Geographic Information System-based Spatial Modelling of Soil-Transmitted Helminth Infections among Preschool-aged Children in Masbate, Philippines

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ABSTRACT

Objectives. Since the effectiveness of the Zero Open Defecation (ZOD) program as a scaling-up approach in lowering the rates of soil-transmitted helminth (STH) infections has not yet been locally explored, this study aimed to (1) describe the association between environmental determinants and STH cumulative prevalence, and (2) to predict the 2020 STH cumulative prevalence.

Methods. A generalized linear regression (GLR) model was used to determine the association of 2014–2015 environmental determinants and observed 2015 STH cumulative prevalence, while a geographically weighted regression (GWR) model was used to produce predicted 2020 STH cumulative prevalence.

Results. ArcGIS' GLR tool with R^2 of 63% found that statistically significant environmental determinants include distance near to water bodies, forest land use, access to sanitary toilet, level one water source, and ZOD status, while the ArcGIS' GWR tool found that *barangays*, Cabangcalan, Matalangtalang, Talabaan, and Talib in Aroroy hypothetically met the national target below 30% for 2020 STH cumulative prevalence.

Conclusion. This study showed that *barangays* with a moderately low percentage of area with freshwater bodies, a moderately high percentage of households with sanitary toilet and level one water source, and a 100% status of ZOD have lower rates of STH cumulative prevalence in preschool-aged children in the selected municipalities in Masbate.

Keywords: Soil-transmitted helminths, environmental determinants, mass drug administration, hygiene, sanitation, geographic information system

INTRODUCTION

Soil-transmitted helminth (STH) infections are caused by nematodes of major concern to humans: the roundworm, *Ascaris lumbricoides*; the whipworm, *Trichuris trichiura*; and the hookworms, *Necator americanus,* and *Ancylostoma duodenale*. They are ranked first among neglected tropical diseases (NTD) in terms of contribution to years lived with disability exposing 386 million preschool-aged children (PSAC) worldwide.[1-3] STH infections persist in soils with adequate shade, moisture, and organic matter, with limited access to adequate water, sanitation, and hygiene (WaSH), and in low- to middle-income countries such as the Philippines.[4-9] Transmission occurs through ingestion of egg from fecally contaminated soil or water and skin penetration of larvae.[1-3] STH infections could lead to lung

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infiltration, appendicitis, obstructive cholecystitis, pancreatitis, peritonitis, volvulus, intestinal obstruction for severe cases, dysentery, rectal prolapse, clubbing of fingers, anemia, diarrhea, hypoalbuminemia, and pneumonitis.[1-3] WHO recommends integrating WaSH, preventive chemotherapy using albendazole (400 mg) and mebendazole (500 mg), and mapping for surveillance to improve the control the STH infections.[2-3]

In the Philippines, the nationwide Zero Open Defecation (ZOD) Program supervised by the Department of Health-Epidemiology Bureau (DOH-EB) in Manila is integrated into the nationwide Disease Prevention and Control Program (DPCP) supervised by the Department of Health-Research Institute of Tropical Medicine (DOH- RITM) in Manila to reduce the prevalence of STH infections below 30% in 2020. The DPCP advocates a WASHED strategy (Table 1) for the comprehensive control of STH infections, which includes long-term interventions such as access to safe water, sanitation, and personal hygiene, with emphasis on the prevention of open defecation in every municipal rural health units (RHUs) and city health offices (CHOs). The ZOD verification process was officially adopted by the DOH in early 2015 and became part of the Philippine Approach to Sustainable Sanitation (PhATSS) with three levels of achievement starting from ZOD (G1) to Total Sanitation (G3) in 2019. Criteria for achieving ZOD (G1) status include declared open defecation free, 100% of household access to sanitary toilets, available water and soap at/or near the toilet in all household toilets, proper disposal of excreta and/or diapers of children, elderly, and persons with disabilities, functional coordinating body in the LGU that addresses water, sanitation, and hygiene (WaSH) issues, existing local ordinance and functional ZOD monitoring team sustaining ZOD status, approved action plan or operational plan and funding allocation to reach basic sanitation (G2) status.[10]

The utility of Geographic Information System (GIS), a computer system designed to integrate, analyze, and visualize spatial information,[11] for spatial targeting of the population requiring preventive chemotherapy and WaSH interventions essential to implement tailored and cost-effective STH control measures has been demonstrated in Brazil, Zimbabwe, and the Philippines using available data on observed STH prevalence and data on environmental factors.[4,6,7,9] STH infections were found to be associated with precipitation, temperature, soil pH, soil moisture, poor households, human development index in Brazil.[4,9] Variables, soil pH, human population density, precipitation, temperature, and vegetation were also found to be relatively important in predicting the distribution of STH infections in Zimbabwe.[7] Magalhaes et al. (2015) found that distance to water bodies and rainfall were associated with an increase in STH infection prevalence, while temperature and vegetation were associated with a decrease in the STH infection prevalence in the Philippines.[6]

Since the effectiveness of the ZOD program as a scaling-up approach of the IHCP in lowering the rates of STH infections for PSAC has not yet been locally explored, this study aimed to (1) describe the association between environmental determinants and STH cumulative prevalence, and (2) to predict the 2020 STH cumulative prevalence among PSAC in the ZOD and non-ZOD *barangays* in the selected municipalities in Masbate based on the significant environmental determinants using ArcGIS Pro's spatial statistics tool.

Table 1. WASHED framework for STH control[10]

Criteria	Strategy
Water	• Access to potable water • Drainage and disposal/re-use/recycling of household wastewater (also referred to as gray water)
Sanitation	• Access to safe and sanitary sanitation facilities • Safe collection, storage, treatment, and disposal/re-use/recycling of human excreta (feces and urine) • Management/re-use/recycling of solid waste

Hygiene/ Education	• Appropriate information regarding prevention and treatment of STH
	• Dissemination of key messages to promote the following practices:
	  • Safe water storage
	  • Safe hand washing and bathing practices
	  • Safe treatment of foodstuffs
	  • Latrine use
	  • Wearing shoes

Deworming	• Regular mass drug administration

METHODS

Study location

Masbate, a province in Region V (Bicol Region) of The Philippines, is bounded by Burias and Ticao Pass in the North, Visayan Sea in the South, San Bernardino Strait in the East, and Sibuyan Sea in the West. It has an approximate land area of 1287.98 km^2, which stretches from latitude 12.3333 and longitude 123.5833, and is composed of twenty municipalities and one city. Most of the bodies of water in Masbate are rivers and in-lake waters, while the common water source in the province is the groundwater source. In this study, the selected municipalities were consisting of Aroroy, Cawayan, Milagros, and Monreal, having 41, 37, 27, and 11 *barangays,* respectively. All *barangays* in the selected municipalities were included in the study to explore spatial variation and distribution for each specified environmental variable and to meet the minimum values per study determinants in running ArcGIS Pro's geographically weighted regression tool. The selected municipalities were suitable sites for the study since these municipalities were from pilot municipalities for the ZOD Program and from participating municipalities in the 2015 STH parasitological survey in Masbate.

