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**Research Article**

**Mapping Strongyles Infection Risk in Cattle Herds: Prevalence, Breed Susceptibility, and Environmental Drivers in Northern Gombe State, Nigeria**

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**ABSTRACT**

Gastrointestinal helminth infections, particularly strongyle nematodes, remain a major constraint to cattle health, productivity, and livelihoods in tropical regions. Within a One Health framework, they affect animal production, contribute to pasture contamination, and indirectly impact human well-being through food security and ecosystem interactions. This study assessed the prevalence, risk factors, and spatial epidemiology of strongyle infections in cattle in northern Gombe State, Nigeria. A total of 1,694 faecal samples were analyzed using flotation techniques, with 671 positives, giving an overall prevalence of 39.61%. Prevalence varied significantly across Local Government Areas ( $\chi^2 = 32.749$ ,  $p < 0.001$ ), indicating spatial heterogeneity. Age and sex were not significantly associated with infection ( $p > 0.05$ ), but body condition score was ( $p = 0.013$ ), with poorly conditioned cattle more likely to be infected (OR = 1.432; 95% CI: 1.084–1.893). Breed differences were observed, with Sokoto Gudali showing higher prevalence (57.89%,  $p = 0.031$ ). Geospatial analyses using GIS, IDW, and GWR showed widespread infection (21.82%–53.37%) and strong spatial variation. Vegetation ( $\beta = 3.95$ ) and temperature ( $\beta = 2.52$ ) were key predictors, soil texture had moderate influence ( $\beta = 0.87$ ), and rainfall showed a weak negative effect ( $\beta = -0.02$ ). Spatial non-stationarity supported the use of local models. High-risk areas were identified in Funakaye, Kwami, and parts of Gombe, with moderate risk in Dukku and central zones. These findings highlight the need for spatially targeted, One Health-based control strategies, including deworming, pasture management, and climate-informed surveillance, and demonstrate the value of geospatial modelling for precision livestock health management in northeastern Nigeria.

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## INTRODUCTION

Gastrointestinal (GIT) helminth infections, particularly strongyle nematodes, continue to pose a significant challenge to livestock health and productivity globally, with disproportionate impacts in tropical and sub-Saharan regions (FAO, 2023; Roeber *et al.*, 2022). In Nigeria, these infections are endemic due to favorable climatic conditions that support larval development and persistence on pasture (Ola-Fadunsin *et al.*, 2020; Odo *et al.*, 2021). The consequences extend beyond animal health, including reduced meat and milk production, economic losses for pastoral households, and threats to food security (Perry & Grace, 2022). From a One Health perspective, strongyle infections represent an interface between animal health, environmental sustainability, and human livelihoods (Destoumieux-Garzón *et al.*, 2021). Contaminated grazing environments serve as reservoirs for parasite transmission, while climate variability influences parasite ecology and exposure risk (Rose *et al.*, 2023). Poor livestock productivity linked to parasitism can indirectly affect human nutrition and income, particularly in pastoral and agro-pastoral communities (FAO, 2023). Traditional epidemiological studies in Nigeria have largely focused on host-level risk factors such as age, sex, and breed, with limited integration of environmental and spatial determinants (Ola-Fadunsin *et al.*, 2020). However, helminth transmission is inherently spatial and environmentally driven, necessitating approaches that capture geographic variability and ecological complexity (Cringoli *et al.*, 2021). Advances in geospatial epidemiology, including GIS-based mapping and spatial regression models, offer powerful tools for identifying transmission hotspots and informing targeted interventions (Rinaldi *et al.*, 2022). Existing studies in Nigeria combine field epidemiology with spatial modelling techniques such as geographically weighted regression (GWR), which can capture localized relationships between infection risk and environmental variables (Fotheringham *et al.*, 2020; Rinaldi *et al.*, 2022). The aim of this study was to determine the prevalence and associated risk factors of strongyle infections in cattle, while characterizing their spatial distribution and environmental determinants across study areas. The findings are intended to support evidence-based, spatially targeted parasite control strategies. Despite growing recognition of these approaches, there remains a knowledge gap regarding the

spatial distribution and environmental drivers of strongyle infections in northern Gombe State.

