**Understanding Temporal Hotspots of Population Growth Using WorldPop Data and ArcGIS Pro’s Space-Time Pattern Mining**

**Abstract**

Nigeria is experiencing rapid and spatially uneven population growth, which presents major challenges for sustainable planning and equitable service delivery. Sectors such as education, healthcare, housing, and infrastructure are increasingly pressured by shifting demographic patterns. However, conventional data sources provide only aggregated or static views of population distribution, limiting the ability of planners and policymakers to respond effectively to emerging needs, especially at the local levels of Local Government Areas (LGAs) and electoral wards.

To address this gap, this study utilizes WorldPop’s gridded population estimates at 100m resolution covering the period 2015 to 2030. These estimates are informed by national census data and aligned with United Nations projections (2020–2030), offering both historical and forward-looking views of population dynamics. We applied zonal statistics to aggregate the annual raster population data to both LGA and ward boundaries, allowing us to monitor changes at multiple administrative levels across Nigeria.

We then employed ArcGIS Pro’s Space-Time Pattern Mining tools, particularly Emerging Hot Spot Analysis (EHSA) and Time Series Clustering, to identify temporal patterns and spatial hotspots of population change. This enabled the detection of areas showing persistent, intensifying, sporadic, or diminishing growth or decline, as well as regions undergoing significant demographic shifts. By integrating both the spatial and temporal dimensions, the analysis reveals granular population trends that are often missed in national-level statistics.

This high-resolution, multi-scale analysis offers critical insights into where population pressure is increasing or decreasing, particularly in urbanizing, peri-urban, and underserved rural areas. The results can support more targeted planning and resource allocation, ensuring that infrastructure, healthcare, education, and social services are directed to where they are most needed.

By combining projected population data with advanced spatial and temporal analysis in ArcGIS Pro, this study demonstrates a replicable, data-driven approach for monitoring population trends and supporting proactive, equitable development in Nigeria. The integration of both LGA and ward-level analysis ensures that decisions are informed at both strategic and operational scales, contributing to more inclusive and spatially informed planning.

**Introduction**

Nigeria is Africa’s most populous nation, experiencing rapid and spatially uneven population growth that poses major challenges for sustainable development and service delivery. Globally, population growth is concentrated in less developed regions, with over half of world population increase between 2020 and 2050 projected to occur in sub-Saharan Africa (United Nations, 2019). Nigeria exemplifies this trend: its population, currently over 220 million, is growing at approximately 2.5% annually and is expected to reach 340–360 million by mid-century, making it the world’s third most populous country (United Nations, 2019). This growth exerts intense pressure on infrastructure, education, healthcare, housing, and other services (WHO, 2023). Critically, this expansion is geographically uneven, urban centers such as Lagos and Abuja are booming due to migration and high fertility, while rural and conflict-affected areas grow more slowly or even lose population. This imbalance exacerbates regional inequalities in access to schools, clinics, water, and roads (Weber et al., 2018).

Traditional data sources in Nigeria struggle to address these challenges. The country’s last national census was conducted in 2006, and subsequent planned censuses have faced repeated delays (Weber et al., 2018). As a result, population counts at local levels remain outdated, and aggregated national statistics often mask local realities, limiting effective planning for Local Government Areas (LGAs) and electoral wards, the administrative units where service delivery occurs (Tatem, 2017).

In this context, high-resolution gridded population datasets offer a powerful alternative for mapping and monitoring demographic change. WorldPop, an academic consortium, produces detailed spatial demographic data by integrating census, survey, satellite, and other inputs (Tatem, 2017). WorldPop’s openly available datasets provide estimated population counts on a 100×100 m grid, continuously updated and aligned with official United Nations figures (WorldPop, 2020). These products have “enhanced the accuracy and detail of population estimates, especially in areas where traditional census data are outdated or unavailable” (HDX Team, 2025, p. 2). Their availability makes it possible to detect localized population trends that are often obscured in aggregated statistics.

This study builds on this foundation by leveraging WorldPop’s high-resolution gridded population data and advanced spatio-temporal analytics to uncover local population dynamics across Nigeria. We focus on two administrative levels, LGAs and wards, to capture both broader district trends and finer community-level changes. By analyzing annual population estimates from 2015 to 2030, we identify areas where population pressures are intensifying or abating in the recent past and near future. Detecting these patterns is crucial for targeted interventions such as education, healthcare, and infrastructure delivery (Weber et al., 2018).

