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SPATIAL MAP OF GEOHELMINTHS INFECTION IN AGRICULTURAL COMMUNITIES AND ITS CONTAMINATION IN SOIL OF JATIAN VILLAGE, JEMBER REGENCY

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Abstract

Introduction: *Geohelminth infections are a neglected global health problem. Data from the World Health Organization (WHO) in 2020 show that more than 24% of the world population is infected by geohelminths. The condition of the agricultural soil, which tends to be loose and moist, supports the development of the infective form of the geohelminth. This makes agricultural communities susceptible to geohelminth infections. This study aimed to determine a spatial map of geohelminth infection in agricultural communities and its contamination in the soil of Jatian Village, Jember Regency.* ***Methods:*** *This study used an observational analytical design and a spatial analysis approach. Sampling was performed using a random sampling method that included 43 samples. Data were obtained by examining soil and stool samples and the coordinates of the sampling locations. Data were analyzed using spatial analysis.* ***Results and Discussion:*** *The results of this study indicated that the prevalence of geohelminth infection in agricultural communities was 23.3%, and its contamination in the soil was 6.98%. Hookworms caused infections among respondents, and contamination in the ground was caused by Hookworms and Strongyloides stercoralis. Clustering analysis results showed that geohelminth infection formed two secondary clusters. Spatial autocorrelation and buffer analysis showed clustering of geohelminth infections within the buffer range (<100 m), indicating that the infection spreads more easily within the cluster.* ***Conclusion:*** *The spatial map showed the distribution pattern of clustered geohelminth infection cases and their contamination in soil within proximity, thereby increasing the risk of geohelminth transmission.*

INTRODUCTION

Geohelminth or Soil-Transmitted Helminth (STH) infection is a worldwide health problem that includes neglected tropical diseases. The number of people infected with *Ascaris lumbricoides* is estimated at 1.2 billion, with 795 million people infected by *Trichuris trichiura* and 740 million by hookworm (1). According to data from the World Health Organization (WHO) in 2020, geohelminths infected more than 24% of the global population. Geohelminths are intestinal worms that require soil as a medium for transmission. A person can be infected by accidentally ingesting worm eggs or hookworm larvae that penetrate the skin (2). The common clinical symptoms of geohelminth infection include abdominal pain, anorexia, abdominal distension, nausea, and diarrhea (3–4). When infected people defecate on the ground because of the lack of a latrine or as a habit, geohelminth eggs and larvae in feces contaminate the soil (5).

Agricultural communities are susceptible to geohelminth infection owing to exposure to soil while working in rice fields or gardens. Research conducted on plantation workers in July showed that nine out of 36 people (25%) were infected by geohelminths (6). Another study on farmers in Bandar Lampung explained that as many as 22 people (40%) were positively infected with STH (7). Several risk factors are associated with geohelminth infections among farmers. When working in the field, many farmers do not use personal protective

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equipment, such as gloves and boots, to prevent direct contact with the soil (4, 8). Many farmers need to be made aware of clean and healthy living behaviors and good environmental sanitation, particularly defecation habits and the availability of latrines. Many farmers defecate in gardens, rivers, or ditches and facilitate the spread of geohelminth infection through soil contaminated with geohelminth eggs and larvae (9–10). Farmers also use human and animal wastes to fertilize crops that may contain geohelminth eggs and larvae (11–12). The soil condition in agricultural areas that tend to be loose and moist strongly supports the development of the infective form of geohelminths. A previous study showed that STH contaminates approximately 66% of the yard's soil in public elementary schools in Bandung city. Larval nematodes, *Ascaris* eggs, *Trichuris* eggs, *Toxocara* eggs, and *Capillaria* eggs were found, and the most common STH was larval nematodes (53%) (13). Another study in Jember that compared the findings of STH eggs and larvae in river areas, plantation worker settlements, and coffee plantation areas showed that plantation worker settlements had the highest contamination rate (25.71%) (14).

The distribution of geohelminth infection in agricultural areas can be determined by spatial analysis using a Geographic Information System (GIS). Spatial data are geographically oriented, and by using specific coordinates, the location, trend, analysis, and modeling of geohelminth infections can be determined (15). Therefore, spatial data can be used as a reference/baseline for geohelminth infection prevention, control, and elimination. This study aimed to determine a spatial map of geohelminth infection in agricultural communities and its contamination in the soil in Jatian Village, Jember Regency.