Data collection and processing

A literature review was conducted to identify the environmental determinants of STH transmission, such as geography and climate, land use, water and sanitation, and MDA coverage. Specific variables with corresponding conditions favorable for STH transmission from each determinant were identified through this study's literature review. Available 2014 to 2020 data on identified environmental determinants were requested and downloaded (Table 2).

This study utilized an ecological design to model and to produce a prediction of the cumulative prevalence of the STH among PSAC in the selected municipalities in Masbate, Philippines. The predictors or exposure variables were composed of environmental determinants, while the variable to predict or outcome variable was the STH cumulative prevalence. The percentage and average were used to describe each specified continuous exposure and outcome variable. The P-value and R-squared (R^2) were used to evaluate the bias and precision of the performance of the generalized linear regression model. The target population and unit of analysis was the *barangay*, the smallest administrative unit in the country. This study utilized the aggregated data by percentage of the 2015 STH parasitological survey among PSAC in similar selected municipalities in Masbate by Belizario et al. (2016) and did not directly involve human participants approved by the UP-Manila Research Ethics Board (2019-520-01).[12] A licensed GIS software, ArcGIS Pro 2.7.1 (ESRI Inc; Redlands, CA, USA), was used for data preparation, standardization, integration, processing, and statistical analysis of the study variables.

The study variables for geography and climate, and land use per *barangay* were standardized based on each raster's percent pixel value using ArcGIS Pro's zonal statistics tool by mean (Table 3).

The generated layers were integrated with the MDA coverage data and observed STH cumulative prevalence data from the 2015 parasitological survey among 1,224 preschool-aged children from 39 *barangays* and 2014-2020 certified ZOD and non-ZOD *barangays* in the municipalities of Aroroy, Cawayan, Milagros, and Monreal in Masbate to create a final dataset for spatial modelling using ArcGIS Pro's spatial statistics tool.

A generalized linear regression model was used to determine the association of 2014-2015 environmental determinants and observed 2015 STH cumulative prevalence, while a geographically weighted regression model was used to produce predicted 2020 STH cumulative prevalence using the 2020 corresponding environmental determinants. P-values at < 0.01 and R^2 were used to evaluate the bias and precision of the generalized linear regression model.

RESULTS

Study variables

On average, the selected municipalities of Aroroy, Cawayan, Milagros, and Monreal in Masbate have moderately high percentages of precipitation at wettest quarter, elevation, and clay soil content for the geography and climate determinants; low percentages of agricultural and forest land use; moderately high percentages of households with sanitary toilets, proper waste disposal, and zero open defecation status; and moderately high MDA coverage in 2014 to 2020 (Table 4).

Performance of the GLR model

The GLR model shows the variability of each environmental parameter in the spatial modelling of the 2015 STH cumulative prevalence (Table 5). Only 5 out of 20 environmental determinants used were statistically significant. All statistically significant environmental determinants, distance near to water bodies, forest land use, access to sanitary toilet, level one water source, and ZOD status followed the known favorable conditions promoting STH transmission.[4-9] Significant environmental determinants such as level one water source and forest land use have a positive association with STH cumulative prevalence, while access to sanitary toilet, ZOD status, and distance near to water bodies have a negative association with STH cumulative prevalence according to their coefficients.

The R^2 for the GLR model revealed that 63% of the 2014 to 2015 data of the environmental determinants used fit the model, which indicates a moderately high precise model.[13]

Prediction of 2020 STH cumulative prevalence

Prediction maps generated by the GWR tool using the 2020 data of statistically significant environmental determinants shows the predicted 2020 STH cumulative prevalence in Aroroy, Cawayan, Milagros, Monreal in Masbate (Figures 1 and 2). Using the 2020 data of the statistically significant environmental determinants, the GWR tool predicted the lowest and highest STH cumulative prevalence of 27% and 83%, respectively. Only 4 out of 116 *barangays* hypothetically met the national target of the IHCP for the prevalence of STH infections below 30% in 2020. Moreover, the generated average percentage of predicted 2020 STH cumulative prevalence in Aroroy, Cawayan, Milagros, and Monreal was 46%, 73%, 52%, and 78%, respectively. The municipality of Aroroy generated the lowest STH cumulative prevalence of 27%. On average, however, none of the four selected municipalities hypothetically met the national target of IHCP below 30% in 2020.

A comparison between 2015 observed and 2020 predicted STH cumulative prevalence in ZOD and non-ZOD *barangays* in the selected municipalities in Masbate shows *barangays* with the closest and furthest 2015 observed and 2020 predicted STH cumulative prevalence (Table 6). The *barangays* with the closest difference between the actual and hypothetical STH cumulative prevalence among PSAC in Masbate sustained STH cumulative prevalence within 76% to 81% from 2015 and 2020. The environmental data of these *barangays* indicate a zero percentage of area near water bodies, a moderate percentage of forest land use, a

Table 2. Environmental determinants, variables, data sources, and conditions promoting STH transmission integrated for a GIS map in the selected municipalities in Masbate, Philippines

