Urban Population Dynamics and Climate Change in Africa

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Africa is projected to add 1,000,000,000 urban residents by 2050 (UN-DESA 2018). In tandem, climate change is creating a host of challenges for Africa's burgeoning urban areas. Sea-level rise threatens coastal neighborhoods and extreme rainfall events are flooding low-income residential areas (Douglas *et al*. 2008). Persistent drought in leaving cities without sufficient water (Grasham *et al.* 2019) and decreasing crop productivity is amplifying food security concerns for urban areas (Tacoli 2013). Many urban Africans struggle to keep cool during frequent extreme heat waves (Ceccherini *et al.* 2017). What is more, climate change may be amplifying urban population growth in drying regions across Africa (Henderson *et al*. 2017, Brückner 2012, Barrios 2006). This convergence of climate change and rapid urban population growth not only threatens African countries' ability to achieve the United Nations Sustainable Development Goals, but also portends increased political instability for many countries across the continent.

Our ability to develop solutions for the duel threat of urban population growth and climate change is stymied by a lack of municipality-level population data for Africa. We simply do not know how many people live in most African cities and towns, much less understand how they are growing over time (Potts 2018, Borel-Saladin 2017, Cohen 2004). Census data is infrequently publicly available, often unreliable, and rarely offered at the municipality level. *At present, gridded population datasets present the only avenue to map and compare urban populations across all African countries using consistent data*. No other geo-located population data can be readily incorporated with climatological data to assess the spatiotemporal relationships between climate change and urban population dynamics.

Key Points

- For most developing countries, gridded population data offers *the only* fine scale, geolocated and consistent population data from which we can map urban populations across Africa.
- OpenStreetMap data provides a way to validate where urban settlements are within gridded population datasets.
- Gridded population data is well-suited for integration with spatiotemporal climate data.
- Users of gridded populations, especially those outside human-settlement research domains, must be aware of the limitations of gridded population datasets. Users should be transparent with how these population estimates are being used. The word *estimate* is key here.

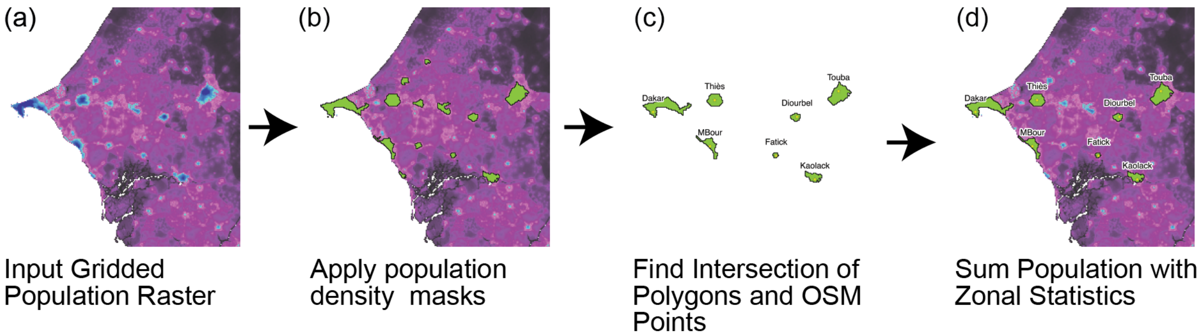

Figure 1 Workflow of method to intersect urban settlement 1,500-300 persons per km^2 density mask from gridded population raster dataset with associated labeled OSM urban point data to estimate the population of individual urban settlements in Africa. Figure from Tuholske *et al*. 2019.

Identifying Urban Populations within Gridded Population Data

Since the 1990s, researchers have generated synthetic gridded population datasets to overcome the lack fine-scale population data across the planet. Yet it is not possible to directly estimate the population of individual urban settlements with these data sets alone. The data are available in raster format, providing a continuous plane of population counts that do not delineate political boundaries or labels. Furthermore, the methodologies and input data used to generate gridded population data sets vary. Finally, we do not have the ability to independently estimate the accuracy of population counts within gridded population datasets.

Table 1 Spatial agreement/disagreement OSM urban settlement point locations with masked 1500-300 persons / km2 urban settlement polygons isolated in gridded population datasets. Table from Tuholske *et al*. 2019.

