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Remote Sensing: Lagos Urban Sprawl

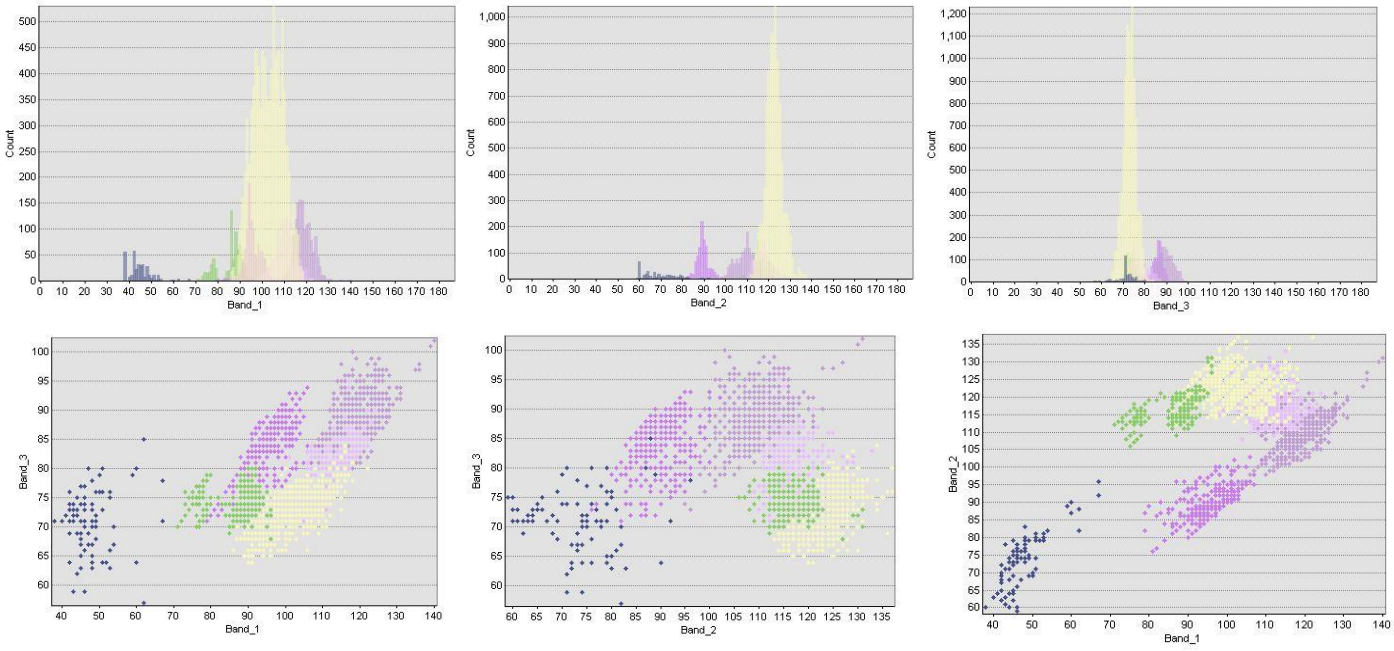
The city of Lagos in Nigeria has grown tremendously in the last decade. The United Nations (UN) estimated the city's population at 1.4 million in 1970, and that number climbed to 12.1 million by 2013. The *New York Times* estimates that Lagos is now home to 21 million people, surpassing Cairo as Africa's largest city. With a current fertility rate of 5.5 children born per woman, the population of Nigeria is predicted to surpass that of the whole of central Africa by 2050.

