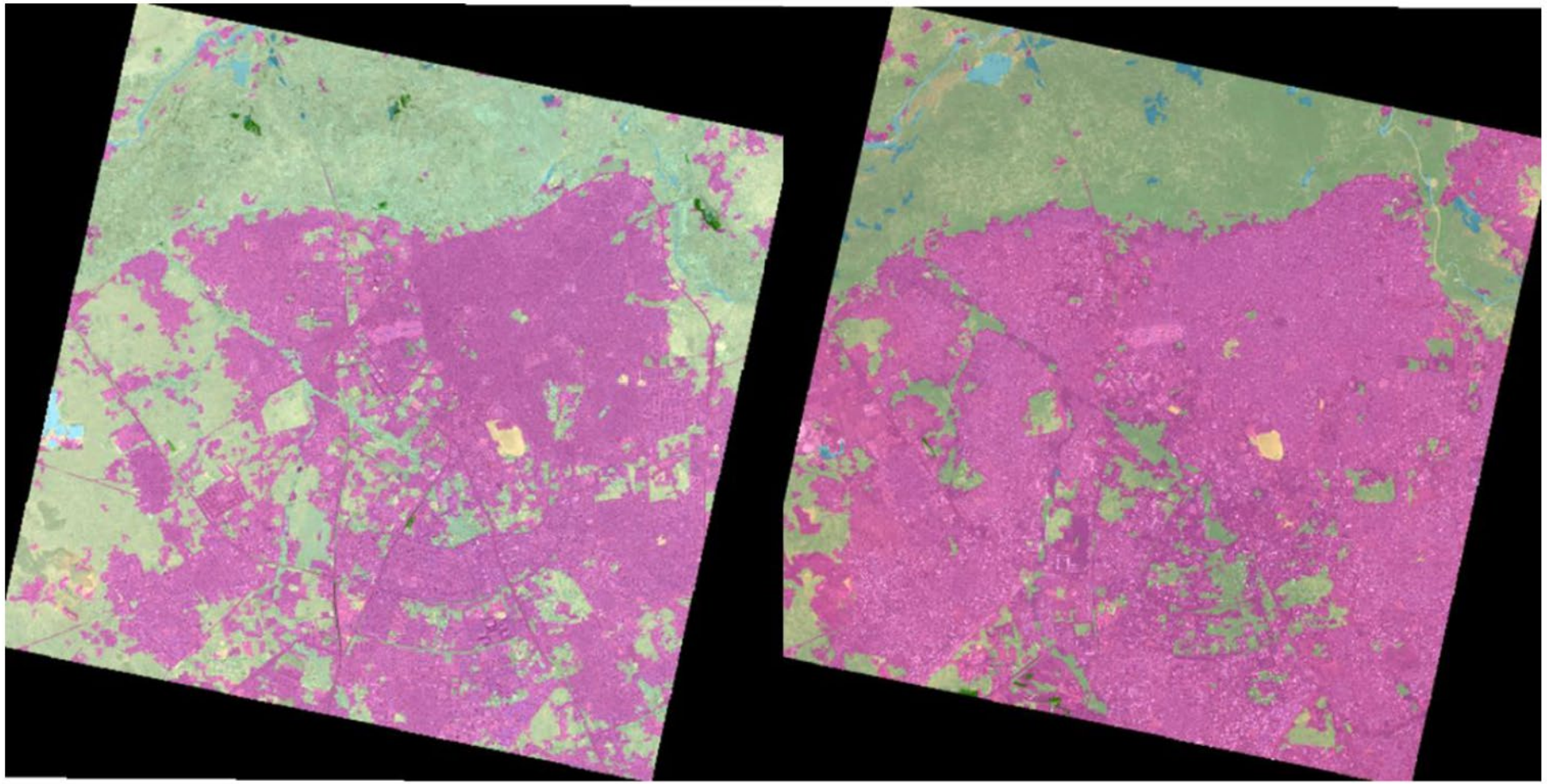


N2

SPOT

Example of new development detected near Kwale

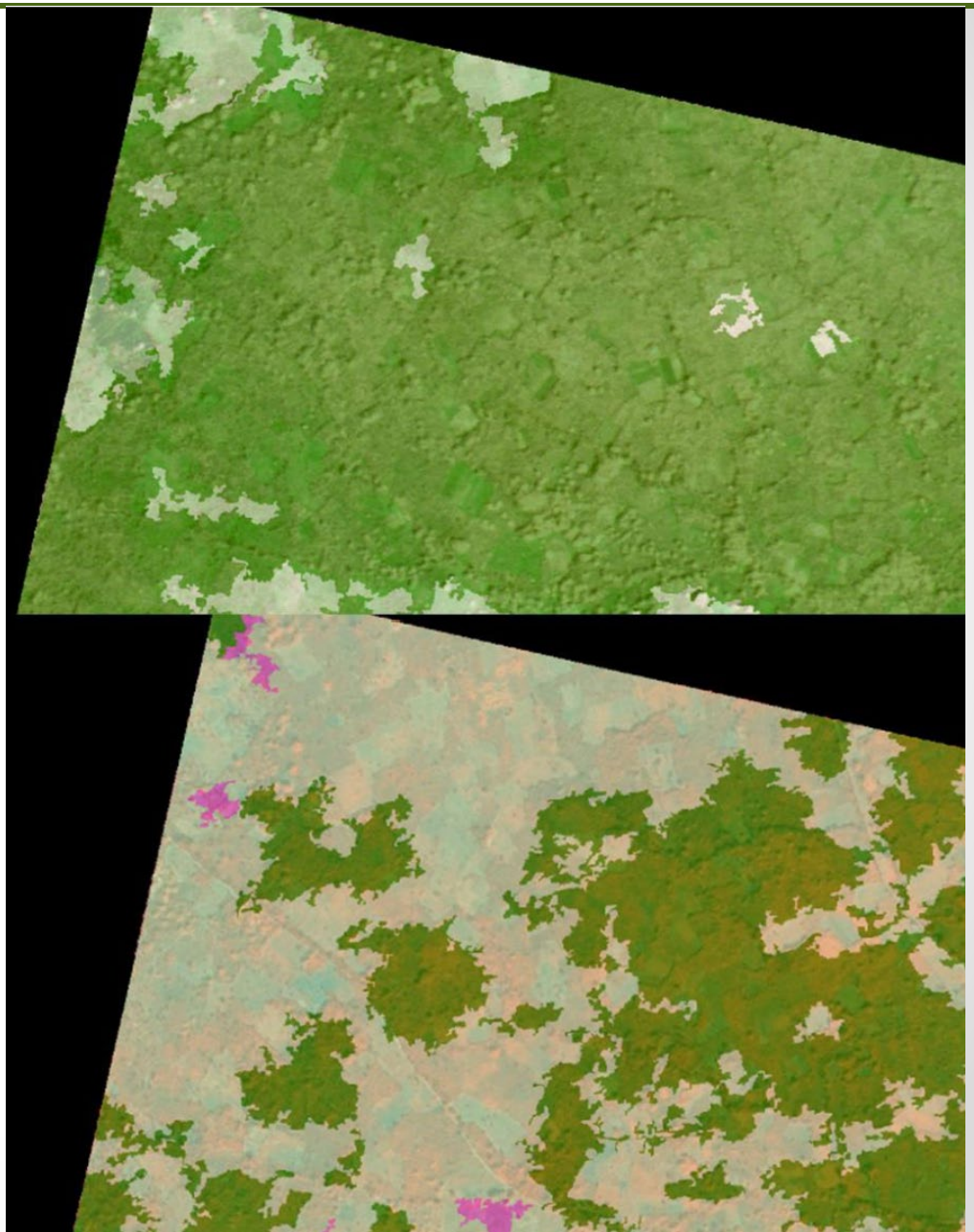
Land cover change detection



Urban Expansion in Sokoto

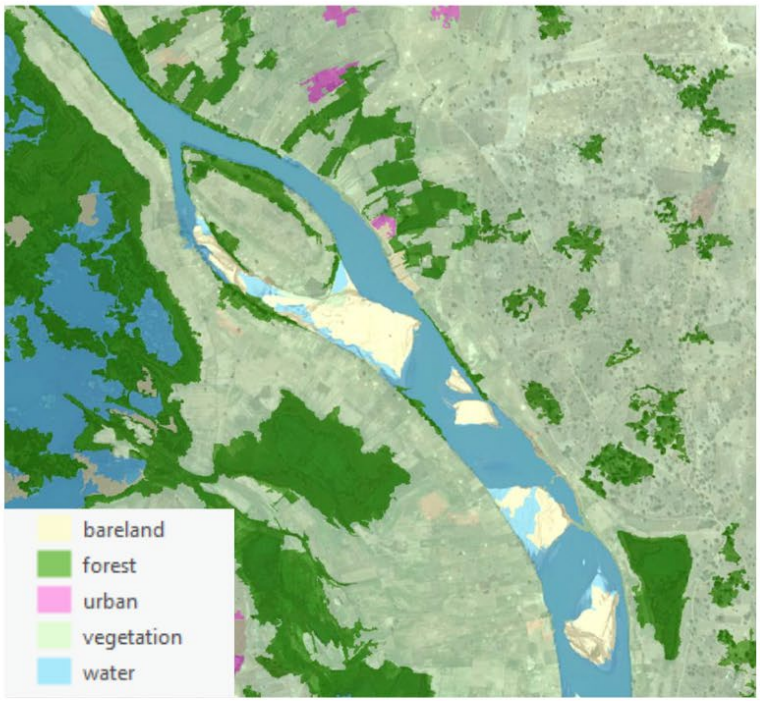
Land cover change detection

Forest to Agricultural Expansion



Land cover change detection

Changes being picked up between water and bare land as rivers migrate; and vegetation mismatches between epochs



N2

SPOT

Conclusion

- 50 AOIs and high quality N2 - SPOT images pairs were successfully identified that provide a representative sample of Nigeria with a time difference of approximately 9 years.
- The project has yielded a set of 50 image pairs processed ready for change detection that can be used in a range of follow up applications.
- The results show that urban land today occupies 3.94% more of Nigeria compared to the N2 baseline.
- The Image change detection has highlighted significant man-made change and the technology can aid image analysts to rapidly identify change for a given area.

Thank You

Land cover change detection

Accuracy Assessment

A) NigeriaSat-2

	Woody Veg	Urban	Vegetation	Water