Environmental Determinants	Variable Name	Variable Description	Data Sources (Relevant Years Collected)	Conditions promoting transmission	References
Geography and climate	Temperature at wettest quarter	Average percentage of temperature at wettest quarter	World Clim (2020)	Decreasing temperature (ideal at 20 to 30°C)	Etewa et al., 2014; Magalhaes et al., 2015; Midzi et al., 2018; Pullan et al., 2011; Scholte et al., 2013;
	Temperature at driest quarter	Average percentage of temperature at driest quarter		Decreasing temperature (ideal at 20 to 30°C)	Etewa et al., 2014; Magalhaes et al., 2015; Midzi et al., 2018; Pullan et al., 2011; Scholte et al., 2013
	Precipitation at wettest quarter	Average percentage of precipitation at wettest quarter		Increasing precipitation (ideal at 80-300 mm)	Chammartin et al., 2014; Magalhaes et al., 2015; Pullan et al., 2011; Scholte et al., 2013
	Precipitation at driest quarter	Average percentage of precipitation at driest quarter		Increasing precipitation (ideal at 80-300 mm)	Chammartin et al., 2014; Magalhaes et al., 2015; Pullan et al., 2011; Scholte et al., 2013
	Canopy cover	Average percentage of canopy cover	USGS (2015), (2020)	Presence of trees providing increasing cover	Etewa et al., 2014; Magalhaes et al., 2015
	Soil moisture	Average percentage of soil moisture within *barangay*		Increasing soil moisture (ideal at 23-80%)	Chammartin et al., 2014; Etewa et al., 2014; Midzi et al., 2018
	Distance near to water bodies	Average percentage of distance near to water bodies within *barangay*		Decreasing distance to water bodies	Etewa et al., 2014; Magalhaes et al., 2015
	Elevation	Average percentage of elevation within *barangay*	SRTM (2014)	Increasing elevation	Midzi et al., 2018; Pullan et al., 2011
	Sandy loam soil content	Percentage of sandy loam soil content within *barangay*	PhilSoil (2004)	Presence of sandy loam soil	Etewa et al., 2014; Midzi et al., 2018
	Loam soil content	Percentage of loam soil content within *barangay*		Presence of loam soil	Etewa et al., 2014; Midzi et al., 2018
	Clay soil content	Percentage of clay soil content within *barangay*		Presence of clay soil	Etewa et al., 2014; Midzi et al., 2018
Land use	Agricultural land use	Percentage of agricultural land use area within *barangay*	USGS (2015), (2020)	Presence of irrigation canal banks and fertilizer	Etewa et al., 2014; Midzi et al., 2018
	Forest land use	Percentage of forest land use area within *barangay*		Presence of vegetation; deforestation	Chammartin et al., 2014; Etewa et al., 2014; Magalhaes et al., 2015; Midzi et al., 2018
Water and sanitation	Level 1 water source	Percentage of households with level one water source within *barangay*	Masbate PHO-HEMS (2015), (2020)	Increasing Level 1 Water Source	Midzi et al., 2018; Scholte et al., 2013
	Level 2 water source	Percentage of households with level two water source within *barangay*		Decreasing Level 2 Water Source	Midzi et al., 2018; Scholte et al., 2013
	Level 3 water source	Percentage of households with level three water source within *barangay*		Decreasing Level 3 Water Source	Midzi et al., 2018; Scholte et al., 2013
	Access to sanitary toilet	Percentage of households with access to sanitary toilet within *barangay*		Decreasing access to sanitary toilet (ideal at <92%)	Midzi et al., 2018; Scholte et al., 2013
	Satisfactory disposal of solid waste	Percentage of households with satisfactory solid waste disposal within *barangay*		Unsatisfactory disposal of solid waste	Midzi et al., 2018
	ZOD status	Average percentage of status of the Zero Open Defecation within *barangay*		Non-ZOD (ideal at <100% sanitary toilets and handwashing facilities)	Midzi et al., 2018; Scholte et al., 2013
MDA Coverage	MDA coverage	Percentage of Mass Drug Administration coverage within *barangay*	Masbate PHO (2014), (2019)	Decreasing MDA coverage rates of albendazole and mebendazole (ideal at <75%)	Belizarion et al., 2016; WHO, 2020

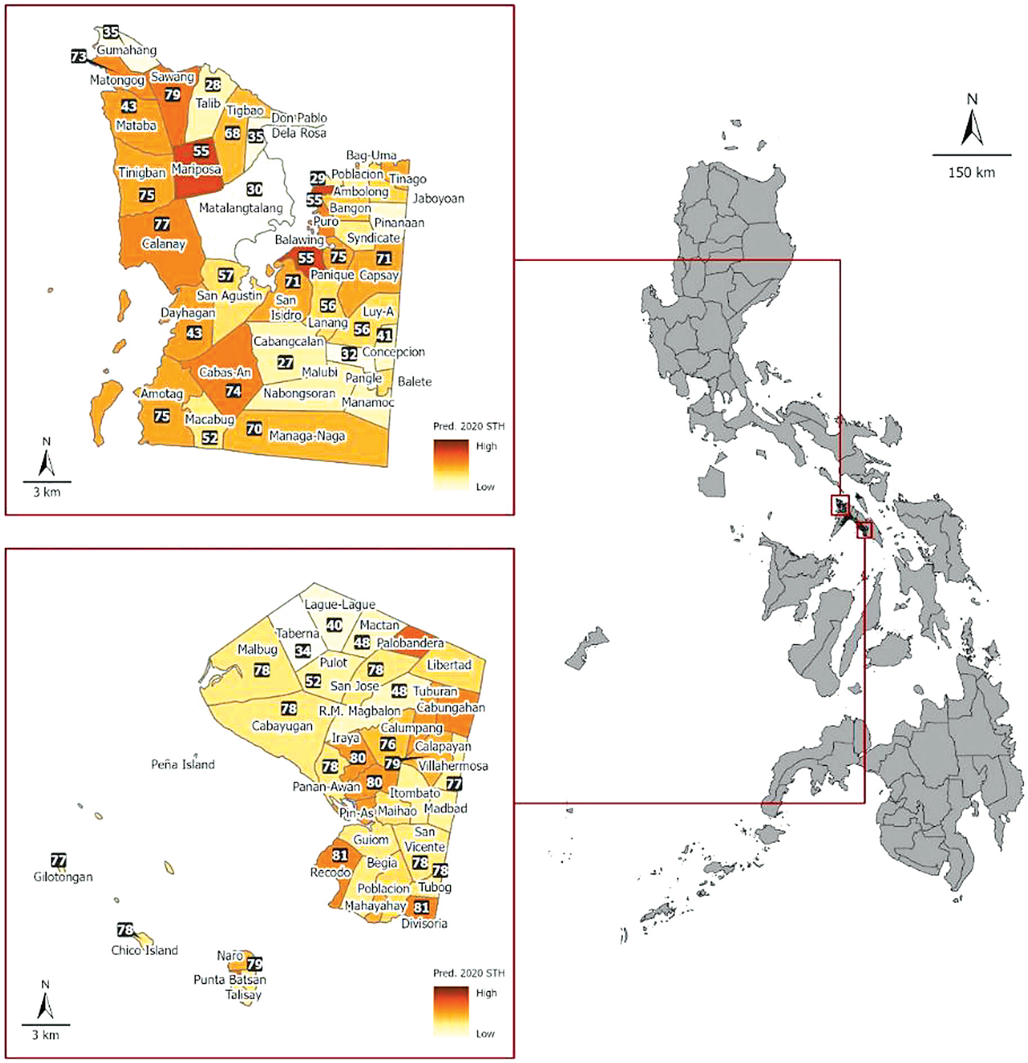

Figure 1. Predicted 2020 STH cumulative prevalence in Aroroy and Cawayan, Masbate, Philippines.