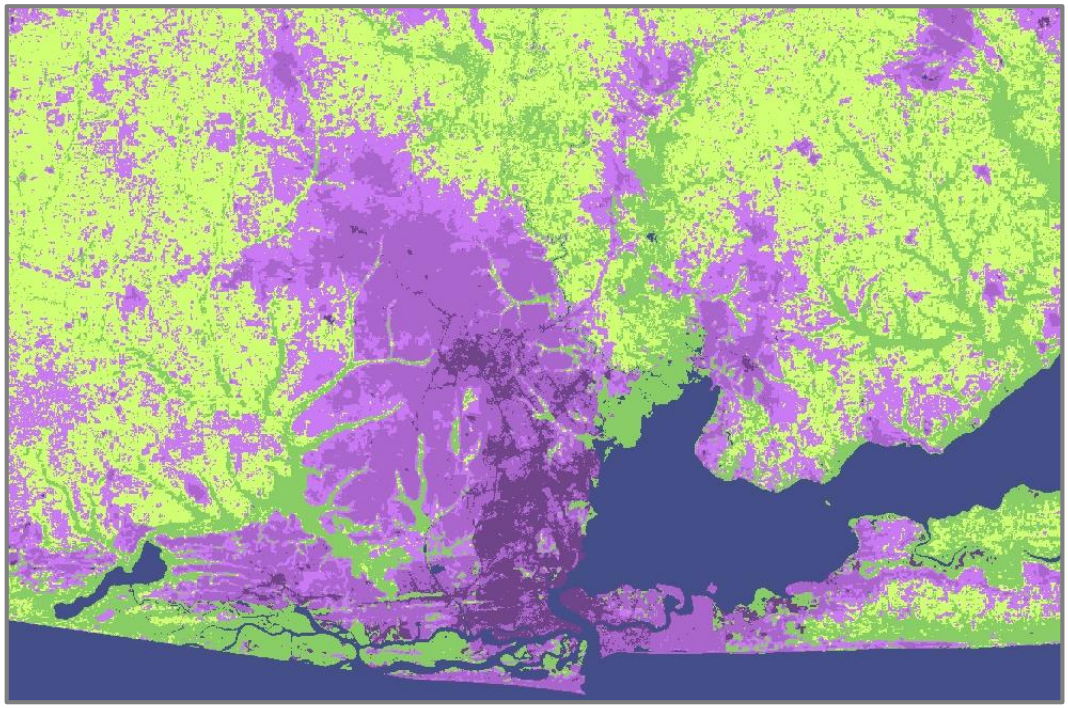
We would like to quantify how Lagos, Nigeria has sprawled over time relative to its population growth to assess the impact of this growing population boom. To accomplish this, we created the ratio of land consumption rate to population growth rate in the Lagos metro region, which is equal to: (*rate of change in new urban development between two time periods/the rate of population change between the same two time periods)*. We were able to calculate these ratios by using the following formula (we may also replace "urban development" with "population" and divide the two to obtain our final ratio):

$$\frac{New\ amount\ of\ urban\ development - Old\ amount\ of\ urban\ development}{Old\ amount\ of\ urban\ development}$$

Using LANDSAT data from December 28, 2002 (classified ***Image 1***) and December 28, 2013 (classified ***Image 2***), both with zero cloud cover to provide the most accurate representation possible, we were able to create a normalized difference vegetation index from our two images to assist in classification of land cover. Training samples were chosen by drawing circular polygons encompassing approximately 40-200 cells each and ranged from counts of 500-1500 (with the exception of two that required additional training sets). This left us with six distinct categories: water, forest & wetlands, rural & agricultural, lower density urban, medium density urban, and highest density urban. The specifications of our two training samples are described below:

The histograms for ***Image 1*** are normal with the exception of water, but show some overlap between categories (mainly rural & agricultural). Their scatterplots are quite normal, with some overlap between water and urban areas. Upon using the maximum likelihood classification tool, which performs a maximum likelihood classification on a set of raster bands and creates a classified raster as output, we observed that our results were quite accurate and decided to keep our initial training sets.





