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Use of geographic information system as a tool for schistosomiasis surveillance in an endemic Municipality in Eastern Samar, The Philippines

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Abstract

This study aimed to demonstrate the use of geographic information systems (GIS) in identifying factors contributing to schistosomiasis endemicity and identifying high-risk areas in a schistosomiasis-endemic municipality in the Philippines, which was devastated by Typhoon Haiyan in 2013. Data on schistosomiasis determinants, obtained through literature review, the Philippine Department of Health, and concerned local government units, were standardized and incorporated into a GIS map using ArcGIS. Data gathered included modifiable [agriculture, poverty, sanitation, presence of intermediate and reservoir hosts, disease prevalence and mass drug administration (MDA) coverage] and non-modifiable (geography and climate) determinants for schistosomiasis. Results showed that most barangays (villages) are characterized by favourable conditions for schistosomiasis transmission

which include being located in flood-prone areas, presence of vegetation, low sanitary toilet coverage, presence of snail intermediate host, high carabao (water buffalo) population density, previously reported ≥1% prevalence using Kato-Katz technique, and low MDA coverage. Similarly, barangays not known to be endemic for schistosomiasis but also characterized by the same favourable conditions for schistosomiasis as listed above and may therefore be considered as potentially endemic, even if not being high-risk areas. This study demonstrated the importance of GIS technology in characterizing schistosomiasis transmission. Maps generated through application of GIS technology are useful in guiding program policy and planning at the local level for an effective and sustainable schistosomiasis control and prevention.

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Introduction

Schistosomiasis, caused by the blood fluke *Schistosoma* spp., is a debilitating and potentially fatal neglected tropical disease (NTD) affecting about 240 million people according to the World Health Organization (WHO, 2020). It persists in areas where access to adequate sanitation and hygiene is limited, and remains a public health concern in low- and middle-income countries such as the Philippines. Transmission occurs through skin penetration by infective cercariae released by the intermediate snail host *Oncomelania hupensis quadrasi* during contact with contaminated waters (WHO, 2020). It is associated with morbidities such as under-nutrition, impaired cognitive processes, decreased work productivity and chronic abdominal or pelvic pain (King *et al.,* 2005). WHO aims to eliminate schistosomiasis by 2030 as a public health problem, defined as reducing prevalence of heavy intensity infections to <1% (WHO, 2020).

In the Philippines, schistosomiasis, caused by *S. japonicum*, remains endemic and according to the Philippine Department of Health (DOH) 189 municipalities and 15 cities in 28 provinces are infected, with approximately 2.5 million people at risk for the infection (DOH, 2018). The local government units (LGUs) in collaboration with DOH, through the Schistosomiasis Control and Elimination Program, implements community-based mass drug administration (MDA) of praziquantel every January as a key strategy for schistosomiasis morbidity control (DOH, 2007; 2016). Other strategies include case-finding and management; promotion of veterinary public health; snail control and surveillance; and improvements in water and sanitation facilities in all endemic areas (DOH, 2018). Pockets of high endemicity, however, are still observed despite a decade of program implementation (DOH, 2018). Among these is the Eastern Samar Province, which remains endemic for schistosomiasis with a prevalence of 4.3% in school-age children according to the regional office of the DOH (DOH RO VIII, 2016). In November 2013, the strongest typhoon (Haiyan) to ever hit the Philippines, devastated the province and posed challenges in schistosomiasis control as it disrupted the local health service delivery and compromised access to safe water and sanitation (United Nations Children's Fund, 2015; Salazar *et al.,* 2017). Inadequate water supply, limited access to sanitation facilities and poor hygiene practices are major contributing factors to the spread of schistosomiasis (Kouadio *et al.,* 2012).

Surveillance is needed to assess the status of schistosomiasis and identify the needed interventions for effective infection control. The WHO recommends mapping of endemicity as part of surveillance to allow identification of high-risk areas for the infection, which allows implementation of targeted delivery of services, especially when resources are limited (WHO, 2020).

The utility of geographic information systems (GIS), a computer-based tool designed to integrate, analyse, and visualize spatial information (Higgs, 2004), in mapping schistosomiasis endemicity has been demonstrated in several studies. It has been effectively used in Anhui Province in China to identify high-risk areas and possible transmission of schistosomiasis in other areas (Hu *et al.,* 2015). In the Philippines, GIS together with remote sensing was used to demonstrate how land use and topography affect spatial distribution of malaria and schistosomiasis in the province of Davao del Norte (Leonardo *et al.,* 2005). In the same province, GIS was also used to determine the relationship of various schistosomiasis determinants which may contribute to transmission of the infection (Belizario *et al.,* 2017). These studies exemplified very well how to visualize the factors contributing to schistosomiasis through GIS maps.

The War-on-Worms, the Nutrition, Water, Sanitation, and Hygiene Project led by the University of the Philippines in Manila in partnership with Plan International Philippines, investigated the status of schistosomiasis in Eastern Visayas (a major group of islands in the Philippines) after Typhoon Haiyan. As part of the project, this study aimed to demonstrate the use of GIS in identifying factors contributing to schistosomiasis endemicity and high-risk areas in an endemic and Haiyan-stricken municipality in Eastern Samar, one of the provinces in Visayas.