## MATERIALS AND METHODS

### Study Area

The study was conducted in northern Gombe State, Nigeria, located between latitudes 10°17'54" N and longitudes 11°09'30" E. The region is characterized by a tropical savanna climate with distinct wet and dry seasons, which strongly influence pasture ecology and parasite transmission dynamics (Caminade *et al.*, 2017; Rose *et al.*, 2022). The area supports predominantly extensive pastoral and agro-pastoral livestock systems, which facilitate continuous exposure of cattle to infective helminth stages (Squire *et al.*, 2018; Kanyari *et al.*, 2022)

### Ethical Clearance

Ethical clearance was sought and obtained from Ahmadu Bello University, Zaria, Committee on Animal and Care (ABUCAUC/2023/011.) and Gombe State Ministry of Agriculture.

### Study Design and Sampling Strategy

A cross-sectional study was conducted during a late rainy single season to estimate the prevalence of helminth infections across five Local Government Areas (LGAs) in Gombe State: Gombe, Funakaye, Dukku, Kwami, and Nafada where herders are predominantly found (Setia, 2016; Thrusfield & Christley, 2018). A multi-stage cluster sampling approach was employed; herds were purposively selected based on consent and willingness to participate, followed by systematic random sampling of 1,694 individual cattle within these clusters to minimize selection bias (Dohoo *et al.*, 2017). To account for the hierarchical structure of the data and potential intra-herd correlation, the herd was treated as the primary sampling unit in the statistical analysis.

### Cattle Demographic Data Collection

For each animal, the following variables were recorded: breed, sex, age (estimated using dentition), and body condition score (BCS), categorized as good, medium, or poor using standardized scoring systems (Nicholson & Butterworth, 1986; Okello *et al.*, 2021).

### Laboratory Analysis (Parasitological Examination)

Fecal samples were collected rectally using sterile techniques and preserved in 5% formalin. They were processed via standard flotation (Zajac & Conboy, 2012; Dryden *et al.*, 2019), a reliable qualitative screening tool whose sensitivity varies with parasite burden and solution specific gravity.

Strongyle eggs were identified microscopically by morphology (oval shape, thin shell, morulated contents; Taylor *et al.*, 2016), but due to overlapping features, classification was limited to 'strongyle-type' eggs. Consequently, results represent a collective prevalence of gastrointestinal nematodes, as morphologic differentiation between genera such as *Haemonchus*, *Ostertagia*, and *Trichostrongylus* was not performed." yielding collective gastrointestinal nematode prevalence. Quality control involved duplicate slide readings for a sample subset (Vadlejch *et al.*, 2018).

### Geospatial Data Processing

Sampling locations were georeferenced using a handheld GPS device (Garmin eTrex 20). Coordinates were imported into ArcGIS 10.3 for spatial analysis. Environmental raster datasets were obtained from publicly available sources and included land use/land cover, temperature, rainfall, Normalized Difference Vegetation Index (NDVI), elevation, slope, and soil texture. All spatial layers were projected to a common coordinate system, resampled to uniform spatial resolution, and clipped to the study area boundary to ensure spatial consistency (Belghith *et al.*, 2019; ESRI, 2020).

### Spatial Analysis and Risk Mapping

Spatial interpolation of prevalence was performed using Inverse Distance Weighting (IDW) to generate continuous surface maps of infection distribution (Lu & Wong, 2019). IDW was selected due to its suitability for moderately dense sampling and ease of interpretation. Model parameters (power value and search radius) were optimized through cross-validation to minimize prediction error (Li & Heap, 2021) (Fig. 1)

### Statistical Analysis

Descriptive statistics were used to summarize prevalence. Associations between infection status and categorical variables were assessed using chi-square tests and odds ratios (OR) with 95% confidence intervals (Dohoo *et al.*, 2017; McHugh, 2019).

### Regression Modelling

Ordinary Least Squares (OLS) Regression and Geographically Weighted Regression (GWR) Herd-level prevalence served as the dependent variable for spatial modeling of environmental predictors. Global relationships were first assessed via Ordinary Least Squares (OLS) regression (Fotheringham *et al.*, 2017), with diagnostics including VIF (multicollinearity), adjusted  $R^2$  (fit), Jarque Bera (normality), and Koenker BP (heteroskedasticity) (Montgomery *et al.*, 2021;

ESRI, 2020). Geographically Weighted Regression (GWR) addressed spatial non-stationarity, allowing location-specific coefficients via adaptive bandwidth (AICc), and Gaussian kernel (Fotheringham *et al.*, 2017; Oshan *et al.*, 2019). LGA-specific prevalence included 95% CIs (Clopper-Pearson for clustered sampling); OLS and GWR were compared using AICc and adjusted  $R^2$

### Risk Mapping

Regression coefficients from the final model were used to generate a composite risk surface through weighted overlay analysis in GIS (Malczewski, 2020). Risk was classified into low, moderate, and high categories using natural breaks (Jenks optimization) to ensure meaningful spatial differentiation (Jiang, 2019).

