

Green infrastructure and nature-based solutions for integrated tick and *Theileria* control at the wildlife-livestock interface in Midlands Province, Zimbabwe

Dr Oliver Vulindhlela Mutero³, Dr Madeline Siyazisiwe Sibula¹, Dr Jenipher Zulu² and Prof Fashion Phiri³

¹National University of Science and Technology, Faculty of Applied Sciences, Bulawayo, Zimbabwe

²Levy Mwanawasa Medical University, School of Health Sciences, Lusaka, Zambia

³Africa Research University, School of Postgraduate Studies, Lusaka, Zimbabwe

Accepted 28, January, 2026

Tick-borne diseases remain a major constraint to cattle production in sub-Saharan Africa, with theileriosis posing a persistent challenge in communal grazing systems. In Zimbabwe's Midlands Province, acaricide-based tick control is increasingly undermined by resistance, inconsistent compliance, and environmental concerns. This study integrated molecular epidemiology, farmer survey data, and ecological analysis to evaluate green infrastructure and nature-based solutions for sustainable tick and *Theileria* control. Ticks collected from cattle in Gweru, Kwekwe and Mvuma districts were screened using PCR, revealing circulation of *Theileria parva*, *Theileria taurotragi*, and locally distinct variants, with higher prevalence in wildlife-livestock interface areas. A structured questionnaire administered to 390 farmers indicated heavy reliance on synthetic acaricides, declining adherence to dipping schedules, and widespread reports of reduced acaricide efficacy. Integrated analysis demonstrated strong associations between interface intensity, tick burden, and infection risk. Based on these findings, a nature-based control framework incorporating botanical acaricides, grazing management, biodiversity-supported biological control, and eco-efficient dipping infrastructure is proposed. The study demonstrates that sustainable control of tick-borne theileriosis requires a shift from chemical dependency towards integrated, ecosystem-based approaches aligned with green infrastructure and One Health principles.

Keywords: Tick-borne diseases; *Theileria*; Integrated tick management; Nature-based solutions; Wildlife-livestock interface; Zimbabwe

1. Introduction

Tick-borne diseases (TBDs) remain among the most important constraints to cattle production in sub-Saharan Africa, particularly in communal systems where extensive grazing, wildlife interactions and ecological heterogeneity favor persistent tick populations and continuous pathogen transmission. Theileriosis (locally termed "January Disease") caused primarily by *Theileria parva* continues to impose severe productivity losses in Zimbabwe. The parasite transmitted mainly by *Rhipicephalus appendiculatus* and maintained through complex transmission cycles involving cattle and African buffalo (*Syncerus caffer*), with buffalo acting as reservoirs of high parasite diversity and major sources of interface-associated infections (Morrison et al., 2020; Allan et al., 2021).

Zimbabwe's national tick control strategy has historically relied on chemical acaricides delivered through plunge dipping. However, increasing acaricide resistance, logistical constraints, declining farmer compliance and environmental contamination increasingly compromise the effectiveness and sustainability of this approach. Resistance to commonly used acaricides is now widespread across Africa, with field efficacy often reduced even where chemicals remain available (Bishop et al., 2023; Evans et al., 2024). Similar challenges are reported globally in tropical and subtropical livestock systems, indicating that chemical dependency alone cannot provide durable control.

Green infrastructure and nature-based solutions (NbS) offer an alternative framework that integrates ecological processes into livestock health management. These approaches align with Integrated Tick Management (ITM) and One Health principles, emphasizing reduced chemical dependency, biodiversity conservation, landscape management and socio-ecological resilience (Lagunes-Quintanilla et al., 2024; Otu et al., 2021). This study applies this framework to tick and *Theileria* control in Midlands Province, Zimbabwe, integrating molecular, epidemiological and socio-economic evidence to inform sustainable intervention strategies.