Materials and methods

Study location

Eastern Samar, a province in the Eastern Visayas region, is composed of 23 municipalities (Philippine Statistics Authority, 2015), ten of which are known to be endemic for schistosomiasis (DOH, 2009). Schistosomiasis prevalence in the province is 4.3% in school-age children (DOH RO VIII, 2016). Oras, a low income municipality, was selected as the study site due to its known endemicity for the infection with 25 out of 42 barangays (villages) known to be schistosomiasis-endemic (DOH RO VIII, 2016) (Figure 1). This selection was based on availability of data on factors contributing to schistosomiasis endemicity as well as active participation of and partnership with local stakeholders, such as the DOH and LGUs, could be counted on.

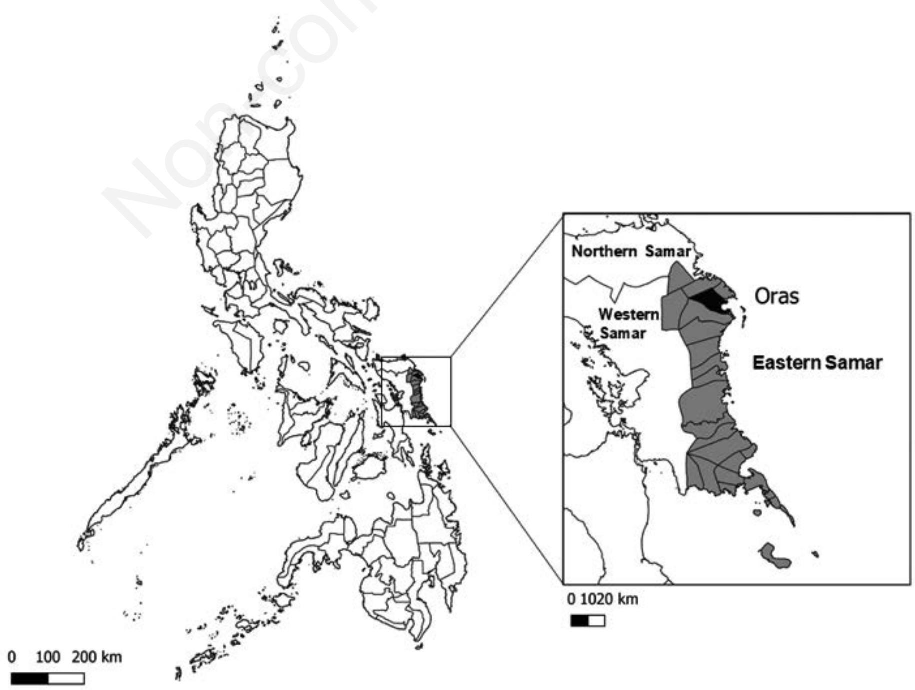

Figure 1. Map of the Philippines (left) and Eastern Samar Province (right) with the Oras Municipality.

Data collection and processing

A literature review was conducted to identify the determinants of schistosomiasis endemicity such as geography and climate; agriculture; poverty; sanitation; presence of intermediate and reservoir hosts; and MDA coverage. Specific variables from each determinant were identified, and conditions favourable for the infection were also obtained through this literature review. Sources of the identified schistosomiasis variables were determined through review of records and consultations with key staff from the DOH Eastern Visayas-Centre for Health Development; the Provincial Health Office of Eastern Samar; and the Municipal Health Office of Oras, through a stakeholders' meeting. The latest quantitative data were obtained from the DOH, concerned LGUs and other relevant local agencies (Table 1).

Data on the determinants and variables identified were entered in ArcGIS, v. 10.2.1 (ESRI Inc.; Redlands, CA, USA) to create map layers. The generated layers were integrated and used to determine high-risk areas for schistosomiasis.

Geographical and climate maps were constructed by adjusting the data to the national bounding box and re-projected to local coordinates. Raster resolution used was one km. Data on types of irrigation and land use (*e.g.,* types of crops planted) for the year 2015 were obtained from the provincial and municipal Planning Development Office.

Poverty incidence data, obtained from the Philippine Statistics Authority was compared with the national target of <14% (NEDA, 2017). Barangays were classified according to sanitary toilet coverage: i) meeting the national target of 100% (DOH, 2010); ii) meeting the LGU target of ≥92% (Eastern Samar Provincial Health Office, 2016); or iii) <92%. Barangays were also classified according to the Rural Sanitation Graduation Framework as either: i) Barangays with open defecation areas; ii) Grade 1 barangays, which have zero open defecation (ZOD) in the village; iii) Grade 2 barangays, which have sustainable sanitation (*i.e.* each household has its own toilet); and iv) Grade 3 barangays, which have complete solid waste and waste water management, including drainage (DOH, 2010)

The locations of snail sites were geo-tagged using a global positioning system (GPS) and marked on the generated GIS map. Data were limited to areas where the DOH routinely conducts malacological surveys. *O. hupensis quadrasi* snail colonies with available data on prevalence of schistosomiasis in snails were classified as either having a prevalence of <8% or one ≥8%. Barangays were also classified as having a carabao (water buffalo) population density of either 0-15 or 16-30 carabaos per 100 population. These thresholds were based on expert opinion.

