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Spatial analysis and autocorrelation of population growth in Zamboanga Sibugay Province: A GIS-based analysis from census data and projections

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Key words: Population dynamics, Spatial analysis, Geographic information system, Zamboanga Sibugay province, Urbanization trends

Abstract

Using Geographic Information System (GIS) techniques on census data and projections, this study presents a thorough spatial analysis of population dynamics within Zamboanga Sibugay Province, Philippines, demonstrating patterns of population distribution, density, and growth. The research reveals trends in population changes over time by using spatial analysis through GIS and secondary data analysis. It reveals notable population increases within the province, particularly in the capital municipality of Ipil, which is attributed to urbanization and the centralization of economic opportunities. The method used estimates future population growth using the Geometric Projection Formula, showing a continuous upward trend throughout the province. By identifying outliers and clusters of similar growth rates, spatial analysis—including Local Moran's I analysis which provides a more intricate understanding of population distribution and its implications for infrastructure development and resource allocation. The findings demonstrate that while some municipalities face depopulation and significant population growth, indicating trends toward urbanization, others observe substantial population growth, underscoring development disparities and the necessity of focused interventions. The study concludes that Zamboanga Sibugay Province faces uneven population growth, which has consequences for strategic planning related to services, infrastructure, and economic opportunities in order to support growth and reduce disparities.

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Introduction

Population distribution, population density, and population growth are important indicators of demographic changes in a given area. In the Philippines, the population is rapidly growing, and this growth is accompanied by changes in population distribution and density. According to the Medium Series of the 2000 Census-based population projections, the Philippine population would continue to grow, increasing from 76.5 million, as of the latest population census conducted in May 2000, to 141.7 million in 2040. Philippine Population Would Reach Over 140 million by the Year 2040, (Final Results From the 2000 Census-based Population Projections) (Philippine Statistics Authority, 2006). To add, it has been recorded that the rural population growth (annual %) in the Philippines was at 0.96838% in 2021, according to the World Bank collection of development indicators, compiled from officially recognized sources.

Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population. Monitoring the growth rate of small towns is relevant for planning development decisions. Also, growing population exacerbates land-use conflicts, regional/tribal warfare, environmental degradation, and competition for scarce resources (Chi and Ventura, 2011). On a larger context, population growth along with composition and distribution is closely linked with land use, land cover, and global climate change which in effect influence the need and demand for policy responses (Salvati, 2012). Also, spatial distribution of populations in connection with settlements location is important for delivering healthcare, distribution of resources, and economic development (Linard *et al.*, 2012).

One way to understand the distribution of people across the world is to reform the world map, not based on the area but according to population. Explicit Investigation of the geography of human population using Geographic Information System (GIS) complements different demographic methods used to characterize other population measures (Hachadoorian *et al.*, 2011). Rapid advances in geospatial data, new technologies, methods of analysis, and computing power have fueled the increase of interest in adding spatial perspective in the study of human population (Almquist and Butts, 2012; Chi and Ventura, 2011; Matthews and Parker, 2013).

The understanding of population growth in an area holds the key to the understanding of the entire demographic structure of the area. Chandna (2008, p, 39) explained that the distribution of population is locational, which refers to the spatial pattern of spread of population such as linear, dispersed, nucleated, agglomerated, etc. On the other hand, the density is more proportional and is concerned with the ratio between the size of population and the area. According to Clarke (1972), the concept of density of population is mostly revealing and is a useful tool in the analysis of the diversity of man's distribution in countries. It is in this context that the studies concerning population distribution and density assume significance for less developed countries.

Thus, using the published census data, this study analyzed the distribution of population, identify the densely populated areas as well as predict the future expected population of Zamboanga Sibugay Province through spatial analysis. This is of significance due to the province's rapid growth rate, which, according to the 2020 Census, stands at 3.5% annually, markedly above the national average. Understanding these patterns is crucial for government and non-governmental organizations alike in planning for infrastructure development, resource allocation, and sustainable environmental management.

