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Exploring Determinants of Child Malnutrition in Marinduque Island, Philippines

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Introduction

Malnutrition in children is a perennial problem in the Philippines (Del Rosario *et al.* 2013; Florencio 2004; Laguna 2015; Rohner *et al.* 2013). According to Kreißl (2009), protein-energy malnutrition (PEM), Vitamin A Deficiency (VAD), Iron Deficiency Anaemia (IDA) and Iodine Deficiency Disorder (IDD) are the four (4) major deficiency disorders among Filipino children. PEM causes high fatality rates among infants and children (Kreißl 2009), and stunting and dangerously low weight among children 0–5 years of age in the Philippines (Cuesta 2007; FNRI 2013). Based on the last National Nutrition Survey, the national average of stunted and underweight children in the country was 30.3% and 19.9%, respectively (FNRI 2013). Although there has been a downward trend in the malnutrition rates of children 0–5 years old since 1990, the prevalence of malnutrition in the Philippines is still above the Millennium Development Goal (MDG) target of 13.6% (FNRI 2013). In 2015, the Global Hunger Index (GHI), which is based on four components: 1) proportion of the population that is undernourished; 2) prevalence of wasting in children under five years old; 3) prevalence of stunting in children under five years old; and, 4) proportion of children dying before the age of five, scored the Philippines at 20.1 (von Grebmer *et al.* 2015), indicating serious levels of hunger.

According to the United Nations Children's Fund (UNICEF) Nutrition Strategy framework(United Nations Children's Fund 1998), inadequate dietary intake and disease are the immediate causes of child malnutrition. At the household level, insufficient access to food leads to inadequate dietary intake while poor water/sanitation and inadequate health services result in a range of diseases, further exacerbated by lack of maternal and childcare practices. These underlying causes of malnutrition at the household level are directly influenced by the quantity and quality of environmental, technological, and human resources at the national level.

A number of factors have been linked to the prevalence of malnutrition in an area (Balk *et al.* 2005; Cuesta 2007; Grace *et al.* 2012; Haile *et al.* 2016; Linnemayr *et al.* 2008; Singh *et al.* 2015). In the Philippines, several studies have examined different factors contributing to malnutrition in children. Magnani *et al.* (1993) showed that food expenditure per head, level of education of the household head, and gender of the child were significant predictors of child nutritional status. Ricci and Becker (1996) found that maternal behavior and household socioeconomic status are primary factors determining stunting and wasting of children in Metro Cebu. Adair and Guilkey (1997) identified diarrhea, febrile respiratory infections, early supplemental feeding, and low birth weight as significantly increasing the likelihood of stunting in children, and Cuesta (2007) emphasized the positive effect on child nutritional status of the adequate provision of water and sanitation. However, none of these studies addresses the impact of ecological factors that might also influence levels of child malnutrition (Balk *et al.* 2005; Dos Santos and Henry 2008).

Study Site

Marinduque (Fig. 1) is an island province situated around 200 km south of the capital, Manila, in the heart of the

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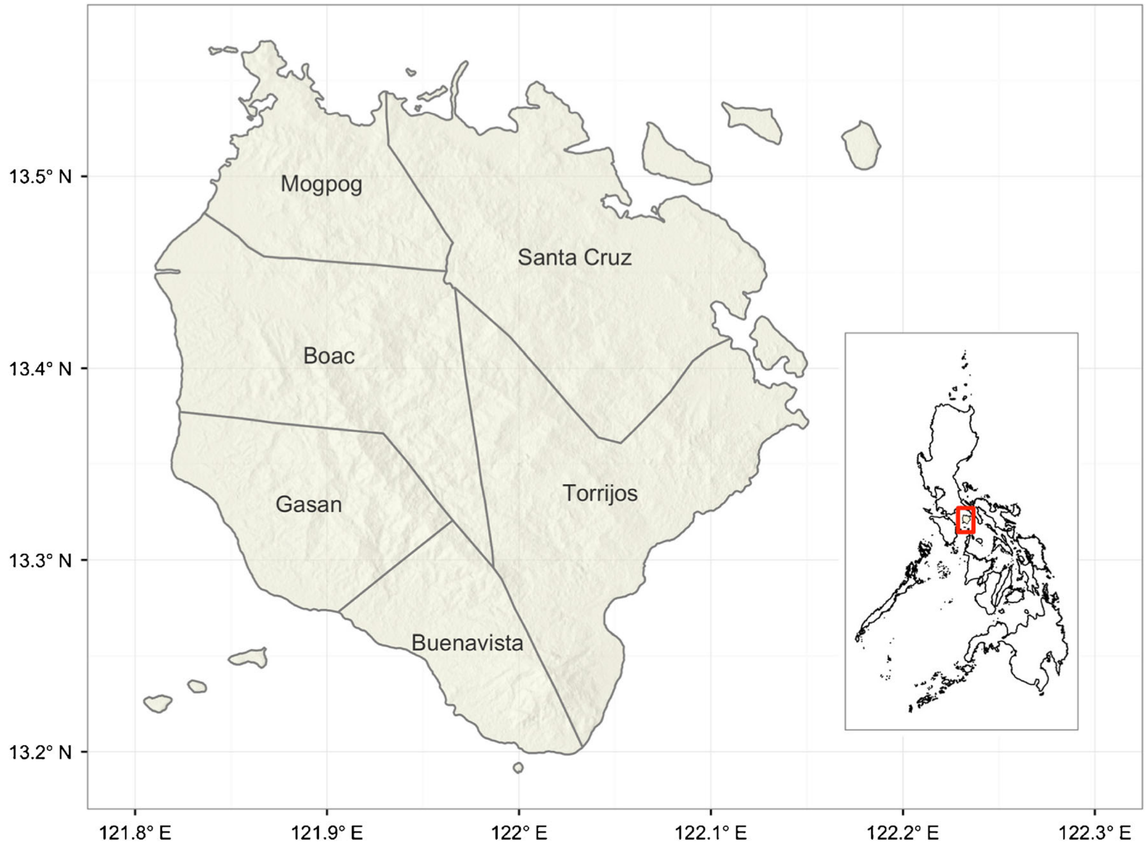