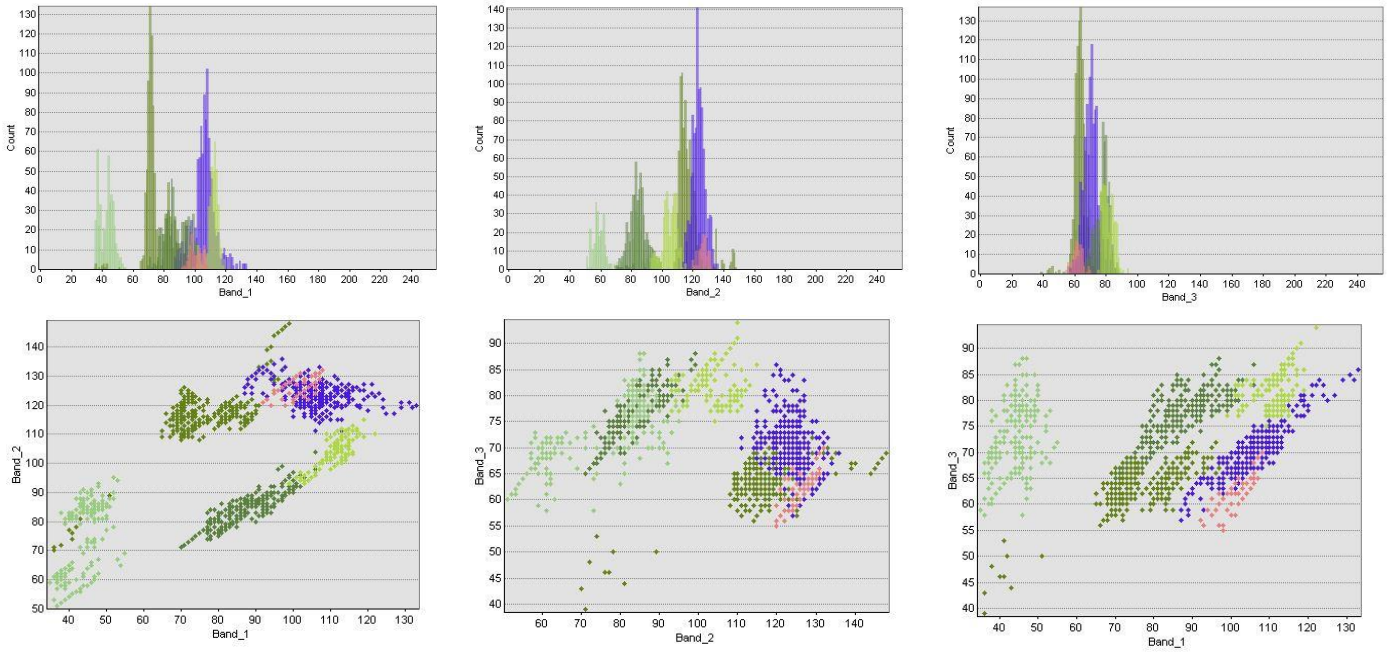
Lagos Land Classification

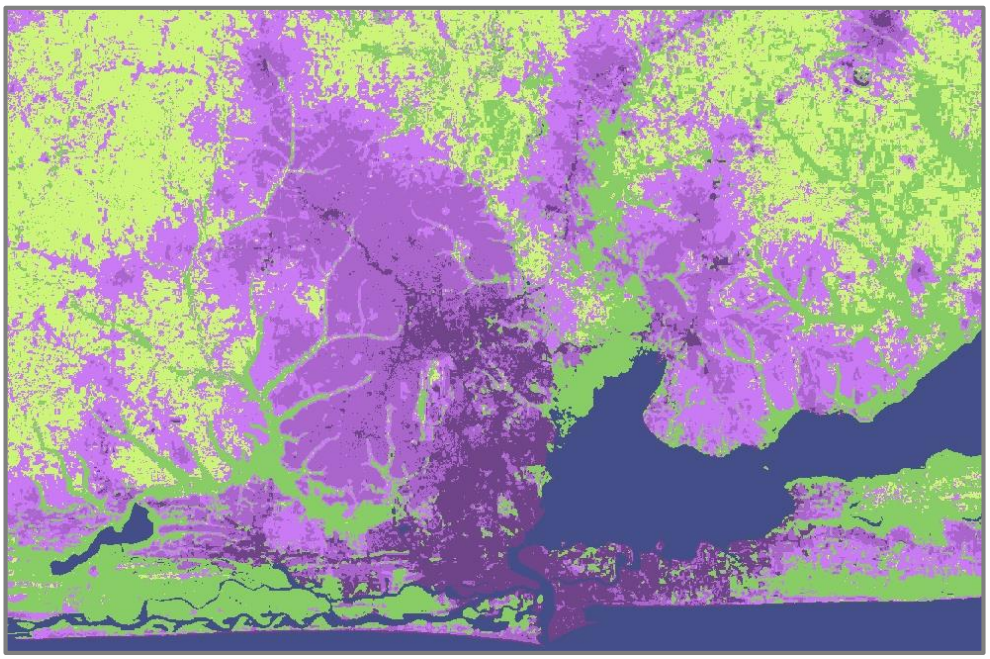
- Water
- Vegetation & Wetlands
- Lower Density Urban
- Highest Density Urban
- Medium Density Urban
- Rural & Agricultural

N

0 2.5 5 10 15 20 Miles

Histograms for ***Image 2*** are also normal, but also show some overlap in classes. To further analyze these classes, we again looked to our scatterplots for clarity. Here we saw little overlap between classes with the exception of the same trouble-making class in ***Image 1***, which we labeled Rural & Agricultural. Because the similarities of this class do not affect the urban areas as intensely, and because the maximum likelihood classification still characterized this well, we chose to keep the classifications as they were.





