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SOIL-TRANSMITTED HELMINTH INFECTIONS IN RELATION TO ENVIRONMENTAL VARIABLES IN TWO LOCAL GOVERNMENT AREAS OF OSUN STATE, NIGERIA

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ABSTRACT

Soil-transmitted helminth (STH) infections remain a major public health concern, particularly among school-aged children in resource-limited settings. Understanding the epidemiological burden and associated environmental variables is vital for effective control strategies. This study assessed the prevalence and spatial distribution of STH infections among school-aged children in Ilesa-West and Olorunda LGAs of Osun State, Nigeria, and determined environmental variables associated with infection. A total of 520 faecal samples from pupils aged 4–14 years were examined using the formol-ether concentration technique. Environmental variables such as Normalised Difference Vegetation Index (NDVI), rainfall, altitude, population density, and land surface temperature were processed and analysed. Data were analysed using SPSS v23 and Bayesian geostatistical modelling. The overall STH prevalence was 13.8%. Ascaris lumbricoides (10 %) was the most prevalent, followed by hookworm (2.9%) and Trichuris trichiura (0.9 %). Prevalence was slightly higher in females (14.1%) and children aged 7–9 years (16.5%), though not statistically significant ($p>0.05$). Bayesian analysis revealed that higher NDVI (OR=1.45, 95% CrI: 1.12–1.89), proximity to water bodies (OR=1.63, 95% CrI: 1.21–2.18), and higher land surface temperature (OR=1.32, 95% CrI: 1.05–1.70) significantly increased the risk of STH infection, whereas altitude (OR=0.78, 95% CrI: 0.62–0.98) showed a protective effect. Rainfall and population density were not significantly associated with STH infection ($p>0.05$). Moderate endemicity of STH persists in Osun State despite ongoing Mass Drug Administration. Environmental variables significantly influenced infection prevalence. Targeted deworming, enhanced WASH infrastructure, and spatial surveillance are recommended.

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1.0 INTRODUCTION

Soil-transmitted helminth (STH) infections are among the most common neglected tropical diseases (NTDs), with a significant burden on children's health and development. Globally, over 1.5 billion people are affected, especially in sub-Saharan Africa, South America, and parts of Asia (WHO, 2023). STHs are caused by *Ascaris lumbricoides, Trichuris trichiura*, and hookworms (*Necatoramericanus and Ancylostoma duodenale*), and transmitted via contact with contaminated soil, often due to inadequate sanitation and hygiene (Kouamé*et al.,* 2025).

Children, especially those aged 5–14, are particularly vulnerable, making them the primary target of preventive chemotherapy (PC) programmes. While mass drug administration (MDA) with albendazole or mebendazole has significantly reduced morbidity, reinfection is common, necessitating integrated control approaches (Ciciriello, *et al.,* 2022). Despite ongoing preventive chemotherapy programmes, soil-transmitted helminth infections continue to pose a considerable public health challenge in many parts of sub-Saharan Africa, including Nigeria. Environmental conditions such as temperature, rainfall, vegetation cover, and soil moisture influence the development, survival, and transmission of infective helminth stages. Consequently, understanding the interaction between environmental factors and infection patterns is essential for designing sustainable and effective control strategies (Oyeyemi and Okunlola, 2023).

Environmental and climatic variables influence soil-transmitted helminth transmission by regulating the persistence and growth of infective stages in the soil and shaping human contact patterns. Rainfall and soil moisture improve egg embryonation and larval survival, while temperature controls developmental rates within optimal thermal ranges. Vegetation cover and land use modify soil microclimates by maintaining moisture and shade, and proximity to water bodies increases transmission risk through continued presence of soil moisture and increased human–environment contact. Recent studies have shown that remotely sensed environmental variables can effectively predict the distribution and transmission risk of soil-transmitted helminths. For example, Xu *et al*., (2023) identified environmental and demographic factors as important predictors of infection prevalence, while Rebollo*et al.,* (2021) demonstrated the usefulness of Bayesian spatial modelling in identifying transmission hotspots in endemic settings. Similarly, Leta*et al.,* (2020) reported significant associations between environmental variables and soil-transmitted helminth distribution. These findings highlight the growing importance of integrating environmental data into helminth epidemiology and control programmes.

Despite these advances, significant gaps remain in understanding the environmental determinants of soil-transmitted helminth transmission at fine spatial scales in Nigeria. Although several studies have documented the prevalence of soil-transmitted helminth infections across different parts of the country, most have focused primarily on parasitological outcomes with limited consideration of environmental drivers and spatial heterogeneity. Furthermore, few studies have integrated remotely sensed environmental variables with advanced spatial modelling approaches to identify localised transmission hotspots. This knowledge gap limits the ability of control programmes to implement targeted and evidence-based interventions. Specifically, the influence of local environmental and land-use variations on STH prevalence and intensity within sub-state regions such as Osun State is poorly characterised. Moreover, few studies have combined parasitological surveys with geospatial modelling at the local government level to identify

environmental risk factors that could guide targeted control (Kwarteng *et al.,* 2025).

Bayesian geostatistical modelling provides a robust framework for examining disease-environment relationships while accounting for spatial dependence in infection data. By integrating parasitological observations with remotely sensed environmental variables, the approach enables improved prediction of infection risk and identification of transmission hotspots. Although this methodology has been applied in several endemic countries, its application for local-scale mapping of soil-transmitted helminth infections in Osun State remains limited. Therefore, the present study provides valuable evidence on the environmental determinants and spatial distribution of STH infections in the study area (Oluwole *et al.*, 2015).

This study addresses these gaps by combining parasitological surveys and Bayesian geostatistical modelling to assess STH infections in Ilesa-West and Olorunda Local Government Areas of Osun State, Nigeria. The objectives are to determine the prevalence and intensity of infections and to identify key environmental predictors, providing locally relevant risk maps to inform evidence-based intervention strategies and contribute to the broader understanding of environmental determinants of STH transmission.

MATERIALS AND METHODS

Study Area

This study was conducted in Osun State, Southwestern Nigeria (7.0°N–8.0°N, 4.0°E–5.5°E), which lies within the tropical rainforest derived savanna transition zone (Fasona and Omojola, 2005). The climate of Osun State is humid tropical, with distinct wet and dry seasons. The rainy season generally extends from April to October, while the dry season occurs from November to March, with rainfall reaching up to about 1,800 mm in many parts of the state (Osun State Government, 2023).

Two LGAs, Ilesa-West and Olorunda, were selected for the study. Ilesa-West is located in the eastern part of Osun State, while Olorunda is located in the central part of the state, adjacent to the state capital, Osogbo. Population projections reported in the Osun State Government's development plan indicate substantial population sizes for both Ilesa-West and Olorunda (Osun State Government, 2023). The predominant economic activities in the study areas include farming, petty trading, artisanal mining, small-scale manufacturing and civil service.

Ethical Approval and Community Engagement

Approval was obtained from the Ladoke Akintola University Teaching Hospital Research Ethics Committee (now Osun State University - UNIOSUN) LTH/EC/2019/04/412. Permissions were granted by the State Universal Basic Education Board and local education authorities. Informed consent and assent were obtained from parents/guardians and pupils, respectively.

Study Design and Population

A cross-sectional design was employed. A total of 520 pupils aged 4–14 were selected from 10 public primary schools (five from each LGA) via multistage random sampling. 60 pupils were chosen at each school, 10 from each class (Primary 1–6), in accordance with WHO guidelines.

Stool Sample Collection and Parasitological Examination

Stool samples were collected in clean, labelled containers and transported in ice-boxes for laboratory examination within 4–6 hours. Samples were processed using the standard formol–ether concentration technique, and helminth eggs were identified microscopically. Infection intensity was determined by egg counts and expressed as eggs per gram of faeces (EPG).

