Population Projection in Palawan using Geographic Information Systems (GIS)

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Abstract: The world's population is continuously rising at unprecedented rates. The impacts of rapid urbanization and population growth, however, are more experienced in less developed countries. The Philippines, on top of its internal, social, environmental, and economical issues, is heavily burdened by the accelerated population rates. To conform to the public's growing demands, accurate population forecasts are needed to plan out future projects and estimations. This paper aimed to investigate the changing population trends in the province of Palawan. By using the 2000 and 2010 census data and QGIS, the province's 2015 population was projected through three basic mathematical projections, namely the linear, geometric, and exponential models. Upon comparison with the 2015 census data, it was observed that 18 of its 23 municipalities are undergoing a linear demographic transition, suggesting that it is the most prevalent growth trend in the province. Low terrain elevation, accessibility of roads, dense residential areas, and tourism have been correlated with the exponential and geometric trends are observed in other municipalities. Because the southern region has flatter terrain and has more accessible road networks, the southern municipalities including Aborlan, Balabac, Bataraza, Brooke's Point, and Quezon are expected to have rapid population growth in the coming years.

Key Words: Geographic Information Systems; Population Projection; Palawan

1. INTRODUCTION

The rapid demographic change encountered by most countries today is due to the accelerated expansion of urban development and the shift of civilizations from agricultural to industrial societies. The world's total population increased by around four billion people since 1950 and this is still expected to increase further over the following decades before it is projected to peak near the twenty-first century. The population may also become more diverse in the coming years as a potential decline in parts of the developed regions and continued rapid growth in less developed regions are expected (Bongaarts, 2009).

The rise and fall of the population, in conjunction with the changes in the composition and distribution of the global population, have a significant impact on the distribution of resources to the people. Population projection is one of the basic prerequisites in the planning of basic needs (Barney, 2013). Understanding the demographic patterns and trends in the population can help policymakers make decisions about social, political, economic, and environmental issues (Mather, 2021). This projection, however, is always subject to uncertainty because factors such as immigration, fertility, and mortality can greatly influence the resulting number (Barney, 2013).

The rapid population growth and widespread urbanization remain as one of the Philippines' prominent concerns. It was named as the 12th most

populous country in 2015, with most of the population concentrated in the highly urbanized National Capital Region (Licuanan, Cabreira, & Aliño, 2019). While the population growth of the country has declined over the years, this trend may not be accurate for provinces that are still continuously developing. This study aims to investigate the rising population rates in the province of Palawan.

2. MATERIALS AND METHODS

2.1 Site Area

Palawan is a Philippine province composed of 1,768 islands, with a narrow main island 625 km long and 40 km wide. It is located southwest of the Luzon peninsula, bounded by the South China Sea on the northwest and the Sulu Sea on the southeast side. It is considered to be the largest province in the country in terms of landmass (PSA, 2002). The province has 23 known municipalities and 433 barangays. According to the 2010 PSA census, the areas with the largest and the lowest population in Region 4B are located in Palawan: the municipality of Puerto Princesa (~223,000) and Kalayaan (~220).

2.2 Population Projection Theories

Projections can either be classified as a trend extrapolation or a Cohort-component technique, which accounts for the demographic change of the population (Bassarsky & Sawyer, 2016). Selecting a forecasting methodology is often dependent on the projection's type of use, output, and geographic coverage. Three trend-based mathematical models were used and compared in the study: the linear, geometric, and exponential projections. Data used for projection is based on the 2000 (PSA, 2003) and 2010 census data (PSA, 2013), whose result is subsequently compared with the 2015 census data (PSA, 2016). It should be noted that the total population was only considered in the calculation. Other significant parameters relating to the population such as the births and deaths and immigration and emigration are excluded in the analysis.