Fig. 1 Location map of Marinduque

Philippine archipelago (Salvacion 2016; Salvacion and Magcale-Macandog 2015),between 121.80–122.18° longitude and 13.18–13.57° latitude. The province is included in the Mindoro-Marinduque-Romblon-Palawan (MIMAROPA) Region, which is among the top three regions of prevalence of malnutrition in the country (FNRI 2013). Based on the 2012 report of the National Nutritional Council (NNC)-MIMAROPA, two out of six municipalities in the province have the highest prevalence of malnutrition in the region (National Nutrition Council 2012). This study explores potential determinants of child malnutrition in the province of Marinduque.

Table 1 List of independent variables tested as possible determinants of malnutrition in Marinduque, Philippines

Variables	Type	Source
Poverty Incidence	Socioeconomic	CBMS
Unemployment Rate	Socioeconomic	CBMS
Proportion of household without access to safe water supply	Socioeconomic	CBMS
Proportion of household without access to sanitary toilet facilities	Socioeconomic	CBMS
Elevation	Topographic	ASTER-GDEM
Slope	Topographic	Derived from ASTER-GDEM
Latitude	Geographic	Calculated from the map
Longitude	Geographic	Calculated from the map
Distance provincial highway	Proximity	Calculated based on OSM
Distance from health facilities	Proximity	Calculated based on georeferenced maps
Total Monthly Rainfall	Climatic	WorldClim Database
Average Monthly Mean Temperature	Climatic	WorldClim Database

Table 2 Local clusters of malnutrition rate in Marinduque

Village	Municipality	Cluster Class	Malnutrition Rate
Bayuti	Boac	High-High	16.7
Hinapulan	Boac	High-High	26.1
Isok I	Boac	Low-High	0.7
Mahinhin	Boac	High-High	39.8
Malusak	Boac	Low-High	0
Mataas Na Bayan	Boac	Low-High	0
Sabong	Boac	High-High	58.1
Tabigue	Boac	High-High	15.3
Tambunan	Boac	High-High	33.3
Bagacay	Buenavista	High-High	28.0
Bagtingon	Buenavista	High-High	21.4
Sihi	Buenavista	High-High	20.7
Timbo	Buenavista	High-High	13.9
Bagong Silang	Santa Cruz	Low-High	1.0
Landy	Santa Cruz	Low-High	1.2
Maharlika	Santa Cruz	Low-High	1.5
Morales	Santa Cruz	Low-High	0
Talawan	Torrijos	High-High	15.7

Methodology

Data Processing

I downloaded a village level boundary map of Marinduque from Global Administrative Areas (www.gadm.org), and gathered village level data on the extent of malnutrition and other socioeconomic indicators from the Community Based Monitoring System (CBMS) (Reyes and Due 2009) report for the province of Marinduque for the year 2008. Data on elevation and road network were downloaded from advanced spaceborne thermal emission and reflection radiometer (ASTER) global digital elevation model (GDEM) (Abrams *et al.* 2015) website (http://gdem.ersdac.jspacesystems.or.jp/) and OpenStreetMap (www.openstreetmap.org), respectively. Locations of health facilities were georeferenced using Google Maps (https://maps.google.com/). Climatic data (i.e., rainfall and temperature) were downloaded and extracted from WorldClim (Hijmans *et al.* 2005) database (www.worldclim.org). I used The *raster* (Hijmans 2014) of package R language (Ihaka and Gentleman 1996; R Core Team 2014) to derive other data such as slope, derived from elevation data using the *terrain* function, and proximity maps (i.e., distance from roads and health facilities), computed from road network data, and georeferenced health facilities using the *distance* function of the package. I calculated mean zonal values for climate, elevation, and proximity measures for each village boundary to match the data aggregation of malnutrition prevalence and other socioeconomic indicators. All data visualization was implemented under R computing environment (Ihaka and Gentleman 1996; R Core Team 2014).

Spatial Clustering Analysis

I analyzed village level data on the extent of child malnutrition for spatial autocorrelation using both global (Jackson *et al.* 2010; Young and Jensen 2012) and local test for association (Anselin 1995) to identify possible clustering of malnutrition in the province as well as to create accurate specifications for a regression model in the presence of spatial autocorrelation.