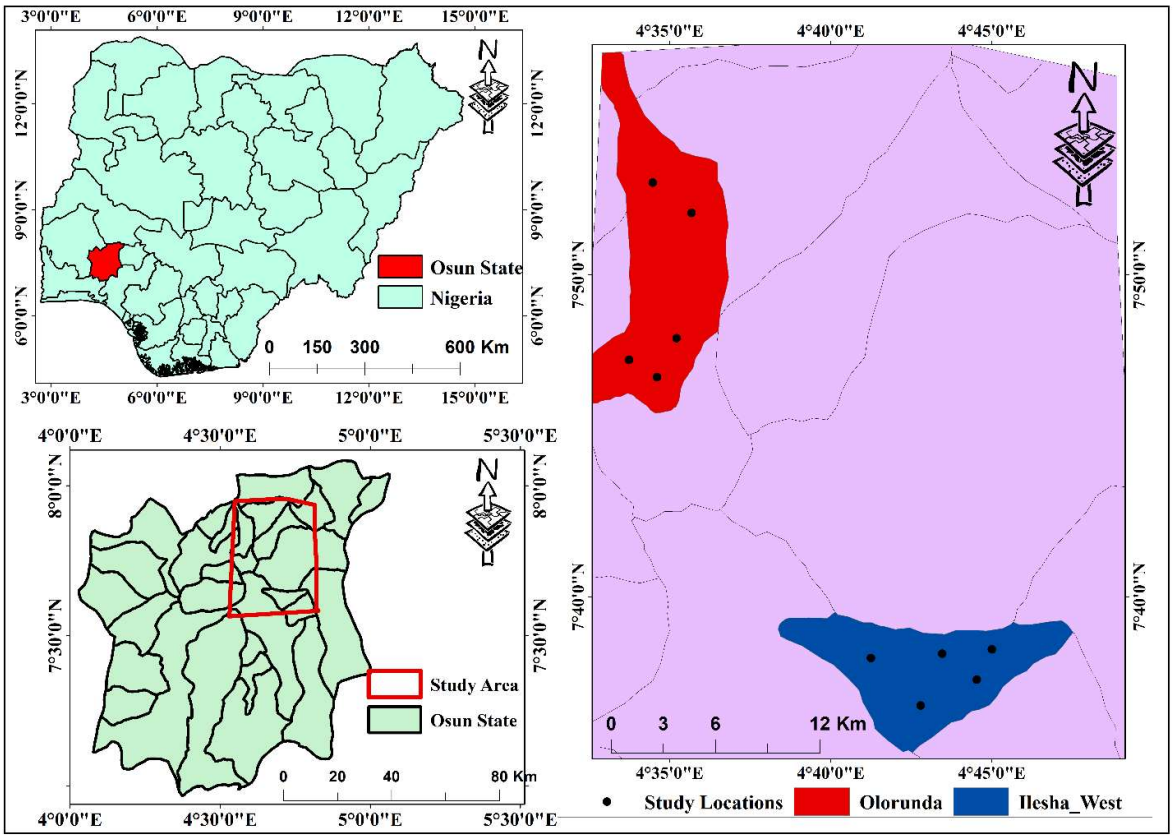


Figure 1: Map of Osun State Showing the two selected Local Government Areas (Ilesha west and Olorunda) and the sampling location

Environmental Data and Geospatial Analysis

Environmental variables were sourced from global and regional datasets (Moderate Resolution Imaging Spectroradiometer (MODIS), Famine Early Warning Systems Network (FEWSNET), Shuttle Radar Topography Mission (SRTM), and WorldPop). Altitude data were obtained from the SRTM, rainfall data from FEWSNET, and population density data from the WorldPop database. NDVI and land surface temperature (LST) were derived from MODIS satellite products and processed in ArcGIS 10.8. The mathematical computation, processing steps, and extraction frameworks for both LST and NDVI were performed using geospatial techniques adapted from the methodological template established by Tiwari and Kanchan (2024). NDVI was generated from MODIS red and near-infrared bands as 16-day composites, calculated as $(NIR - \text{Red})/(NIR + \text{Red})$, where NIR and Red represent near-infrared and red reflectance bands, respectively. Sixteen-day composite products were used to minimise cloud contamination and atmospheric effects.

Data Analysis

Data were analysed using IBM SPSS Statistics version 23 and R software. Descriptive statistics were used to summarise the prevalence and intensity of soil-transmitted helminth infections. Chi-square tests were employed to assess associations between infection status and categorical variables, including sex, age group, school, and local government area. Analysis of variance (ANOVA) was used to compare mean infection intensities among groups, with statistical significance set at $p < 0.05$.

Generalised linear models were fitted to evaluate the effects of environmental variables on infection prevalence. Bayesian hierarchical binomial geostatistical models were subsequently fitted to assess spatial variation in infection risk while accounting for spatial dependence among sampling locations. Bayesian inference was performed using the Integrated Nested Laplace Approximation (INLA) framework in R, and the fitted models were used to generate predictive risk maps for the study area.

RESULTS

Prevalence of STH among the Sampled Population

The overall prevalence of 72(13.8%), with *Ascaris lumbricoides* being the most common 52(10.0%), followed by hookworm 15(2.9%) and *Trichuris trichiura* 5(1.0%). Females had a slightly higher prevalence (14.1%) than males (13.6%) ($p = 0.860$). Pupils aged 7–9 years had the highest prevalence 32(16.5%) and those aged 4–6 years the lowest 15(10.7%) ($p = 0.497$). The highest school-level prevalence in Ilesa-West was at Faith Academy 11(22.0%) and in Olorunda at Saint Michael School 9(17.6%), with both LGAs recording 4(8.0%) as the lowest prevalence in at least one school. Differences by gender, age, school, and LGA were not statistically significant ($p > 0.05$) (Table 1).

Analysis of Environmental Variables and Prevalence in the Study Area.

A total of six environmental covariates; altitude, rainfall, Normalised Difference Vegetation Index (NDVI), land surface temperature (LST day and night), and population density were included in the generalised linear model. Urban/rural classification was not analysed due to lack of heterogeneity, as all selected schools were located in rural settings. The mean values and ranges of the environmental covariates across the study locations are summarized in Table 2. Altitude values ranged from 3,384 m to 6,508 m, with a mean of 4,866 m. Rainfall ranged from 99.71 cm to 127.00 cm, with a mean of 110 cm. Population density varied between 15.51 and 78.94 persons/km² (mean: 49.14). Land surface temperature during the day had a mean value of 35.40°C, while nighttime LST averaged 21.26°C. NDVI values ranged between 0.14 and 0.36, with a mean of 0.23.

For *Ascaris lumbricoides*, the effect of environmental covariates is presented in Table 3. The NDVI was the only variable significantly associated with infection (estimate = 14086.9; 95% CI = 14037.1–14136.6; $p = 0.043$). Other variables including altitude, rainfall, population density, and LST (day/night) were not statistically significant predictors, as their confidence intervals included 1 and p-values were > 0.05.

For *Trichuris trichiura* infection (Table 4), none of the environmental variables showed significant associations. Although rainfall and population had estimates above 1 (1.18 and 1.03, respectively), their 95% confidence intervals included 1, and p-values were not significant.

In the case of hookworm infection, as shown in Table 5, population density was significantly associated (estimate = 0.89; 95% CI = 0.81–0.97; $p = 0.003$). Other covariates including NDVI, rainfall, and LST day and night were not significantly associated with hookworm infection.
For any STH infection (Table 6), none of the environmental variables were significantly associated. Although land surface temperature during the day had a high odds ratio (6.33), its confidence interval was wide and included 1, indicating lack of significance.