2.2.1 Linear Projection

A population is growing or decreasing linearly if a common difference causes the change per time. Equation 1 shows the linear projection used in the study (Ayhon, 2018; Bassarsky & Sawyer, 2016). Linear or arithmetic projections, however, are often not used in planning as they can underestimate the population growth (PAS, 1950).

$$P_t = P_0 + (P_0 - P_b)\frac{t}{n} \quad \text{(Eq. 1)}$$

where:

P_t = Projected population after t years
P_0 = Population in the launch year
P_b = Initial population (base period)
t = Number of years in the projection
n = Number of years in the base period

2.2.2 Geometric Projection

The population under a geometric projection is expected to change by a percentage rate or multiplier per period. This results in a different absolute change each year (Ayhon, 2018). The formula for the geometric projection is depicted in Equation 2, whereas the geometric growth rate (r) is represented in Equation 3 (Bassarsky & Sawyer, 2016).

$$P_t = P_0(1 + r)^t \quad \text{(Eq. 2)}$$

where:

P_t = Projected population after t years
P_0 = Initial population (base period)
t = Number of years in the projection
r = Average geometric growth rate

$$r = \left[\left(\frac{P_0}{P_b}\right)^{1/n}\right] - 1 \quad \text{(Eq. 3)}$$

where:

P_b = Initial population (base period)

P_0 = Initial population at launch year
n = Number of years in the base period

2.2.3 Exponential Projection

A population undergoing exponential growth is said to be more realistic as it is a continuous process, compared to an increase due to constant increments (linear projection) or interest-like rates (geometric projection) (Ayhon, 2018). Results from exponential projections are expected to be similar to the geometric projection, but the change develops continuously

(Bassarsky & Sawyer, 2016). Equation 4 shows the exponential projection formula while Equation 5 shows the exponential rate of change.

$$P_t = P_0 e^{rt} \quad \text{(Eq. 4)}$$

where:

P_t = Projected population after t years
P_0 = Initial population at launch year
t = Number of years in the projection
r = Average annual exponential rate of change

$$r = \left[ln\left(\frac{P_0}{P_b}\right)\right]/n \quad \text{(Eq. 5)}$$

where:

P_b = Initial population (base period)
P_0 = Initial population at launch year
n = Number of years in the base period

2.3 Population Projection using QGIS

Geographic Information Systems (GIS) are software for storing, transforming, editing, and visualizing geographic data. GIS also helps in representing graphical data and spatial relationships (Howari & Ghrefat, 2021), making it useful for population projection studies. Quantum Geographic Information Systems ver. 3.14.16 (QGIS 3.14.16) is free to use and available for download at their website (www.qgis.org).

The assessment of Palawan's population was performed in three parts: computing the rate of increase from 2010 to 2015 per municipality, determining the most accurate trend by comparing the results of the three scenarios, and projecting the 2020 population. A spatial assessment was also performed based on terrain using Shuttle Radar Topography Mission (SRTM) Digital Terrain Elevation Data, road network, and residential area using OpenStreetMap (OSM) GIS data to determine the factors which may have caused the increase in population in the province. Municipalities that will have a rapid population increase in the coming years will also be predicted based on the collected information.

3. RESULTS AND DISCUSSION

3.1 Rate of Increase

Results have shown that most of the province have a growth rate between 2% to 4% for the years 2010 to 2015. The average growth rate in the same period is around 2.58%, which is quite larger than the country's overall growth rate in 2010, at around 2% (Amante, 2010.). Balabac (3.5%), Batarazan (4.4%), Linapacan (4.4%), San Vicente (3.6%), and Puerto Princesa (3.2%) were among the municipalities with the highest population growth rate in the province.

3.2 Linear, Geometric, and Exponential Projection

The spatial representation of the trend in each municipality is shown in Figure 1, which reveals that 18 of the 23 cities in the province had linear projection as its closest approximation. Only two municipalities (Quezon, El Nido) are under a geometric trend and three municipalities (Sofronio Espanola, Rizal, Coron) are under an exponential trend. The average percent error for linear, geometric, and exponential projections was computed to be 4.79%, 6.3%, and 6.43%, respectively. The relative closeness of values between geometric and exponential analyses can be attributed to similarity in the derivation of their formulas. A high percentage difference of almost 20% was also observed in the municipality of Cagayancillo as the population decreased by 831 people from 2010 to 2015.

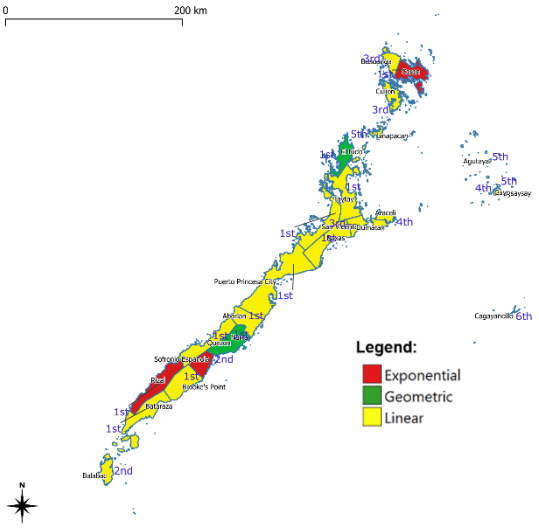

Fig. 1. The municipality class category and prevalent mathematical trend for each town in Palawan