Materials and methods

Secondary Data Analysis was employed in this study. Utilizing existing data from national censuses, demographic surveys, and local government databases to gather information on population size, distribution, and characteristics over time.

Moreover, spatial analysis was employed in the use of GIS software to create maps showing the spatial distribution of the population and its change over time, estimation of population densities and identifying areas of significant population growth or decline to pinpoint regions of high demographic pressure or areas experiencing depopulation.

The researchers also used the Geometric Projection Formula (Eq. 1) in estimating the future population growth of Zamboanga Sibugay Province. Geographical projection is the most used projection method. It focuses on the percentage change rather than the numeric change of the population. Instead of consistency in numeric increase, it assumes the growth rate (Eq. 2) is constant.

$$P_t = P_o (1 + r)^n \quad \text{(Eq. 1)}$$

Where, P_t = Projected Population, P_o = Base Year Population, r = Growth Rate, n = Number of Periods

$$\text{Growth Rate (\%)} = \{(\text{New Population} - \text{Original Population})/ \text{Original Population}\} \times 100 \quad \text{(Eq. 2)}$$

Ethics statement

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. Moreover, the authors affirm that no intellectual property was appropriated or obtained through unethical means in the course of this research. All necessary steps were undertaken to ensure the ethical acquisition of data. Furthermore, the authors disclose that the data were analyzed using a licensed ARCGIS Pro software, adhering to all terms and conditions of the software license. This has facilitated the responsible handling and analysis of the data in accordance with the highest ethical standards for research.

Results and discussion

Current population status of Zamboanga Sibugay province

Maps of total population in the Province for different census period were shown in Fig. 1 and 2.

Between 2015 and 2020, the total population of Zamboanga Sibugay has increased from 633,129 to 669,840, indicating a population growth of 36,711 people over the 5-year period. Ipil remains the most populated municipality over the years, and its population has increased by 14,745 from 2015 to 2020. As the provincial capital, Ipil likely offers more economic opportunities, services, and infrastructure, attracting more people to move there for work, education, and better living standards. On the other hand, Imelda, despite being the least populated, actually decreased in population by 1,998 during the same period. The decrease in population could be due to several factors such as lack of job opportunities, migration to urban areas, or possibly natural demographic changes.

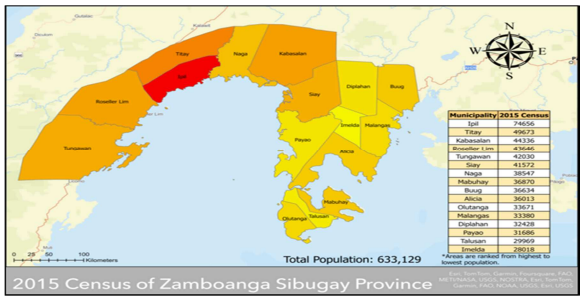

Fig. 1. 2015 Census based on Philippine Statistics Agency (Zamboanga Sibugay Profile – PhilAtlas, 1903)

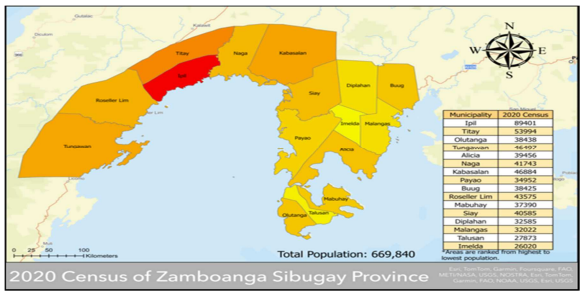

Fig. 2. 2020 Census based on Philippine Statistics Agency (Zamboanga Sibugay Profile – PhilAtlas, 1903)

The trend shows an overall increase in the population of the province, with the capital Ipil growing the most significantly (Fig. 3). This suggests urbanization trends, where the central municipality draws people from less populated areas.

