The last urban frontier: Assessing drivers of urbanization and tradeoffs among social and ecosystem services associated with LCLUC in Africa

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BACKGROUND

Urbanization continues to be one of the leading drivers of Land Cover Use Change (LCLUC) globally, although African countries appear to be at the forefront of these current urban expansion trends. To date, the study of urbanization and its impacts has occurred at two very different scales and resolutions: (1) Large scale (regional, national, or global), lower resolution (≥30m pixels) urbanization patterns, and (2) small scale (city, neighborhood, parcel), high resolution (~1m pixels) studies of urban heterogeneity. One approach is good for understanding urban growth, while the other method's strength enables scientists to analyze landscape quality, human-environmental interactions, and trade-offs in ecosystem services. This project aims to merge these divergent characterizations of urbanization using a multi-tiered framework so that we can capture large scale urbanization processes, while still quantifying the heterogeneity and quality of urban land uses across three African case study countries: Ethiopia, Nigeria, and South Africa. Furthermore, with this approach we can capture diverse multi-functional land uses within and around cities that provide important ecosystem services to people near and far.

PROJECT OBJECTIVES

1) Data fusions for enhanced moderate resolution LCLUC classifications (tiers 1 and 2);
2) Identify "LCLUC hotspots" using the SDG indicator 11.3.1 and assess trade-offs and synergies of social and ecosystem services;
3) Moderate and VHR data fusion for fine resolution LCLU and change detection within focal urban hotspots (tier 3);
4) Assess the equitable distribution of social and ecological services within focal urban hotspots to support policy and sustainable planning.

Sustainable Development Goal 11:
Make cities and human settlements inclusive, safe, resilient and sustainable.

Target 11.3: *By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management by all countries.*
Indicator 11.3.1 – *Ratio of land consumption rate (LCR) to population growth rate (PGR).*

Formulas:
LCR = LN(Area of urban extent t1/Area of urban extent t2) / Years between t1 and t2

PGR = LN(Total population t1/Total population t2) / Years between t1 and t2

11.3.1 Ratio = LCR / PGR

Target 11.7: *By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.*
Indicator 11.7.1 – *Average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities.*

Formulas:
11.7.1 Ratio = (Public open space area + area of streets) / Total area of urban agglomeration

Figure 1. SDG goals and indicators included within our project analyses.

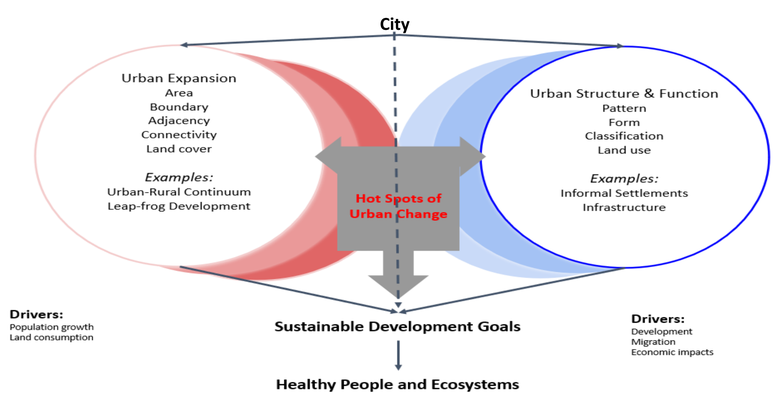
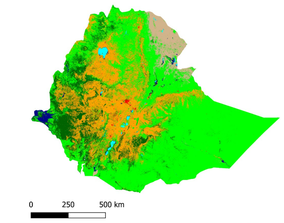
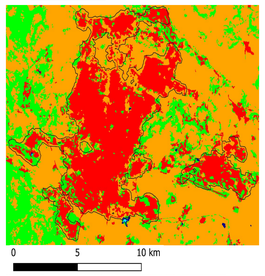


Figure 2. Changes within cities can happen at multiple scales and represent both expansion of the city footprint, as well as changes within the current city footprint. Identifying hotpots of urban change may benefit from the inclusion of factors from both types of change. Such efforts are best supported by a multi-tiered framework of land use as well as finer resolution land cover change mapping.

3-TIERED LCLU MAPPING (2016-2020)

We are developing a multi-resolution data fusion framework for LCLUC mapping which will dissect the urban agglomeration into more refined land cover driver urban classes with fine resolution identification of features and resources within classes. Spatial products will support the assessment of United Nations defined Sustainable Development Goal (SDG) indicators, identify hotspots of urbanization-driven LCLUC, and aid in sustainable urban planning for equitable access to services. These frameworks will also include change detection within each tier (*not presented here*).