### RESULTS

In table 1, the overall prevalence of strongyle infection recorded in this study was 39.61% (671/1694), there was a statistically significant variation in prevalence across Local Government Areas (LGAs) ( $\chi^2 = 32.749$ ,  $p < 0.001$ ) The prevalence of strongyles was relatively uniform across age groups: Calves: 38.50%, Young: 39.22% and Adults: 40.00%. There was no statistically significant association ( $p > 0.05$ ) between age and infection (Table 2) Body condition showed a significant association with strongyle infection: Good: 37.88%, Medium: 39.12% and Poor: 47.19% ( $p = 0.013$ ). Cattle with poor body condition were significantly more likely to be infected (OR = 1.432, CI: 1.084–1.893). (Table 3) Breed-related differences were observed: Sokoto Gudali: 57.89% (significant,  $p = 0.031$ ), White Fulani: 39.24% (not significant) and Red Bororo: 33.33% (not significant) (Table 4). Male cattle showed a slightly higher prevalence (40.58%) compared to females (38.83%), but the difference was not statistically significant ( $p = 0.494$ ) (Table 5).

The geospatial distribution of Strongyle species across the five LGAs of Northern Gombe State showed a wider range with values spanning from 21.82% to 53.37% (Fig. 1). This indicates that Strongyle species model identified vegetation as the strongest predictor of strongyle prevalence ( $\beta = 3.95$ ), indicating that areas with dense vegetation are significantly associated with higher infection risk due to favorable moist microclimatic conditions for larval survival. Temperature also showed a strong positive association ( $\beta = 2.52$ ), reflecting its role in accelerating larval

development. Soil texture had a moderate positive effect ( $\beta = 0.87$ ), likely due to improved moisture retention that enhances larval persistence. In contrast, rainfall exhibited a slight negative relationship ( $\beta = -0.02$ ), suggesting that excessive rainfall may reduce larval survival through runoff or waterlogging. Land use/land cover showed only a minimal positive influence ( $\beta = 0.04$ ) (Fig. 2). is more widely distributed and exhibits a generally higher prevalence across the study area. The Geographically Weighted Regression (GWR)

Spatially, moderate risk of strongyle infection was predominant in Dukku and central areas, while higher risk zones were concentrated in Funakaye, Kwami, and parts of Gombe, reflecting localized environmental conditions that favor parasite transmission (Fig. 3)

**Table 1:** Prevalence of Strongyles identified in Cattle Herds Per Local Government Area in Northern Gombe State

Parasite	Local Government Areas					Total n = 1694	Chi Sqaure	p-value
	Gombe n = 318	Funakaye n = 361	Dukku n = 374	Kwami n = 315	Nafada n = 326			
Strongyles	P (%) 129 (40.57)	P (%) 114 (31.58)	P (%) 124 (33.16)	P (%) 150 (47.62)	P (%) 154 (47.24)	P (%) 671 (39.61)	32.749	0.000

P = Prevalence; n = population

**Table 2:** Age-Specific Prevalence and Association of Strongyles Identified in Cattle Herds in northern Gombe state

Parasites	Age group	No E.	P. (%)	OR	CI	Chi-square	p-value
Strongyles	Calve	200	77 (38.50)	0.949	0.701-1.284	0.070	0.791
	Young	459	180 (39.22)	0.978	0.785-1.217	0.022	0.883
	Adult	1035	414 (40.00)	1.043	0.854-1.274	0.130	0.719
	Total	1694	671				

OR = Odd Ratio and CI = Confidence Interval. P= Prevalence; No. E. = Number Examined

**Table 3:** Body Condition Score Specific Prevalence and Association of Strongyles Recovered in Cattle Herds in Northern Gombe State

Parasites	BCS	No. E.	P.(%)	OR	CI	Chi-square	p-value
Strongyles	Good	829	314 (37.88)	0.868	0.714-1.054	1.900	0.168
	Medium	634	248 (39.12)	0.968	0.791-1.183	0.073	0.787
	Poor	231	109 (47.19)	1.432	1.084-1.893	6.056	0.013
	Total	1694	671				