3.3 Factors Affecting Population Growth

3.3.1 Terrain

Existing GIS data of Palawan was examined to check if external factors may have impacted the population trends for each municipality. The first factor assessed was the terrain of the province. Figure 2 shows the digital elevation map of Palawan. A mountainous terrain was observed throughout the province's mainland, and even in the islands in the northern region. Flatter regions or locations below 60m in elevation were mainly seen in the coastlines of the southern municipalities.

It was also observed that residential areas were only erected in locations with an elevation of fewer than 60 meters, implying that urban development may not occur in heavily mountainous regions. The municipalities of Rizal and Narra, which were undergoing a geometric and exponential trend, likely have a greater demographic trend because they have long and flat coastlines, a possible source for residential expansion. The southern municipality of Sofronio Espanola was observed to be under an exponential trend despite having high elevations, presumably because it is a new municipality and thus has a lot of potential for development. The non-linear trends observed for the northern municipalities El Nido and Coron was likely due to its popularity as a tourist spot.

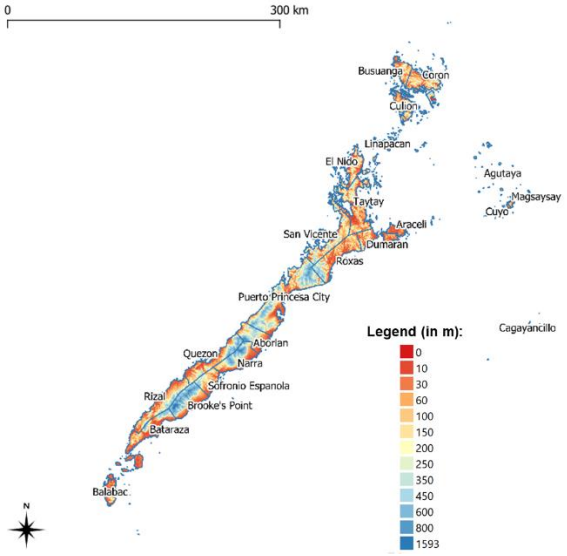

Fig. 2. Digital Elevation Map of Palawan

3.3.2 Distribution of Road Networks

The second factor assessed was the distribution of road networks in the province. Figure 3 shows the road and contour map of Palawan. The southern region of the province had a more accessible road network as the main roads from Puerto Princesa city is directly connected to the western (Rizal, Quezon) and eastern (Narra, Sofronio Espanola, Brooke's Point, Bataraza) municipalities. On the other hand, the road network in the northern region is sparser and it passes through numerous mountainous regions, making it less appealing to developers and immigrants alike. The accessibility of Narra, Rizal, and Sofronio Espanola may have brought them to more rapid population trends than other municipalities.

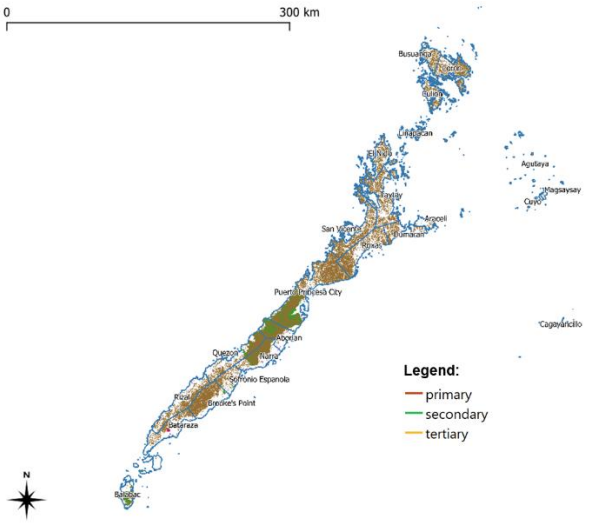

Fig. 3. Road and Contour Map (60m) of Palawan

3.3.3 Distribution of Residential Areas

The last factor assessed was the distribution of residential areas. Since residential areas were only constructed in flatter areas, they tended to be scattered in most municipalities. To determine if the spatial distribution and concentration of the population had a significant impact on the population growth, the perimeter over area index of the residential areas was computed A lower value of this index would imply that residents are highly concentrated while a larger value would indicate that there are multiple residential areas are distributed

and spread out throughout the municipality. Results have shown that all municipalities with an exponential and geometric trend had a value not exceeding 150, whereas the average index for the province was around 163. This suggests that areas with less, but more concentrated residential areas have more potential for population growth.