METHODS

The design of this study was cross-sectional and was analyzed using a spatial approach. This research was conducted in Jatian Village, Pakusari District, Jember Regency, and the Parasitology Laboratory of the Faculty of Medicine, University of Jember, from November 2021–March to 2022. This research was approved by the Research Ethics Commission of the Faculty of Medicine, University of Jember, with ethics certificate number 545/H25.1.11/KE/2021.

The subjects in this study were from the agricultural community, which included farmers and their families living in Jatian Village, Jember Regency, with exclusion criteria for taking deworming medicine in the last three months. The data in this study were obtained from the results of soil examination, stool examination, and coordinates of the sampling location. The stools were collected from agricultural communities willing to participate in the research by providing informed consent. The stool sample was placed in a closed, wide-mouthed container for immediate laboratory examination using the Kato-Katz method. The remaining stool in the container was placed in 10% formalin for further examination using sedimentation and flotation methods. The soil samples were examined by the flotation method using a saturated MgSo4 solution. According to WHO guidelines, geohelminth eggs and larvae were identified under a microscope at 100 and 400x magnification. Coordinate data collected using the Garmin GPS were entered into the software program for mapping and spatial analysis. Spatial analysis was performed using spatial overlays, buffers, clustering, and autocorrelation techniques.

RESULTS

Geohelminth Infection in Agricultural Community and its Contamination in Soil

The results of the examination of stool and soil samples in Table 1 show that the number of positive stool samples was 10 (23.3%), and the number of positive soil samples was three (6.98%).

Table 1. Distribution of Geohelminth Species in Stool and Soil Samples

Sample	Number (%)		Negative	Total (%)
	Hookworm	*S. stercoralis*		
Fecal Sample	10 (23.3%)	0 (0%)	33 (76.7%)	43 (100%)
Soil Sample	2 (4.65%)	1 (2.33%)	40 (93.02%)	43 (100%)

Hookworm eggs were found to be the only geohelminth infection in stool samples, as shown in Figure 1.

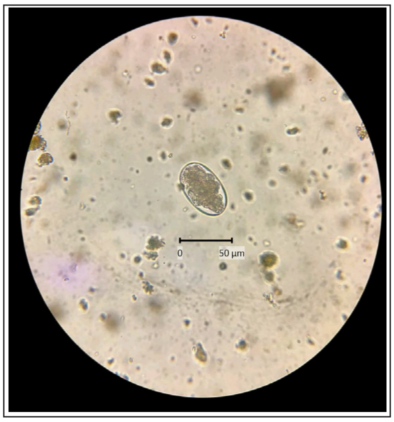

Figure 1. Hookworm Eggs Observations in Stool Samples

The positive soil samples were contaminated by hookworm larvae (4.65%) and *Strongyloides stercoralis* larvae (2.33%), as shown in Figure 2.

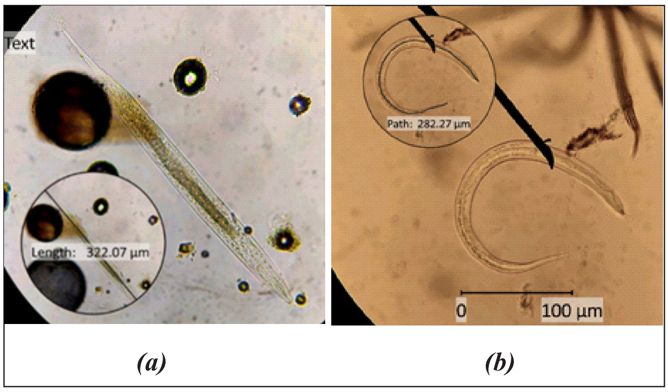

Figure 2. Geohelminth Observations on Soil Samples. *(a)* Hookworm Rhabditiform Larvae; *(b) Strongyloides stercoralis* Filariform Larvae

Spatial Analysis of Geohelminth Infection with its Contamination in Soil

Spatial analysis was performed using spatial overlays, buffers, clustering, and autocorrelation techniques. The results of the overlay analysis showed that cases of geohelminth infection tended to cluster in geohelminth-contaminated soil, but some points were spread. A more detailed description of the map is presented in Figure 3.