OR = Odd Ratio and CI = Confidence Interval. P= Prevalence; No. E. = Number Examined

**Table 4:** Breed Specific Prevalence and Association of Strongyles Recovered in Cattle herds in Northern Gombe State

Parasites	Breed	No. E	P. (%)	OR	CI	Chi-square	p-value
Strongyles	White Fulani	1641	644 (39.24)	0.622	0.360-1.076	2.469	0.116
	Sokoto Gudali	38	22 (57.89)	2.134	1.112-4.093	4.679	0.031
	Red Bororo	15	5 (33.33)	0.761	0.259-2.235	0.055	0.815
	Total	1694	671				

*OR = Odd Ratio and CI = Confidence Interval. P= Prevalence; No. E. = Number Examined*

**Table 5:** Sex specific Prevalence and Association Strongyles Recovered in Cattle Herds in Northern Gombe State

Parasites	Sex	No. Ex.	Prevalence (%)	OR	CI	Chi-square	p-value
Strongyles	Male	754	306 (40.58)	1.076	0.885-1.309	0.467	0.494
	Female	940	365 (38.83)	0.929	0.764-1.130	0.467	0.494
	Total	1694	671				

*OR = Odd Ratio and CI = Confidence Interval. P= Prevalence; No. E. = Number Examined*