	GHS-Pop 2000	GHS-Pop 2015	WorldPop 2015	LandScan 2015	WPE 2016
Masked 1500-300 persons / km^2 urban settlement polygons	45,303	46,100	12,453	28,663	30,532
OSM “towns” that do not intersect with masked 1500-300 persons / km^2 urban settlement polygons out of 8,863 total OSM “towns”	3,441	3,025	5,612	3,704	3,692
OSM “cities” that do not intersect with masked 1500-300 persons / km^2 urban settlement polygons out of 950 total OSM “cities”	119	104	197	45	92
Masked 1500-300 persons / km^2 urban settlement polygons that intersect with one or more OSM urban settlement points and have >5,000 people*	4,486	4,784	2,536	4,045	4,167

Volunteered geographic information (VGI) from OpenStreetMap provides a novel avenue to map urban settlement populations with gridded population datasets (Tuholske *et al*. 2019). Within the OSM typology, 'places' are known population settlements, or 'nodes', labeled as either a 'city', 'town', or 'village'. At present, OSM point data lists 950 cities and 8,863 towns in Africa. OSM urban point data can be used to validate the locations of urban areas within gridded population datasets (Fig. 1). First, a population density threshold[1] is applied to a gridded population dataset to isolate urban from non-urban populations in a gridded population dataset. These urban areas are then turned into polygons and intersected with OSM urban point data. All urban settlement polygons that spatially intersect with one or more OSM city or town

[1] Strict population density thresholds are not necessarily the only criteria that identify urban settlements versus rural, nor do settlements necessarily follow a strict urban–rural dichotomy. But few alternatives exist when using gridded population datasets.

point are retained. All else are dropped (Table 1). The retained urban settlement polygons are then overlaid on the original raster to calculate the population for each settlement polygon using zonal statistics.

Intersecting OSM urban polygons with gridded population datasets produces consistent and comparable geo-located estimates of urban population for over 4,500 urban locations in Africa. But it also allows reveals variation among gridded population datasets and highlights potential modeling artifacts within gridded population datasets. For example, when using established urban population density thresholds[2] over 45,000 individual 'urban' areas are identified in Africa using the Global Human Settlement Layer Population dataset (GHS-Pop). Surely this is an extreme over-estimate of urban areas in Africa (Table 1). Intersecting OSM point data provides a way to validate that an urban settlement actually exists within a gridded population dataset. The resulting urban settlements can then be used to assess urban population distributions. (see Tuholske *et al.* 2019).

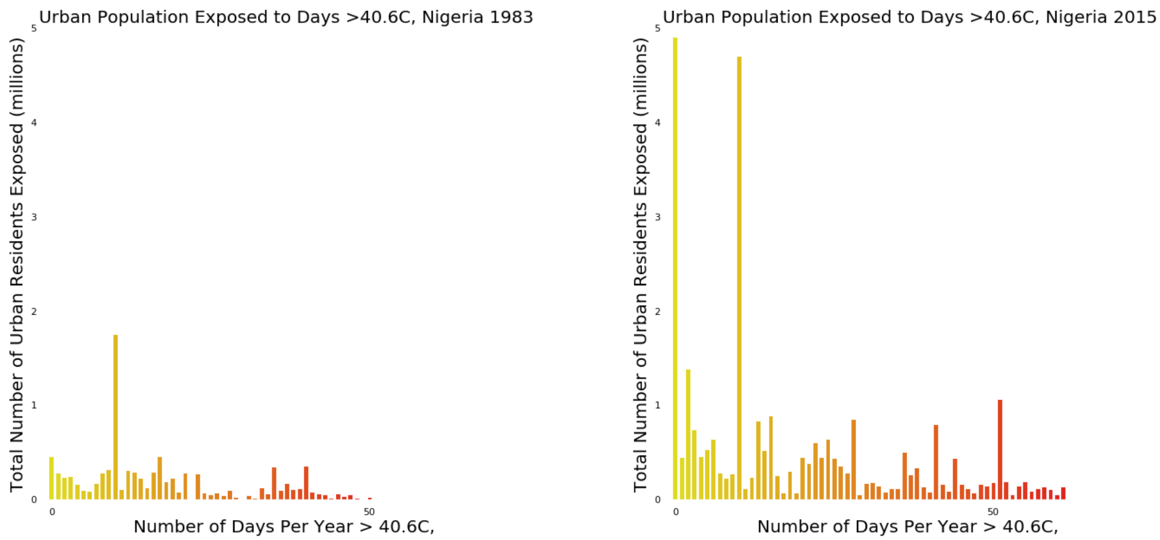

Figure 3 Number of days per year over 40.6 C (105 F) to which urban populations in Nigeria are exposed in 1983 and 2015, using CHIRTSmax and Global Human Settlement Layer Urban Centers Database data (GHS-UCDB). The United States Weather service defines an extreme heat event as any day with a maximum temperature greater than 105 degrees Fahrenheit

Climate Threats & Urban Population Dynamics

Gridded Population datasets offer an exceptional opportunity to study how climate change is affecting urban populations. Once urban areas have been identified in gridded population datasets, geospatial climatological datasets can easily be integrated. By way of example, gauging urban population exposure to extreme heat events across Africa is a key component to overall urban risks to climate change. To this end, the Climate Hazards Center at the University of California, Santa Barbara, recently released the Climate Hazards Center Infrared Temperature with Stations data set (CHIRTSmax). This dataset is a quasi-global (60S-60N), high resolution (0.05 degree, ~5 km2) maximum temperature data set that combines station data and geostationary satellite temperature observations (Funk *et al.* 2019). Intersecting CHIRTSmax daily temperature maximum with urban areas identified in gridded population datasets provides a unique window that can support the evaluation of urban population exposure to extreme heat at high spatial and temporal scales (Fig. 2). Without gridded population data, this type of analysis would not be possible and

[2] The European Union degree of urbanization (DEGURBA) classification for high-density urban areas (cities), or urban cores, is 1,500 people per km^2 and lower-density urban clusters (towns and suburbs) have a minimum of 300 people per km^2.

policymakers, across levels of governance, would have little ability to anticipate how extreme temperatures are affecting urban populations across Africa.

