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Spatial analysis of human population distribution and growth in Marinduque Island, Philippines

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Abstract This study assessed the spatial distribution of population growth of Marinduque, an island province in the heart of the Philippines. Based on the results, population of the province varies across time and space while densely populated areas are concentrated in coastal, flat and relatively flat regions. From 1990–2010, majority of the villages in the province experienced an increase in population. Global Moran's *I* test on the change in population and population growth rate suggests there is spatial clustering of these two variables among villages. Local Moran's *I* test validated such results and was able to detect several High–High and Low–High clusters of villages.

Introduction

Small islands are composed of small land masses surrounded by ocean and are commonly prone to either hydrological and geological disasters (Mimura et al., 2007; Polido et al., 2014). According several researchers (i.e. Nagarajan, 2006; Polido et al., 2014; Pungetti, 2012), small islands are living laboratories where people can see and experience impact of their actions to the environment and how it affects the entire island system.

Monitoring population growth in small islands is very important because of its limited natural and space resources. High population densities in small islands demand high resources and can also pose threats to the island's unique biodiversity due to overexploitation and habitat degradation (Leunufna and Evans, 2014; Polido et al., 2014). In addition, growing population exacerbates land-use conflicts, regional/tribal warfare, environmental degradation, and competition for scarce resources (Chi and Ventura, 2011). On the other hand, small population in an island can result to limited pool of skills (Polido et al., 2014). 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 (CHDGC, 1994; Hunter et al., 2000; 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).

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According to Hachadoorian et al. (2011) population data are naturally spatial because human beings inhabit geographic space. 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). Matthews and Parker (2013) reviewed and provided numerous examples of different demographic researches that incorporate spatial perspective.

Analysis of spatial autocorrelation helps to determine relationship among variables in space (Young and Jensen, 2012). To evaluate the degree of similarity of observation across space, global indices of spatial autocorrelation are commonly used (Jackson et al., 2010). Moran's I is a global index of spatial autocorrelation widely used and tested for studying spatial autocorrelation over the past 50 years (Bae et al., 2008; Jackson et al., 2010; Young and Jensen, 2012; Zhang and Lin, 2007). On the other hand, while global indices like Moran's I can measure spatial association of the entire data set, use of local indicators for association local spatial clusters (LISA, Anselin, 1995) is needed to identify clusters of high (hot) and low (col) spots across space (Bae et al., 2008; Rossen et al., 2014).

Using the published census data, this paper assessed population distribution and growth at the village level of Marinduque, an island province in the Philippines. The study also used the popular Moran's I (Moran, 1948) and Local Moran's I (Anselin, 1995) to evaluate spatial clusters of population growth among villages in the province.

Materials and methods

Study area

Marinduque is an island province situated around 200 km south of Manila (Fig. 1). The island province is considered the heart of the Philippine archipelago because of its location and geometric shape. Six (6) municipalities consists the province covering around 96 thousand hectares of land (Table 1). Generally, the province topography is hilly and mountainous with rolling and steep slopes (Fig. 2). Farming and fishing are the major source of income in the province. Based on the National Statistical Coordination Board (http://www.nscb.gov.ph), Marinduque is the lowest income province in the region and almost 24% of the province population is under poverty.

Table 1 Income class, area, and area coverage of six municipalities of Mariduque (Data Source: NSCB, 2015).

Municipality	Income class	Area (ha)	Percentage of area
Boac	1st	21,265	22.17
Buenavista	4th	7860	8.19
Gasan	3rd	11,930	12.44
Mogpog	3rd	8780	9.15
Sta. Cruz	1st	24,660	25.71
Torrijos	3rd	21,430	22.34

Data

Village level population data of Marinduque for the census periods of 1990, 1995, 2000, 2007 and 2010 was obtained from the National Statistics Office (NSO) (http://census.gov.ph) of the Philippine Statistics Authority (PSA) while village GIS boundary map of the province was downloaded from Global Administrative Areas website (http://www.gadm.org/).

Analysis and visualization

Data processing and analysis was carried under R software environment (R Core Team, 2014) using the different packages. Change in population and population growth rate was computed between census data for 1990 and 2010. Population change was calculated as the difference between population count for each village between 1990 and 2010 (Eq. (1)) while population growth rate was calculated as the difference between population count for 2010 and 1990 divided by the total population during 1990 multiplied by 100 (Eq. (2)). Average annual population growth rate from 1990 to 2010 was calculated by dividing the computed growth rate with the number of year difference between the two periods, which is 20 years. Spatial data such as administrative boundary, elevation, and slope were handled and process using *maptool* (Bivand and Lewin-Koh, 2014) and *raster* (Hijmans, 2014). Spatial analysis (i.e. global and local Moran's I test) was carried using *spdep* (Bivand, 2015). Result from spatial analysis was managed and visualized using *plyr* (Wickham, 2011), *ggplot2* (Wickham, 2009), *RColorBrewer* (Neuwirth, 2014), and *gridExtra* (Auguie, 2012) packages.

$$Change\,in\,Population = Population\,2010 - Population\,1990 \tag{1}$$

$$Growth\,Rate(\%) = \frac{Population\,2010 - Population\,1990}{Population\,1990} \times 100 \tag{2}$$

Results

Population, population density, population growth

Maps of total population in the province for different census period were shown in Fig. 3. These maps showed no distinct pattern in terms of total population per village in the province. Population distribution of Marinduque is similar to other small islands where most of the population are concentrated in the coastal region (Mimura et al., 2007). Population density maps of the province (Fig. 4) showed that since 1990, densely populated villages were concentrated in either coastal or those relatively flat (i.e. flat to gently undulating) portions of the province. On the other hand, as of 2010, the village of Balanacan (Mogpog) has the highest population count (3216) while Tumapon (Boac) has the lowest (129). The village of Mercado (Boac) was the most densely populated village in the province with around 14 thousand persons/km^2 while Tabionan (Gasan) ranks as the least densely populated village (37.6 persons/km^2). In terms of population growth rate, majority (82%) of the villages showed positive increase in population (Fig. 5a) except those villages located in the east to