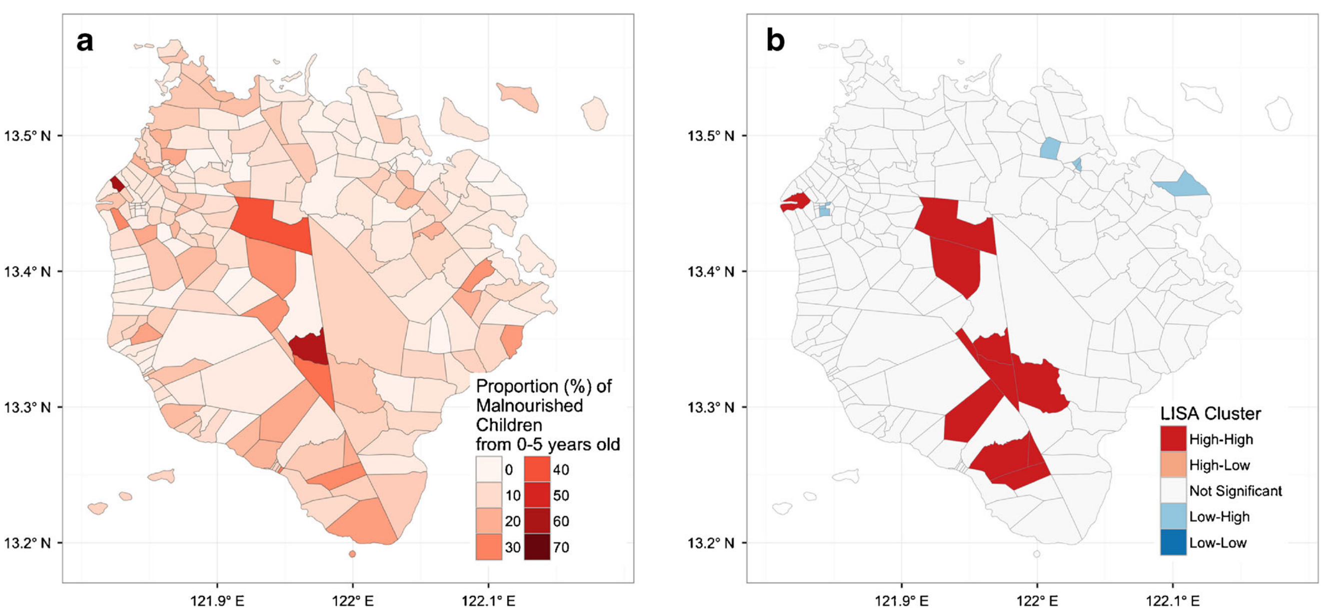

Fig. 2 Spatial distribution (**a**) and clustering (**b**) of malnutrition rate in Marinduque

Regression Analysis

I used multiple linear regression to determine which among the independent variables (Table 1) have significant effect on village level malnutrition. First, I constructed a full model with the proportion of malnourished children as the dependent variable and all the other variables (Table 1) as independent variables. Second, I used Akaike Information Criterion (Akaike 1974) via the *stepAIC* function of *MASS* package (Venables and Ripley 2002) in *R* software (Ihaka and Gentleman 1996; R Core Team 2014) for automatic model selection. I then used step-wise variable selection to reduce the number of independent and remove collinear variables (Lachniet and Patterson 2006). Lastly, I created a spatial regression model based on the final model from step-wise regression following the spatial autocorrelation test.

Results

Spatial Patterns of Village Level Malnutrition Rate

On average, the village level child malnutrition rate in the province is around 9% with minimum of 0% (recorded in 14