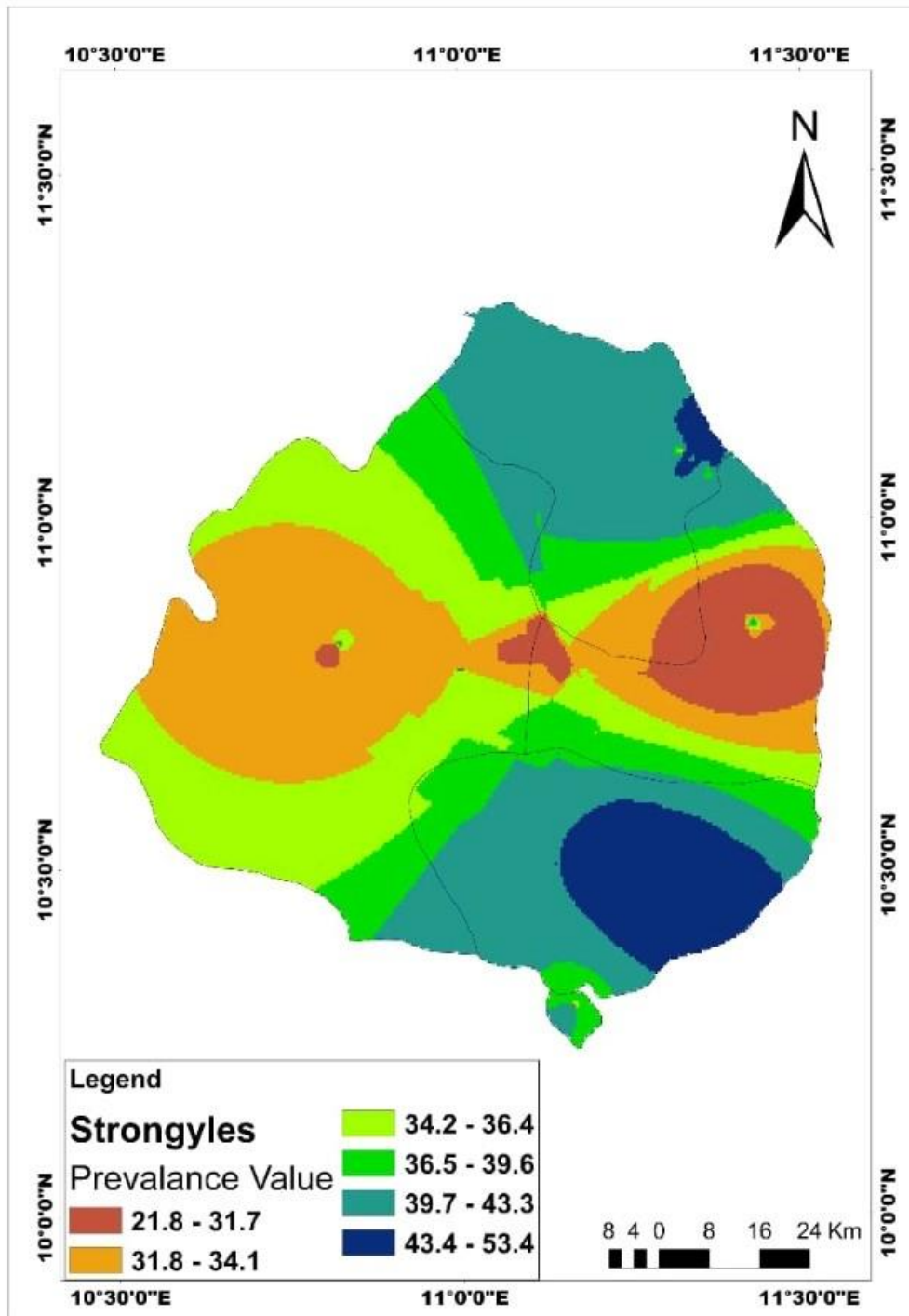


Figure 1: Geospatial distribution of Strongyles Across