Table 3. Study variables

Geography and climate	Source
Temperature at wettest quarter (degree Celsius)	(WorldClim bioclimatic variables for 1970 to 2000)
Temperature at driest quarter (degree Celsius)	(WorldClim bioclimatic variables for 1970 to 2000)
Precipitation at wettest quarter (degree Celsius)	(WorldClim bioclimatic variables for 1970 to 2000)
Precipitation at driest quarter (degree Celsius)	(WorldClim bioclimatic variables for 1970 to 2000)
Canopy cover (index)	Post-processed 2015 and 2020 Landsat 8 Normalized Difference Vegetation Index (NDVI)
Soil moisture (index)	Post-processed 2015 and 2020 Landsat 8 Normalized Difference Moisture Index (NDMI)
Distance near to water bodies (sq. m)	Post-processed 2015 and 2020 Landsat 8 ISO Cluster Unsupervised Classification of land use
Elevation (m asl)	NASA's 90m resolution SRTM data
Sandy loam, loam, and clay soil content (sq. m)	2004 PhilSoil project
Land use	**Source**
Forest land use (sq. m)	Post-processed 2015 and 2020 Landsat 8 ISO Cluster Unsupervised Classification of land use
Agricultural land use (sq. m)	Post-processed 2015 and 2020 Landsat 8 ISO Cluster Unsupervised Classification of land use

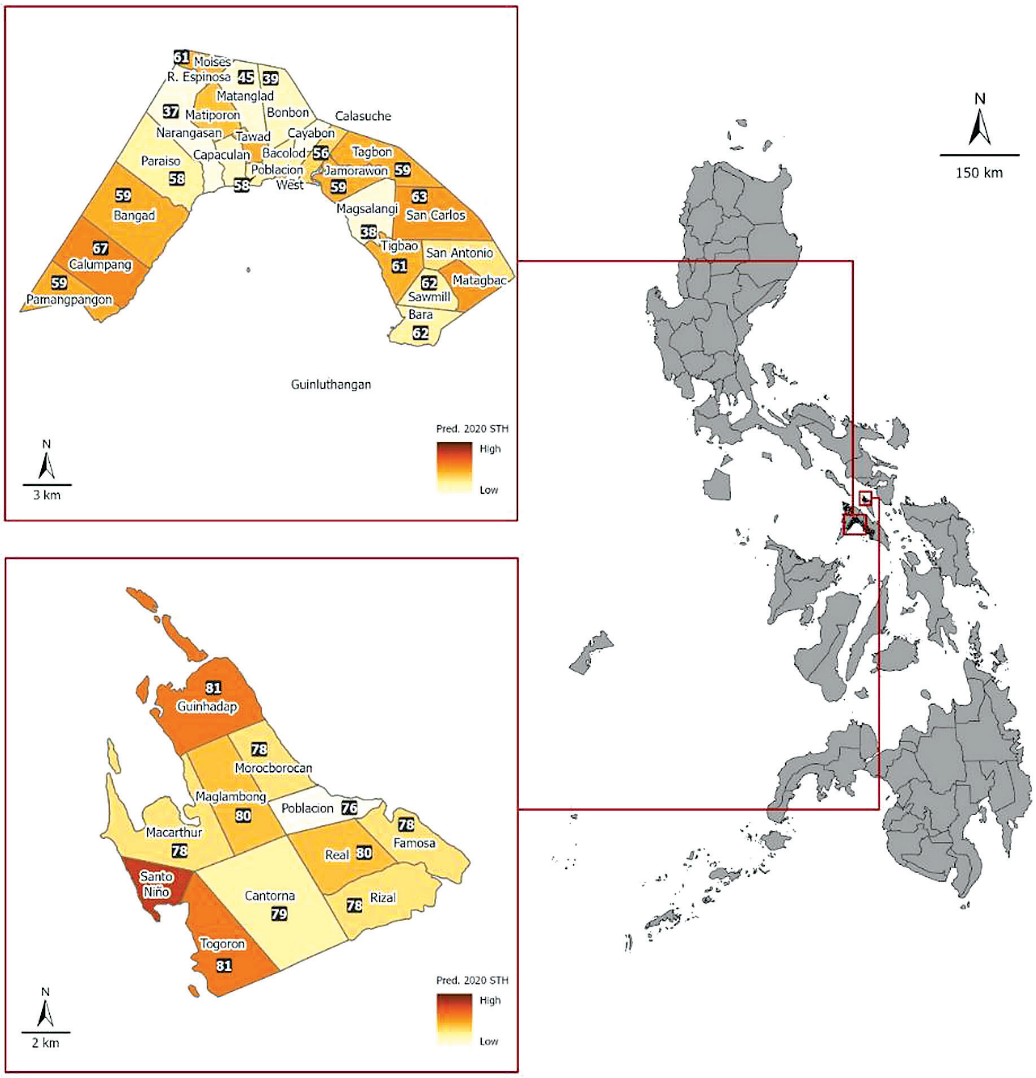

Figure 2. Predicted 2020 STH cumulative prevalence in Milagros and Monreal, Masbate, Philippines.

moderately low percentage of households with sanitary toilet, a moderate to low percentage of households with level one water source, and a zero percent status of ZOD from 2015 to 2020.

Barangays Begia, Cawayan and Cantorna, Monreal generated the closest 2015 observed and 2020 predicted STH, while *Barangays* Poblacion East, Milagros and Tuburan, Cawayan generated the furthest difference between the actual and hypothetical STH cumulative prevalence among PSAC in Masbate (Table 7).

Spatial Risk Prediction

The coefficients for the statistically significant environmental determinants and the 2020 predicted STH cumulative prevalence in the selected *barangays* in Masbate, identifies the clustering of *barangays* where statistically significant favorable environmental conditions for STH transmission can be found (Table 8; Figures 3 to 6).