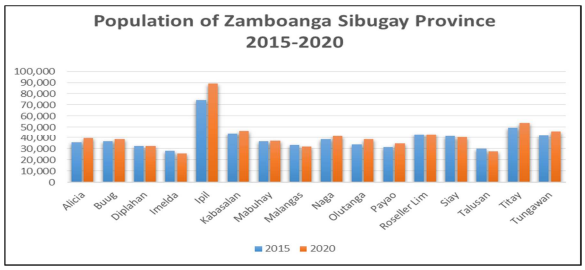

Fig. 3. 2015-2020 Distribution of Population in Zamboaga Sibugay Province per muncipality based on Philippine Statistics Agency (Zamboanga Sibugay Profile-PhilAtlas, 1903)

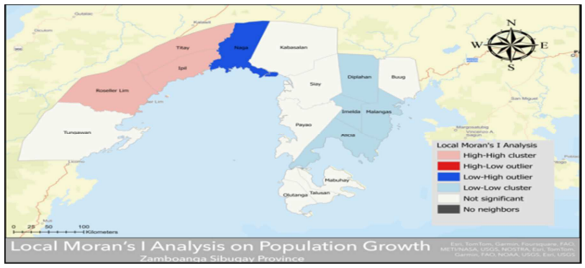

Fig. 4. Local Moran's I analysis on change of population growth

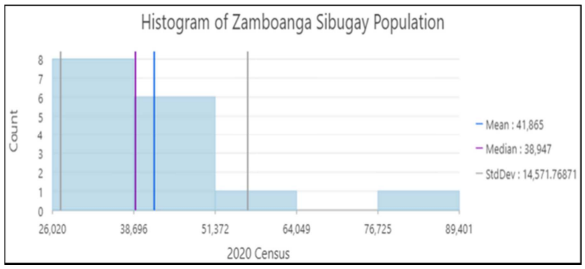

Fig. 5. Histogram of Zamboanga Sibugay population based on Local Moran's I analysis

Local Moran's I analysis on change of population growth and population growth rate

Fig. 4 displays the results of a Local Moran's I analysis on population growth for Zamboanga Sibugay Province. The Local Moran's I is a statistic used in spatial analysis to identify clusters of similar values and spatial outliers (Moran, 1948).

According to the Local Moran's I Analysis, Roseller Lim, Titay and Ipil are areas shaded in light pink which indicates as High-High cluster. These represent locations with high population growth that are also surrounded by other areas with high population growth. These are considered clusters where the condition is similar and geographically concentrated.

The municipality of Naga is identified as Low-High Outlier. These areas have low population growth but are next to areas with high population growth. They are considered outliers due to the contrast in conditions with their immediate neighbors. The Municipalities of Diplahan, Imelda, Malangas and Alicia are area clusters where there is low population growth surrounded by areas with similar low population growth rates. While, Buug, Kabasalan, Mabuhay, Olutanga, Payao, Siay, Talusan and Tungawan are areas who do not show significant clustering either high or low and do not appear to be part of any particular trend.

The results suggest that there is a notable spatial pattern to population growth in this province, with certain areas showing strong clustering effects. Policymakers and planners can use this information to understand demographic trends better and allocate resources, plan infrastructure, or implement programs targeting specific areas with distinct growth patterns (Chi and Marcouiller, 2011; Chi and Ventura, 2011).

Fig. 5 shows the histogram of Zamboanga Sibugay population based on Local Moran's I analysis which represents the distribution of population counts from the 2020 Census in the Zamboanga Sibugay province. It shows how many areas (count) fall into each population range (bin). The chart indicates the mean population is 41,865, the median is 38,947, and the standard deviation is 14,571.76871. Further, the histogram shows that most areas have a population between 26,020 and around 51,372. The highest bar indicates that the most common population range is between approximately 26,020 and 38,696. Therefore, the distribution appears to be right-skewed since the mean is higher than the median, indicating that there are a few areas with a much higher population compared to most of the areas.