the Study Area

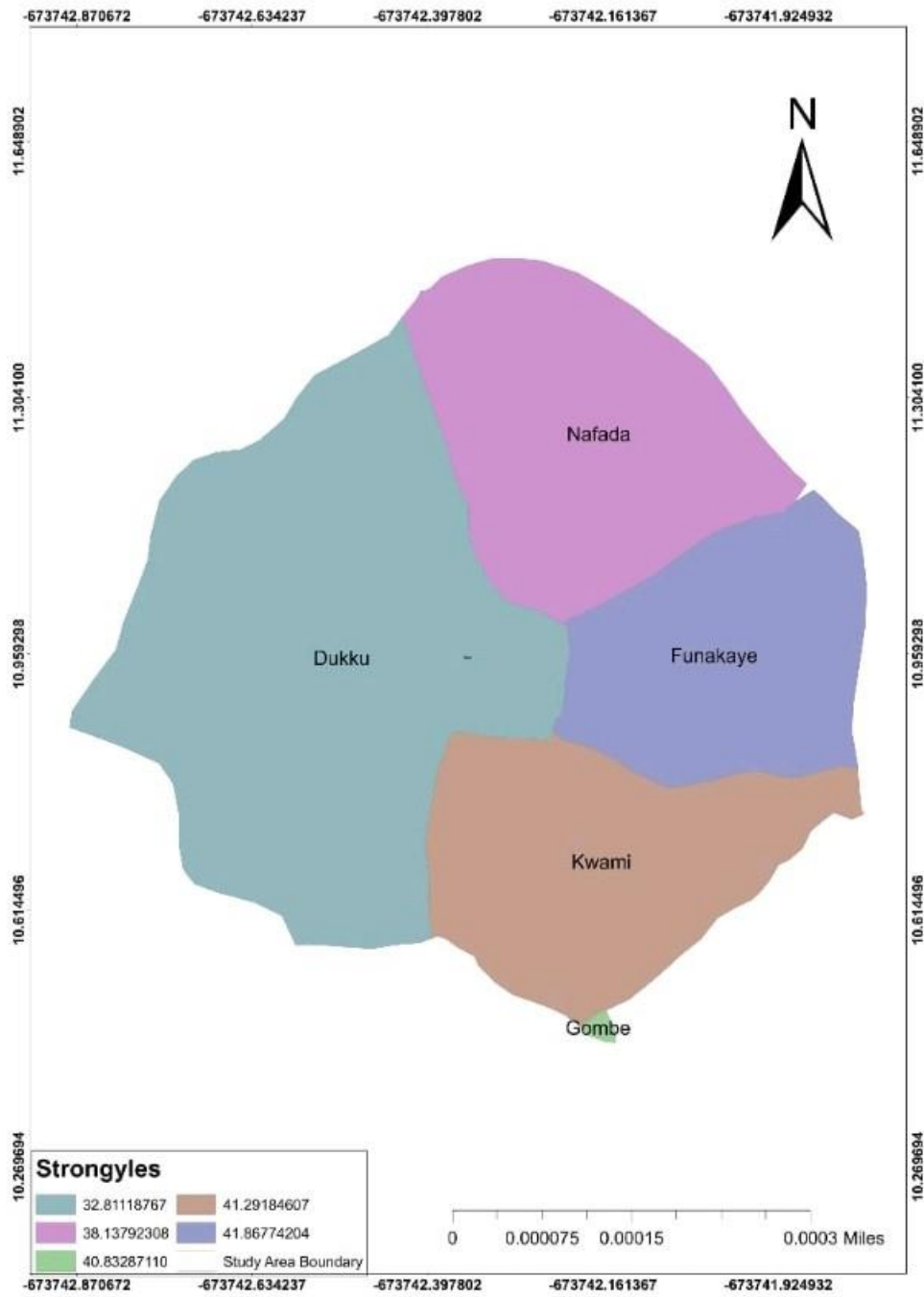
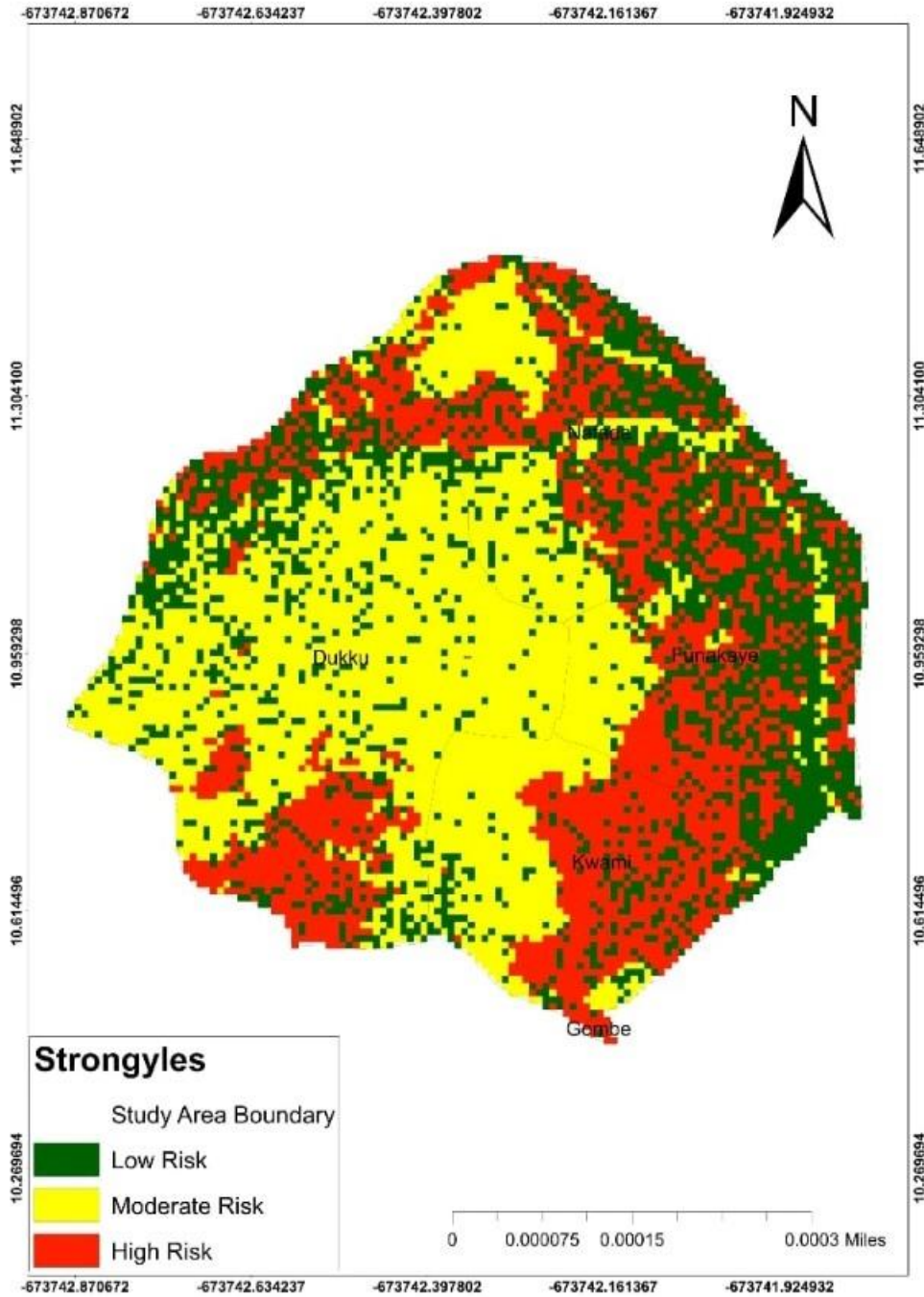