DISCUSSION

This study described the association between environmental determinants such as geography and climate, land use, water and sanitation, and MDA coverage with STH cumulative prevalence using 2014 to 2015 data in the selected municipalities in Masbate. The GLR tool generated statistically significant environmental determinants, namely, distance near to water bodies, forest land use, household with sanitary toilet, households with level one water source, and ZOD status. All significant determinants followed the known favorable conditions promoting STH transmission. However, there were two environmental determinants among the non-significant determinants, namely, temperature at driest quarter and canopy cover, that differ from the known conditions favorable for STH transmission in Egypt, Brazil, Zimbabwe, and Africa[4,5,7-9] but followed the favorable conditions for STH transmission in

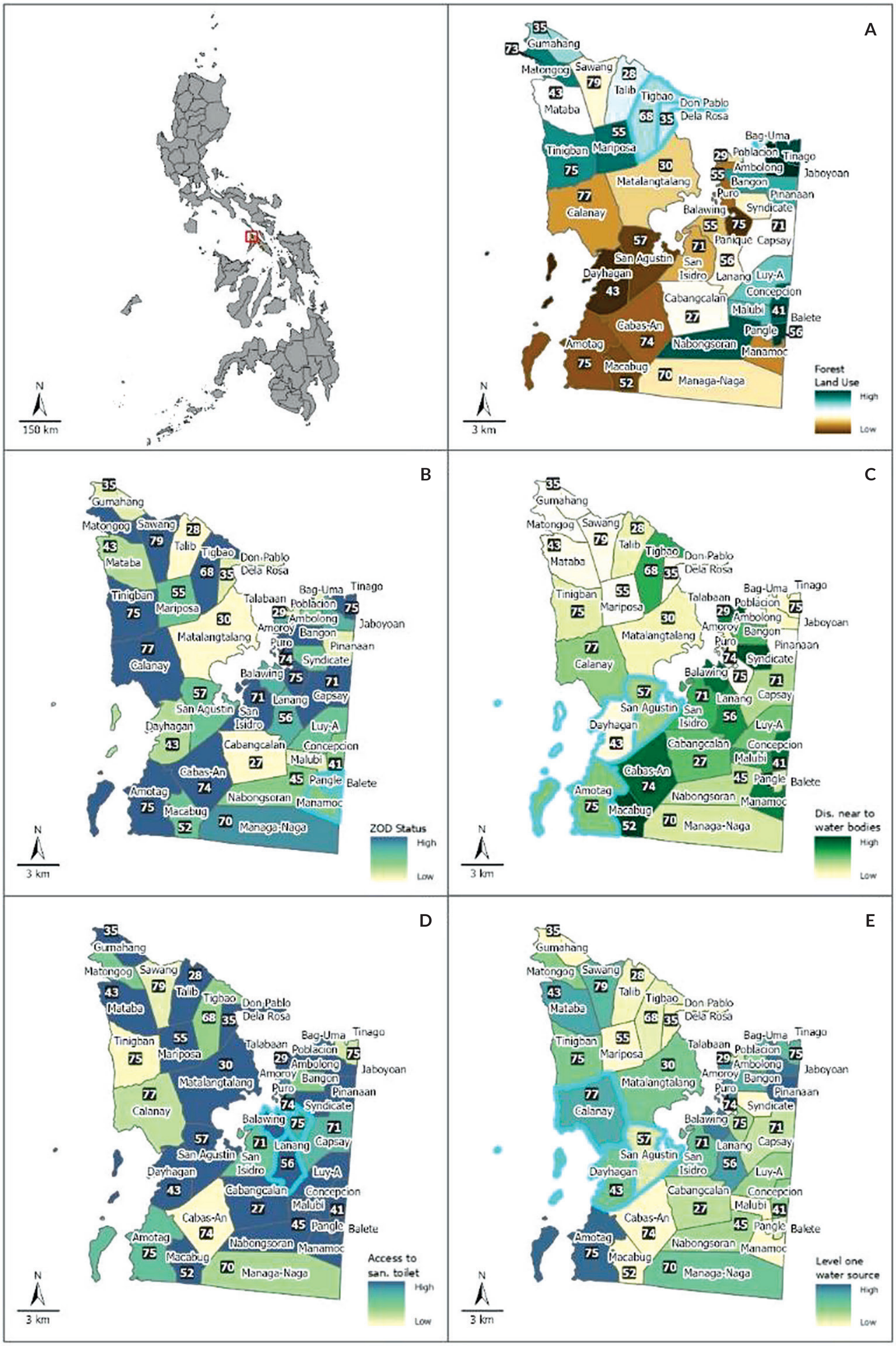

Figure 3. Predicted 2020 STH cumulative prevalence and GWR local coefficients per statistically significant environmental variables, **(A)** forest land use, **(B)** ZOD status, **(C)** distance near to water bodies, **(D)** access to sanitary toilet, and **(E)** level one water source in Aroroy, Masbate, Philippines.