Following covariate selection, NDVI, distance to water bodies, and land surface temperature (day) were retained as key predictors for building the spatial and non-spatial models for *Ascaris, hookworm*, and Trichuris infections (Table 7). In the non-spatial model for *Ascaris lumbricoides*,

NDVI > 0.33 was positively associated with infection (odds ratio = 1.15; 95% CI = 0.23–2.07). In the Bayesian spatial model, a similar positive association was observed (OR = 1.17; 95% Bayesian credible interval = 0.25–2.16). Distance to water bodies > 3.02 km showed an inverse association with Ascaris infection (OR = 0.64; 95% CI = –0.81–0.76), as did high LST during the day (OR = –0.01; 95% CI = –0.08–0.78), although these were not significant in the spatial model. For hookworm, NDVI > 0.33 had a negative association in the non-spatial model (OR = –0.47; 95% CI = –1.90–0.96), with similar negative trends observed for distance to water and LST, though none reached statistical significance. No environmental variable was found to be significantly associated with *Trichuris trichiura* infection in either the spatial or non-spatial model. Overall, NDVI and proximity to water bodies emerged as relevant environmental predictors for Ascaris and hookworm infections, while no strong environmental correlation was observed for Trichuris infection.

Table 1: Prevalence of Soil Transmitted Helminth infections in relation to sex, age group in Ilesa-west and Olorunda Local Government area

Categories	NE	*A. lumbricoides* NP (%)	*T. Trichiura* NP (%)	Hookworm NP (%)	Aggregated STH Infection NP (%)
Sex					
Male	265	27(10.2)	3(1.1)	6(2.3)	36(13.6)
Female	255	25(9.8)	2(0.8)	9(3.5)	36(14.1)
Total	520	52(10.0)	5(1.0)	15(2.9)	72(13.8)
X^2, Df, p-value		0.021,1,0.884	0.165,1,0.685	0.743,1,0.389	0.031, 1, 0.860
Age group in years					
4-6	140	9(6.4)	1(0.7)	5(3.6)	15(10.7)
7-9	194	23(11.9)	4(2.1)	5(2.6)	32(16.5)
10-12	145	15(10.3)	0(0)	4(2.8)	19(13.1)
>13	41	5(12.2)	0(0)	1(2.4)	6(14.6)
Total	520	52(10.0)	5(1.0)	15(2.9)	72(13.8)
X^2, Df, p-value		2.965,3, 0.397	4.362,3,0.225	0.338,3,0.953	2.380,3,0.497
Ilesa-west LGA					
Faith Academy	50	9(18.0)	1(2.0)	1(2.0)	11(22.0)
NUD Moroko	50	1(2.0)	1(2.0)	2(4.0)	4(8.0)
NUD Odo-ona	56	9(16.1)	0(0.0)	0(0.0)	9(16.1)
The Sincere	50	6(12.0)	1(2.0)	0(0.0)	7(14.0)
Zumura	56	6(10.7)	0(0.0)	3(5.4)	9(16.1)
Total	262	31(11.8)	3(1.1)	6(2.3)	40(15.3)
X^2, df, p-value		7.490, 4, 0.112	2.266,4,0.687	5.511, 4, 0.239	3.911,4,0.418
Olorunda LGA					
AUD Sabo	50	2(4.0)	1(2.0)	1(2.0)	4(8.0)
Abdul-azeez Asalafy	52	5(9.6)	0(0.0)	2(3.8)	7(13.5)
Faozul-wajanat	56	4(7.1)	0(0.0)	2(3.6)	6(10.7)
Saint Micheal	51	6(11.8)	0(0.0)	3(5.9)	9(17.6)
Surajudeen	49	4(8.2)	1(2.0)	1(2.0)	6(12.2)
Total	258	21(8.1)	2(0.8)	9(3.5)	32(12.4)
X^2, df, p-value		2.268, 4, 0.687	3.238,4,0.519	1.523,4, 0.823	2.385,4,0.665
Overall prevalence	520	52(10.0)	5(1.0)	15(2.9)	72(13.8)
X^2, df, p-value		12.535, 9, 0.185	5.495,9,0.789	6.898, 9, 0.648	7.308, 9, 0.605

NE = Number Examined

Table 2: Descriptive Statistics for the Remotely Sensed Environmental Variables Across the Study Local Government Areas

	X ± SD	Minimum	Maximum
Altitude (m)	4866.1±1271	3384	6508
Rainfall (cm)	110.06±11.6	99.71	127.00
Population	49.14±17.8	15.51	78.94
LST Day	35.40±1.59	31.6267	37.6720
LST Night	21.26±1.00	18.8311	21.9257
NDVI	0.23±0.006	.1481	.3618

X: Mean; SD: Standard Deviation; LST: Land Surface Temperature; NDVI: Normalised Deviation Vegetation Index

Table 3: Generalised Linear Model on the Effect of Remotely Sensed Environmental Variables on Prevalence of Ascaris spp in Ilesa-West and Olorunda Local Government Areas

Variables	OR	SE	95% CI	p-value
Intercept	0.013	57.9919	-113.65– 113.68	0.942
Altitude (m)	0.996	0.0025	0.99-1.00	0.082
Rainfall (cm)	0.778	0.2691	0.25-1.31	0.351
Population	0.588	0.0943	0.40-0.77	0.576
LST Day (0C)	8.322	1.3093	5.76-10.89	0.106
LST Night (0C)	0.377	2.3924	-4.31-5.06	0.683
NDVI	14086.9	25.3934	14037.1 – 14136.6	0.043

SE: Standard Error; CI: Confidence Interval; LST: Land Surface Temperature; NDVI: *Normalised Deviation Vegetation Index

Table 4: Generalised Linear Model on the Effect of Remotely Sensed Environmental Variables on Prevalence of *Trichuris trichiura*

Variables	OR	SE	95% CI	p-value
Intercept	0.00	10.62	-20.8-20.82	0.942
Altitude (m)	1.00	0.0005	1.00-1.00	0.082
Rainfall (cm)	1.18	0.049	1.08-1.27	0.351
Population	1.03	0.0173	1.00-1.07	0.576
LST Day (0C)	0.50	0.2398	0.03-0.97	0.106
LST Night (0C)	1.75	0.4382	0.89-2.61	0.683
NDVI	0.00	4.6513	-9.12-9.11	0.043

OR: Estimates; SE: Standard Error; CI: Confidence Interval; LST: Land Surface Temperature; NDVI: Normalised Difference Vegetation Index

Table 5: Generalised Linear Model on the Effect of Remotely Sensed Environmental Variables on Prevalence of Hookworm

Variables	Estimate	SE	95% CI	p-value
Intercept	0.00	24.6241	-48.26-48.26	0.357
Altitude (m)	1	0.0011	0.99- 1.00	0.919
Rainfall (cm)	0.64	0.1143	0.42- 0.87	0.697
Population	0.89	0.04	0.81- 0.97	0.003
LST Day (0C)	1.55	0.5559	0.46 – 2.64	0.431
LST Night (0C)	2.69	1.0158	0.70 – 4.68	0.331
NDVI	0.03	10.7823	-21.10 – 21.17	0.750

OR: Estimates; SE: Standard Error; CI: Confidence Interval; LST: Land Surface Temperature; NDVI: Normalised Difference Vegetation Index

Table 6: Generalised Linear Model on the Effect of Remotely Sensed Environmental Variables on Prevalence of any Soil Helminths Infection