**Literature Review**

**Population Data for Development Planning**

A key challenge in development planning is obtaining reliable, up-to-date population data at fine spatial scales. Many low- and middle-income countries, including Nigeria, have censuses that are infrequent and quickly outdated, while vital registration systems are incomplete (Tatem, 2017). This data gap undermines planning: as Tatem (2017) notes, everything from “planning for elections, calculating per-capita GDP, to measuring demand for services” depends on knowing how many people live in each locality (p. 3).

Nigeria’s situation illustrates these issues. The 2006 census recorded about 140 million people, but political and logistical hurdles have delayed subsequent censuses, so official local populations remain static in records, even as the country has grown by more than 80 million people (Weber et al., 2018). Agencies like the UN and World Bank provide population estimates, but these do not capture subnational distributions.

To address this gap, high-resolution gridded datasets have emerged globally, such as the Gridded Population of the World (GPW), LandScan, and most recently, WorldPop (Tatem, 2017). WorldPop’s approach uses machine learning-based dasymetric mapping, disaggregating census counts into 100 m grid cells using remote sensing, land use data, roads, and settlement footprints (WorldPop, 2020). These datasets are calibrated to UN Population Division totals each year, ensuring consistency (United Nations, 2019).

The utility of these datasets is widely documented. For instance, Weber et al. (2018) demonstrated how “census-independent” population estimates could be developed for northern Nigeria using satellite imagery and micro-surveys, producing credible 90 m resolution maps. Leasure et al. (2020) similarly employed a Bayesian framework to integrate sparse data sources and create uncertainty-aware population maps in Nigeria.

WorldPop data have been adopted in numerous humanitarian and development contexts. The UN OCHA Humanitarian Data Exchange now hosts over 1,000 WorldPop datasets used for estimating populations at risk in crises (HDX Team, 2025). These data are flexible, they can be aggregated to any boundary (e.g., LGAs, wards, disaster zones) or integrated with other spatial layers such as flood risk maps (HDX Team, 2025).

**Spatio-Temporal Analysis and Hotspot Detection**

Recent advances in spatio-temporal analysis allow researchers to move beyond static snapshots and examine trends over time. The ArcGIS Pro Emerging Hot Spot Analysis (EHSA) tool extends the Getis-Ord $Gi^\*$ statistic into the time dimension, identifying whether hotspots (clusters of high values) or coldspots (clusters of low values) are new, intensifying, persistent, or diminishing (Cheng-Chia, 2020). This method has been used in crime analysis, housing vacancy (Morckel & Durst, 2023), and environmental change monitoring.

Time Series Clustering, also in ArcGIS Pro, groups locations with similar temporal trajectories using $k$-means or $k$-medoids algorithms (Cheng-Chia, 2020). This can reveal common trend patterns, such as rapid urbanization versus gradual rural decline. While these tools have been underutilized in demography, they are well-suited to exploring population change when applied to multi-year gridded datasets.

**Materia and Method**

**Study Area**

The study area is Nigeria, located in West Africa between latitudes 4°N and 14°N and longitudes 3°E and 15°E. It is bounded to the north by Niger Republic, to the east by Chad and Cameroon, to the west by the Benin Republic, and to the south by the Atlantic Ocean’s Gulf of Guinea. Nigeria is strategically situated on the Gulf of Guinea coastline, which supports its role as a regional economic hub and a key transit corridor in West Africa (National Population Commission [NPC], 2006).

Nigeria has a total land area of approximately 923,769 km², making it Africa’s 14th largest country by area (World Health Organization [WHO], 2023). The country operates a three-tier administrative structure: 36 states and the Federal Capital Territory (FCT), 774 Local Government Areas (LGAs), and 8,809 electoral wards (also called political or registration wards), which represent the lowest formal administrative units (Independent National Electoral Commission [INEC], 2022).

Each state comprises multiple LGAs, and each LGA is subdivided into several wards. These wards serve as the primary units for electoral administration, community-based planning, and grassroots service delivery. Population distribution across these units is highly heterogeneous, with densely populated urban wards in major metropolitan areas like Lagos, Kano, and Abuja contrasting sharply with sparsely populated rural wards in northern and riverine regions (Weber et al., 2018).

According to Nigeria’s most recent national census conducted in 2006, the country had a total population of 140,431,790 persons, comprising 71,345,488 males and 69,086,302 females (NPC, 2006). The most populous state at that time was Lagos State with 9.0 million people, while Bayelsa State was the least populated with 1.7 million people (NPC, 2006). By 2023, the United Nations estimated Nigeria’s population to have surpassed 220 million, reflecting an annual average growth rate of approximately 2.5% (United Nations, 2019; WHO, 2023). This makes Nigeria the most populous country in Africa and the seventh most populous globally.