Prevalence of schistosomiasis per barangay was compared with the national target of <1% (DOH, 2007). Selected barangays were also classified based on seroprevalence. Based on prevalence, the barangays were classified as high-risk (≥50%); moderate-risk (10-50%); or low-risk (<10%) communities (WHO, 2006). seroprevalence of ≥10% were considered favourable for schistosomiasis transmission based on expert opinion. The MDA coverage for schistosomiasis per barangay in 2016 was obtained from Oras Rural Health Unit (2016) and compared with the target coverage of <75% (WHO, 2006).

A workshop involving representatives from DOH and involved LGU offices was held in September 2017 to present data on schistosomiasis determinants. A prototype GIS map was developed thereafter. Standardized data, following the specifications of ArcGIS 10.2.1, were incorporated in the GIS map by digitizing or tracing the location, path, or boundary of geographic features. Each GIS map layer corresponded to a unique schistosomiasis

Table 1. Determinants, variables, data sources, and conditions favourable for schistosomiasis transmission integrated in GIS map for Eastern Samar, the Philippines.

Determinant	Variable	Data source (year of collection)	Condition promoting transmission	Reference
Geography and climate	Topography	Eastern Samar PPDO (2015) Oras MPDO (2015)	Presence of bodies of freshwater	Grimes *et al.*, 2015
	Flood-prone areas		Presence of flood-prone areas	Katanha & Masocha, 2014
	Temperature	World Clim (2000)	Temperatures ranging from 15.4-30°C	Yang *et al.*, 2007; Zhou *et al.*, 2009
Agriculture	Irrigation	Eastern Samar PPDO (2015)	Presence of irrigation canals and dams	McManus *et al.*, 2010
	Land use (*e.g.* types of crops planted)	Oras MPDO (2015)	Lands used for vegetation	Zhang *et al.*, 2003
Poverty	Poverty incidence	PSA (2015)	Poverty incidence of >14%	NEDA, 2017
Sanitation	Sanitary toilet coverage	Oras MHO (2016)	Below the LGU target of 92%	Philippine DOH, 2010
	ZOD status	Eastern Samar PHO (2016)	Non-ZOD	Philippine DOH, 2010
Presence of intermediate hosts	Snail colonies	Philippine DOH RO VIII (2015)	Presence of snail colonies	Philippine DOH, 2007
	Schistosomiasis prevalence in snails		Prevalence of infection in snails of ≥ 8%	Expert opinion
Presence of animal reservoir hosts	Carabao population density	Eastern Samar PAGRO (2016)	Presence of carabao as animal reservoir host	Gray *et al.*, 2009
Disease prevalence	Schistosomiasis prevalence using Kato-Katz technique	Philippine DOH RO VIII (2016)	Schistosomiasis prevalence of ≥1%	WHO, 2012
	Schistosomiasis seroprevalence using ELISA antibody	Belizario *et al.* (2018)	Schistosomiasis seroprevalence of ≥10%	Expert opinion
MDA coverage	MDA coverage of praziquantel	Philippine DOH RO VIII (2016)	<75% MDA coverage rates of praziquantel	WHO, 2012

DOH, Department of Health; DOH RO VIII, Department of Health Regional Office VIII; ELISA, enzyme-linked immunosorbent assay; MDA, mass drug administration; MHO, Municipal Health Office; MPDO, Municipal Planning and Development Office; NEDA, National Economic and Development Authority; PAGRO, Provincial Agricultural Office; PHO, Provincial Health Office; PPDO, Provincial Planning and Development Office; PSA, Philippine Statistics Authority; WHO, World Health Organization; ZOD, zero open defecation.

determinant and were overlaid in the computer to highlight patterns and trends. Colours and symbols were used to distinguish different attributes. Follow-up workshops were conducted in November 2017 to discuss the draft version of the GIS map and in January 2018 to discuss the pre-final version.

Results

Geography, climate, and agriculture

Oras has forested areas in the western part of the municipality and wide plains in the central lowland areas. All the 25 barangays known to be schistosomiasis-endemic are adjacent to each other in the lowland areas. These include Batang, Cadia-an, Cagpile, Cagtu-og and Rizal in the North; Balingasag, Gamot and Naga in the West; Agsam, Balocawe, Binalayan, Burak, Paypayon and Tawagan in the East; and Bagacay, Bantayan, Bato, Dalid, Dao, Factoria, Japay, Kalaw, Mabuhay, Saugan and Trinidad in the South. Barangays not known to be endemic for the infection are mostly near the coastal areas and not adjacent to major bodies of freshwater. Flood-prone areas are concentrated in the southern and south-eastern lowland areas, and the barangays known to be endemic are located around major rivers of these plains. Temperatures in the study are vary within the 15.4-29.0°C range, with known schistosomiasis-endemic barangays having relatively high temperatures, except those in the southern area. The mountainous part of Oras consists of shrub lands or forests, while the lowlands are mostly used as rain-fed rice fields, which are also seen near flood-prone areas (Figure 2).

Poverty and sanitation

Oras had a poverty incidence of 54% in 2015 and overall sanitary toilet coverage of 72% in 2016. Twenty-eight out of the 42 barangays had <92% sanitary toilet coverage. Those in the East (Malingon, Pangudton and Riverside) as well as in the South (Dalid and Mabuhay) have <100% sanitary toilet coverage although they were declared G1 ZOD barangays (Figure 3).