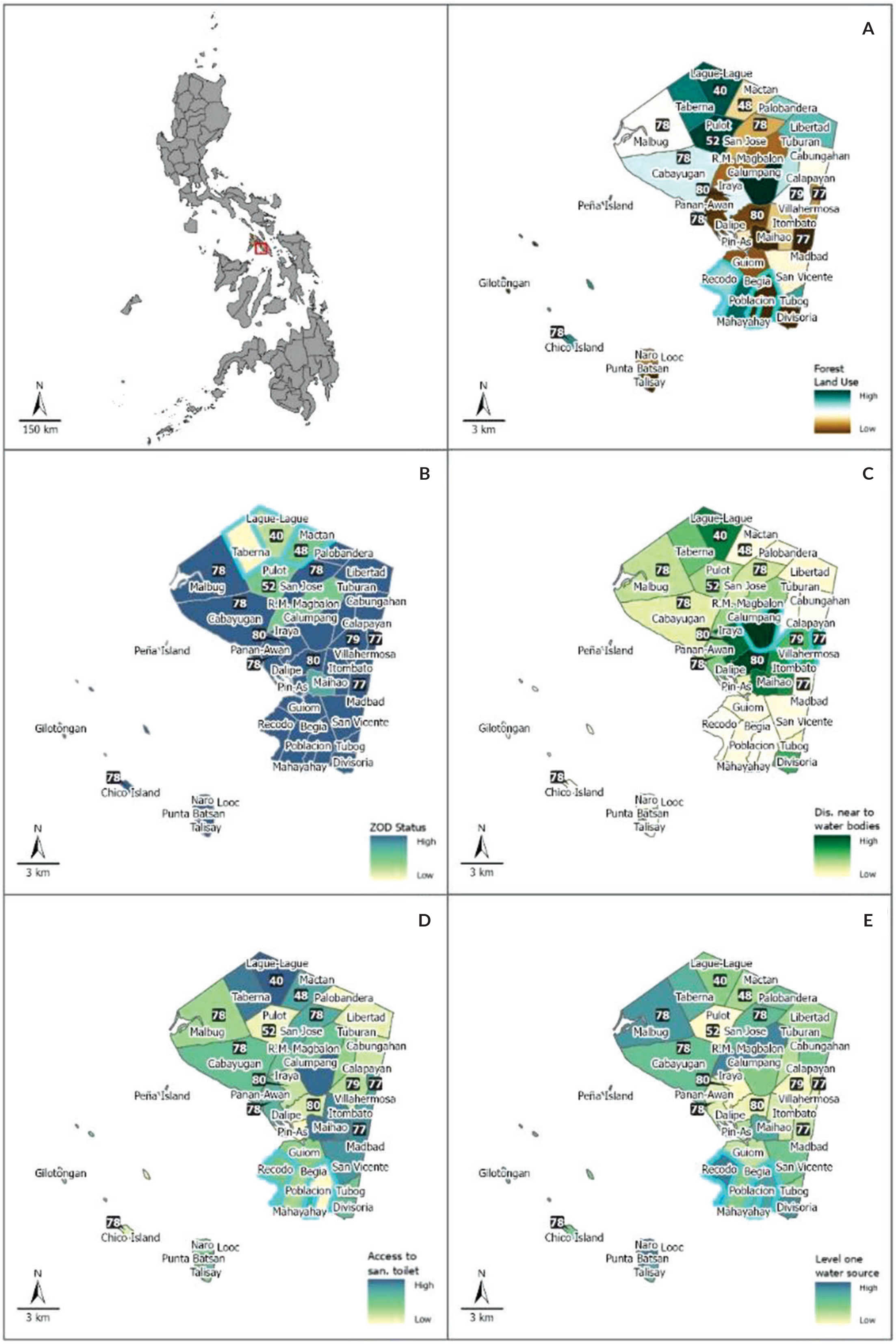

Figure 4. Predicted 2020 STH cumulative prevalence and GWR local coefficients per statistically significant environmental variables, **(A)** forest land use, **(B)** ZOD status, **(C)** distance near to water bodies, **(D)** access to sanitary toilet, and **(E)** level one water source in Cawayan, Masbate, Philippines.

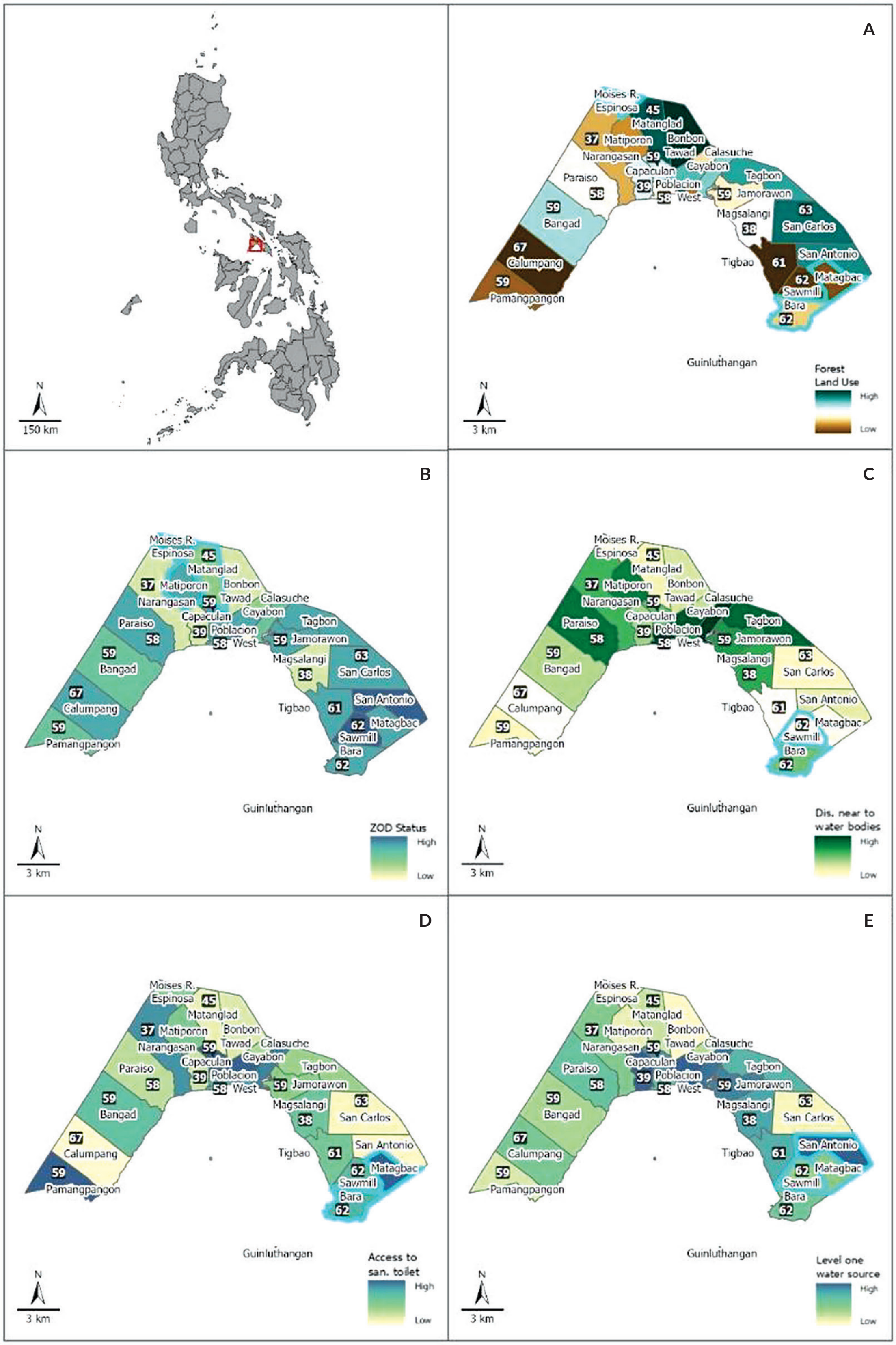

Figure 5. Predicted 2020 STH cumulative prevalence and GWR local coefficients per statistically significant environmental variables, **(A)** forest land use, **(B)** ZOD status, **(C)** distance near to water bodies, **(D)** access to sanitary toilet, and **(E)** level one water source in Milagros, Masbate, Philippines.

