Household Wealth in HD: Mapping the Demographic and Health Surveys Wealth Index in Sub-Saharan African Cities with Very-High-Resolution Satellite Data

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Abstract
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The challenge

The high degree of data scarcity in countries of the Global South (GS) hinders systematic evidence-based policy making, particularly with respect to addressing the United Nations Sustainable Goals (UN SDG). At the urban level, up-to-date access to detailed demographic, socio-economic, epidemiological, and bio-physical information is a challenging task. Demographic and Health Surveys (DHS) are a rich source of such information and available in most countries of the GS. Nonetheless, modelling DHS variables for intra-urban analyses is quite challenging as they are randomly displaced to secure privacy. Here, we tackle this issue through the use of satellite derived indicators, machine learning and spatial optimization methods and apply them to model the DHS Household Wealth Index (WI) across several sub-Saharan African cities.

Methodology

Land use/land cover (LULC) information produced for the cities of Dakar (Senegal), Ouagadougou (Burkina Faso), Kampala (Uganda) and Dar es Salaam (Tanzania) are used as input to machine learning in order to predict the DHS WI. The LC maps were initially produced from processing Pleiades and Worlview-3 satellite images at a 50 centimetres resolution through a Geographic Object-Based Image Analysis (GEOBIA) framework while the LU maps are produced at the street-block level, utilizing OpenStreetMap data. All LULC maps are publicly available at Zenodo repositories. To prepare the LULC data for the proposed analysis, we extracted class proportions in buffers around the available DHS survey locations in the 4 cities. To mitigative the effects of displacements with proposed an optimization technique based on random sub-sampling of various locations within the buffers.

Results

Validation of our method in Dakar demonstrated reliable results with or without optimization. The range of agreement between our proposed models and census data at various spatial scales was moderate (correlation coefficient = 0,40-0.59). The relationships between the remotely sensed variables and the WI was mostly non-linear. Notably, LULC classes with a strong socio-economic burden (i.e., street-blocks classified as deprived, or the proportion of swimming pools) exhibited remarkable relationships with household wealth and are semantically interpretable. Consequently, we created predictive DHS WI models for all four cities (Figure 1).

Outlook for the future

A limitation of using satellite VHR information is the increased cost, image-processing knowledge and computational resources needed. Encouragingly, technological advances have allowed for large-scale computing using cloud systems which helps mitigate these issues. Future work should investigate the contribution of open-access satellite data (i.e., Sentinel 1 and 2) for modelling DHS variables, as the transferability potential of our framework will then be truly valorised. Particular focus should be given on secondary cities in the Global South, as they are in the process of rapid transformation and receive most of the current burden of the urbanization increase. Moreover, attempts to model other variables from the breadth and width of DHS information should be encouraged, as the WI is only but a small subset of the potential indicators that can be produced. Finally, the proposed methods and outputs are aimed to enhance evidence-based policy making and help relevant organization, authorities and stakeholders to drive policies and actions in support of the most vulnerable populations.

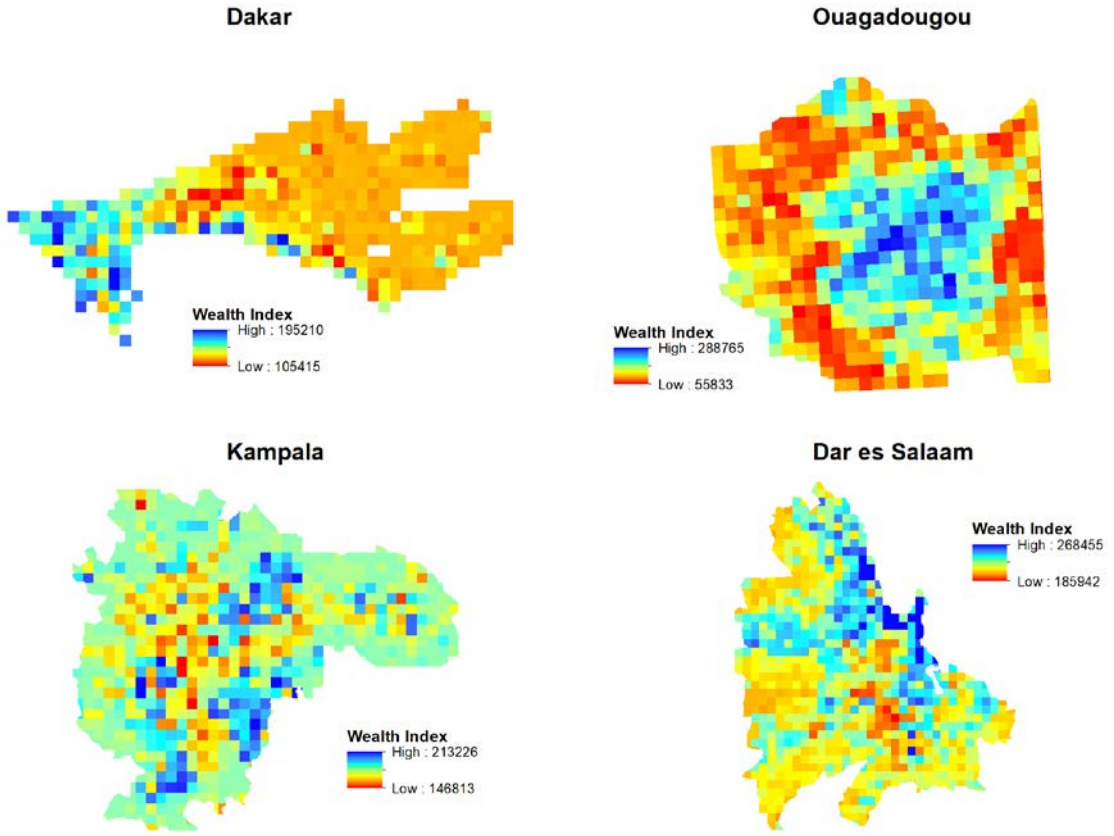

Figure 1. Predicted Wealth Index at a 1-kilometer spatial resolution, across four Sub-Saharan African cities.