Intermediate snail hosts and animal reservoir hosts

Information on the presence of the non-human hosts is shown in Figure 3. Six out of the ten identified snail colonies in Oras were in flood-prone areas where sanitary toilet coverage was below the provincial target. Four snail colonies were in barangays not known to be endemic (Buntay, Cagdine and Iwayan) in the North and San Roque in the East. Prevalence of schistosomiasis in snails were <8% in Cagdine and ≥8% in Agsam, Buntay, Cadia-an, Iwayan, Paypayon and San Roque. High carabao population densities were observed in known endemic barangays, namely Rizal in the North;

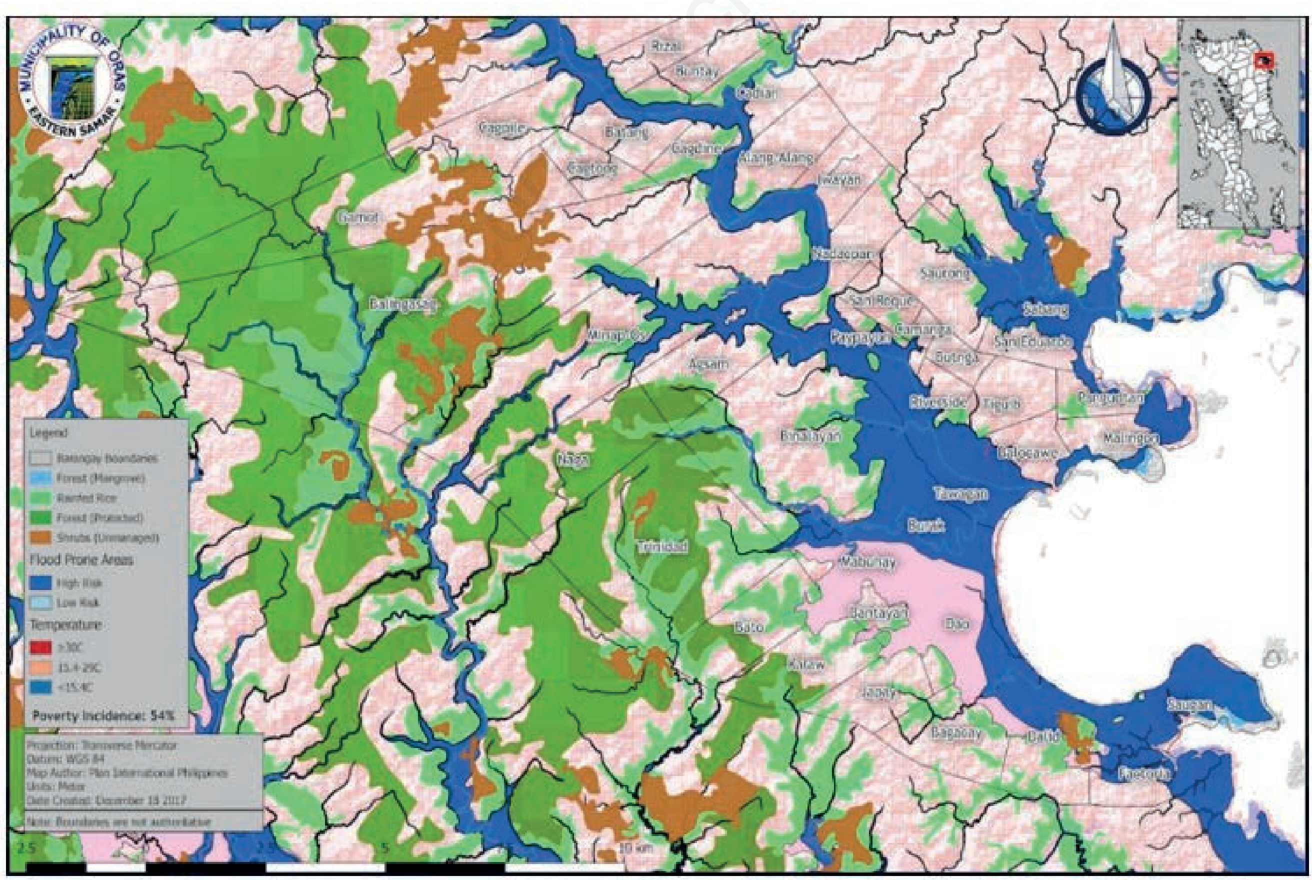

Figure 2. Topography, flood-prone areas, temperature and poverty incidence in Oras, Eastern Samar.

Binalayan and Trinidad in the East; Naga in the West; and Bato and Kalaw in the South (Figure 3).

Schistosomiasis prevalence and mass drug administration coverage

Schistosomiasis prevalence of ≥1% was found in 11 barangays in the North (Alang-alang, Batang, Cadia-an, Cagtu-og and Iwayan), in the East only Agsam, in the West only Cagpile, and in the South Bantayan, Dalid, Dao and Mabuhay. Two of these barangays, Alang-alang and Iwayan, were not known to be endemic for the infection. Data on seroprevalence were only available in the barangays of Binalayan, Mabuhay, Saugan and Tiguib. Moderate seroprevalence (10-49%) was observed in Tiguib, whereas high seroprevalence (≥50%) was reported in the three other barangays. High prevalence and seroprevalence were observed in Mabuhay, while high seroprevalence but 0% prevalence (using stool examination by Kato-Katz) were recorded in Saugan. The reported MDA coverage of praziquantel in all barangays was <75% (Figure 4). The Municipal Health Office had no available praziquantel for MDA of the barangays Butinga and Sta. Monica.