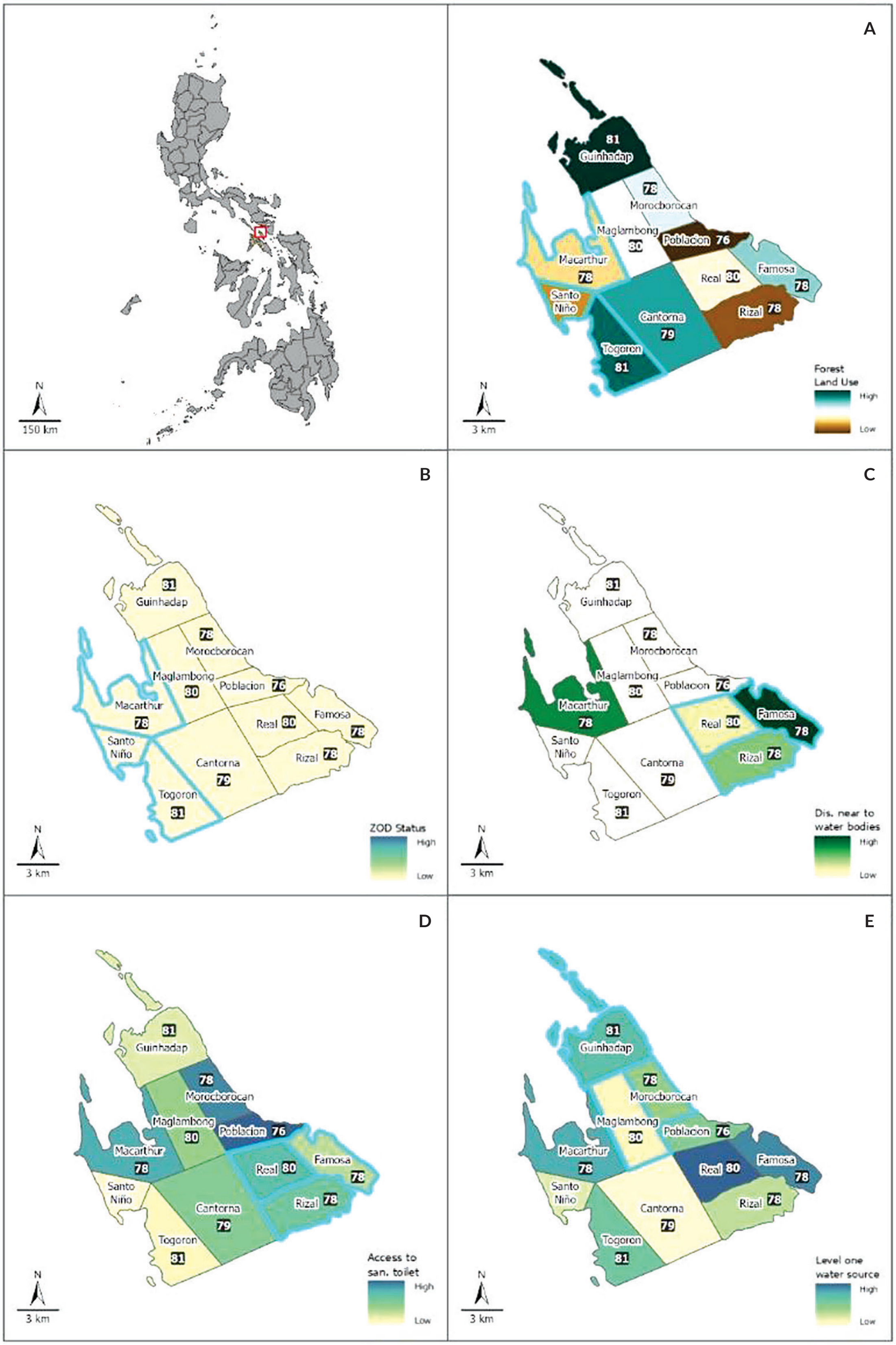

Figure 6. Predicted 2020 STH cumulative prevalence and GWR local coefficients per statistically significant environmental variables, **(A)** forest land use, **(B)** ZOD status, **(C)** distance near to water bodies, **(D)** access to sanitary toilet, and **(E)** level one water source in Monreal, Masbate, Philippines.

Table 4. Descriptive data of the study variables across the *barangays* in the selected municipalities in Masbate, Philippines

Variable Name	Minimum (%)	Maximum (%)	Average (%)
STH cumulative prevalence			
2015 STH cumulative prevalence	18.00	100.00	63.00
2020 STH cumulative prevalence	27.00	83.00	63.00
Environmental determinants			
2015 Temperature at wettest quarter	26.53	28.13	26.90
2015 Temperature at driest quarter	26.53	27.95	26.65
2015 Precipitation at wettest quarter	774.5	974.00	829.12
2015 Precipitation at driest quarter	229.61	2500.00	295.37
2015 Canopy cover	0.17	0.43	0.35
2015 Soil moisture	0.02	0.25	0.16
2015 Distance near to water bodies	0.00	65.69	11.69
2015 Elevation	3.69	215.70	51.17
2015 Sandy loam soil content	0.00	107.44	14.39
2015 Loam soil content	0.00	44.96	0.93
2015 Clay soil content	0.00	383.67	66.72
2015 Agricultural land use	0.00	659.45	35.60
2015 Forest land use	0.00	198.59	22.61
2020 Forest land use	0.00	83.51	23.72
2015 Level one water source	0.00	100.00	32.19
2020 Level one water source	0.00	100.00	43.70
2015 Level two water source	0.00	95.00	32.52
2015 Level three water source	0.00	60.44	5.83
2015 Access to sanitary toilet	3.75	100.00	57.92
2020 Access to sanitary toilet	2.6	100.00	75.44
2015 Satisfactory solid waste disposal	0.00	100.00	51.92
2015 ZOD Status	0.00	100.00	14.66
2020 ZOD Status	0.00	100.00	51.72
2014 MDA Coverage	33.93	100.00	77.57

Table 5. Coefficient and p-value of environmental determinants using GLR

Variable Name	Coefficient (r)	p-value
2015 Forest land use	0.24	0.00*
2015 ZOD Status	-0.22	0.00*
2015 Distance near to water bodies	-0.29	0.01*
2015 Access to sanitary toilet	-0.22	0.01*
2015 Level one water source	-32.18	0.01*
2015 Temperature at driest quarter	24.63	0.08
2015 Precipitation at wettest quarter	0.01	0.12
2015 Temperature at wettest quarter	-24.03	0.15
2015 Level two water source	-0.09	0.19
2015 Agricultural land use	0.03	0.24
2015 Clay soil content	0.06	0.28
2015 Sandy loam soil content	0.08	0.31
2015 Soil moisture	71.25	0.34
2015 Canopy cover	-32.18	0.55
2015 Satisfactory solid waste disposal	-0.03	0.61
2014 MDA Coverage	-0.02	0.76
2015 Loam soil content	0.06	0.84
2015 Precipitation at driest quarter	24.63	0.85
2015 Level three water source	0.00	0.95
2015 Elevation	0.00	0.99

