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A spatio-temporal analysis of climate variability and a selected zoonotic disease distribution in Binga District, Zimbabwe. A quantitative research protocol

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Introduction: Climate warming in the coming years is anticipated to greatly influence the relationships between pathogens and their animal and human hosts. Vector-borne illnesses are particularly vulnerable to rising temperatures, as temperature changes can modify development rates, geographical spread, and transmission patterns of vectors. Trypanosomiasis remains a neglected zoonotic disease still prevalent in Zimbabwe, with Binga being significantly impacted by it. Consequently, this study aims to explore how climate variability and change have influenced the epidemiology of this disease among the human population in Binga from 2000 to 2025.

Methods: As this is protocol for proposed research, a quantitative cross-sectional survey will be designed using secondary data sources and the administration of a mapping guide (2000–2025) to uncover the effects of climate variability and change on trypanosomiasis in the Binga District. The data collection checklist and questionnaire will be administered using Kobo Collect. The collected data will be analyzed both descriptively and inferentially to determine the incidence and prevalence rates, as well as their association with climate variability, including rainfall and temperature, and various socio-demographic characteristics. Regression analysis will be employed to evaluate the association between changes in temperature, variations in rainfall, and the distribution of cases. Rainfall and temperature will be mapped for specific three-year intervals (2000, 2003, 2006, 2009, 2012, 2015, 2018, 2021, 2025) from 2000 to 2025 and overlaid with cases of trypanosomiasis and hotspot maps generated using ArcGIS Pro. Predictive maps of climate variability and disease prevalence will be developed.

Discussion: The outcome of this proposed research has the potential to influence decision-making to plan for disease control, thus resulting in an improvement in programming. Knowledge of how climate variations and change affect the epidemiology of the disease will enable decision-makers to plan control strategies to mitigate the effects of the disease.

KEYWORDS

Binga, climate change, climate variability, trypanosomiasis, zoonotic

1 Introduction

Over the last century, the World Health Organization (WHO) has recorded several major human African trypanosomiasis (HAT) epidemics, with the first being in the Uganda Congo Basin from 1896 to 1900 and the last in the late 1990s (1, 2). Trypanosomiasis is a vector-borne disease caused by protozoan parasites transmitted between humans and animals by tsetse flies (*Glossina* spp.) (3). Recent epidemiological studies have increasingly highlighted the role of climate change in shaping the distribution and incidence of trypanosomiasis (4, 5). Climate-driven changes in temperature and rainfall patterns influence tsetse fly habitats, altering their geographic range and, consequently, disease transmission dynamics (6). Temperature increase has been associated with the contraction of tsetse populations in some regions while expanding their range into previously cooler upland areas (4). The term "climate change" refers to enduring alterations in weather patterns and temperatures that are primarily driven by human actions, such as burning fossil fuels (7, 8). Climate variability refers to short-term, natural fluctuations in climate conditions that occur over months, seasons, or a few years, driven by natural processes within the Earth's systems (9, 10).

This disease has two known forms: HAT and animal African trypanosomiasis (AAT) (1). HAT, often referred to as sleeping sickness, is caused by the parasites *Trypanosoma brucei gambiense* and *Trypanosoma brucei rhodesiense*. *T. b. gambiense* leads to a chronic form of the disease and can be found in 24 nations across West and Central Africa, responsible for 92% of the cases reported globally, while *Trypanosoma brucei rhodesiense*, located in 13 countries of Eastern and Southern Africa, makes up 8% of the reported cases. American trypanosomiasis, commonly known as Chagas disease, is caused *Trypanosoma cruzi* and transmitted by kissing bugs (Triatominae), primarily occurring in Latin America, which distinguishes it from HAT (1). The major symptoms of HAT are neuropsychiatric, including behavioral problems, personality disorders, sleep disturbances, and coma. If left untreated, this disease can result in death (11).

Climate modelling studies suggest that future warming scenarios may further shift tsetse distributions, increasing the risk of HAT in new regions (5, 12). For example, in Zimbabwe, it is projected that rising temperatures could make cooler highland areas more suitable for tsetse flies, potentially leading to new disease foci (4). The incidence of HAT varies from region to region (13). Multiple studies have established that tsetse flies are found in sub-Saharan Africa and that only specific species are responsible for transmitting the disease (14–16). The disease has a focal distribution ranging from single villages to entire regions, and its incidence can vary from one village to the next. HAT primarily poses a risk to communities in isolated rural locations that have restricted access to healthcare, making its identification and treatment more difficult (17). War, displacement, and poverty also affect these populations, favoring transmission (18). Studies have demonstrated that climate variability interacts with land-use changes to influence tsetse fly abundance (5). For example, deforestation and agricultural expansion have reduced tsetse habitats in some areas, while climate-induced vegetation and water availability shifts have created new breeding sites elsewhere (4). Such dynamics complicate control efforts, necessitating adaptive strategies that account for both climatic and anthropogenic drivers.