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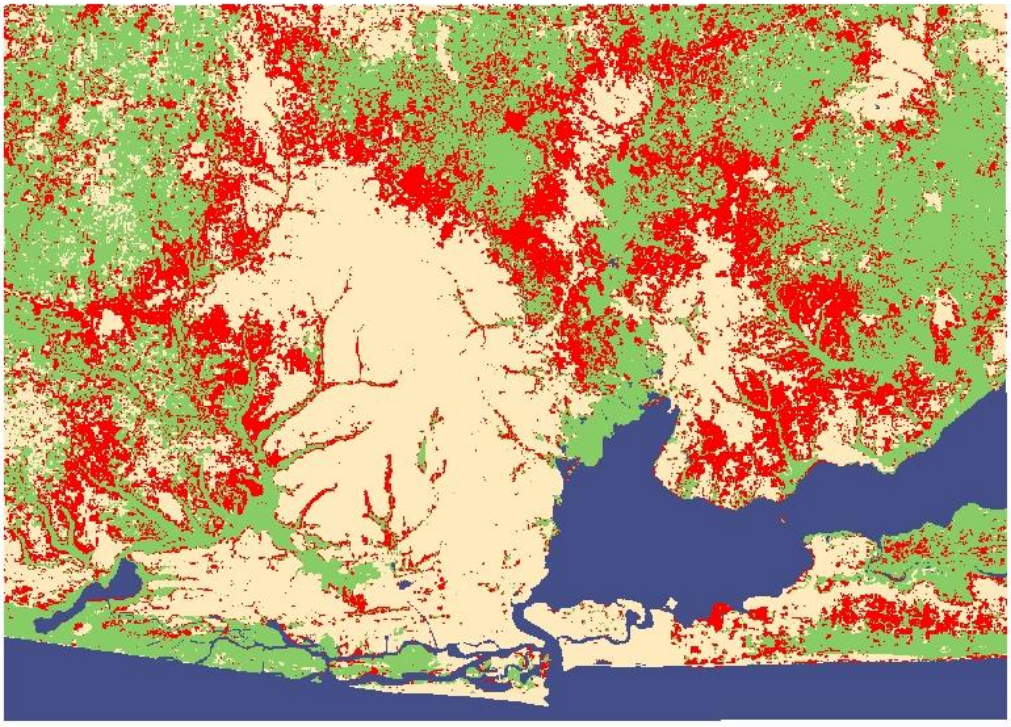
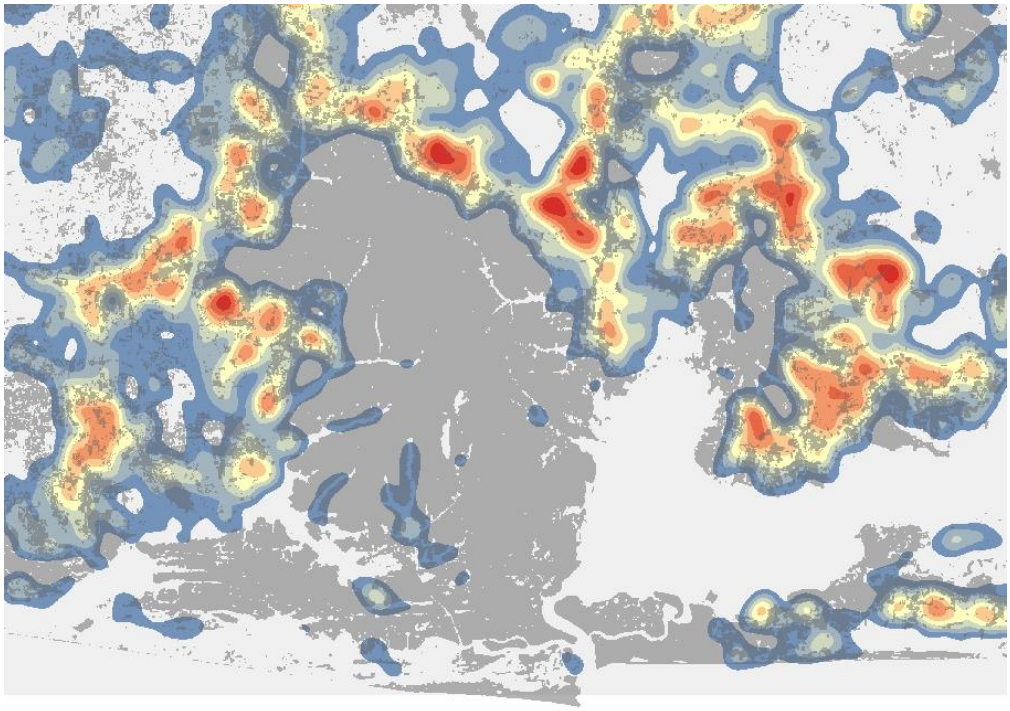
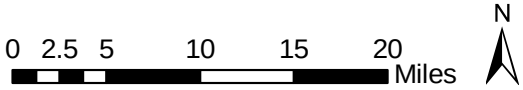
N