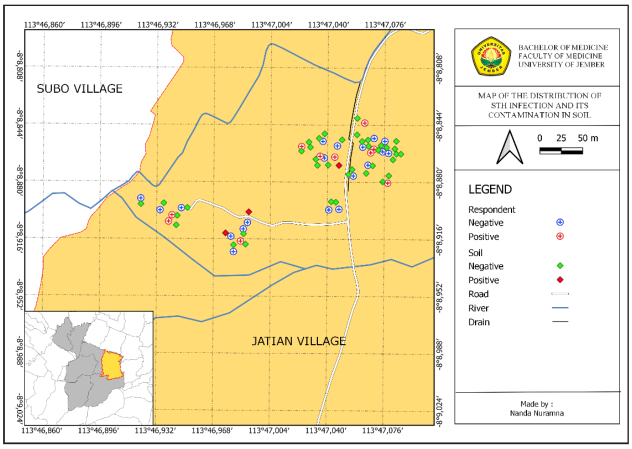

Figure 3. Map of Geohelminth Infection Distribution with Contamination on Soil

Cluster analysis was used to identify high-risk areas, as shown in Figure 4. The data used to carry out this analysis were the coordinates of the respondent's location and the date of illness based on the date of stool examination. SaTScan analysis showed that geohelminth infection cases in Jatian Village, Jember Regency, formed two secondary clusters, as shown in Figure 4. Secondary cluster 1 occurred in the southwest area of Jatian Village with a radius of 97.06 m and included three cases. The results of the secondary Cluster 1 analysis were statistically significant, with a p-value of 0.039. Secondary cluster 2 occurred in the northern area of Jatian Village with a radius of 36.89 m and included five cases. The results of the analysis of secondary cluster 2 were not statistically significant (p = 0.763). Twelve respondents resided within the range of secondary cluster 1 were 12 respondents, and three were positively infected with geohelminths. This indicates that 25% of all respondents in the field of secondary cluster 1 were significantly at risk of geohelminth infection.

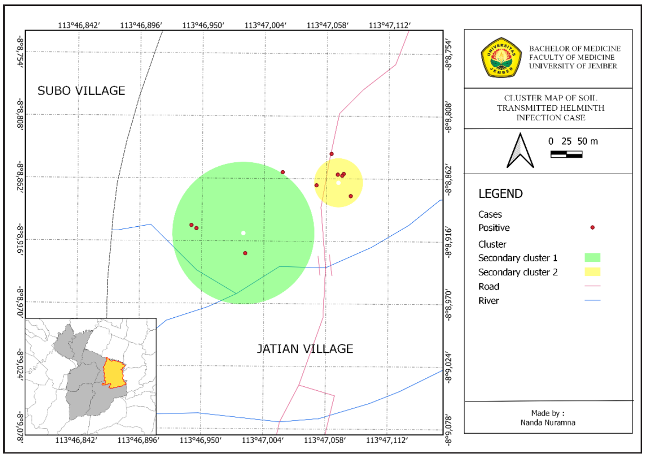

Figure 4. Geohelminth Infection Case Clustering Map

Spatial autocorrelation was used to determine the distribution pattern of geohelminth infections in Jatian Village, Jember Regency. In this study, spatial autocorrelation was analyzed using the Moran index method. The Moran's index value obtained was 0.696. This is in the $0<I\leq 1$ range, indicating a positive spatial autocorrelation. This suggests that each location of respondents who were positively infected with geohelminth has similar attribute values. The z-score and p-value are 2.495 and 0.013, which indicate that the distribution of geohelminth infection prevalence in Jatian Village, Jember Regency, is clustered.