Since 2001, the WHO has engaged in several control strategies to ensure that the disease is contained and possibly eradicated (1). Public and private partnership-initiated HAT surveillance to ensure appropriate surveillance and response. Active case-finding conducted by mobile teams in villages has been the cornerstone of HAT control since colonial times (19). Despite these efforts, underreporting remains a major challenge, particularly in regions where climate variability has altered disease patterns (20). A study in Uganda found that 93% of HAT-related deaths were unreported, highlighting gaps in surveillance (21). This underreporting is exacerbated in areas where climate shifts have led to unexpected outbreaks, overwhelming local health systems. The study emphasizes the need for improved reporting systems to better understand and address the burden of this neglected tropical disease.

Significant initiatives aimed at managing the disease through various strategies have resulted in a consistent reduction in the number of sleeping sickness cases reported across Africa since the 1930s (11). Over the past five years, the Democratic Republic of Congo (DRC) has indicated that 61% of reported cases (averaging 522 cases per year) in Angola, Central African Republic, Chad, Congo, Gabon, Guinea, Malawi, and South Sudan fell within the

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range of 10 to 100 cases. Meanwhile, Cameroon, Côte d'Ivoire, Equatorial Guinea, Uganda, Tanzania, Ethiopia, and Zambia have reported between one and ten cases, and sporadic cases have been observed in Burkina Faso, Ghana, Kenya, Nigeria, and Zimbabwe over the last decade (2). The WHO statistics show that the measures taken to eradicate the disease have led to a historic low in HAT occurrences, with fewer than 2000 cases reported in 2017 and under 1000 cases in 2018, staying below the 2022 threshold (2). The projected population at risk during the years 2016 to 2020 was 55 million, with merely 3 million categorized as being at moderate to high risk (2).

As of 2019, it was estimated that the area in Zimbabwe affected by tsetse flies covered 30,000 km², representing 17% of the 180,000 km² that was originally suitable for tsetse fly infestation (17). In Zimbabwe, the more severe version of HAT, which is caused by *Trypanosoma brucei rhodesiense*, appears irregularly, and the tsetse fly vector cohabits with the human population (17). The latest case of sleeping sickness in humans was noted in 2019. However, some regions of the country with a high malaria burden also exhibit a significant prevalence of sleeping sickness (22). Various species of trypanosomes are harmful to livestock, leading to animal African trypanosomiasis (AAT or nagana) and causing significant production declines (16). Although rising temperatures might account for the decline in tsetse populations in specific regions, research has indicated that higher temperatures could have rendered some cooler, elevated areas in Zimbabwe more conducive for tsetse, potentially resulting in the establishment of new disease hotspots (4). As a result, it is essential to measure the scale and geographic distribution of the shifts in tsetse fly populations and trypanosomiasis. Research has indicated that Human African Trypanosomiasis (HAT) could potentially be reported in colder areas of Zimbabwe due to the chance of tsetse populations and Brucei infections resurfacing in various regions of Southern Africa that were previously thought to be safe (4, 23). One study identified Hwange National Park in Zimbabwe and Kruger National Park in South Africa as high-risk areas for the resurgence of AAT (4).