2. Materials and Methods

2.1 Research paradigm, approach and design

The study was conducted within a pragmatic research paradigm, recognizing tick-borne disease as a biological, ecological and social phenomenon. A convergent parallel mixed-methods design was adopted, integrating quantitative molecular epidemiology with a structured farmer survey, in line with established mixed-methods methodological guidance (Creswell & Plano Clark, 2018; Tashakkori & Teddlie, 2021). The overall design was cross-sectional and explanatory, appropriate for estimating prevalence, identifying ecological gradients and examining associations between infection outcomes and management practices.

2.2 Study area

The study was conducted in Gweru, Kwekwe and Mvuma districts of Midlands Province, Zimbabwe. The province is characterized by savannah grasslands, variable rainfall and extensive communal grazing systems, with frequent wildlife-livestock interaction.

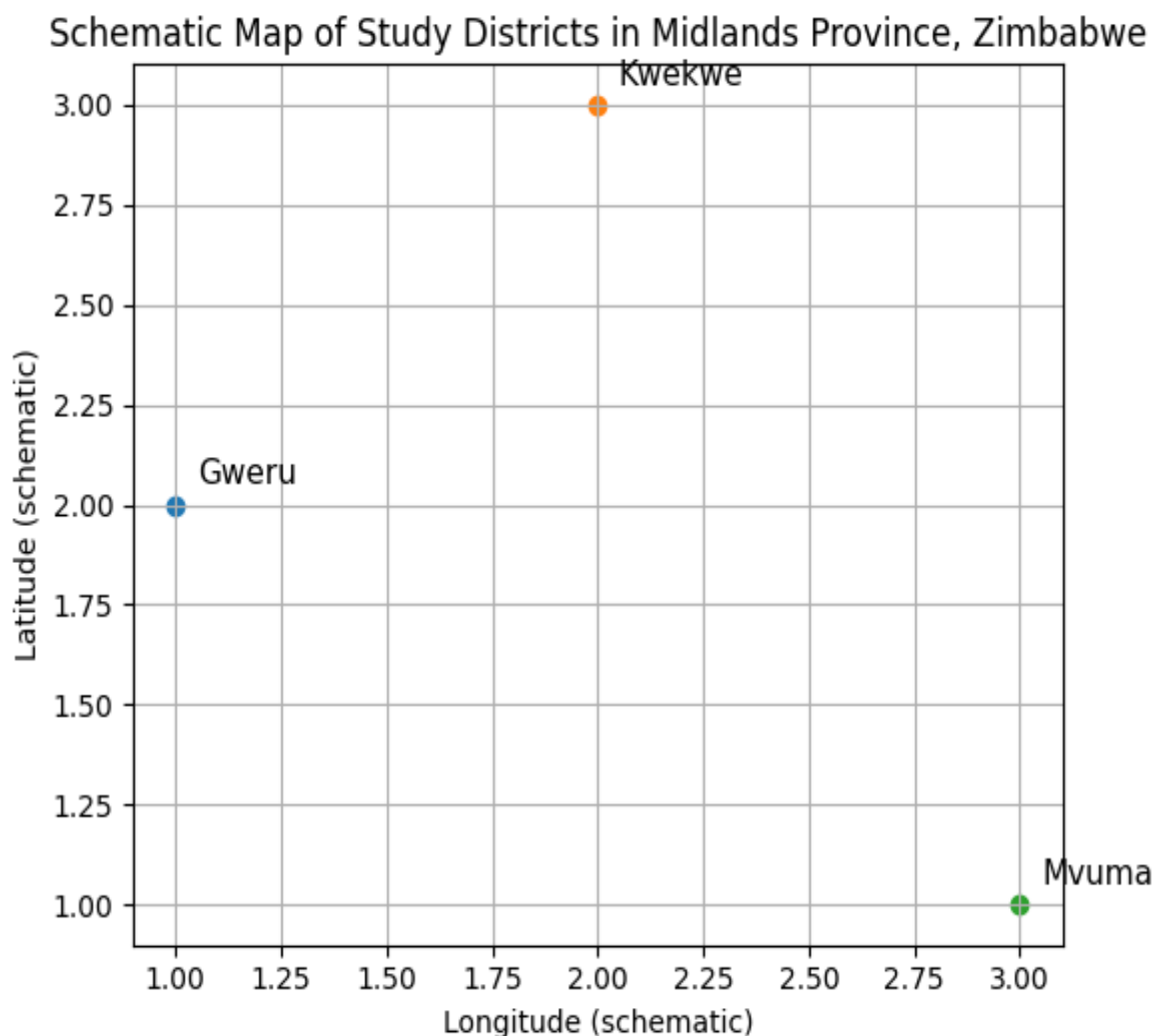


Figure 1: Schematic map showing the relative locations of Gweru, Kwekwe and Mvuma districts, Midlands Province, Zimbabwe

2.3 Sample size determination

The farmer survey sample size ($n = 390$) was calculated using standard formulas for cross-sectional studies, assuming an expected TBD prevalence of 50%, a 95% confidence level and a 5% margin of error, with adjustment for non-response. Tick sample size ($n = 300$) exceeded minimum requirements for molecular prevalence estimation and allowed district-level comparisons. These sample sizes are comparable to, or larger than, those used in recent regional and international tick-borne disease studies.

2.4 Tick sampling and molecular analysis

Ticks were collected from cattle at dip-tanks and grazing areas using forceps and preserved in 70% ethanol. DNA extraction followed standard protocols, and PCR targeting the 18S rRNA gene was used to detect *Theileria* spp. Positive amplicons were sequenced to confirm species and assess genetic diversity.

2.5 Farmer survey

A structure questionnaire was administered to 390 cattle owners to capture data on acaricide use, dipping frequency, grazing practices, wildlife contact, perceived tick burden and control challenges. Inclusion criteria were ownership of ≥ 5 cattle and residence within the study districts for ≥ 2 years.

2.6 Statistical analysis