Variables	Estimate	SE	95% CI	p-value
Intercept	0.00	52.4852	-102.87099- 102.87	0.469
Altitude (m)	0.99	0.0023	0.9924965 – 1.00	0.256
Rainfall (cm)	0.88	0.2435	0.40347367 – 1.36	0.603
Population	0.87	0.853	-0.7999098 – 2.54	0.109
LST Day (0C)	6.33	1.185	4.01183106 – 8.66	0.119
LST Night (0C)	1.68	2.1652	-2.5634455 – 5.92	0.811
NDVI	6.33	22.9821	6.33– 6.33	0.092

NDVI: Normalised Difference Vegetation Index
OR: Estimates; SE: Standard Error; CI: Confidence Interval; LST: Land Surface Temperature;

Table 7: Posterior Estimates of the Spatial and Non-spatial Models for Soil-Transmitted Helminth Infections

Species	Variable	Non-Spatial Binomial Regression		Bayesian Spatial Model	
		Coefficient	Confidence Interval (CI)	Coefficient	Bayesian Credible Interval (BCI)
Ascaris lumbricoides					
	NDVI				
	< = 0.333	0			
	>0.333	1.15	(0.23, 2.07)	1.17	(0.25, 2.16)
	Distance to Water body				
	< = 3.02km	0			
	>3.02 km	0.64	(-0.81, 0.76)	0.66	(-0.09, 1.41)
	Land Surface Temperature- Day(0C)				
	< =31.95	0			
	>31.95	-0.01	(-0.08, 0.78)	-0.02	(-1.24, 1.13)

Species	Variable	Non-Spatial Binomial Regression		Bayesian Spatial Model	
		Coefficient	Confidence Interval (CI)	Coefficient	Bayesian Credible Interval (BCI)
Hookworm					
	NDVI				
	< = 0.333	0			
	>0.333	-0.47	(-1.90, 0.96)		
	Distance to Water body				
	< = 3.02km	0			
	>3.02 km	-0.41	(-2.03, 1.21)		
	Land Surface Temperature- Day(0C)				
	< =31.95	0			
	>31.95	0.43	(-0.99, 1.86)		
Trichuris trichiura					
	NDVI				
	< = 0.333	0			
	>0.333	-1.30	(-3.92, 1.31)		
	Distance to Water body				
	< = 3.02km	0			
	>3.02 km	1.30	(-1.31, 3.92)		
	Land Surface Temperature- Day(0C)				
	< =31.95	0			
	>31.95	-2.09	(-5.45, 1.26)		
	Spatial Range (km)			6.84	(1.44, 27.87)

Modeling the effects of remotely sensed variables on STH in Ilesa-west and Olorunda LGAs

In Ilesa West, altitude ranged from 355m to 601m and did not significantly affect infection prevalence (8–22%) (Figure 2a). In Olorunda, altitude ranged from 285m to 393m, with no clear effect on STH prevalence (Figure 2b).

Land Surface Temperature (Day) In Ilesa West, ranged from 34.52ºC to 36.16ºC, showing a positive correlation with hookworm prevalence, except at NUD Moroko which deviated from the trend (Figure 2c). In Olorunda, Land Surface Temperature (Day) ranged from 31.63ºC to 37.67ºC, but *A. lumbricoides* prevalence showed no correlation (Figure 2d).

Higher prevalence of soil-transmitted helminths (STHs), particularly *Ascaris lumbricoides*, was observed in areas with relatively lower night-time land surface temperatures (21.7°C), such as Odo Iro. In contrast, locations with slightly higher night-time temperatures exhibited comparatively lower prevalence levels (Figure 2e). Higher STH prevalence was observed in cooler regions night-time land surface temperatures (18.83–19.5°C), particularly in the northern parts of the study area. Conversely, lower prevalence was recorded in warmer zones (above 21°C) in the southern region in Olorunda local Government Area (Figure 2f).

In Ilesa West, NDVI values (0.16–0.29) suggested poor to fair vegetation, and lower NDVI correlated with reduced *A. lumbricoides* prevalence (Figure 1g). In Olorunda, NDVI (0.15–0.36) also

positively correlated with *A. lumbricoides* prevalence (Figure 2h).

In Ilesa West, *A. lumbricoides* and *T. trichiura* showed no correlation with population density, while hookworm prevalence was inversely related (Figure 2i). In Olorunda, Higher soil-transmitted helminth (STH) prevalence, especially Ascaris, was observed in areas with lower population densities (15.5–30), Conversely, areas with higher population densities (above 70), like Sabo, exhibited comparatively lower STH prevalence (Figure 2j).

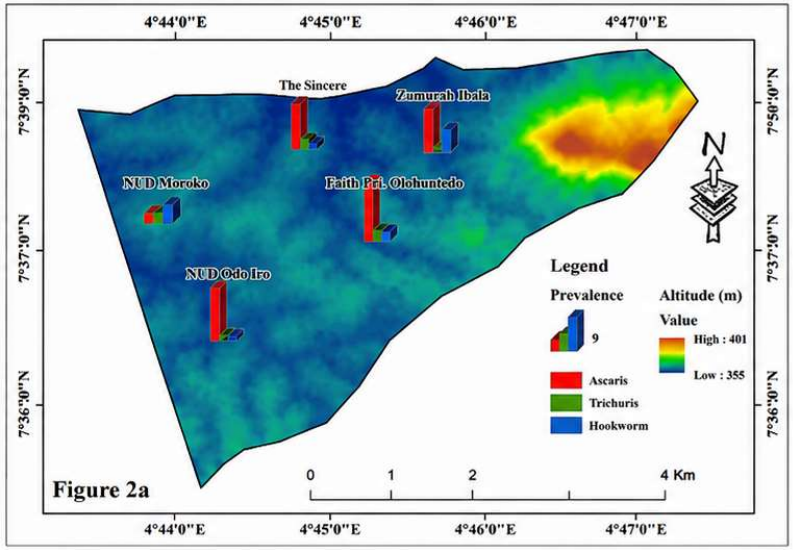
In Ilesa West, rainfall influenced STH prevalence. Generally, areas with more rainfall showed higher infection rates, especially for *A. lumbricoides* (Figure 1k). Rainfall in Olorunda LGA was low and uniform. Despite similar rainfall across locations, there were varying levels of STH infections, especially Ascaris (Figure 2l).

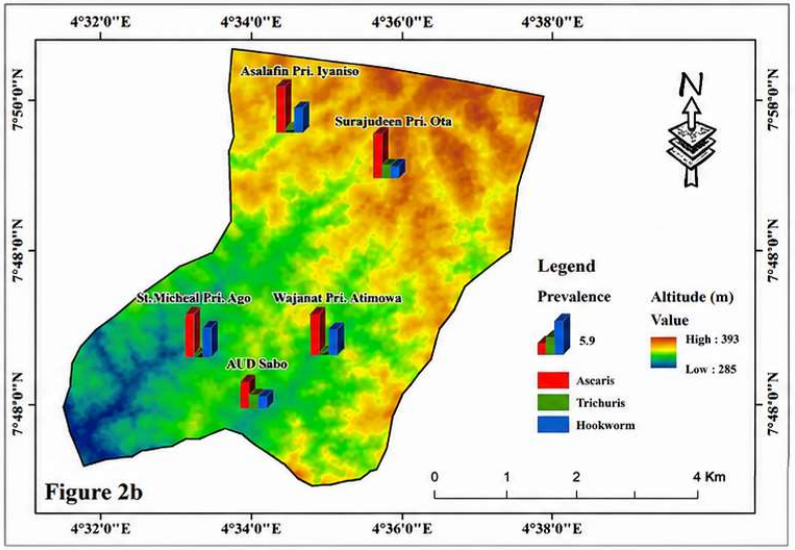
The spatial risk prediction map for soil-transmitted helminth (STH) infections in Ilesa West Local Government Area (LGA) illustrates spatial heterogeneity in transmission risk. The western part of the LGA is characterized by the lowest predicted risk, the eastern region exhibits the highest risk, while central areas displayed moderate risk levels (Figure 3a). In contrast, the risk map for Olorunda LGA reveals a different pattern, with the southeastern region exhibiting the lowest predicted risk, the southwestern region showing the highest, and the rest of the LGA presenting intermediate risk levels (Figure 3b).