Schistosomiasis determinants and conditions considered

Table 2 summarizes the presence of favourable conditions for schistosomiasis transmission in Oras, Eastern Samar. Favourable conditions include location in flood-prone areas, presence of vegetation, <92% sanitary toilet coverage, presence of snail colonies, carabao population density of 16-30 per 100 population, previously reported ≥1% prevalence of human schistosomiasis by stool examination, and <75% MDA coverage. Twenty-six out of 42 barangays in Oras are in flood-prone areas and have vegetations such as rice fields and shrublands. Twenty-eight barangays did not meet the provincial target for sanitary toilet coverage, 19 of which were known to be endemic for schistosomiasis. Ten snail colonies were reported, six of which were in known endemic barangays and four in barangays not known to be endemic. Higher carabao density was observed in the known endemic barangays compared to those where endemicity was not known. All barangays with ≥1% human prevalence were located in flood-prone areas. No barangays have reached the MDA coverage target. In those considered to be non-endemic, such as Buntay, Iwayan and San Roque, were observed to have five out of seven identified conditions known to be favourable for schistosomiasis transmission.

Discussion

Topography, flood-prone areas, temperature, human activities (*e.g.*, agriculture), poverty, sanitation, spatial distribution of intermediate and reservoir hosts, existing infection prevalence and

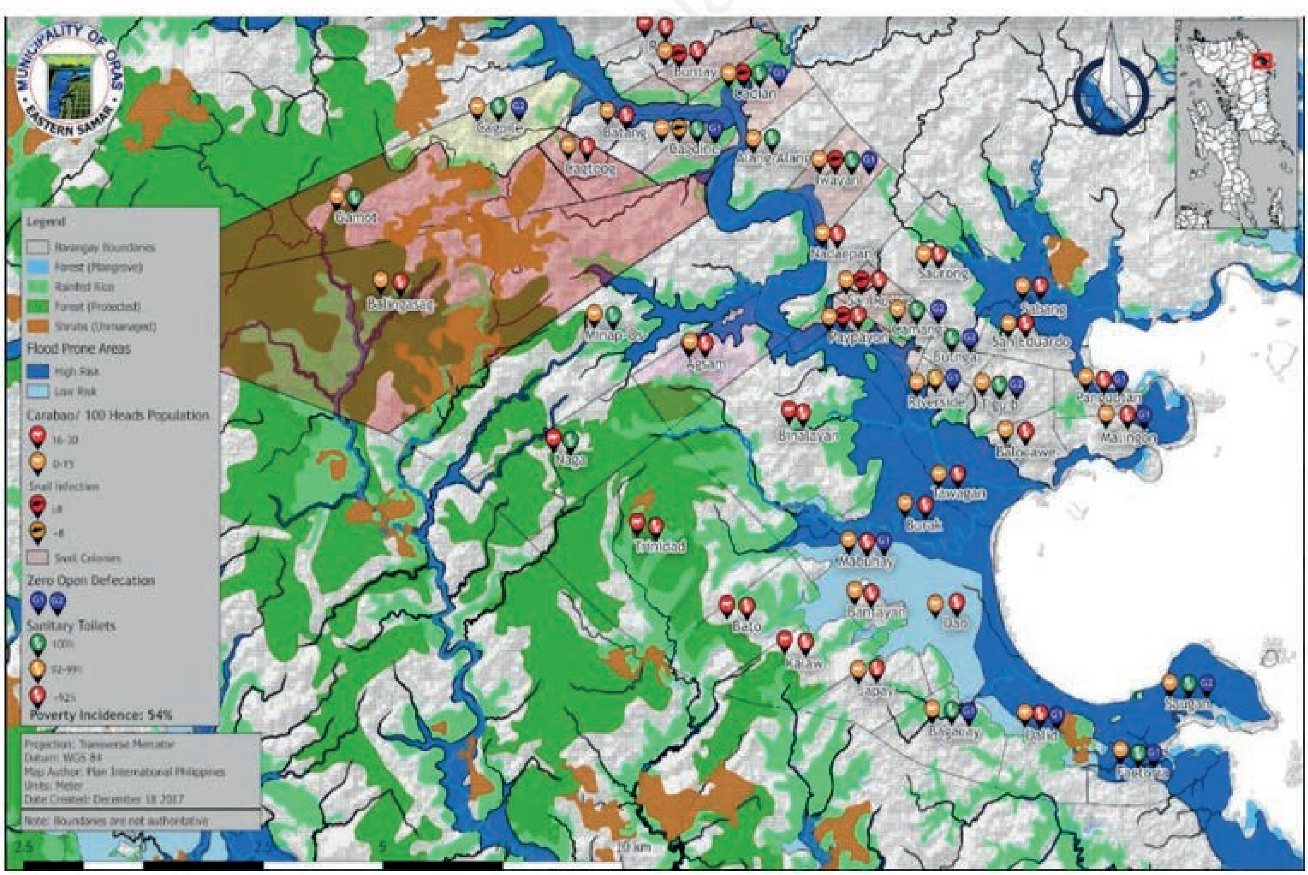

Figure 3. Carabao population density, snail prevalence, distribution of snail colonies and sanitation data in Oras, Eastern Samar overlaid with topography, flood-prone areas and poverty incidence.