**Statistically significant p-value (p < 0.01)*

Table 6. ZOD and non-ZOD *barangays* with closest and furthest 2015 observed values and 2020 predicted values of STH cumulative prevalence

ZOD Status	Municipality	*Barangay*	Observed 2015 STH Cumulative Prevalence (%)	Predicted 2020 STH Cumulative Prevalence (%)	Difference (%)
Non-ZOD	Cawayan	Tuburan†	18	80	62
		Begia*	76	78	2
	Monreal	Cantorna*	81	79	2
ZOD	Milagros	Poblacion East†	100	31	69

**Closest 2015 observed and 2020 predicted STH cumulative prevalence; †Furthest 2015 observed and 2020 predicted STH cumulative prevalence*

Table 7. Data of statistically significant environmental determinants of the *barangays* with closest 2015 observed and 2020 predicted STH cumulative prevalence

Environmental Determinants	Begia, Cawayan	Cantorna, Monreal	Poblacion East, Milagros	Tuburan, Monreal
2015 Forest land use	40.30	56.25	16.81	20.52
2020 Forest land use	11.80	61.92	4.20	6.41
2015 ZOD Status	0.00	0.00	100.00	0.00
2020 ZOD Status	0.00	0.00	100.00	0.00
2015 Distance near to water bodies	0.00	0.00	25.54	0.00
2015 Access to sanitary toilet	34.32	32.57	100.00	23.03
2020 Access to sanitary toilet	43.69	58.43	98.96	46.69
2015 Level one water source	73.17	22.48	61.02	36.91
2020 Level one water source	47.33	18.37	100.00	36.91

the Philippines by Magalhaes et al. (2015) due to typhoons at driest quarter and deforestation.[6]

Most of the statistically significant environmental determinants were related to water and sanitation determinants. It is expected since it is known that the environmental conditions where the PSAC lives were highly dependent on water and sanitation. In the municipalities with lower rates of predicted 2020 STH cumulative prevalence, such as Aroroy and Milagros, most of the *barangays* were ZOD certified.

Moreover, this study also evaluated the bias and precision of models used by the GLR tool. The GLR tool generated 63% R^2, which indicates a moderately high precise model.[13] This study was able to predict the 2020 STH cumulative prevalence in PSAC in the ZOD and non-ZOD *barangays* in the selected municipalities in Masbate using the GLR tool – generated statistically significant environmental determinants. The four *barangays* that hypothetically met the national target of IHCP below 30% STH cumulative prevalence were found in Aroroy, Masbate. These *barangays* have observed STH cumulative prevalence in 2015 that ranges from 71% to 86%. Despite the landfall of typhoons, Tisoy and Ursula in 2019 and pandemic in 2020, *barangays* Cabangcalan, Matalangtalang, Talabaan, and Talib in Aroroy managed to sustain their perfect percentages of households with sanitary toilets and prevent revocation of their ZOD certificates since 2014.

The *barangays* with the closest difference between the actual and hypothetical STH cumulative prevalence among PSAC in Masbate exhibited a major increase and decrease; Tuburan, Cawayan generated 2020 predicted STH cumulative prevalence of 81% in comparison to its observed 2015 STH cumulative prevalence of 18%, while Poblacion East, Milagros generated 2020 predicted STH cumulative prevalence of 31% in comparison to its observed 2015 STH cumulative prevalence of 100%. On the one hand, the environmental data of Tuburan, Cawayan shows a zero percentage of area near water bodies, a low percentage of forest land use, a moderately low percentage of households with sanitary toilet and level one water source and a zero percent status of ZOD from 2015 to 2020. On the other hand, the environmental data of Poblacion East, Milagros shows a 25 percentage of area near water bodies, a low percentage of forest land use, a moderately high percentage of households with sanitary toilet and level one water source, and a 100% status of ZOD.

The prediction of the 2020 STH cumulative prevalence in *barangay* Poblacion East was largely affected by the data on statistically significant environmental determinants for geography, and water and sanitation, which suggests that *barangays* with a moderately low percentage of area with fresh water bodies, a moderately high percentage of households with sanitary toilet and level one water source, and a 100% status of ZOD lowers the rates of STH cumulative prevalence in PSAC in Masbate.

The results of this study were interpreted considering the study's limitations. Limitations of the study include the limited sample size of *barangays* with observed 2015 STH cumulative prevalence in generating the model for predicting the 2020 STH cumulative prevalence, poor reliability of ZOD certification for monitoring and evaluation of DPCP for helminths, unavailability of data on the water quality of water sources and nearby fresh water bodies within a *barangay*, and the poor generalizability of the results since significant environmental determinants may vary in other municipalities. Moreover, the prediction model was able to identify areas only at the *barangay* level lacking a goodness-of-fit test due to unavailable actual 2020 data of statistically significant environmental determinants.

CONCLUSION

Identifying significant environmental determinants and predicting disease prevalence are possible using GIS. The ArcGIS' GLR tool with R^2 of 63% generated five out of twenty statistically significant environmental determinants, namely, distance near to water bodies, forest land use, households with sanitary toilet, households with level one water source, and ZOD status. Moreover, the ArcGIS' GWR tool produced a prediction of 2020 STH cumulative prevalence, which revealed that *barangays* with a moderately low percentage of area with freshwater bodies, a moderately high percentage of households with sanitary toilet and level one water source, and a 100% status of ZOD have lower rates of STH cumulative prevalence in PSAC in selected municipalities in Masbate.

The Philippine Approach to Sustainable Sanitation (PhATSS) approach to STH control must be strictly practiced. DOH-RITM and DOH-EB must strictly encourage the CHOs and municipal RHUs to follow the WASHED framework of the DPCP in the identified priority *barangays* in Masbate. In addition to MDA in the prioritized *barangays*, the CHOs and RHUs must enforce the ZOD certification, proper installation and distance of sanitary toilets and water sources, filtered handpumps, and proper handling and storage of water containers. Moreover, future studies in modelling STH cumulative prevalence must investigate reliable approaches to the integration of water and sanitation data such as water quality of water sources and nearby freshwater bodies and ZOD certification with the STH transmission.

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Statement of Authorship

All authors participated in the data collection and analysis and approved the final version submitted.

Author Disclosure

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