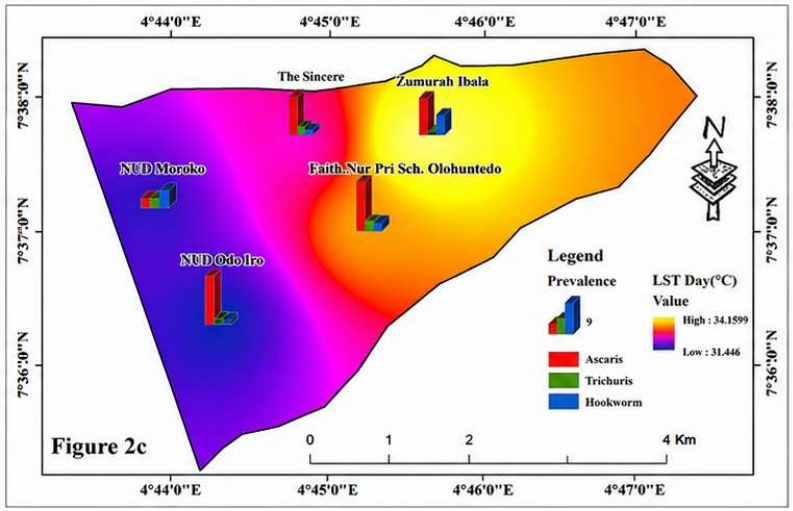
The predictive risk map for *Ascaris lumbricoides* infection in Ilesa West LGA shows a generally moderate risk across the majority of the area, with a pronounced hotspot of elevated infection risk located in the northeastern part of the LGA (Figure 3c). Similarly, the risk distribution for *Ascaris lumbricoides* in Olorunda LGA also indicates a generally moderate risk level, with the presence of both localized hotspots and zones of very low predicted risk. However, comparison of peak prevalence values reveals that Ilesa West LGA recorded a higher maximum predicted risk (17.9681) compared to Olorunda LGA (11.7298), indicating a relatively higher overall risk of *Ascaris* infection in Ilesa West (Figure 3d).

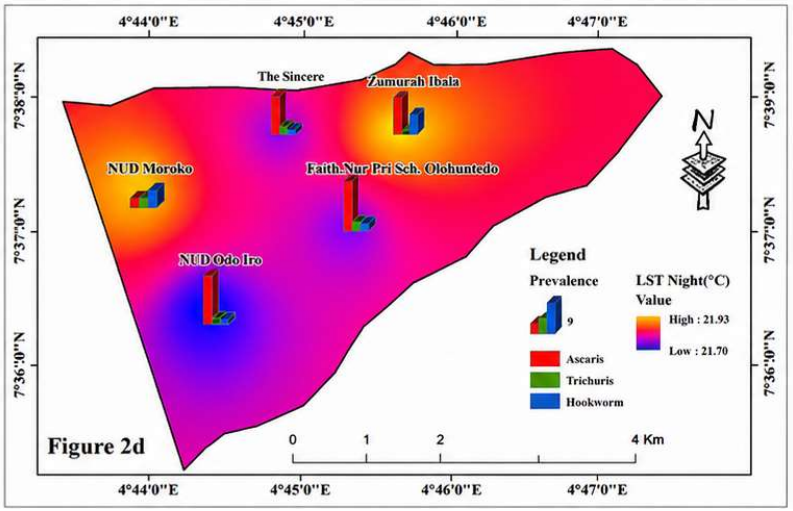
The predictive map for *Trichuris trichiura* infection in Ilesa West LGA also indicates a moderate overall risk level, with predicted values ranging from 1.56636 to 1.9985. Despite this relatively narrow range, certain locations exhibit very low predicted risk, while the highest values are concentrated in the northeastern portion of the LGA (Figure 3e). In Olorunda LGA, *Trichuris* infection risk follows a similar pattern, with predicted values ranging from 0.00016 to 1.9991. Both high and low-risk areas are found predominantly in the southern part of the LGA. Overall, the risk profile for *Trichuris trichiura* infection is comparable between the two LGAs (Figure 3f).

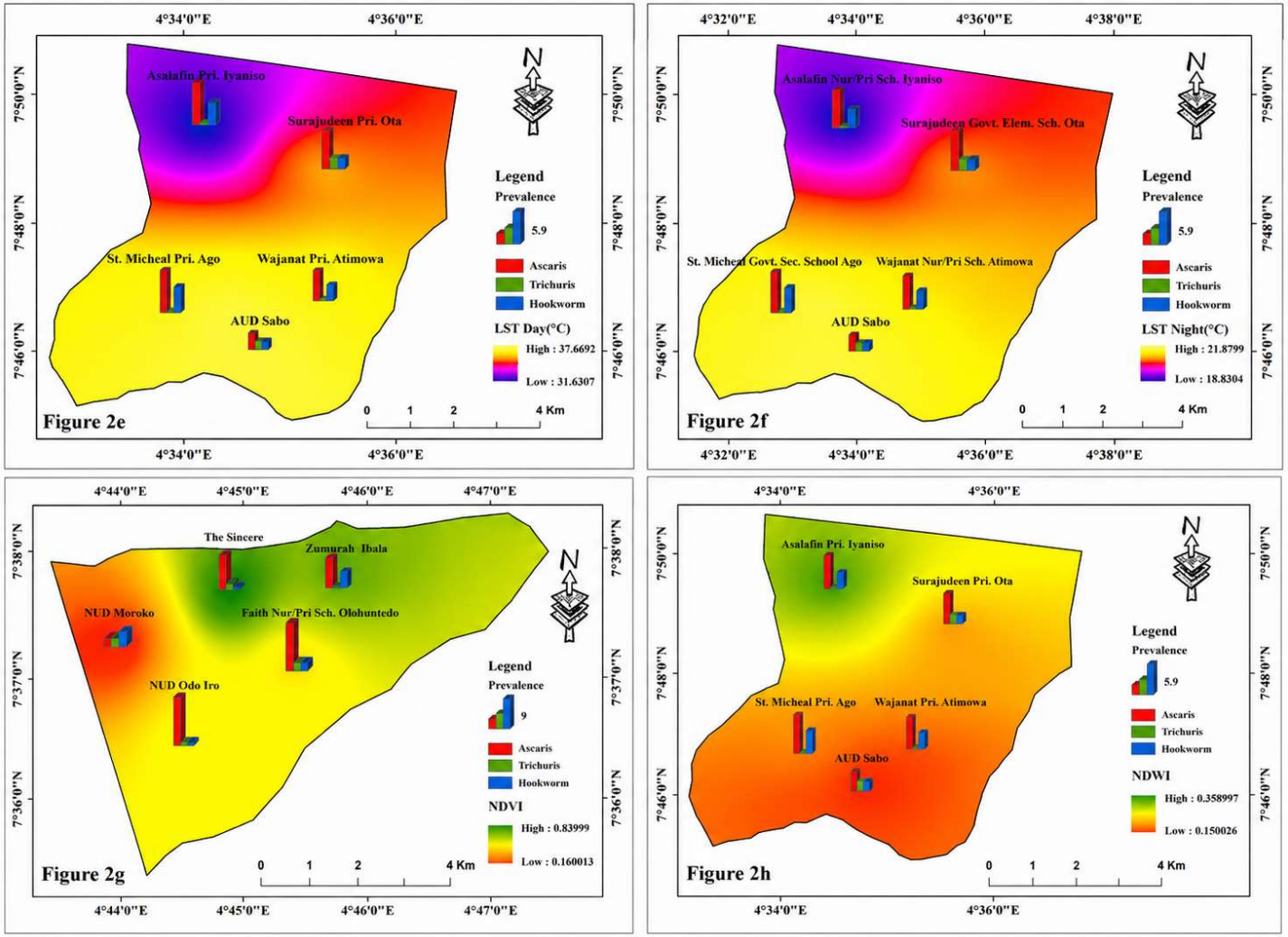
For hookworm infections, the predictive risk map in Ilesa West LGA reveals a predominantly low infection risk across the region, with only a few isolated areas particularly in the northeastern part showing slightly elevated risk levels. The predicted risk values range from 2.4837 to 5.3994, but the overall risk remains low (Figure 3g). Conversely, Olorunda LGA presents a medium level of hookworm infection risk across the entire LGA, with conspicuous spikes in the southern region. The maximum predicted risk value of 5.8992 and a range of 2.0001 highlight a relatively higher burden of hookworm infection in Olorunda compared to Ilesa West LGA (Figure 3h).