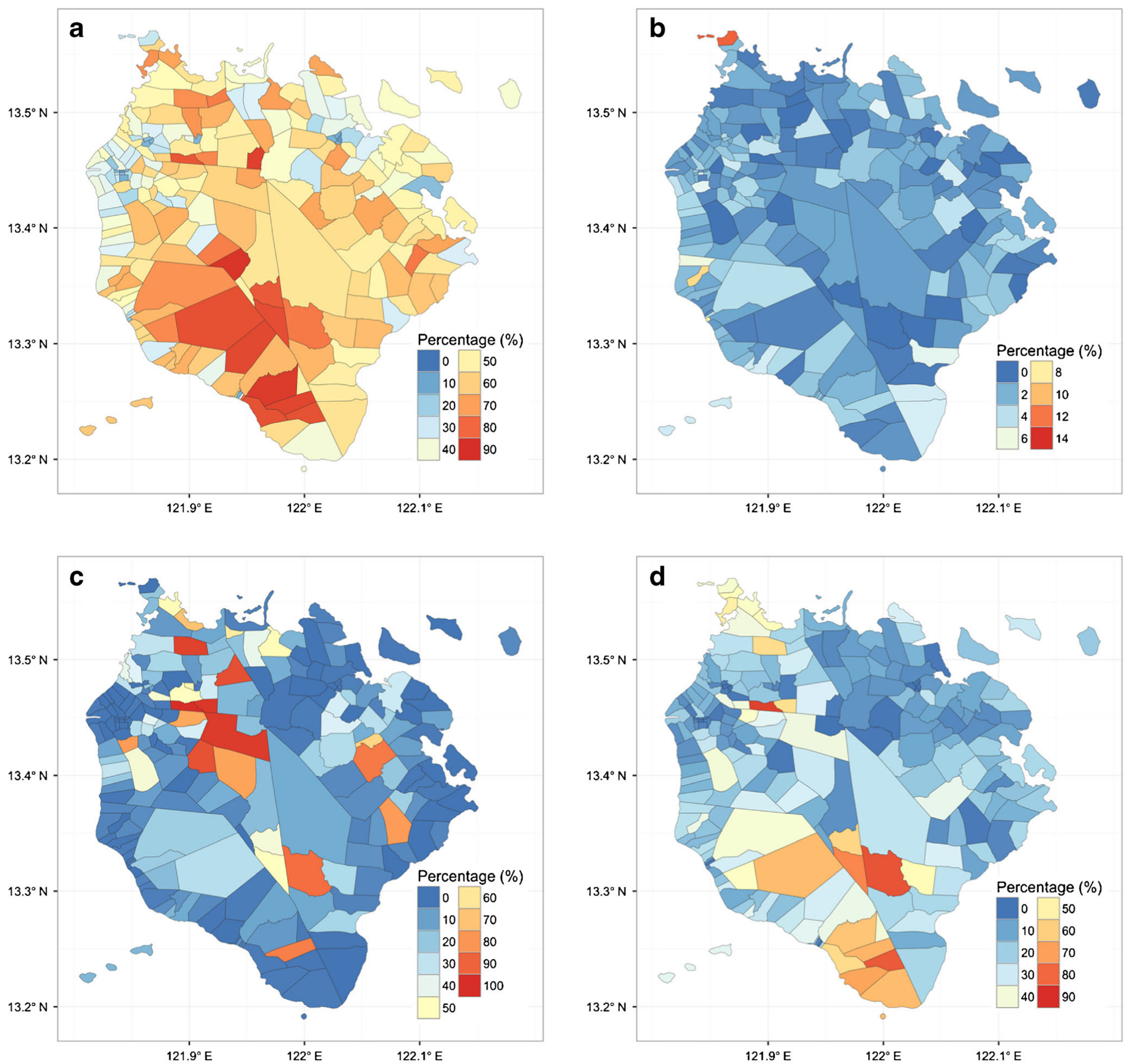

Fig. 3 Spatial distribution of (**a**) poverty incidence; (**b**) unemployment rate; (**c**) proportion of household without access to safe water; and, (**d**) proportion of household without access to sanitary toilet facilities

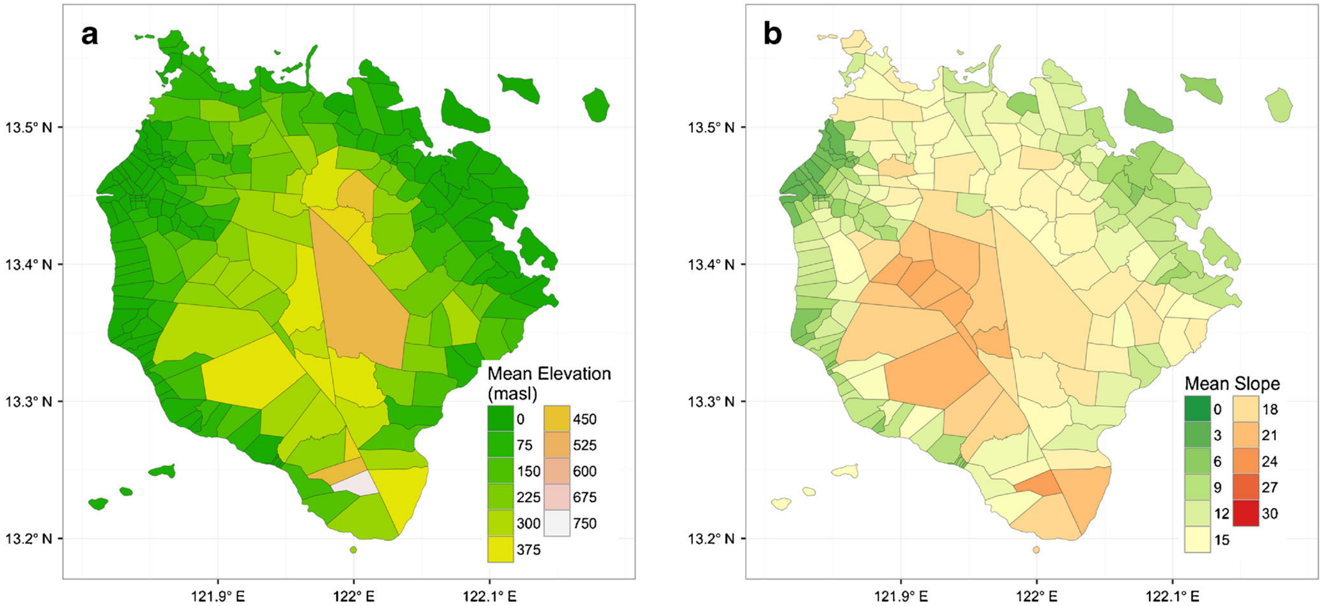

Fig. 4 Village level mean (**a**) elevation; and (**b**) slope

villages) and maximum of 61% (recorded in the village of Pili in the municipality of Boac. However, almost 21% (45 out of 218) of the villages have a malnutrition rate above the 13.6% national target (FNRI 2013). The majority (51%) of these 45 villages are located in the municipalities of Boac (31%) and Mogpog (20%). Global Moran's I result (0.11) suggests significant (*p-value* < *0.01*) low spatial clustering of village level malnutrition in the province. Based on local indicators of spatial association (LISA) (Anselin 1995) 18 significant clusters were identified (Table 2). Eleven of the 18 villages were identified as High-High clusters while the remaining seven fall on the Low-High cluster (Fig. 2).