But researchers must be fully transparent about the caveats and limitations of integrating these datasets. Like climatological data, gridded population datasets are our best estimates of urban populations and contain uncertainty. They should be treated as such. For example, the CHIRTSmax datasets covers only land surface temperatures (Fig 3). Calculating average maximum daily temperature maximum across the areal extent of an urban area that overlap CHIRTSmax ocean pixels will likely over-estimate average maximum temperatures. Cooler temperatures along coastal areas of the urban settlement will not be included in the average. It is imperative that these types of caveats are clearly both recognized and clearly presented by researchers using gridded population estimates.

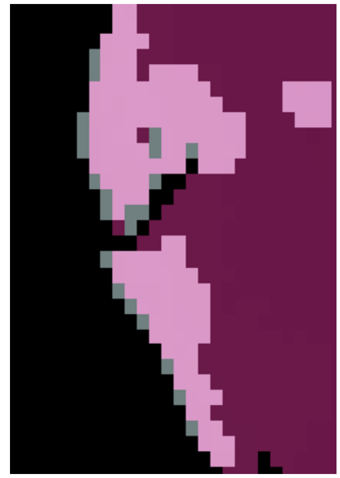

Figure 3 Coastal CHIRTSmax pixels overlaid with GHS-UCDB data near Tampa, FL. Black pixels are ocean, light pink are urban areas, dark pink are rural areas, and gray pixels are urban areas that overlap with ocean CHIRTSmax pixels.

Concluding Remarks

Given rapid urbanization across Africa, accurate and fine-scale measurement of urban populations is key to understanding how urban areas will respond to climate change. While gridded population datasets do have limitations, they offer the best available data to identify and map urban populations. OpenStreetMap data can assist with this endeavor. Such integrated geospatial approaches are required to advance our understanding of complex, human-natural systems if we are going to develop sustainable solutions for the myriad of problems climate changes poses for Africa's urban population.

References

Barrios, S., Bertinelli, L., & Strobl, E. (2006). Climatic change and rural–urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics*, *60*(3), 357-371.

Borel-Saladin, J. (2017). Where to draw the line: Data problems and other difficulties estimating urbanisation in Africa. *Development Southern Africa*, *34*(2), 137-150.

Brückner, M. (2012). Economic growth, size of the agricultural sector, and urbanization in Africa. *Journal of Urban Economics*, *71*(1), 26-36.

Ceccherini, G., Russo, S., Ameztoy, I., Marchese, A. F., & Carmona-Moreno, C. (2017). Heat waves in Africa 1981–2015, observations and reanalysis. *Natural Hazards and Earth System Sciences*, *17*(1), 115-125.

Cohen, B. (2004). Urban growth in developing countries: a review of current trends and a caution regarding existing forecasts. *World development*, *32*(1), 23-51.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., McLean, L., & Campbell, J. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. *Environment and urbanization*, *20*(1), 187-205.

Funk, C., Peterson, P., Peterson, S., Shukla, S., Davenport, F., Michaelsen, J., ... & Rowland, J. (2019). A High-Resolution 1983–2016 T max Climate Data Record Based on Infrared Temperatures and Stations by the Climate Hazard Center. *Journal of Climate*, *32*(17), 5639-5658.

Grasham, C. F., Korzenevica, M., & Charles, K. J. (2019). On considering climate resilience in urban water security: A review of the vulnerability of the urban poor in sub-Saharan Africa. *Wiley Interdisciplinary Reviews: Water*, *6*(3), e1344.

Henderson, J. V., Squires, T., Storeygard, A., & Weil, D. (2017). The global distribution of economic activity: Nature, history, and the role of trade. *The Quarterly Journal of Economics*, *133*(1), 357-406.

Potts, Deborah. "Urban data and definitions in sub-Saharan Africa: Mismatches between the pace of urbanisation and employment and livelihood change." *Urban Studies* 55.5 (2018): 965-986.

Tacoli, C. (2013). Urban poverty, food security and climate change. *IIED Briefing Paper-International Institute for Environment and Development*, (17149).

Tuholske, C., Caylor, K., Evans, T., & Avery, R. (2019). Variability in urban population distributions across Africa. *Environmental Research Letters*.

UN-DESA 2018 World Urbanization Prospects 2018 https://esa.un.org/unpd/wup/ (Accessed: 30 August 2018).