MDA coverage affect schistosomiasis transmission (Chen *et al.,* 2015; Peng *et al.,* 2010; Zhou *et al.,* 2009). This study showed that flood-prone areas, presence of vegetations, low sanitary toilet coverage, presence of intermediate and reservoir hosts and low MDA coverage are conditions that should help identifying high-risk areas for schistosomiasis. Most of these determinants may be classified as modifiable, *i.e*. those where interventions are available to address them. However, the list includes also non-modifiable ones where interventions could only mitigate the effects.

The modifiable determinants in this study included presence of vegetation, sanitary toilet coverage and distribution of intermediate and reservoir hosts, prevalence of schistosomiasis, MDA coverage and poverty.

Vegetation, such as shrubs and rice crops, were found to be present in 8 out of 11 barangays with high prevalence of schistosomiasis, but they were also found in most other barangays. Vegetations commonly surrounds water bodies and are important in creating a conducive environment for breeding of the intermediate snail host of *S. japonicum* (Gordon *et al.,* 2019). Weeding and thorough ploughing of rice fields or the change of land use from rice production to other crops are some of the practices proven to eliminate snail habitats (Gordon *et al.,* 2019).

Twenty-eight barangays have low sanitary toilet coverage, 19 of which are known to be endemic. Low sanitary toilet coverage may encourage practice of open defaecation which contributes to ongoing transmission of schistosomiasis. Improving access to safe water and sanitation through health education and construction of sanitary toilets may help control the infection (Grimes *et al.,* 2015).

Only ten snail colonies were identified by DOH; six in known endemic barangays and four in non-endemic barangays. Most of the identified snail colonies in Oras were in flood-prone areas. The *O. hupensis quadrasi* snail is amphibious but prefers an aquatic environment, such as wet soil surfaces, swamps, rice fields, ponds and the banks of rivers and streams. Preference of snails to aquatic environment makes chemical snail control difficult due to the risk of contaminating water and/or food sources (Gordon *et al.,* 2019). Environmental modification through concrete-lining of canals, reclamation of swamps and clearing of vegetation have proved to reduce snail habitats in China and Japan (WHO, 2017).

Higher carabao population densities were observed in known endemic barangays. Bovines, such as carabaos, are considered as major reservoir hosts of *S. japonicum*. This is because infected bovines excrete up to 60 kg of stool daily into water bodies, such as lakes and rivers, where the animals frequently immerse or graze (Gray *et al.,* 2009). Also, humans frequent these water sources, which highlight the importance of engaging the veterinary public health sector in providing technical assistance on animal surveillance and developing control strategies for the reservoir hosts (WHO, 2012). Deworming of bovines or replacement with tractors have been shown to be effective strategies in controlling schistosomiasis transmission (Gray *et al.,* 2009).

Reported schistosomiasis prevalence of ≥1% were found in 11 barangays, two of which were considered non-endemic before this