4°44'0"E
4°45'0"E
4°46'0"E
4°47'0"E
7°39'0"N
7°37'0"N
7°36'0"N
The Sincere
Zumurah Ibala
NUD Moroko
Faith Pri. Olohuntedo
NUD Odo Iro
N
Legend
Prevalence
9
Altitude (m)
Value
High : 401
Low : 355
Ascaris
Trichuris
Hookworm
0 1 2 4 Km
Figure 2a


4°32'0"E
4°34'0"E
4°36'0"E
4°38'0"E
7°50'0"N
7°48'0"N
7°46'0"N
7°58'0"N
Asalafin Pri. Iyaniso
Surajudeen Pri. Ota
St. Micheal Pri. Ago
Wajanat Pri. Atimowa
AUD Sabo
N
Legend
Prevalence
5.9
Altitude (m)
Value
High : 393
Low : 285
Ascaris
Trichuris
Hookworm
0 1 2 4 Km
Figure 2b


4°44'0"E
4°45'0"E
4°46'0"E
4°47'0"E
7°38'0"N
7°37'0"N
7°36'0"N
The Sincere
Zumurah Ibala
NUD Moroko
Faith.Nur Pri Sch. Olohuntedo
NUD Odo Iro
N
Legend
Prevalence
9
LST Day(°C)
Value
High : 34.1599
Low : 31.446
Ascaris
Trichuris
Hookworm
0 1 2 4 Km
Figure 2c


4°44'0"E
4°45'0"E
4°46'0"E
4°47'0"E
7°38'0"N
7°37'0"N
7°36'0"N
7°39'0"N
The Sincere
Zumurah Ibala
NUD Moroko
Faith.Nur Pri Sch. Olohuntedo
NUD Odo Iro
N
Legend
Prevalence
9
LST Night(°C)
Value
High : 21.93
Low : 21.70
Ascaris
Trichuris
Hookworm
0 1 2 4 Km
Figure 2d


4°34'0"E
4°36'0"E
7°50'0"N
7°48'0"N
7°46'0"N
Asalafin Pri. Iyaniso
Surajudeen Pri. Ota
St. Micheal Pri. Ago
Wajanat Pri. Atimowa
AUD Sabo
N
Legend
Prevalence
5.9
Ascaris
Trichuris
Hookworm
LST Day(°C)
High : 37.6692
Low : 31.6307
0 1 2 4 Km
Figure 2e
4°32'0"E
4°34'0"E
4°36'0"E
4°38'0"E
Asalafin Nur/Pri Sch. Iyaniso
Surajudeen Govt. Elem. Sch. Ota
St. Micheal Govt. Sec. School Ago
Wajanat Nur/Pri Sch. Atimowa
AUD Sabo
LST Night(°C)
High : 21.8799
Low : 18.8304
Figure 2f
4°44'0"E
4°45'0"E
4°46'0"E
4°47'0"E
7°38'0"N
7°37'0"N
7°36'0"N
The Sincere
Zumurah Ibala
NUD Moroko
Faith Nur/Pri Sch. Olohuntedo
NUD Odo Iro
9
NDVI
High : 0.83999
Low : 0.160013
Figure 2g
Asalafin Pri. Iyaniso
Surajudeen Pri. Ota
St. Micheal Pri. Ago
Wajanat Pri. Atimowa
AUD Sabo
NDWI
High : 0.358997
Low : 0.150026
Figure 2h