Fig. 6 shows the Population's Moran's Scatterplot, which is used to show the correlation between the population value of an area and the average population value of its neighbors (spatial lag).

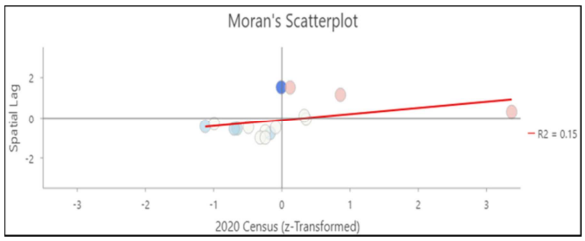

Fig. 6. Moran's scatterplot of Zamboanga Sibugay population based on 2020 census

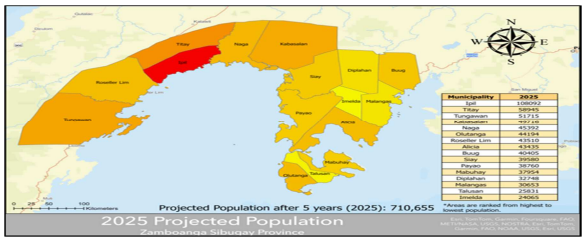

Fig. 7. 2025 Distribution of Projected Population in Zamboaga Sibugay Province per muncipality using geometric projection formula (Gokarna and Aryal, 2020

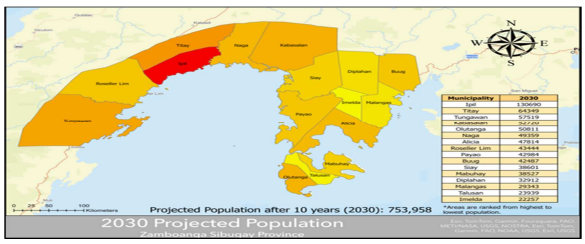

Fig. 8. 2030 Distribution of Projected Population in Zamboaga Sibugay Province per muncipality using geometric projection formula (Gokarna and Aryal, 2020

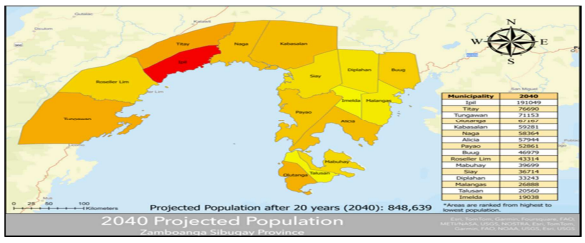

Fig. 9. 2040 Distribution of Projected Population in Zamboaga Sibugay Province per muncipality using geometric projection formula (Gokarna and Aryal, 2020

The data points are Z-transformed values, which means they are standardized values that show the number of standard deviations away from the mean. An R^2 value of 0.15 is shown, which indicates that 15% of the variation in the spatial lag of population can be explained by the population value of the area itself.

Moreover, the red line represents the fit line, which shows the overall trend of the data points. If the line slopes upwards (as it does in this case), it suggests a positive spatial autocorrelation: areas with higher populations tend to be surrounded by areas with higher populations. This corresponds with the red areas in the first map indicating high-high clusters. The blue and pink points may represent the outliers, which do not follow the general trend: blue points are likely the high-low outliers (areas with high population but surrounded by low population areas) and pink points the low-high outliers (areas with low population but surrounded by high population areas). However, since the R^2 value is relatively low, the spatial pattern is not strongly pronounced, suggesting that while there is some degree of spatial autocorrelation, other factors may also be influencing population distribution in this region (Harris and Jarvis, 2014)

Projected population of Zamboanga Sibugay Province

The projected population data for Zamboanga Sibugay for the years 2025, 2030, 2040, and 2050 indicate a continuing trend of population growth (Fig. 7-10). This is based on the data available from the 2015-2020 census with a constant growth rate.