Quantitative data were analyzed using SPSS version 26. Descriptive statistics summarized demographic characteristics, compliance patterns and prevalence. Bivariate associations were examined using chi-square tests and Pearson correlations. Multivariate predictors of high infection risk were assessed using binary logistic regression with adjusted odds ratios (AORs) and 95% confidence intervals. Potential confounders – including cattle age, breed, sex, body condition, seasonal variation, acaricide type and frequency, grazing system and proximity to wildlife – were included in regression models. Significance was set at $\alpha = 0.05$.

2.7 Reliability, validity and ethics

Laboratory reliability was ensured through standardized protocols and inclusion of positive and negative controls. Survey reliability was strengthened through enumerator training and pre-testing. Construct and content validity were enhanced through triangulation with molecular and ecological data. Ethical approval was obtained from the relevant institutional ethics committee; informed consent was obtained from all participants; animal handling adhered to veterinary welfare guidelines.

2.8 Methodological integration across research stages

This study employed a convergent parallel mixed-methods design, with integration embedded throughout the research process. At the design stage, molecular analysis and the farmer survey were planned concurrently and given equal priority. At the data collection stage, tick sampling and surveys were conducted simultaneously within the same districts and time period. At the analysis stage, datasets were analyzed independently using appropriate epidemiological and statistical methods, followed by systematic comparison through joint interpretation. At the interpretation stage, findings were synthesized through meta-inference to explain transmission patterns and inform development of green infrastructure and nature-based solutions, consistent with recommended mixed-methods integration practice (Creswell & Plano Clark, 2018; Tashakkori & Teddlie, 2021).

3. Results

3.1 Farmer Compliance with Acaricide-Based Tick Control

Compliance with dipping programs varied across districts, with fewer than half of respondents adhering fully to recommended schedules (Table 1). Partial compliance, including irregular attendance and unscheduled chemical application, was common.