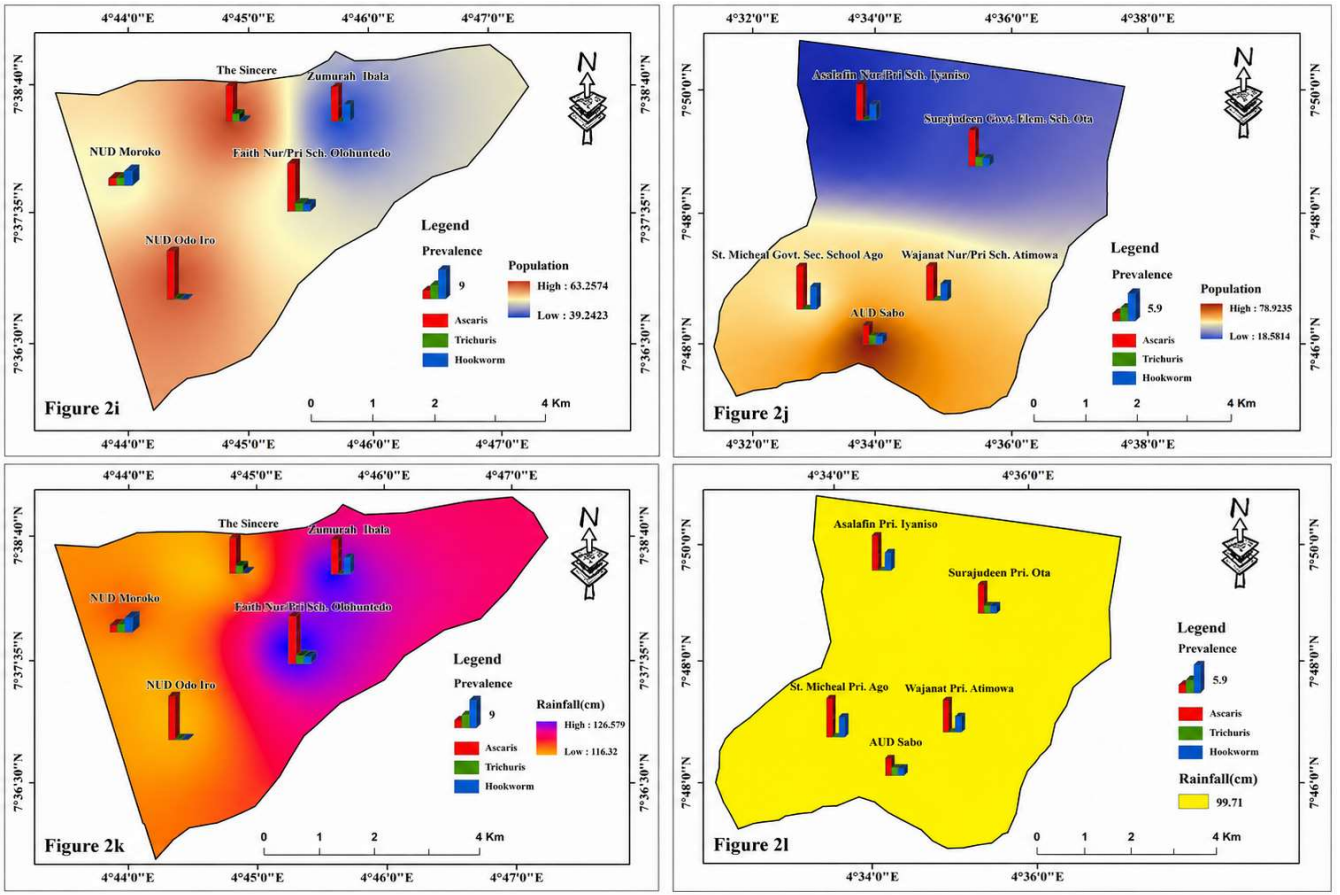
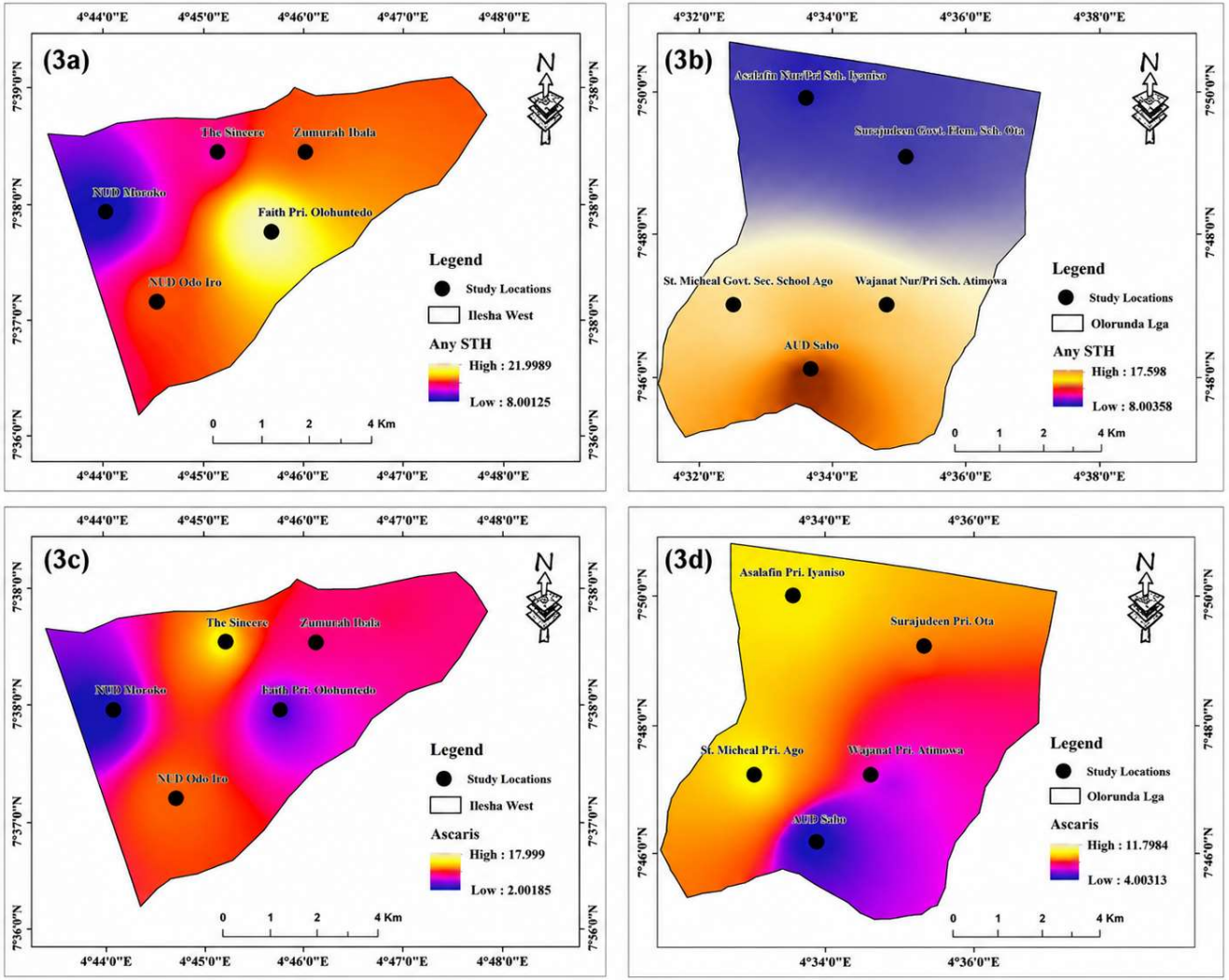


Figure 2. Spatial distribution of soil-transmitted helminth (STH) infection risk by altitude in: **(2a)** Ilesa West LGA, (**2b)** Olorunda LGA, showing variation with elevation; Relationship between land surface temperature Ilesa West LGA: (**2c**) (daytime) and (**2d)** (nighttime) and predicted STH infection; Spatial mapping of STH risk by: (**2e)** daytime and (**2f)** nighttime land surface temperature in Olorunda LGA; Predicted STH risk distribution in: (**2g)** Ilesa West LGA and (**2h)** Olorunda West LGA as influenced by vegetation cover (NDVI); Population density and its spatial association with STH prevalence in: (**2i)** Ilesa West LGA and (**2j)** Olorunda West LGA; Spatial distribution of STH infections in: (**2k)** Ilesa West LGA and (**2l)** Olorunda West LGA in relation to average rainfall levels


(3a)
The Sincere
Zumurah Ibala
NUD Moroko
Faith Pri. Olohuntedo
NUD Odo Iro
Legend
Study Locations
Ilesha West
Any STH
High : 21.9989
Low : 8.00125
(3b)
Asalafin Nur/Pri Sch. Iyaniso
Surajudeen Govt. Elem. Sch. Ota
St. Micheal Govt. Sec. School Ago
Wajanat Nur/Pri Sch. Atimowa
AUD Sabo
Legend
Study Locations
Olorunda Lga
Any STH
High : 17.598
Low : 8.00358
(3c)
The Sincere
Zumurah Ibala
NUD Moroko
Faith Pri. Olohuntedo
NUD Odo Iro
Legend
Study Locations
Ilesha West
Ascaris
High : 17.999
Low : 2.00185
(3d)
Asalafin Pri. Iyaniso
Surajudeen Pri. Ota
St. Micheal Pri. Ago
Wajanat Pri. Atimowa
AUD Sabo
Legend
Study Locations
Olorunda Lga
Ascaris
High : 11.7984
Low : 4.00313
N
0 1 2 4 Km