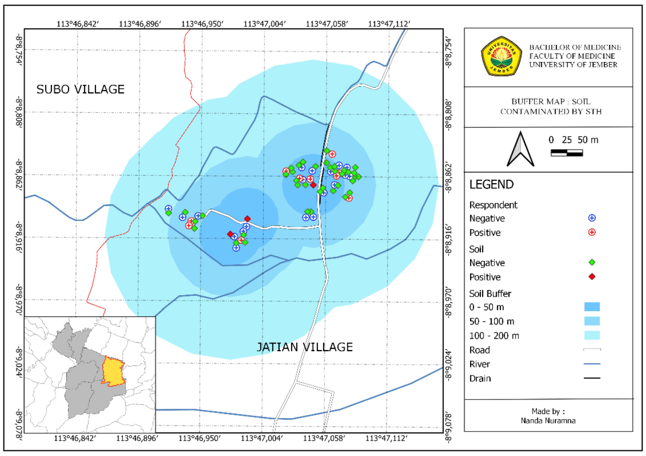

Figure 5. Geohelminth Contaminated Soil Buffer Map

Geohelminth-contaminated soil buffers were used at depths of 50, 100, and 200 m (Figure 5). The buffer analysis aimed to determine whether the geohelminth infection was within the range of the contaminated soil buffer. The results showed that 24 respondents were in the buffer of <50 m, and six were positively infected with geohelminths. Respondents had a 25% chance of being infected with geohelminths in the range of <50 m. In the 50–100 m buffer, there were 18 respondents, four of whom were positively infected with geohelminths. These results also showed that in a buffer of 50–100 m, respondents had a 22.22% chance of being infected with geohelminths. Another respondent was in a buffer of more than 100 m and was not infected with geohelminths because the respondents had no chance of being infected with geohelminths from contaminated soil.

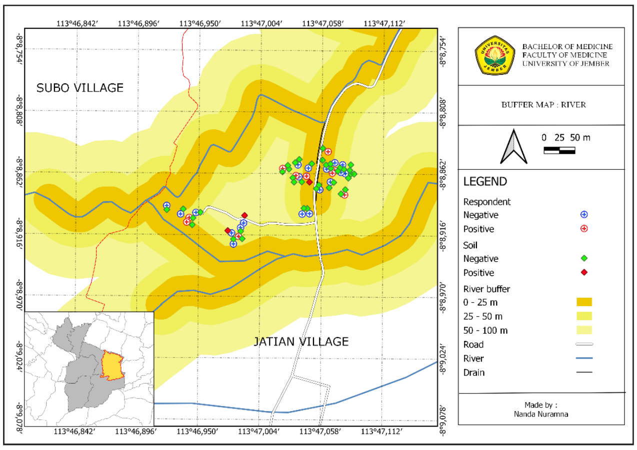

Figure 6. River Buffer Map

Buffer analysis was also carried out on rivers around Jatian Village to determine the distance between the respondent's residence and the river, which could be a source of STH infection. River buffering was performed at 25, 50, and 100 m depths. The results showed that respondents infected with geohelminths resided at a distance of <50 m from the river and only one respondent resided at a distance of >50 m from the river (Figure 6).

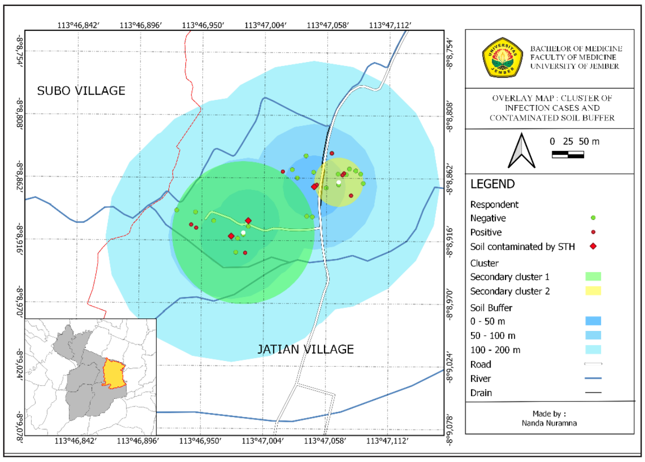

Figure 7. Overlay Map: Geohelminth Infection Case Cluster and Contaminated Soil Buffer

The geohelminth infection case clustering map was overlaid with a geohelminth-contaminated soil buffer map (Figure 7). The map showed that the secondary cluster center was formed within a buffer range of <25 m from the geohelminth-contaminated soil, and secondary cluster center two was created within a buffer range of <50 m from the geohelminth-contaminated soil. The geohelminth-contaminated soil buffer map was overlaid with the river buffer map. The results showed a wedge between the STH-contaminated soil buffer and the river buffer in all residential areas of Jatian Village (Figure 8).