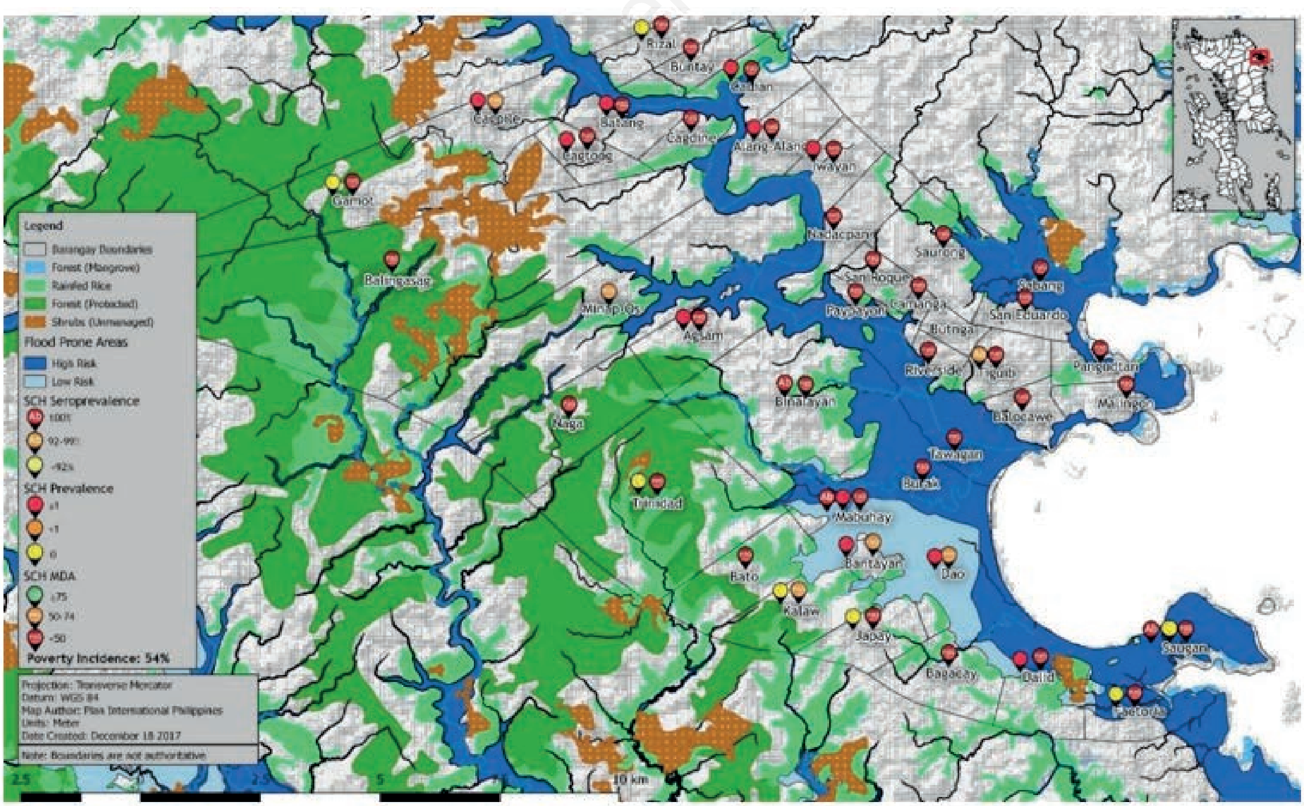

Figure 4. Schistosomiasis seroprevalence and prevalence and mass drug administration coverage of praziquantel in Oras, Eastern Samar overlaid with topography, flood-prone areas and poverty incidence.

Table 2. Favourable conditions for schistosomiasis transmission in Oras, Eastern Samar, the Philippines.

Barangays	Favourable conditions						
	Flood-prone areas	Presence of vegetation	Sanitary toilet coverage <92%	Presence of snail colonies	Carabao density of 16-30 per 100 population	Prevalence of ≥1% using Kato-Katz technique	<75% MDA coverage of praziquantel
Known endemic barangays							
Agsam	Red	Red	Red	Red	Green	Red	Red
Bagacay	Green	Red	Red	Green	Green	n/a	Red
Balingasag	Red	Red	Red	Red	Green	n/a	Red
Balocawe	Red	Green	Red	Green	Green	n/a	Red
Bantayan	Red	Green	Red	Green	Green	Red	Red
Batang	Red	Red	Red	Red	Green	Red	Red
Bato	Green	Red	Red	Green	Red	n/a	Red
Binalayan	Red	Red	Red	Green	Red	n/a	Red
Burak	Red	Green	Red	Green	Green	n/a	Red
Cadia-an	Red	Red	Green	Red	Green	Red	Red
Cagpile	Red	Red	Green	Green	Green	Red	Red
Cagtu-og	Green	Red	Red	Green	Green	Red	Red
Dalid	Red	Red	Green	Green	Green	Red	Red
Dao	Red	Green	Red	Green	Green	Red	Red
Factoria	Red	Red	Red	Green	Green	Green	Red
Gamot	Green	Red	Green	Red	Green	Green	Red
Japay	Green	Red	Red	Green	Green	Green	Red
Kalaw	Green	Red	Red	Green	Green	Green	Red
Mabuhay	Red	Green	Red	Green	Green	Red	Red
Naga	Red	Green	Green	Green	Red	n/a	Red
Paypayon	Red	Red	Red	Red	Green	n/a	Red
Rizal	Red	Red	Red	Green	Red	Green	Red
Saugan	Red	Red	Green	Green	Green	Green	Red
Tawagan	Red	Green	Red	Green	Green	n/a	Red
Trinidad	Green	Red	Red	Green	Red	Green	Red
Not known endemic barangays							
Alang-alang	Red	Red	Green	Green	Green	Red	Red
Buntay*	Red	Red	Red	Red	Green	n/a	Red
Butinga	Red	Green	Green	Green	n/a	n/a	n/a
Cagdine	Red	Red	Green	Red	Green	n/a	Red
Camanga	Red	Red	Green	Green	Green	n/a	Red
Iwayan*	Red	Red	Green	Red	Green	Red	Red
Malingon	Red	Red	Red	Green	Green	n/a	Red
Minap-os	Red	Red	Green	Green	Green	n/a	Red
Nadacpan	Red	Red	Red	Green	Green	n/a	Red
Pangudtan	Red	Red	Red	Green	Green	n/a	Red
Riverside	Red	Red	Green	Green	Green	n/a	Red
Sabang	Red	Red	Red	Green	Green	n/a	Red
San Eduardo	Red	Red	Red	Green	Green	n/a	Red
San Roque*	Red	Red	Red	Red	Green	n/a	Red
Sta. Monica	n/a	n/a	Red	Green	n/a	n/a	n/a
Saurong	Red	Red	Red	Green	Green	n/a	Red
Tiguib	Red	Red	Green	Green	Green	n/a	Red

[Red] Presence of favourable condition for schistosomiasis
[Green] Absence of favourable condition for schistosomiasis
n/a, no available data.
*Barangays not known to be endemic with 5 out of 7 conditions favourable for schistosomiasis transmission.

study, something which shows that surveillance should not only be limited to the known endemic barangays. The use of more accurate diagnostic tools, *e.g.*, detection of the circulating cathodic schistosome antigen in the definitive host (van Dam *et al.*, 2015) and detection of the infection in the snail by means of loop-mediated isothermal amplification (Qin *et al.*, 2018), would be more helpful in mapping out possible sources of infection especially in low-transmission areas. Serological techniques may also be considered for surveillance particularly in low-endemicity area where determining exposure, which serology detects, is more important than differentiating past from active infection. Limitations, such as cross-reactivity and false positive reactions, must however be considered in the interpretation of the results (WHO, 2017). As observed in this study, prevalence of <1% using the Kato-Katz technique was reported in Saugan, while >50% seroprevalence was reported.