Socioeconomic Indicators

Based on the 2008 Marinduque CBMS report, the average poverty incidence in the province is around 50% with a minimum of 7.1% and maximum of 89.1%. In fact, 108 out of 218 (49.5%) villages in the province have a poverty incidence of more than 50%. On the other hand, the village level unemployment rate in Marinduque is very low, on average around 2.0%, with a minimum of 0% and maximum 12.6%. This four times lower than the national average (8%) during the same year (2008) and three times lower than the present national average of 6.1% (PSA 2016b). However, in 19 of the 218

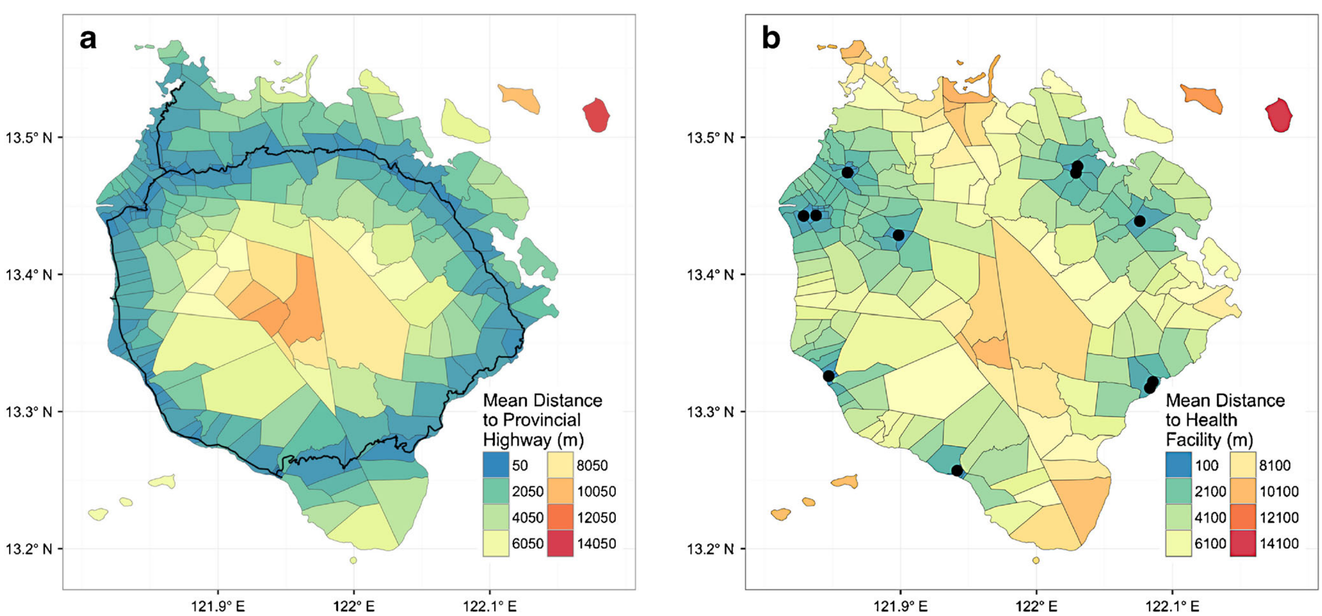

Fig. 5 Mean village level distance to (**a**) provincial highway (black line); and, (**b**) health facilities (black dots)

villages 50% of the households do not have access to a safe water supply. On average 5% of households do not have access to a safe water supply, with a minimum of 0% and maximum of 100%. In addition, there are still villages in the province where households do not have access to sanitary toilet facilities - overall, about 19% of village households do not have access to sanitary toilet facilities (Fig. 3).

Topographic Factors

The average elevation of villages in the province is around 19 masl, with the lowest at 11 masl and the highest at 734 masl. The average slope of villages is around 12°, minimum of 3° and maximum of 23° (see Salvacion 2016) (Fig. 4).

Proximity

One village, Mongpong, an island village of the municipality of Sta. Cruz, is farthest from both the main highway and the closest health facilities at approximately 14 km. The provincial highway traverses fewer than half (42%) of all the villages in the province but on average villages are within 2 km. The average distance of villages from health facilities in the province is around 4 km (Fig. 5).

Climatic Factors

Rainfall in the provinces varies from January to December (Fig. 6). The highest rainfall (331 mm) is during October