3.4 Projected Population by 2020

Figures 4a and 4b show Palawan's population in 2015 and the projected population in 2020, respectively. Comparisons between populations from 2015 to 2020 have shown a marginal increase, with one city even experiencing a decline in number. Socioeconomic conditions such as Palawan's predominant rural classification may be a factor for the minor growth rate in the population

3.5 Future Development of Other Municipalities

The future development in the province is tied with the possibility of construction in the area and thus is likely correlated with the flatter regions and the road distribution in a city. In addition to these factors, the classes of each municipality in Palawan were assessed, to determine if their current income can induce urban expansion in their respective area. The southern region of the province was observed to have high classes (1st and 2nd only) while the northern region had both low and high classes (from 1st to 6th) as indicated in Figure 1. Because of these observed factors, it is presumed that the southern municipalities including Aborlan, Balabac, Bataraza, Brooke's Point, and Quezon will undergo a significant demographic change in the coming years.

4. CONCLUSIONS

This study was able to assess growth rates and provide an approximation of future trends employing three basic methods of projection to forecast population trends in Palawan. Results have indicated that most of the province is currently undergoing a linear demographic transition, and the potential for population expansion was attributed to the flatter terrain (< 60m) and the accessible road networks. Since southern municipalities have a flatter terrain and have more connecting roads, it has great potential for future developments which in turn can cause rapid population growth. The natural and geographic characteristics of a region can play a major role in speed of its development.

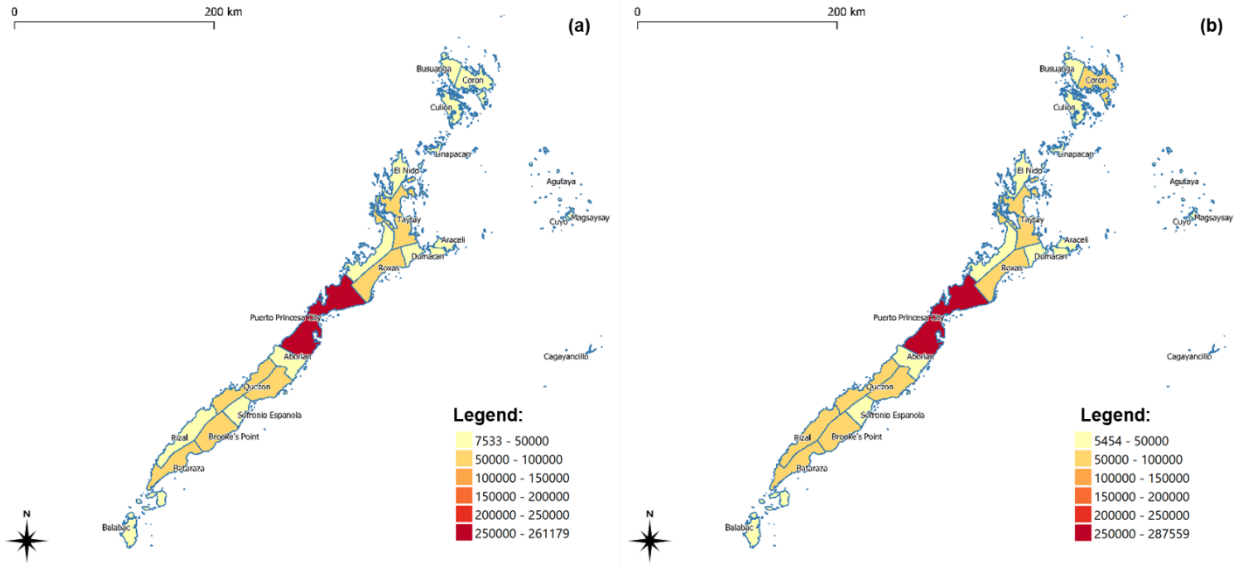

Fig. 4. (a) Population in Palawan in 2015 and (b) Projected Population in Palawan in 2020

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