There is a consistent upward trend in the overall population of the province, with the capital municipality of Ipil growing the most robustly. This trend suggests a centralization of the population in Ipil, possibly due to better job prospects, healthcare, education, and other amenities. Imelda remains the least populated municipality throughout the projections, and its population is seen to decrease over time.

Numerous factors impact changes in an area's population (Chi and Marcouiller, 2011; Chi and Ventura, 2011). Broad categories including

demographics, socioeconomics, transportation accessibility, natural amenities, and biophysical and policy conditions pertaining to land use and development can include these factors (Chi and Marcouiller, 2011; Chi and Ventura, 2011). Population change is influenced by temporal and spatial influences, political, geographic, and cultural factors (Chi and Ventura, 2011; Entwisle, 2007). Chi and Ventura (2011) state that when examining population change, there are four (4) factors to take into account. First off, a variety of factors impact and influence population change, and no single factor has the ability to pinpoint the exact direction and size of the change. Second, due to different population redistribution processes over time, the influences of various factors that affect population change evolve over time. Third, there is a possibility that population shifts in one area will affect nearby areas as well (spill-over effect). Finally, the impact of various factors differs depending on the specific characteristics of an area (rural, suburban, and urban).

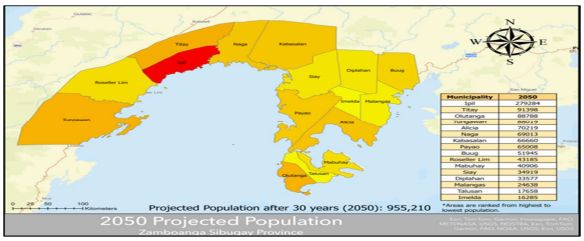

Fig. 10. 2050 Distribution of Projected Population in Zamboaga Sibugay Province per muncipality using geometric projection formula (Gokarna and Aryal, 2020

In the case of Zamboanga Sibugay Province, these multifaceted factors likely interplay in unique ways, shaping the population patterns observed and projected over time, as well as the spatial distribution across the province's varied geographic and administrative regions.

Conclusion

The progression from the 2015 Census data to the 2020 Census data demonstrates the spatial shifts and changes in the population of Zamboanga Sibugay Province over time. Changes in color intensity on the maps, which show increases or decreases in population density, can be used to identify areas that have undergone notable growth or decline.

The temporal perspective, the histogram, and the Moran's Scatterplot analyses when combined provide a more comprehensive picture of the province's population dynamics. The moderate spatial autocorrelation and the right-skewed distribution of the 2020 data indicate that a few areas experiencing rapid population growth may be the main drivers of the region's overall trend. These might be places with more urbanization or economic opportunity that draw in more people.

The choropleth maps' historical data provide a more thorough understanding of the population's changing trends in particular areas. For example, if populations in areas that were lower in 2015 have increased significantly by 2020, this may be a sign of new developments or migration trends. On the other hand, regions that have experienced little to no change—or even a decline—may be dealing with issues like out-migration, economic challenges, or other problems that policymakers should take seriously.

Further, the population growth projection for Zamboanga Sibugay from 2020 to 2050 shows a steady increase in population throughout the province, with notable variations among its municipalities. The region's capital, Ipil, is expected to grow at the fastest rate, indicating a potential hub for migration and economic growth in the area and a potential continuation of the urbanization trend. Smaller towns like Imelda, on the other hand, are experiencing a decline in population, which highlights potential difficulties in preserving the region's economic and demographic vitality. In order to accommodate growth and address disparities, these projections highlight the necessity of strategic planning in the areas of infrastructure, services, and economic opportunities.

This study concludes that from the combination of all these data points, patial distribution, histogram statistics, and temporal change, it suggests that the

Province is experiencing uneven population growth, with certain areas growing much faster than others. This could have implications for resource allocation, infrastructure development, and service provision, requiring targeted strategies that address both the high-growth areas and the areas that may be at risk of being left behind.

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