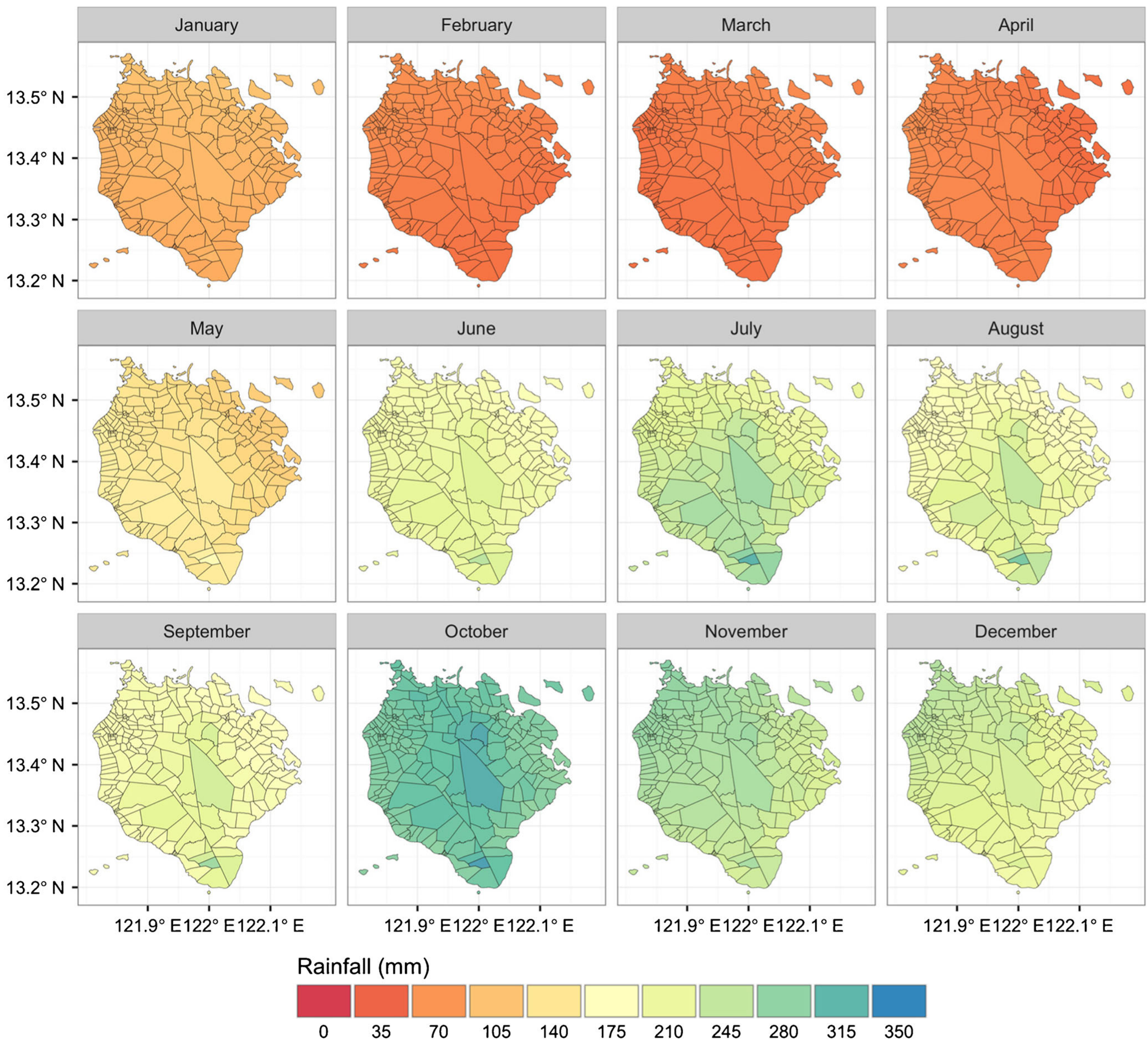

Fig. 6 Monthly village level rainfall map of Marinduque

while the lowest (10 mm) is during March. Average monthly mean temperature also varies (Fig. 7). In addition, there is large within month variation in average monthly mean temperature. The lowest (22.3 °C) is during the month of Janurary while the highest (28.8 °C) is during May.

Regression Analysis

Of the 34 variables tested as explanatory factors of levels of child malnutrition in the province, only two showed significance (Table 3): distance to the provincial highway and average monthly mean temperature during April. On the other hand, when the model was reduced using stepwise regression technique, eight of 13 exploratory variables showed significance (Table 4): access to sanitary toilet facilities; distance to provincial highway; rainfall during February, August, and December; average monthly mean temperature during July and November; and, latitudinal position. However, when the explanatory variables from the reduced model were used for spatial lag regression to account for the spatial relationship of malnutrition prevalence (Fig. 2b), all 13 variables showed significance (Table 5). Variables with the reduction standard in standard error were also observed. Proportion of households without access to safe water; proportion of households without access to sanitary toilet facilities; distance to provincial highway; rainfall during January, September, and December; and mean monthly average temperature during