Community-based MDA of praziquantel in known endemic areas is recommended by WHO as a strategy to control morbidity and reduce transmission (WHO, 2006). In Oras, generally low MDA coverage was observed in both known and not known endemic barangays. House-to-house delivery of the drug, improving health awareness through health education and ensuring sufficiency of drug supply are among the strategies which can help improve MDA coverage (Deardorff *et al.,* 2018).

Oras, a known endemic municipality, had a high poverty incidence (54%) (NEDA, 2017). Poverty often restricts community access to clean water sources and basic sanitation facilities and forces people to engage in occupations which exposes them to infection, such as fishing and farming (King, 2010). The infection leads to decreased productivity in the community creating a vicious cycle of schistosomiasis and poverty. Uplifting the economic status of the community through poverty reduction strategies may help in controlling schistosomiasis and ending the cycle (Karunamoorthi *et al.,* 2018).

Flood-prone areas, topography and temperature were considered non-modifiable determinants in this study. Although non-modifiable, appropriate preventive measures can be applied to mitigate the infection risk. Eighteen out of 25 known endemic barangays were in flood-prone areas. Flooding brought by typhoons may lead to snail dispersal increasing the area of potential snail habitats. Studies in China found that spread of *O. hupensis quadrasi* snails to farmlands could still be observed ten years after a flood (Zhou *et al.,* 2001). An outbreak may also occur since flooding may expose more people to contaminated water as the cercariae are reported to survive for up to 48 hours after release from the intermediate snail host (Kerr, 2004). Health education focusing on effective protection against schistosomiasis during flooding and strengthening surveillance after floods with respect to infection outbreaks and new snail habitats are strategies which may be helpful in reducing the infection risk. Collaboration among the regional health and agricultural offices, disaster risk reduction management units, LGUs, private sector and other stakeholders should be strengthened, with sharing of resources encouraged (Wu *et al.,* 2008).

Land elevation may affect transmission, as low-land areas near water bodies may become potential animal habitats (Gordon *et al.,* 2019). We showed that most of the known endemic barangays were in low-land areas, which are adjacent to each other, similar to the findings in Davao del Norte (Belizario *et al.,* 2017). Other studies have shown that *S. japonicum* only develops in *O. hupensis quadrasi* at temperatures higher than 15.4°C, with the fastest development occurring at 30.0°C (Yang *et al.,* 2007; Zhou *et al.,* 2009). A similar temperature range was reported in this study as well as in the study conducted in Davao del Norte (Belizario *et al.,* 2017). Effective snail control strategies, as discussed earlier, may help mitigate the risk in low-land areas and in areas with suitable temperature range for the development of snail habitats with infected snails.

This study showed the usefulness of GIS technology in identifying and mapping possible high-risk areas for schistosomiasis. Through the generation of map layers, different schistosomiasis determinants could be visualized, and they proved to be helpful in identifying possible high-risk areas. This study considered the focal distribution of schistosomiasis by obtaining barangay-level data compared to the municipal-level data of the previous study in Davao del Norte (Belizario *et al.,* 2017).

Application of other technologies in conjunction with GIS may improve the use of maps in surveillance. Remotely sensed data may be used to predict spread of schistosomiasis in nearby provinces by observing snail habitats in different ecologies (Seto *et al.,* 2002). Spatio-temporal pattern analysis in GIS may also be used to investigate possible re-emergence or spread of schistosomiasis in areas where the infection has been eliminated or is not known to be endemic, respectively (Yang *et al.,* 2013). Transmission models may be used to study the spatial spread of schistosomiasis, allowing prediction of future hotspots of the infection (Ciddio *et al.,* 2016).

As seen in this study, also non-endemic barangays, such as Buntay, Iwayan and San Roque, have areas with favourable conditions for schistosomiasis transmission. Thus, these areas should be included in active surveillance to investigate possible spread of schistosomiasis (Kouadio *et al.,* 2012). Efficient and sustainable program implementation may be possible through the use of GIS since the generated maps can be used by the LGU in Oras to develop an action plan to enhance the local implementation of the schistosomiasis control program by tailoring it to the needs of each barangay.

Limitations of the study

The study was limited by the unavailability of data on geographical location of irrigation canals from the concerned offices. Another limitation was the absence of updated data on temperature in Eastern Samar LGU. These limitations may be addressed through development of standard procedures in collecting and processing data for GIS. Data on snail colonies were also limited to areas routinely surveyed by the DOH and presence of snail colonies in other areas remains unknown. Improving the design of malacological surveillance is needed to help interrupt schistosomiasis transmission, which is defined as 0% incidence in human, snails and animals for 5 years (DOH, 2018). Malacological surveillance can be improved by adopting statistically valid procedures in identifying snail sites, training of personnel on malacological survey, and performing sentinel surveillance twice a year.

Conclusions

Efficient and sustainable program implementation is possible through the use of GIS. Generation of maps including areas with favourable conditions for schistosomiasis should lead to better prevalence surveys. Further improvements would follow by strengthening health education in areas where MDA and sanitary toilet coverage are low, implementing snail control in all areas with snail colonies, and focusing on the role of reservoir hosts in areas with high carabao population densities.

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