The country’s population is unevenly distributed, with major urban centers such as Lagos, Abuja, Kano, Port Harcourt, and Ibadan exhibiting very high population densities, often exceeding 4,000 persons per square kilometer. In contrast, arid northern states such as Yobe and Borno and riverine areas of the Niger Delta have lower population densities (Weber et al., 2018). The large spatial disparities in population distribution across states, LGAs, and wards underscore the need for fine-grained population data to support equitable planning and service delivery.

**Data Sources and Aggregation**

We used WorldPop’s annual 100 m resolution gridded population datasets for Nigeria (2015–2030) as the primary data source (WorldPop, 2024). These datasets redistribute official national and subnational counts into grid cells using covariates such as land cover, settlement footprints, and infrastructure (WorldPop, 2020). Each year’s dataset is adjusted to match the UN Population Division’s national totals (United Nations, 2019).

To analyze population change at the LGA and ward levels, we obtained boundary shapefiles from Nigeria’s National Population Commission, Independent National Electoral Commission, and UN OCHA COD datasets. We used ArcGIS Pro’s Zonal Statistics tool to aggregate grid cell counts to each administrative boundary for each year (2015–2030). This yielded annual population totals for all 774 LGAs and ~8,800 wards.

**Space-Time Pattern Mining**

We structured the aggregated data into ArcGIS Pro’s space-time cube format. Each LGA and ward was treated as a location with a time series of annual population change values (i.e., year-to-year difference).

1. Emerging Hot Spot Analysis (EHSA): We ran EHSA on both the LGA and ward cubes using the 15 nearest neighbors to identify statistically significant hotspots and coldspots of population growth or decline (Cheng-Chia, 2020). Areas were classified as new, intensifying, diminishing, sporadic, persistent, or no pattern, with a 95% confidence threshold.
2. Time Series Clustering: We applied the Time Series Clustering tool using the Profile (Correlation) mode, normalizing each time series and allowing the tool to determine the optimal number of clusters (Cheng-Chia, 2020). Clusters were mapped and interpreted as distinct patterns of population change.

**Validation and Limitations**

We compared WorldPop-derived 2020 LGA populations against official estimates where available, and tested EHSA with different neighborhood definitions. Results were robust, but we note that gridded population estimates carry inherent uncertainty, especially for projected years (WorldPop, 2024). EHSA results are also scale-sensitive, so we analyzed both LGAs and wards to mitigate this limitation.

**Result and Discussion**

**Conclusion**

**References**

Cheng-Chia, H. (2020, August 3). Analyzing your temporal data with the Time Series Clustering tool in ArcGIS Pro. Esri ArcGIS Blog.

HDX Team. (2025, March 25). WorldPop’s Population Estimates on HDX. Centre for Humanitarian Data (OCHA) Blog.

Morckel, V., & Durst, N. (2023). Using Emerging Hot Spot Analysis to explore spatiotemporal patterns of housing vacancy in Ohio metropolitan areas. Urban Affairs Review, 59(2), 309–338. https://doi.org/10.1177/10780874211056777

Tatem, A. J. (2017). WorldPop, open data for spatial demography. Scientific Data, 4, 170004. https://doi.org/10.1038/sdata.2017.4

United Nations, Department of Economic and Social Affairs, Population Division. (2019). World Population Prospects 2019: Highlights. New York: United Nations.

Weber, E. M., Seaman, V. Y., Stewart, R. N., Bird, T. J., Tatem, A. J., McKee, J. J., ... & Reith, A. E. (2018). Census-independent population mapping in northern Nigeria. Remote Sensing of Environment, 204, 786–798. https://doi.org/10.1016/j.rse.2017.09.030

World Health Organization. (2023). Nigeria: Population Data. WHO Data Repository.

WorldPop. (2020). Nigeria 100m Population Dataset (UN Adjusted) [Data set]. University of Southampton.

WorldPop. (2024). WorldPop 2015–2030 Gridded Population Estimates (R2024) [Data set]. University of Southampton.

Independent National Electoral Commission (INEC). (2022). National Register of Electoral Wards. Abuja: INEC.

National Population Commission (NPC). (2006). 2006 Population and Housing Census of the Federal Republic of Nigeria. Abuja: NPC.

United Nations, Department of Economic and Social Affairs, Population Division. (2019). World Population Prospects 2019: Highlights. New York: United Nations.