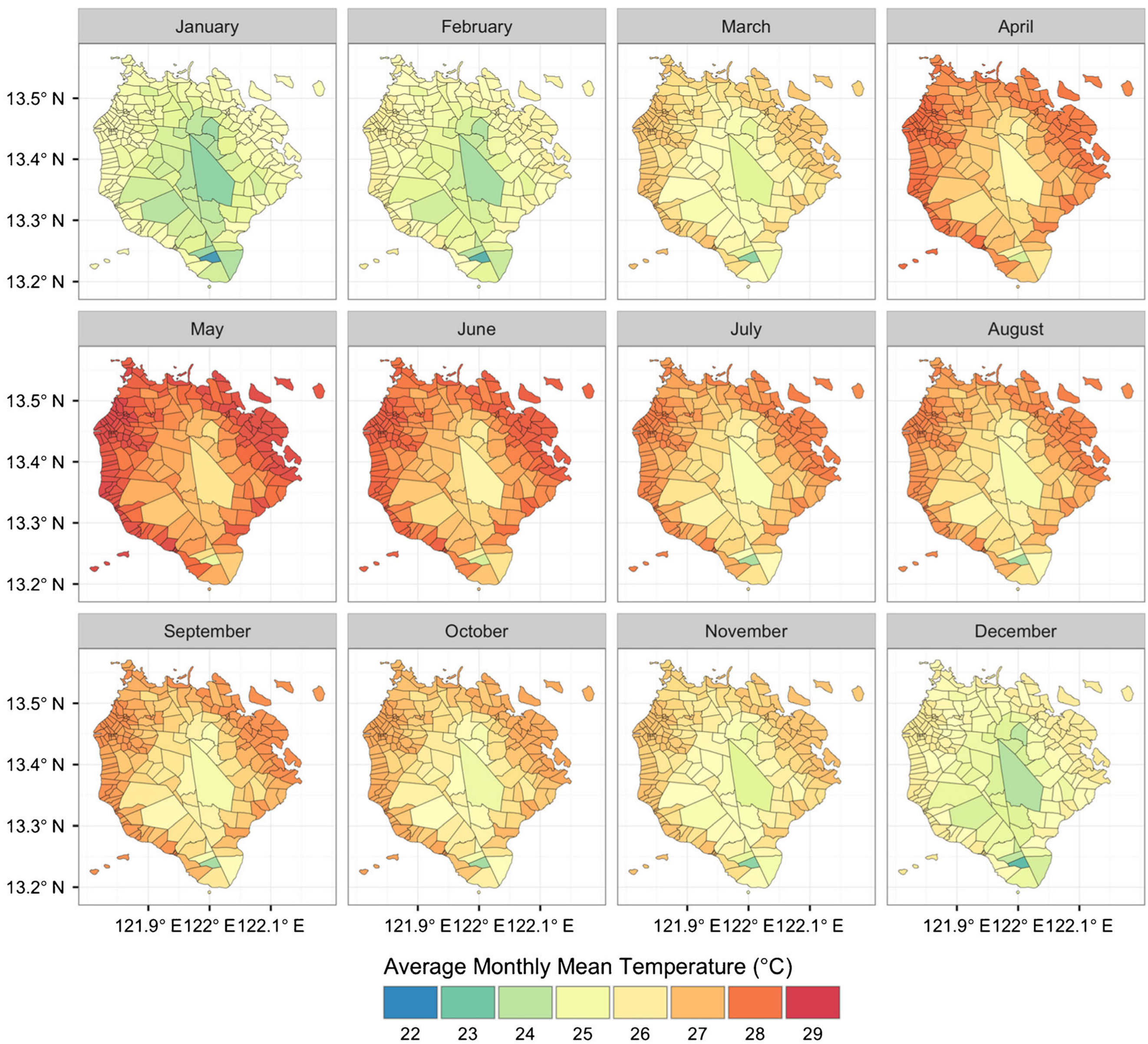

Fig. 7 Monthly village level average monthly mean temperature map of Marinduque

Table 3 Full model coefficients of different determinants of malnutrition in Marinduque

Variables	Coefficient	Standard Error	*p*-value
Poverty Incidence	0.05	0.05	0.31
Unemployment Rate	−0.27	0.37	0.47
Proportion of Household Without Access to Safe Water	0.05	0.03	0.09 *
Proportion of Household Without Access to Sanitary Toilet Facilities	0.07	0.05	0.15
Mean Elevation	−0.02	0.04	0.55
Mean Slope	−0.30	0.28	0.28
Longitude	−166.00	129.70	0.20
Latitude	−144.00	109.00	0.19
Distance to Health Facilities	0.00	0.00	0.84
Distance to Provincial Highway	0.00	0.00	0.04 *
Rainfall (January)	2.23	2.38	0.35
Rainfall (February)	−4.73	2.62	0.07
Rainfall (March)	1.42	2.51	0.57
Rainfall (April)	0.69	2.80	0.81
Rainfall (May)	−3.43	2.14	0.11
Rainfall (June)	2.67	2.70	0.32
Rainfall (July)	1.29	2.23	0.56
Rainfall (August)	−1.87	2.10	0.37
Rainfall (September)	0.42	1.93	0.83
Rainfall (October)	−2.57	1.47	0.08 *
Rainfall (November)	0.22	1.94	0.91
Rainfall (December)	1.79	1.76	0.31
Mean Temperature (January)	21.34	28.41	0.45
Mean Temperature (February)	20.05	25.72	0.44
Mean Temperature (March)	15.08	26.13	0.56
Mean Temperature (April)	−57.64	26.76	0.03 *
Mean Temperature (May)	−4.69	28.14	0.87
Mean Temperature (June)	9.18	28.36	0.75
Mean Temperature (July)	20.21	26.52	0.45
Mean Temperature (August)	10.21	26.70	0.70
Mean Temperature (September)	15.83	25.88	0.54
Mean Temperature (October)	−19.61	24.46	0.42
Mean Temperature (November)	−45.63	29.60	0.12
Mean Temperature (December)	−10.10	29.01	0.73

p-value followed by asterisk (*) is significant at $\alpha = 0.1$

the month of July showed positive regression coefficients to the prevalence of child malnutrition in the province. This means that a unit increase in these variables will increase prevalence of child malnutrition in the province. However, a small increase in the prevalence of child malnutrition is expected from increase in these variables as reflected on the calculated regression coefficient. For these variables, mean temperature during July showed the highest coefficient (46.04) while distance to provincial highway showed the lowest (0.00). Slope; rainfall during February, August, and October; mean temperature during April and November; and latitudinal location negatively impact child malnutrition prevalence in the province. The highest negative coefficient (in terms of magnitude) was calculated for latitudinal location (−196) while the lowest was calculated for slope (−0.39).