Figure 2: Modelled Map of Strongyles in the Study Area



**Figure 3:** Risk Map of Strongyles in the Study Area

**DISCUSSION**

The findings indicate that gastrointestinal helminthiasis is a significant challenge for cattle in northern Gombe State, consistent with endemic reports across sub-Saharan Africa (Ola-Fadunsin *et al.*, 2020; Terfa *et al.*, 2021). Spatial variations with higher prevalence in Kwami and Nafada compared to Funakaye likely stem from localized

differences in grazing density and management and pasture contamination. Such spatial heterogeneity has been widely documented, with environmental contamination and grazing intensity being major drivers of strongyle transmission (Kanyari *et al.*, 2022). However, the study is constrained by its cross-sectional design, specifically that sampling occurred only during the late rainy season. This single-term snapshot may

not capture the full impact of rainfall; while moisture typically aids larval migration, heavy late-season rains can also "wash away" larvae or alter grazing paths, potentially explaining why rainfall did not linearly predict infection intensity. Additionally, reliance on fecal egg counts (FEC) may miss pre-patent or hypobiotic infections, and the absence of data on recent anthelmintic use remains a confounding factor in determining true transmission drivers. The variation suggests that geographical and management factors strongly influence infection rates.

This finding contrasts with the conventional expectation that younger animals exhibit higher susceptibility due to immature immunity. However, similar patterns have been reported where continuous exposure leads to comparable infection levels across all age groups, particularly in extensively managed systems (Squire *et al.*, 2018). The lack of significant difference can be attributed to endemic stability of infection, persistent environmental contamination, and inadequate deworming practices across all age categories. This result indicates that sex is not a major determinant of strongyle infection in this population. Previous studies have similarly reported minimal or no sex-based differences, suggesting that exposure risk rather than physiological sex differences plays a dominant role (Nwosu *et al.*, 2020). This finding on body condition score highlights a bidirectional relationship: helminth infections contribute to weight loss and poor productivity, while poor nutrition weakens immunity and increases susceptibility. This study agrees with the statement that animal body condition is the most relevant risk factor for gastrointestinal strongyles, with a higher prevalence of parasites found in animals with poor body condition (Terfa *et al.*, 2023; Singh *et al.*, 2022).

The breed-specific prevalence signifies that the significantly higher prevalence in Sokoto Gudali cattle may reflect genetic susceptibility, differences in adaptation to local environmental conditions, and management practices specific to this breed. In contrast, White Fulani cattle, which are widely adapted to northern Nigerian conditions, may exhibit greater resilience to parasitic infections, as previously reported (Ibrahim *et al.*, 2021).

Geographically Weighted Regression and risk mapping show that strongyle distribution is strongly shaped by environmental factors, with

vegetation ( $\beta = 3.95$ ) and temperature ( $\beta = 2.52$ ) as the main drivers. Dense vegetation and moderate temperatures enhance larval survival and development, while moisture-retaining soils support viability. Rainfall slightly reduces persistence, and grazing landscapes modestly increase exposure. High-risk areas include Funakaye, Kwami, and parts of Gombe, with Dukku and central zones at moderate risk, highlighting the need for targeted control and grazing management. These results align with studies showing that vegetation, temperature, and soil moisture strongly influence gastrointestinal nematode transmission (Morgan *et al.*, 2021; Rose *et al.*, 2022; Caminade *et al.*, 2023).

### CONCLUSION

This study provides a spatially explicit and environmentally informed analysis of Strongyles infections in cattle within northern Gombe State, integrating epidemiological data with geospatial modeling to identify localized risk patterns. By combining host-related factors (age, sex, breed, and body condition) with environmental drivers such as vegetation and temperature, the research advances understanding of the complex interactions influencing helminth transmission in semi-arid production systems. Importantly, the findings highlight the value of risk mapping for guiding precision livestock health interventions and optimizing resource allocation in endemic regions. These findings provide a One Health-informed evidence base for designing environmentally sensitive, spatially targeted helminth control strategies that support livestock productivity, ecosystem health, and rural livelihoods. Targeted Deworming using risk maps to focus treatments on high-infection areas, better Grazing to manage pastures and rotate herds to reduce parasite exposure. One Health Approach by Combining veterinary care with environmental monitoring. Advanced Testing using DNA or larval testing to identify specific parasite species, Long-term Tracking by Monitoring herds year-round to understand seasonal infection trends are recommended.

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### CONFLICT OF INTEREST

I declare that there is no conflict of interest in respect to this article.

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