0 2.5 5 10 15 20 Miles

New, High-Density Urban Areas as of 2013







The images to the left show new urban growth in Lagos since 2002 (**in red**), and highest-density new urban growth (also in red). This information was obtained by subtracting our original 2002 urban area from our 2013 urban area, the combining those results.

While the first image is quite striking the kernel density map of new, high-density urban areas is of particular interest to planners because it can help assess where to focus resources to help control the recent population boom.

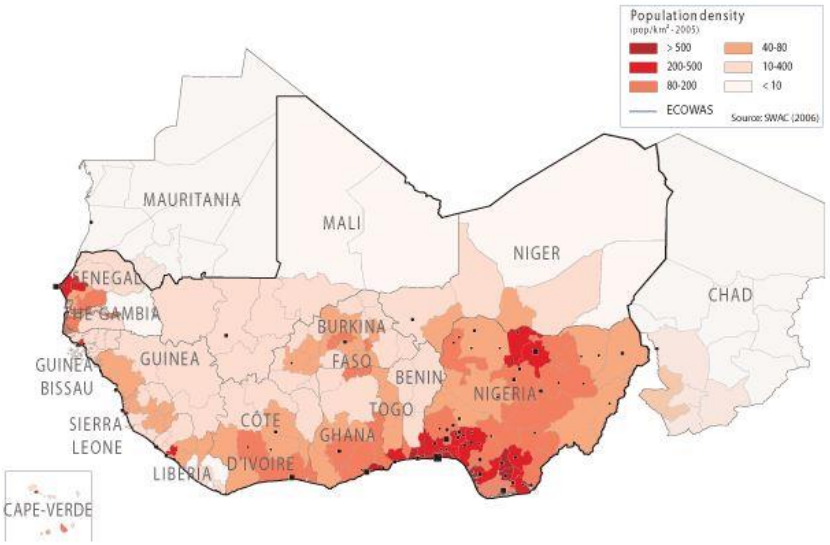
As we can see here, much of the sprawl from 2002-2013 has been concentrated on the eastern portion of the city, and branching outward in all directions from the Lagos Lagoon.

In 4235 km^2, we counted a total of 1638500 (384/km^2) cells of "urban" areas in 2002 and additional 689278 (163/km^2) urban cells in 2013. Our ratio for density, or land consumption rate, is 42.1%. This can be described as:

$$\frac{2327778 - 1638500}{1638500}$$

According to the UN, the population of Lagos was 7.875 million in 2002—this number shot to 13.862 million by 2013. Our ratio is calculated at 76%, and is described as follows:

$$\frac{13.862 - 7.875}{7.875}$$



Dividing the rate of change in new urban development between two time periods by the rate of population change between the same two time periods gives us a final ratio of **55.4%**, and leaves us with a quantifiable indication of how much Lagos sprawled over time relative to its population growth. By assessing the impact of this growing population boom, we hope to bring attention to the broader implications of urban sprawl, especially in the case of cities whose infrastructures cannot support the combination of booming populations and land use. As the population density map above illustrates, West Africa as a whole must respond to these challenges. I believe that a variety of remote sensing and image analysis techniques, such as identifying areas with the highest proportion of land consumption as seen in the kernel density map on the previous page, will assist planners and decision-makers in making the soundest infrastructural and social judgements possible for a wealth of international cities.