Table 1: Compliance of cattle owners with recommended dipping schedules across study districts (n = 390)

DISTRICT	FULLY COMPLIANT (%)	PARTIALLY COMPLIANT (%)	NON-COMPLIANT (%)
GWERU	44.6	39.2	16.2
KWEKWE	38.3	45.0	16.7
MVUMA	36.1	47.7	16.2
OVERALL	39.7	44.0	16.3

3.2 Constraints Affecting Tick and Theileriosis Control

Respondents identified multiple operational and ecological constraints affecting tick control (Table 2). Acaricide shortages and suspected resistance were the most frequently reported challenges.

Table 2: Farmer-reported constraints affecting tick and theileriosis control

CONSTRAINT	FREQUENCY (%)
Acaricide shortages	28.5
Reduced efficacy/ resistance	22.8
Irregular dipping	18.7
High chemical cost	14.9
Poor grazing management	9.4
Wildlife-cattle interaction	5.7

3.3 Molecular Detection of *Theileria* spp.

PCR screening of ticks using ITS2-F and ITS2-R primers revealed multiple *Theileria* species and variants, with *T. parva* being the most prevalent (Table 3). Mixed infections were detected across all districts.

Table 3: Prevalence of *Theileria* species detected in ticks (n = 300)

SPECIES/ VARIANT	PREVALENCE (%)
<i>T. parva</i>	32.3
<i>T. taurotragi</i>	14.7
Local variant	11.0
Mixed infections	6.0
Negative	36.0

3.4 Wildlife-Livestock Interface and Infection Risk

Tick burden and *Theileria* positivity increased with intensity of wildlife-livestock interaction (Table 4), indicating strong ecological influence on transmission dynamics.

Table 4: Association between wildlife-livestock interface intensity, tick burden and *Theileria* infection

INTERFACE CATEGORY	MEAN TICK LOAD	THEILERIA POSITIVITY (%)
HIGH	42.1	56.7
MODERATE	28.4	34.2
LOW	16.7	18.3

3.5 Nature-Based Solutions and Green Infrastructure

The integrated findings informed development of a nature-based control framework (Table 5), linking ecological interventions with expected epidemiological outcomes.

Table 5: Proposed nature-based and green infrastructure interventions for sustainable tick control

INTERVENTION	ECOLOGICAL PRINCIPLE	EXPECTED OUTCOME
ROTATIONAL GRAZING	Disrupts tick life cycle	Reduced tick density
BOTANICAL ACARICIDES (<i>LIPPIA JAVANICA</i> , <i>ALOE</i> SPP.)	Biodegradable phytochemicals	Slowed resistance development
VEGETATIVE BUFFER ZONES	Habitat modification	Reduced tick movement
BIODIVERSITY-SUPPORTED PREDATION	Natural regulation	Sustained tick suppression
ECO-EFFICIENT DIP-TANKS	Reduced chemical runoff	Lower environmental impact

4. Discussion

The present study demonstrates that tick-borne theileriosis in Midlands Province is driven by interacting ecological, biological and management factors, and that chemical-only control strategies are insufficient to address this complexity. The detection of diverse *Theileria* variants, particularly in wildlife-livestock interface areas, is consistent with findings from other districts in Zimbabwe such as Mhondoro-Ngezi, Lupane and Matobo, as well as regional studies from South Africa, Zambia, Tanzania and Kenya, where buffalo-associated *T. parva* contributes substantially to parasite diversity and infection pressure (Morrison et al., 2020; Mbizeni et al., 2024). Similar interface-driven dynamics have been reported globally in

vector-borne protozoan systems, underscoring the broader relevance of these findings.

The cross-sectional mixed methods design was appropriate for identifying epidemiological associations and ecological gradients, while molecular diagnostics strengthened internal validity by providing objective infection data. Statistical analyses were matched to data type, with descriptive statistics summarizing prevalence and compliance, and regression-based approaches used to explore associations while controlling for confounders. Potential confounding variables – including cattle age, breed, sex, body condition, seasonal variation, acaricide type and frequency, grazing system and proximity to wildlife – were explicitly considered and adjusted for where possible. Although residual confounding cannot be fully excluded in observational studies, this approach aligns with best practice in veterinary epidemiology.