Over the last century, various tsetse fly control measures have been deployed in Zimbabwe, including bush clearance, wildlife extermination, ground and aerial spraying with insecticides, bait technologies, and the release of sterile insects (16). Nonetheless, the most significant influence on tsetse populations has come from both the organized and unregulated influx of individuals into regions affected by tsetse (2). The clearance of land for agriculture, combined with the use of crop spraying chemicals for cotton and tobacco, has also contributed to reductions in tsetse fly populations in certain areas (16). However, climate variability causes seasonal changes, which, according to previous studies, have resulted in alterations in commonly known suitable areas for the vector, thus causing changes in the distribution of the disease (24–26). This has presented significant challenges, particularly in the management of infectious diseases associated with vectors that have thrived under climate-induced changes in weather patterns, including the rise in temperatures and unpredictable rainfall patterns in Zimbabwe (27–29). Therefore, this study aimed to determine the extent to which these climatic variabilities have occurred and how they affect the distribution of the disease. Areas that have the potential to harbor the vector will be identified so that they can be closely monitored for any incidence of the disease. In addition, there could be a more targeted approach to eradicate the disease in these hotspots. This will reduce costs, leading to a more efficient disease management strategy. While studies have been done around the globe, there is limited literature on the influence of climate variability and change on the incidence and prevalence of trypanosomiasis in Binga district, Zimbabwe. Therefore, this study aims to explore how climate variability and change have affected the occurrence of trypanosomiasis cases within the district. The study will map the distribution of trypanosomiasis, rainfall and temperature patterns over the last 15 years. This study will provide insights that will facilitate trypanosomiasis management interventions in this region.

2 Methodology

2.1 Research approach

This study will be conducted in two phases to uncover the impact of climate variability on the occurrence of trypanosomiasis in Binga District. First, this study will be initiated by a comprehensive literature review to investigate existing information on the effects of climate variability and change on trypanosomiasis. The proposed design for the second phase of this study is a cross-sectional quantitative approach to assess the changes in the prevalence trends of trypanosomiasis against climatic conditions over the selected years. A quantitative approach was chosen, as it can assist in the comparison of the changes in prevalence trends of the disease over time. The sporadic nature of the disease will allow researchers to follow up on the exact locations of cases over the selected years. See Table 1 for the methodology.

2.2 Study area/setting

This study will be conducted in the Binga district, which has been purposely selected for its known affiliation with trypanosomiasis; therefore, studying the disease in such a setting might provide a more accurate representation of the association between climate variability and change and the epidemiology of the disease. Daily temperatures vary from 33 °C, with the colder season seeing temperatures around 28 °C. The region experiences high humidity due to a four-month wet season from November to March, resulting in more than a 33% likelihood of rainfall each day. The area is underdeveloped, hosting a population of under 200,000 people, where the commercial farming of kapenta, bream, tilapia, and tiger fish forms part of the district's livelihood strategies (31).

2.1.1 Phase 1: preliminary literature review

2.1.2 Review title

Impact of climate change and variability on the occurrence and distribution of Trypanosomiasis: a scoping review of literature.

TABLE 1 Summary of research approach.

Study phase	Objective	Research questions	Data sources and tools	Data management, analysis and presentation
Literature review	1. To determine the relationship between climatic variability/ change and the prevalence of zoonotic diseases focusing on trypanosomiasis 2. To assess the specific influence of rainfall patterns on trypanosomiasis. 3. To establish the specific influence of temperature fluctuation on the occurrence of trypanosomiasis. To 4. explore the strategies for managing trypanosomiasis amid changing climatic conditions.	1. What are the effects of climate change and variability on the prevalence of trypanosomiasis as presented in the literature over time? 2. What is the association between rainfall patterns and the prevalence of trypanosomiasis 3. How have temperature fluctuations impacted the prevalence of trypanosomiasis? 4. What strategies have been used to manage trypanosomiasis amid changing climatic conditions?	✓ Research studies, both quantitative and qualitative, as well as reports published in English in peer-reviewed journals up to the year 2025, are accessible via Dimensions, EBSCO, Cochrane Library, PUBMED, Web of Science, and Science Direct.	✓ Develop a Data collection form guided by the JBI Manual Kmet and colleagues (30)
Quantitative inquiry	1. To determine the trends of trypanosomiasis in Binga district for the period 2000 to 2025.	1. What are the trends of trypanosomiasis in Binga district for the period 2000 to 2025?	✓ Review of secondary data from the district hospital ✓ Cases ✓ Health Care Service Providers ✓ Questionnaire ✓ Data Extraction guide	✓ Descriptive statistics to indicate the prevalence of the disease in the region. ✓ Statistical inference to identify the connections between various variables as well as the frequency and occurrence rates.
	2. To determine the temperature and rainfall patterns for the period 2000 to 2025.	2. What are the temperature and rainfall patterns for the period 2000 to 2025?	✓ Remotely sensed satellite imagery ✓ Google Earth ✓ Data from the Meteorological Department of Zimbabwe.	✓ ArcGIS Pro spatial analysis and presentation of data
	3. To spatially analyze and map the distribution of trypanosomiasis cases against rainfall and temperature patterns.	3. How is the distribution of cases spatially related to rainfall and temperature patterns?	✓ Geospatial data collected using Kobo Collect	✓ ArcGIS Pro mapping of cases
	4. To determine the statistical association between changes in temperature and rainfall and the distribution of cases.	4. Is there a statistically significant association between changes in temperature/rainfall patterns and the distribution of trypanosomiasis cases?	✓ Data from objectives 1-3	✓ Development of hotspot and predictive maps ✓ Regression Analysis
	5. To develop a predictive model for vector habitat suitability and potential future disease hotspots within the study area.	5. Can a predictive model be developed to forecast potential future vector habitats and disease hotspots ?	✓ Google Earth ✓ Data from the Meteorological Department of Zimbabwe	✓ Utilize local climate changes to monitor possible variations in the presence and spread of vectors throughout the nation. ✓ Predictive hotspot maps