Woody Veg	**0.56**	0.07	0.37	0
Urban	0	**0.84**	0.16	0
Vegetation	0	0.17	**0.82**	0
Water	0	0.12	0.01	**0.86**
Precision	**0.71**	**0.85**	**0.79**	**0.98**
Recall	**0.56**	**0.84**	**0.82**	**0.86**
Accuracy				**0.84**

B) SPOT

	Woody Veg	Urban	Vegetation	Water
Woody Veg	**0.85**	0.03	0.06	0
Urban	0.01	**0.91**	0.07	0
Vegetation	0.14	0.08	**0.78**	0
Water	0	0.01	0.01	**0.96**
Precision	**0.87**	**0.89**	**0.80**	**0.99**
Recall	**0.89**	**0.91**	**0.78**	**0.97**
Accuracy				**0.90**

- 50% training-testing splits, based on polygons not pixels
- All classes have high accuracy
- Main source confusion is between vegetation and woody vegetation

Data Processing

Consideration for Image Sample Selection

The 50 AOIs and their images were selected by considering the following criteria:

- The selection was made focusing on regional capitals.
- Cloud cover Consideration: Identifying AOIs with low or no cloud cover in both N2 and SPOT imagery.
- Image quality. Avoiding images with band registration and radiometric calibration concerns.
- Seasonality. Aim to find pairs of N2 and SPOT imagery with matched seasonality.
- Spatial distribution. Image pairs are targeted to achieve an approximately even distribution
- across Nigeria. The objective is a sample that is statistically representative of the whole
- country.
- Sample size. A 10x10km (100km2) area was targeted for each sample. In some
- circumstances this was not possible because of the extent of respective N2 and SPOT
- images

Image Characteristics

	NigeriaSat-2		SPOT 6 & 7	
Wave bands	**Resolution**	**Spectral range**	**Resolution**	**Spectral range**
Blue	5 metres GSD	455-520nm	6 metres GSD	450-520nm
Green		525-600nm		530-600nm
Red		635-690nm		620-690nm
Near infrared		775-900nm		760-890nm
Panchromatic	2.5 metres GSD	520-900nm	1.5 metres GSD	450-750nm

Land cover change detection

Land cover map results

Class probabilities show good representation of land cover transitions

- N2 resolution is well suited for woody cover
- Urban and water extents are very well defined

Multi-resolution segmentation used to create a basemap for both SPOT and N2 to then compare.

- Land cover probability maps are used to assign each segment a land use class
- These are then compared segment by segment and assigned a change flag:

– No Change
– Or T0 class to T1 class