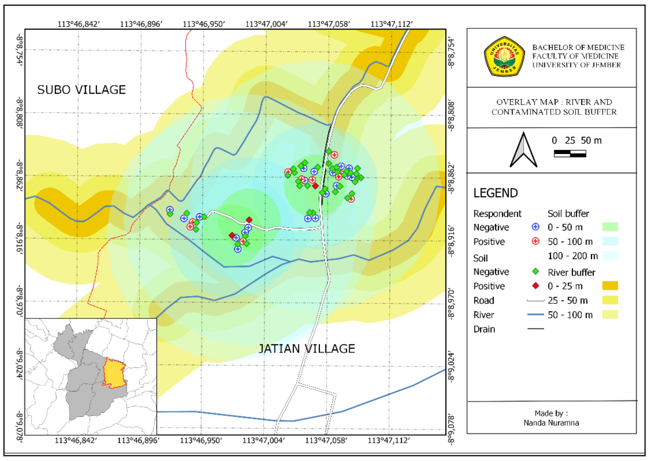

Figure 8. Overlay Map: Geohelminth Contaminated Soil Buffer and River Buffer

DISCUSSION

This study showed that the prevalence of geohelminth infection in Jatian village is low (23.3%). This result is consistent with research conducted in Kaliputih village, Jember, in 2019, which showed that nine (25%) Kaliputih plantation workers were infected by STH (6). Another study on agrarian communities in Nigeria showed that 34.2% of the individuals were infected with at least one STH. Hookworms were the most prevalent (18.1%), followed by Ascaris lumbricoides (16.8%) (16). Internal and external factors influence the prevalence of geohelminth infections in different areas. Internal factors such as poor community hygiene, socioeconomic factors, and the education level of farmers who tend to be low may lead to unhealthy habits that facilitate the transmission of geohelminth infection (17–18). Respondents with bad habits, such as frequent contact with the ground, poor use of Protective Personal Equipment (PPE), bathing and defecating in rivers, and risk of geohelminth infection. External factors, including an agricultural environment suitable for geohelminth development into an infectious stage, can cause a high incidence of geohelminth infections (19). Environmental conditions in Jatian Village, which tend to be moist and loose, also support the development of geohelminth eggs and larvae. The transmission of geohelminths can occur when the skin contacts hookworm larvae in the soil or when infective geohelminth eggs are ingested (20).

This study found only hookworm eggs in stool samples (10 samples) positive for geohelminth infection.

This result supports a previous study showing that the highest intensity of hookworm infection was found in adults and agricultural workers (1). Another study on farmers in Bandar Lampung also showed that the worm that infected farmers the most was hookworm (13 farmers, 59.1%) (7). Research on agricultural communities in the Bolivian Amazon also showed that the species that infected the most agricultural communities was the hookworm (83%) (16). Hookworm infection, which is relatively high in agricultural communities, can be caused by an environment suitable for the development of hookworms into infective larvae. Loose soil containing high humus in plantation areas and home gardens makes it easier for hookworm larvae to move and position themselves to penetrate the skin (21). Therefore, PPE such as footwear and gloves can prevent hookworm larvae penetration. Almost all the respondents wore footwear when leaving the house, but the majority of respondents still needed to wear adequate PPE when working in the rice field. Most respondents used open hands to plant rice and make contact with the soil, and only five wore footwear and gloves. Therefore, the risk of hookworm transmission through the skin of the hands is high, as long as they are still in contact with the ground.

The prevalence of geohelminth-contaminated soil was 6.98% in 43 soil samples. This result is lower than the research conducted in the Silo sub-district, Jember Regency, which found that STH contamination was 25.71% in garden workers' settlements (14). Another study showed that STH contamination in rural Philippine soil was very high at 70%, with the highest percentage in the yard area (42.8%) (13). The low soil geohelminth contamination in Jatian Village could be caused by people who do not have latrines and prefer to defecate in the river than on the ground. Sources of geohelminth contamination in the soil can also originate from animals around the yard, such as farm animals, cats, and dogs.

Hookworms and *Strongyloides stercoralis* larvae were found to contaminate the soil at the research site. This result supports previous research conducted in garden workers' settlements in the Silo sub-district, Jember Regency, which showed that hookworm larvae were found to contaminate the most (50%) (14). Two factors can cause soil to be contaminated by hookworm larvae; some residents may be infected with hookworms and open defecation or come from infected animals. This result also supports another study that stated that Widodaren plantation workers defecated in the garden, and 29.4% of respondents were positively infected by STH (22). *Strongyloides stercoralis* larvae were also observed in this study. *Strongyloides stercoralis* has two life cycles: the parasitic cycle in the human body and the free-living cycle in the soil. *Strongyloides stercoralis* can survive and thrive in soil without infecting humans by eating the bacteria present in the soil (23–24). These results also show that the soil in the agricultural area is very suitable for growing hookworms and *S.stercoralis* larvae. Therefore, contaminated soil could be a source of geohelminth transmission for farmers.