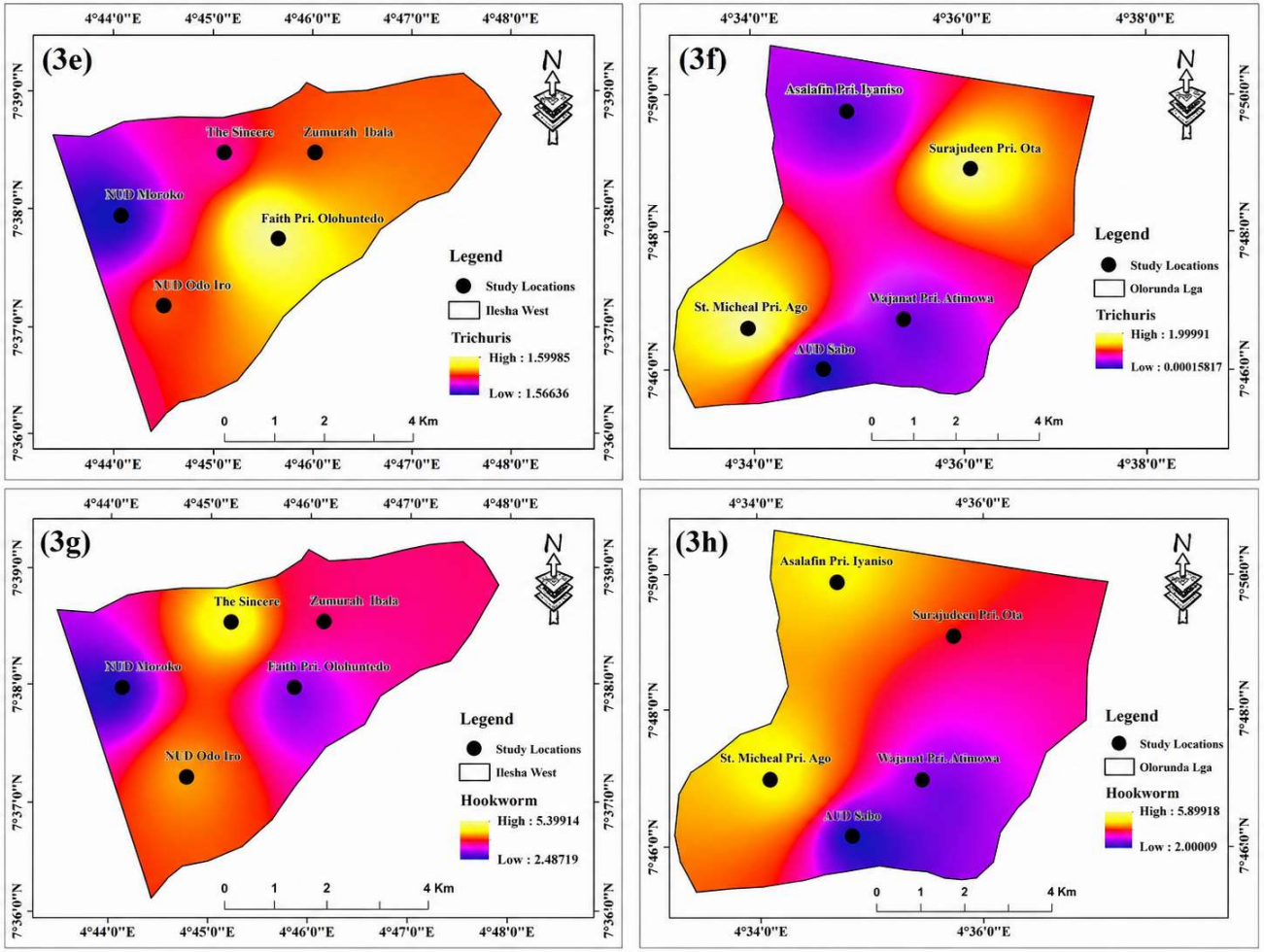


Figure 3. Predicted risk map of any soil-transmitted helminth (STH) infection in **(3a)** Ilesa West LGA and (3**b)** Olorunda West LGA; Predicted risk map of *Ascaris lumbricoides* infection in: (**3c)** Ilesa West LGA and **(3d)** Olorunda LGA; Predicted risk map of *Trichuris trichiura* infection in: **(3e)** Ilesha LGAand **(3f)** Olorunda LGA; Predicted risk map of hookworm: **(3g)** infection in Ilesa West LGA and **(3h)** transmission risk across Olorunda LGA

DISCUSSION

This study employed Bayesian geostatistical models to investigate the environmental determinants and spatial distribution of soil-transmitted helminth (STH) infections in two LGAs of Osun State, Nigeria. The overall STH prevalence (13.8%) is indicative of moderate endemicity, aligning with WHO's 10–20% prevalence bracket that recommends annual mass drug administration (MDA). Xu *et al*., (2023) reported that the prevalence of soil-transmitted helminths in Shandong Province was influenced by several environmental and demographic factors.

The predominance of *A. lumbricoides* is consistent with findings by Oluwole *et al.,* (2015) and Imalele *et al.,* (2023), who reported similar patterns in other parts of Southwestern Nigeria. Its resilience has been attributed to the durability of its ova and its ability to thrive in humid, organic-rich soil environments. Our study identified Normalised Difference Vegetation Index (NDVI), proximity to water bodies, and land surface temperature (LST) as key predictors for *A. lumbricoides* and hookworm infections. Areas with dense vegetation (NDVI > 0.33) and proximity to water bodies (<3.02 km) were associated with increased risk, likely due to higher soil moisture that favours egg survival and larval development. This corroborates findings by Yapi *et al.,* (2016) and Lai *et al.,* (2013).

Hookworm infection was significantly associated with population density, and inversely related to vegetation cover and temperature, as also observed by Lai *et al.,* (2013). The lower association with NDVI aligns with the parasite's reliance on well-drained, less vegetated soils for larval migration. *Trichuris trichiura*, on the other hand, showed no significant environmental associations, echoing reports from Karshima (2018) that its transmission may be more closely tied to individual hygiene and defecation habits than environmental factors.

Our spatial analysis revealed considerable heterogeneity in STH risk, with hotspots in northeastern Ilesa West and southern Olorunda. Such micro-geographic variability in transmission has been highlighted in previous spatial modelling work by Yapi *et al.,* (2016), indicating the importance of sub-LGA targeting of interventions. Ilesa West had a higher peak prevalence for *A. lumbricoides*, while Olorunda had a higher predicted burden of hookworm. These findings emphasise the need for location-specific strategies rather than uniform intervention across LGAs.

The absence of significant associations between overall STH infection and most environmental covariates could be due to the suppressive effect of repeated Mass Drug Administration (MDA) which may reduce the prevalence of infection while not eliminating transmission completely. This aligns with the observation of Karshima, (2018), who reported low intensities but persistent prevalence in MDA-covered communities.

In this study, the integration of Bayesian geostatistical modelling with spatial analysis was crucial for generating high-resolution risk maps and identifying environmental determinants of STH infections. Bayesian models offer a powerful framework for handling uncertainty and incorporating spatial correlation, which is especially important in parasitic disease mapping where infection data are often sparse or clustered. The approach allows for more robust estimation of infection risk and its association with environmental variables such as NDVI, temperature, and proximity to water bodies. Coupling this with spatial prediction enabled the identification of micro-level hotspots that may be missed by conventional epidemiological methods. This combined methodology not only enhances the precision of public health decision-making but also optimises resource allocation by directing

interventions to the most affected areas. Similar benefits have been reported by Lai *et al.,* (2013), and Pillan *et al.,* (2011), who demonstrated the utility of Bayesian spatial modelling in targeting helminth control programmes in endemic regions.

CONCLUSION

Soil-transmitted helminth infections remain moderately endemic in the study area, with *Ascaris lumbricoides* predominating despite ongoing mass drug administration. Bayesian geostatistical modelling identified key environmental predictors for *Ascaris* and hookworm and revealed micro-geographic transmission hotspots, demonstrating the value of integrated spatial approaches for accurate risk estimation.

RECOMMENDATIONS

STH control programmes should integrate preventive chemotherapy with geospatially targeted environmental and sanitation interventions. Routine spatial surveillance and longitudinal monitoring are recommended to support evidence-based planning and optimise resource allocation.

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Conflict of interest: The authors affirm that there are no conflicts of interest related to this study.

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