Discussion

Of the 34 variables analyzed for potential effect on the prevalence child malnutrition in the province, only 13 were included in the final model (spatial lag). Among the socioeconomic variables, access to safe water supply and access to sanitary

Table 4 Reduced model coefficients of different determinants of malnutrition in Marinduque

Variables	Coefficient	Standard Error	*p*-value
Proportion of Household Without Access to Safe Water	0.05	0.03	0.07 *
Proportion of Household Without Access to Sanitary Toilet Facilities	0.10	0.04	0.02 *
Slope	−0.38	0.23	0.10 *
Latitude	−194.40	63.56	0.00 *
Distance to Provincial Highway	0.00	0.00	0.01 *
Rainfall (January)	1.53	0.93	0.10 *
Rainfall (February)	−2.34	0.99	0.02 *
Rainfall (August)	−0.78	0.30	0.01 *
Rainfall (October)	−0.94	0.61	0.13
Rainfall (December)	1.06	0.37	0.00 *
Mean Temperature (April)	−29.04	18.52	0.12
Mean Temperature (July)	46.31	17.81	0.01 *
Mean Temperature (November)	−44.37	20.65	0.03 *

p-value followed by asterisk (*) is significant at $\alpha = 0.1$

toilet facilities were the two factors identified as effecting village level child malnutrition in the province. Several studies report an association between improved water supply and sanitation and better growth outcomes of children (see Ngure et al. 2014). Merchant *et al.* (2003) reported that children from households with water and sanitation showed the lowest incidence of stunting and that stunted children from such households have 17% greater chance of reversing their condition than stunted children from households without either of the facilities. Mean slope of the village showed significant a negative influence to child malnutrition. Hoddinott and Kinsey (2001) identified acres of sloped and steeply sloped land holdings as having a negative effect on children's growth in Zimbabwe, although the relationship is not significant.

Table 5 Spatial lag model coefficients of different determinants of malnutrition in Marinduque

Variables	Coefficient	Standard Error	p-value
Access to Safe Water	0.05	0.03	0.06 *
Access to Sanitary Toilet	0.10	0.04	0.01 *
Slope	−0.39	0.20	0.00 *
Latitude	−194.40	63.56	0.00 *
Distance to Provincial Highway	0.00	0.00	0.05 *
Rainfall (January)	1.57	0.51	0.00 *
Rainfall (February)	−2.39	0.71	0.00 *
Rainfall (August)	−0.79	0.20	0.00 *
Rainfall (October)	−0.96	0.43	0.03 *
Rainfall (December)	1.08	0.20	0.00 *
Mean Temperature (April)	−28.22	10.16	0.01 *
Mean Temperature (July)	46.04	8.07	0.00 *
Mean Temperature (November)	−45.42	8.87	0.00 *

p-value followed by asterisk (*) is significant at $\alpha = 0.1$

Distance to provincial highway showed significant but minimal effect on malnutrition in the province. However, according to de Sherbinin (2011), isolated regions, also described as "spatial poverty traps," are more likely to suffer malnutrition because they lack health services. A south to north trend in the village level prevalence of child malnutrition in the province can be attributed to the spatial arrangement and income class of different municipalities (PSA 2016a). The municipalities of Boac, Mogpog, and Sta Cruz that are located in the northern portion of the province were classified as first, first, and third class municipalities while the municipalities of Gasan, Torrijos, and Buenavista were classified as third, third, and fourth class municipalities, respectively. Monthly climatic conditions have contrasting influence on the prevalence of child malnutrition in the province. These linkages can be associated with agricultural production (Bain *et al.* 2013; Grace *et al.* 2012; Jankowska *et al.* 2012; López-Carr *et al.* 2015; Tirado *et al.* 2015), water availability (Bain *et al.* 2013; Grace *et al.* 2012; Jankowska *et al.* 2012), occurrence of different climate driven diseases (Bain *et al.* 2013; Khader *et al.* 2015; Tirado *et al.* 2013), and climatic disasters (Hoddinott and Kinsey 2001; Rodriguez-Llanes *et al.* 2016). Further, investigation is recommended to elucidate such associations.

Summary and Conclusion

This study explores potential determinants of malnutrition in the province of Marinduque, Philippines. A total of 34 variables were initially tested as potential determinants. Using step-wise regression this number was reduced to 13 in the final regression model. Among the social indicators tested, proportion of household with without access to safe water supply, and proportion of household without access to sanitary toilet facilities were included in the final model. In terms of topography, proximity, and geographic indicators slope, distance to provincial highway, and latitudinal location (north vs. south) of villages were the significant factors. Lastly, for climatic indicators rainfall during February, August, October, and December, and mean temperature during April, July, and November were significant. Factors that could have direct impact on health outcomes at the village level, such as unemployment rate, poverty incidence, and distance to health facilities, showed no significant effect. Further study is suggested to determine established linkage between climate and child malnutrition since the effect of climate can be both direct and indirect. Furthermore, information on how climate affects children's health in the province can assist provincial and national policy makers design appropriate measures to mitigate possible negative impacts of climate change. The results presented here can in the meantime can be used as a guide for the design of health policies to be implemented in the province, specifically improving the availability and access to public health facilities, the provision of safer water supplies and sanitary toilet facilities, and improved road to allow for easier mobility.

Compliance with Ethical Standards

Conflict of Interest The author declares no conflict of interest.

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