2.1.3 Background

Trypanosomiasis is a vector-borne disease that is expected to respond to climate change (16). Several studies have shown that the distribution of tsetse flies is largely dependent on bioclimatic factors, such as temperature and rainfall (32). Climate variation causes changes that directly affect the existence of the vector, reservoir, susceptibility of the host, and interactions between the host, reservoir, and vector (33). Climate has direct and indirect impacts on transmission, influencing both the timing and intensity of outbreaks. It creates a temporal connection and affects geographical spread, as well as establishes a spatial relationship between numerous infectious diseases in both humans and animals (34). It is reported that heavy rain could result in increased vector quantities.

Although the temperature rise might account for the decline in tsetse fly populations in certain regions, research has pointed out that increasing temperatures could have rendered some higher, cooler regions of Zimbabwe more favorable for tsetse, potentially resulting in the development of new disease hotspots (4, 20, 35, 36). To fully understand the implications of changes in tsetse fly populations and the spread of trypanosomiasis, it is crucial to quantify both the magnitude and the geographical distribution of these shifts. Lord et al. suggested that there is a real possibility of Human African Trypanosomiasis (HAT) being reported in the cooler regions of Zimbabwe. This concern arises from the potential resurgence of tsetse fly populations and the subsequent infections from *Trypanosoma brucei* in various areas of Southern Africa that were previously thought to be at low risk. Such developments could significantly alter our understanding of the disease's dynamics and its impact on both human and animal health in the region (4).

Throughout the past century, Zimbabwe has implemented a diverse array of control measures to combat the tsetse fly. These historical strategies, such as bush clearing and insecticide spraying, aimed to reduce tsetse habitats (16). However, other factors have influenced populations differently. The most significant factor recently affecting tsetse distribution has been human migration into infested areas, often linked to agricultural expansion. As more land is converted into agricultural fields, natural habitats are altered. Furthermore, the application of chemical pesticides and fertilizers in cash crop farming (e.g., cotton, tobacco) can sometimes create disturbed environments where tsetse flies may thrive, despite overall habitat loss (16).

Numerous research studies have explored the connection between climate change and climate variability and their impact on various diseases. These investigations serve as a foundational framework for understanding how shifts in our climate can correlate with the emergence and spread of health-related issues (34). This review aims to determine the relationship between selected climatic conditions and their influence on similar zoonotic diseases, with an emphasis on trypanosomiasis. We will further explore strategies that have been used to effectively manage trypanosomiasis under changing climatic conditions in various regions.

2.1.4 Main objective

This study aims to determine the relationship between climate variability and change and trypanosomiasis prevalence. The specific objectives of this study are listed in Table 1.

2.1.5 Methodology

2.1.5.1 Inclusion and exclusion criteria

This scoping review will examine studies on the impact of climate change and variability on zoonotic diseases. It will also include research that discusses adaptation strategies for managing zoonotic diseases in the context of changing climatic conditions. The review will focus on studies published in English from January 2000 to December 2025 in reputable peer-reviewed journals worldwide. It will target both original quantitative and qualitative research, as well as reports obtained from sources such as Dimensions, Cochrane, EBSCO, Scopus, Web of Science, PUBMED, and ScienceDirect, to ensure a comprehensive search (37). This scoping review will exclude all studies that focused on the impact of climate variability and change on other vector-borne diseases that were not zoonotic. Literature sources published in languages other than English will be excluded.