Declining compliance and perceived acaricide failure mirror patterns reported elsewhere in Zimbabwe and across Africa, where resistance, cost and operational challenges undermine chemical control programs (Bishop et al., 2023; Evans et al., 2024). These findings reinforce global calls for integrated Tick Management that reduces chemical dependency while preserving efficacy. Nature-based solutions and green infrastructure provide practical mechanisms to operationalize ITM by addressing ecological drivers of tick persistence, reducing environmental contamination and enhancing system resilience (Lagunes-Quintanilla et al., 2024).

Nevertheless, adoption of NbS requires careful consideration of context, farmer capacity and institutional support. Botanical acaricides and ecological interventions must be standardized, validated and supported by extension services. Policy frameworks must evolve to recognize ecosystem-based approaches as legitimate components of national control strategies. Future research should prioritize longitudinal designs, resistance surveillance and pilot trials integrating ecological and chemical interventions.

5. Conclusions

Sustained control of tick-borne theileriosis in communal cattle systems requires a shift from chemical dependency towards integrated, ecosystem-based management. Green infrastructure and nature-based solutions provide viable, scalable and environmentally responsible complements to acaricide-based programs.

6. Declarations

Ethics approval: Obtained from the Department of Veterinary Services (DVS), Ministry of Lands, Agriculture, Fisheries, Water and Rural Development, Midlands Province, Gweru, Zimbabwe; National University of Science and Technology Institutional Research Board, Bulawayo, Zimbabwe and Africa Research University, Lusaka, Zambia.

Funding: This research received no external funding.

Conflict of interest: The author declares no conflict of interest.

Data availability: Data are available from the corresponding author upon reasonable request.

References

- Allan, Fiona K., Toye, Philip G., McKeever, Declan J., & Morrison, W. Ivan, 2021. Antigenic diversity in *Theileria parva* populations from cattle and African buffalo. *Frontiers in Genetics* 12, 684127. <https://doi.org/10.3389/fgene.2021.684127>
- Bishop, Richard P., Odongo, David O., Mwaura, Samuel, Nene, Vishvanath & Morzaria, Subhash P., 2023. Control of ticks and tick-borne diseases in Africa through improved diagnosis and use of acaricide resistance data. *Parasites & Vectors* 16, 206.
- Creswell, J.W., Plano Clark, V.L., 2018. *Designing and Conducting Mixed Methods Research*, 3rd ed. Sage Publications, Thousand Oaks.
- Evans, Alexander R., George, James E., Olafson, Pia U., & Miller, Robert J., 2024. Acaricide resistance status of livestock ticks from East and West Africa. *Int. J. Parasitol.: Drugs Drug Resist.* 25, 100541.
- Lagunes-Quintanilla, Rosa, Rodriguez-Vivas, Roger I., Ojeda-Chi, Mario M., & Perez-Cogollo, Luis C., 2024. Integrated tick management in extensively raised cattle. *Frontiers in Veterinary Science* 11, 1497840.
- Mbizeni, Sithembiso, Potgieter, Fredrik T., Latif, Abdalla A., & Troskie, Morne, 2024. Buffalo-associated *Theileria parva* at livestock-game interfaces. *Veterinary Parasitology: Regional Studies and Reports* 47, 100963.
- Morrison, W. Ivan, McKeever, Declan J., & Mwaura, Samuel N., 2020. *Theileria parva*: adaptation from buffalo to cattle. *International Journal for Parasitology* 50, 403-412.
- Otu, Aniekeme, Ebenso, Basse, Okuzu, Okechukwu & Osifo-Dawodu, Evelyn, 2021. Africa needs to prioritize One Health approaches. *Nature Medicine* 27, 943-946.
- Tashakkori, A., Teddlie, C., 2021. *Mixed Methods Research: Integrating Quantitative and Qualitative Approaches*. Sage.