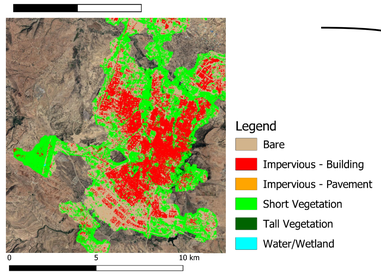
TIER 1: Land Use Mapping

National extents & 30m resolutions

Annual LU maps across our 3 countries using a hybrid mapping approach. Some spatial and temporal filtering within post-processing steps has helped with map performance not reflected in prelim model results below. *Only showing Ethiopia results for space.*

PRELIM Ethiopia LU Accuracies			
	User	Producer	Harmonic Mean
Agriculture	0.78	0.66	0.72
Developed	0.74	0.46	0.57
Forest	0.99	0.70	0.82
Rangeland	0.70	0.76	0.73
Bare	0.73	0.84	0.78
Water	0.94	0.99	0.97
Wetland	0.61	0.56	0.58
TOTAL			0.75

Predictor Sets
- Landsat 8
- Sentinel 1
- VIIRS Nightlight
- Topography
- Bioclimatic



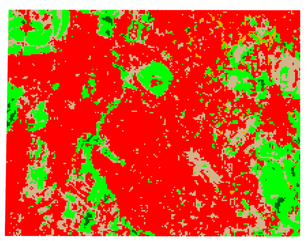
TIER 2: Urban Land Cover Mapping

City extents & 10m resolutions

Dissecting the "red blobs" of single development class LU maps. Annual LC maps within all cities identified in our automated delineation of cities. Finer resolutions and LC driven classes better represent the heterogeneity across urban environments and inform ecosystem service assessments. .

PRELIM Ethiopia Urban LC Accuracies			
	User	Producer	Harmonic Mean
Barren	0.68	0.32	0.44
Building	0.63	0.86	0.73
Pavement	0.7	0.35	0.47
Veg_short	0.85	0.98	0.91
Veg_tall	0.89	0.46	0.61
TOTAL			0.79

Predictor Sets
- Sentinel 2
- Sentinel 1
- Topography
- Bioclimatic



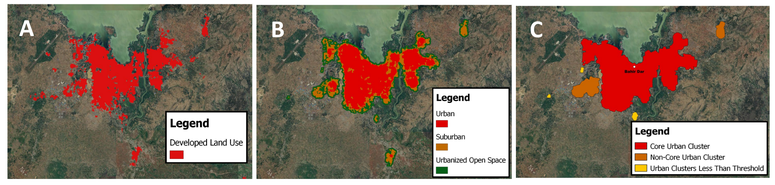
TIER 3: VHR Land Cover Mapping

Focal "Hotspot" Cities, VHR objects

Within focal identified "hotspots" of urban LCLU, we will employ an OBIA approach to develop fine resolution LCLU products and quantify changes and trends across the last 5 years

AUTOMATED DELINEATION OF URBAN BOUNDARIES

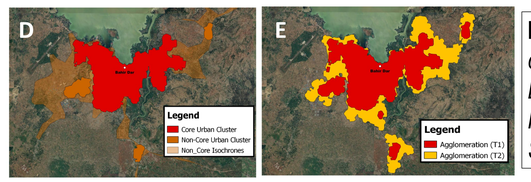
A first step for many urban LCLUC assessments, including supporting the calculation of SDG 11.3.1, is he delineation of urban boundaries in a repeatable and robust way that can be applied consistently across space and time. Considering cities are constantly growing at innumerable temporal and spatial rates and undertake a diversity of forms, the creation of a globally consistent approach has proven a complex and arduous task. Our work pairs an adapted urban classification method with open source datasets and tools to identify functionally connected urban areas to examine trends across urban agglomerations, main cities, satellite cities and connected small cities and towns across national extents.



There are several steps to determine the extent and configuration of a city for multi-date change detection among other applications.

A->B: We utilize the Atlas of Urban Expansion definitions to classify developed pixels into three types – urban, suburban and rural determined by the proportion of developed pixels within the Walking Distance Circle (approximately a ten-minute walk from the focal pixel to the edge of the circle).

B ->C: Once potential urban extent clusters are extracted, we then classify each cluster by various characteristics, resulting in a classification of core clusters and non-core clusters.



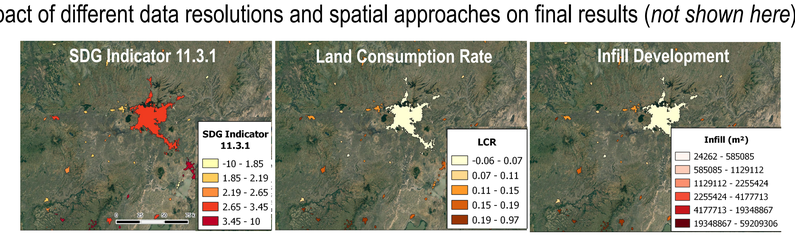
F *We can now calculate change rates and patterns.*
Land Consumption Rate = 0.15
Pop Growth Rate = 0.024
SDG 11.3.1 Ratio = 6.3

C->D: We then use isochrone mapping to associate clusters and identify what primary cores are within a certain travel distance of each other.

D->E: 5. This gives us a rough estimate of our urban extent which we call the unconfigured agglomeration. We can apply this method across different years, as well as employ various overlap analyses and filters to make sure clusters and cores are comparable across years.

IDENTIFYING URBAN LCLUC "HOTSPOTS"

A major goal of this research is to contribute to the comprehension of SDG Indicator 11.3.1 and its role as an indicator of rapid change "hotspots" (as well as to contribute to inputs and analyses of additional SDG indicators). We also want to evaluate the value of incorporating multiple measures of urban patterns and change into our "hotspot" analyses, and test for the impact of different data resolutions and spatial approaches on final results (*not shown here*).



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