2.1.5.2 Search strategy

The keywords "Climate Variability," "Climate Change," "Prevalence," "Rainfall," "Sleeping Sickness," "Strategies," "Temperature," "Trypanosomiasis," and "Zoonotic" will be used to search for relevant literature from Dimensions, Cochrane, PUBMED, and Science Direct. Electronic databases will be searched for literature published from January 2000 to December 2025. The following search string will be employed: "Climate change and variability AND trypanosomiasis" OR "Climate change and variability on effects on zoonotic diseases" OR "Association between rainfall patterns and the prevalence of trypanosomiasis" OR "Temperature fluctuations and their effect on the prevalence of trypanosomiasis" AND "Strategies to manage trypanosomiasis amid changing climatic conditions." In addition, the snowballing technique will be utilized to identify and gather relevant articles.

2.1.5.3 Methods of review

The titles and abstracts of the articles and reports will undergo an independent review process by a minimum of two reviewers. To enhance methodological rigor, a third reviewer with expertise in statistics will be included in the team. This approach aims to identify those works that are pertinent to the objectives of this scoping review. In cases where reviewers encounter disagreements regarding the relevance of specific materials, these differences will be addressed and resolved through constructive discussions. Following this initial screening, at least two reviewers will conduct a thorough examination of the full texts of the articles and reports that meet the established inclusion criteria. Any remaining discrepancies in their evaluations will also be resolved through open dialogue, ensuring a comprehensive and collaborative review process.

2.1.5.4 Data extraction and synthesis

Literature that has been downloaded will be uploaded into the Rayyan software, which is designed for literature reviews and facilitates the inclusion and exclusion of sources, ensuring that only pertinent material is considered. This process will guarantee that nearly all research conducted on the topic is reviewed, resulting in thorough insights into how climate variability and change have influenced the incidence of trypanosomiasis (38). This program additionally provides recommendations regarding potentially overlooked literature based on the search terms and strategies used (37, 38). Based on multiple studies, using a combination of Web of Science, Scopus, and Dimensions can yield an accuracy rate exceeding 96% when retrieving the necessary literature. This combination enhances the comprehensiveness of the scoping review conducted with these databases (37). The data extraction protocol will be derived from the JBI guideline manual, utilizing the scoping review checklist from the manual. This will assist in the collection, extraction, and analysis of data from the existing literature. Additionally, organizing information, identifying trends, and developing themes will ensure that the results are presented in a thorough yet comprehensible manner. The processes for data collection and analysis, which will culminate in the submission of a review paper to a journal, are scheduled to take place between June and July 2026.

2.1.5.5 Quality assessment

The quality of every study will be assessed by three separate reviewers based on standard criteria for evaluating primary research articles, modified from the purposive rating tool derived from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) (39). The principal objective of this evaluation tool is to assess the scientific quality and methodological rigor of scoping reviews.

2.2 Step 2: quantitative survey

2.2.1 Data collection methods and tools

A data capture form will be utilized within the Kobo toolbox to identify the data needs for this research, with all data being gathered through this instrument. To analyze the trends in trypanosomiasis for the specified years, secondary data from health facilities will be examined with the assistance of available healthcare professionals and our data extraction guide. All available confirmed trypanosomiasis case records for the Binga District from 2000 to 2025 will be included. Secondary data will be obtained from healthcare facilities located in Chibondo, Dandamera, Doma, Mabhiza, Mwalukanga, and Nyamiyu Clinic, and this information will be reviewed at Binga District Hospital with the help of local healthcare workers and the data extraction guide. Data collection concerning trypanosomiasis cases will occur at the Binga District Hospital, which has a solid database of health statistics relevant to the district. This facility acts as a central repository for extensive information pertaining to various health issues, including trypanosomiasis. After the preliminary data collection, researchers will methodically track the specific locations of reported cases to accurately pinpoint their geographical coordinates. The researchers plan to record the coordinates of reported cases throughout the designated timeframe of this study (2000–2025), which will be intentionally selected to provide a comprehensive overview of the disease distribution over the years. The study period will be segmented into 3-year intervals, meaning data will be collected for the years 2000, 2003, 2006, 2009, 2012, 2015, 2018, 2021, and 2025. Detailed information about the data collection tool can be found in Supplementary File 1 (supporting information).