Spatial Analysis of Geohelminth Infection and its Contamination in Soil

Overlay mapping of the distribution of geohelminth infections and geohelminth contamination of the soil in Jatian Village indicates that cases of geohelminth infection occur in areas around contaminated soil. Living close to soils contaminated by geohelminths has a greater risk of disease. Most of this area is used for agricultural land, and the residential houses are close to each other. On average, the distance between adjacent houses was at most 5 m. This condition could narrow the scope of interaction between people and increase the risk of transmission through geohelminth-contaminated soil.

Cluster analysis was performed to determine the location of the formation of the geohelminth infection cluster and the extent to which the radius of the cluster was formed. The results of cluster analysis using mapping and spatial analysis software showed the formation of two secondary clusters with a radius of 97.06 m and 36.89 m. Based on the results of the analysis, the first secondary cluster was statistically significant (p-value<0.01), while the second secondary cluster was not statistically significant (p-value >0.01). The first secondary cluster, 1, formed with a radius of 1.69 km and was statistically significant (p=0.011). The second secondary cluster was formed with a radius of 0.41 km and was not statistically significant (p=0.069). The secondary cluster with no statistical significance indicated a low cluster value and less influence between proximity to position, number of cases, and time of illness. The formation of clusters suggests transmission of geohelminth infection in the study area. The presence of people infected with geohelminths in the cluster area will affect people who live within the cluster range by increasing the transmission of geohelminths (25). The data of this study showed that in the first secondary cluster, 25% of people were at a high risk of being positively infected with geohelminths. This number was more significant in the second secondary cluster (33.33%).

The Moran's I index of the spatial analysis showed positive spatial autocorrelation. This means that between cases of geohelminth infection, there were similar values and clustering of cases in Jatian

Village and Jember Regency. This result is in line with a study that reported that the distribution of dengue cases in Tasikmalaya from 2011 to 2015 showed a positive autocorrelation, and the Moran index showed a clustered distribution pattern (26). Another study also showed a positive autocorrelation in the distribution of dengue cases in Bandung (27). Different results were shown by the study in Bantul Regency, which stated that based on autocorrelation analysis, no spatial correlation occurred in cases of STH infection; however, there was spatial correlation based on the soil type map and the number of cases (28). The Moran index value indicates a high number of cases in the area; the higher the Moran index, the higher the number of cases in the area studied (29–30). The Moran index also indicates the possibility of another geohelminth infection case if a positive case is found in the same cluster area.

Buffer analysis of the geohelminth-contaminated soil showed that all cases were within the buffer range (<100 m), and 60% of the cases were very close to the contaminated soil (<50 m). This condition will increase the respondent's risk of being infected by geohelminths because the location of the respondents' close houses is still within the buffer range.

Buffer analysis of the river showed that most geohelminth infection cases occurred at a distance of less than 50 m from the river. The residents bath, wash, and defecate in the river. This habit can contaminate rivers with geohelminths and can become a source of infection. The map of the contaminated soil buffer and river buffer showed that the distance between the respondent's residence and the source of infection, both land and rivers, is very close, thereby increasing the risk of transmission.

The overlay between the clustering of geohelminth infection cases and infected soil buffers showed that the cluster's center was near the area of contaminated soil. Contaminated soil around settlements can be a source of transmission in agricultural communities. The overlay map of the geohelminth-contaminated soil buffer with the river buffer also showed an intersection between the contaminated soil buffer and the river buffer in all residential areas of Jatian Village. This means that residential areas at the intersection of these two buffers have a high risk of geohelminth transmission. In intersecting areas, the risk of transmission is higher because of geohelminth contamination in rivers and soil. Therefore, the agricultural community must prevent geohelminth transmission by changing defecation habits and using footwear and gloves as personal protective equipment.

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CONCLUSION

The prevalence of geohelminth infection in the agricultural community in Jatian Village was low (23.3%), as was soil contamination (6.98%). Hookworms were the only geohelminths that infected the agricultural community, while hookworms and *Strongyloides stercoralis* larvae contaminated the soil. Spatial mapping showed that the distribution pattern of geohelminth infection cases was clustered, and the clustering occurred within a buffer range with a radius of <100 m. Two secondary clusters showed that geohelminth transmission occurred at distances close to the source of infection (infection cases and contaminated soil).

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