Data regarding the cases will be gathered from Binga District Hospital, which maintains all the statistics for the area. The researchers will then trace the precise locations of these cases, where they were originally documented, to acquire the actual coordinates. The locations of the schools, hospitals, and homesteads where the cases occurred will be noted. Information will be stored in the Kobo Collect Toolbox for further analysis. Climate data will be obtained from the Meteorological Department of Zimbabwe, alongside remotely sensed imagery for the chosen years. Geospatial data will be sourced from Google Earth Engine, including (1): Land Surface Temperature data from MODIS with a 1km resolution (MOD11A2.061 product), and (2) Precipitation data from CHIRPS at a 5km resolution. These datasets will undergo analysis for specific years (2000, 2003, 2006, 2009, 2012, 2015, 2018, 2021, and 2025) to illustrate temperature and rainfall trends. The climate data will be resampled to align with the 1km resolution of the case location data, where needed, ensuring spatial consistency in our overlay analysis. The cases will then be separately mapped for the specified years. Multi-criteria Overlay Analysis will subsequently be utilized to designate or pinpoint areas favorable for breeding tsetse fly vectors for hotspot mapping. This analysis will take into account various environmental factors (humidity, temperature, elevation, and the distributions of humans, livestock, and wildlife) that the identified areas should exhibit.

2.2.2 Data analysis

The data collected during this research will be preserved for analysis using the Kobo Collect application. This information will undergo examination to produce descriptive statistics that highlight the prevalence of the disease in the region, alongside inferential statistics aimed at assessing the relationships between various factors and the incidence/prevalence of the disease. Additionally, the Kobo Collect toolbox captures the geographical coordinates of the cases as well as weather trends for the designated years. These coordinates will be imported into the ArcGIS Pro software to map the spread of cases throughout the district. Data will also be transferred to ArcGIS Pro from the Google Earth Engine to visualize temperature and rainfall trends for the selected years. Line charts will represent trypanosomiasis trends over the available years to identify any significant increases or decreases in case numbers linked to climate variability and change. Regression analysis will be employed to evaluate the correlation between fluctuations in temperature, rainfall, and case distribution. The findings from this study will be presented as layered maps, particularly highlighting regions with high disease prevalence. One anticipated outcome of this research is a risk map, which is a crucial tool for public health decision-making and prioritizing vector-borne disease management, as it aids in directing prevention and control efforts effectively.

2.3 Proposed timelines

This research is a study protocol. As of the submission of this manuscript, the study has not yet commenced participant recruitment or data collection. No results have been generated, and no stages of the primary research have been completed at this point. The proposed timeline for the study is as follows:

- ✓ Scoping Literature Review: The comprehensive literature review and subsequent manuscript development are scheduled to be conducted between Jan and May 2026.
- ✓ Data Collection: Collection of secondary trypanosomiasis case data and climate data from the identified sources is projected to begin in May to June 2026 and is expected to be completed by December 2026.
- ✓ Data Analysis and Results: Data analysis, spatial mapping, and the interpretation of results are planned for June to October 2027.

3 Anticipated results

This study is anticipated to generate a comprehensive analysis of the spatio-temporal dynamics between climate variability and human African trypanosomiasis (HAT) in Binga District from 2000 to 2025. The initial scoping review is expected to synthesize global evidence, firmly establishing the multifaceted influence of climate on trypanosomiasis epidemiology. It will likely confirm that temperature fluctuations directly impact tsetse fly survival, reproduction, and geographic range, potentially contracting habitats in some areas while expanding them into previously cooler uplands. Furthermore, the review is anticipated to highlight the critical role of rainfall patterns, revealing a non-linear relationship where both droughts and extreme precipitation can alter the availability of suitable breeding sites and vegetation cover, thereby affecting vector abundance.

Building on this foundational knowledge, the quantitative analysis of Binga District is expected to reveal distinct temporal and spatial patterns. The analysis of secondary health data will likely show a non-uniform trend in HAT incidence, characterized by peaks and troughs that correlate with specific climatic events rather than a simple linear progression. Concurrently, the remotely sensed climate data is projected to demonstrate a discernible warming trend and increased variability in rainfall over the 25 years. The core of the anticipated findings lies in the spatial analysis. The overlay of disease case maps with climate layers in ArcGIS Pro is expected to reveal a strong spatial coincidence, identifying clear hotspots in areas that have historically maintained optimal microclimatic conditions for tsetse flies. More critically, this analysis is poised to identify emerging risk areas and locations that were previously less suitable but have become more conducive for the vector due to shifting temperature and rainfall patterns, potentially exposing new populations to the disease.

The statistical analysis is predicted to quantify these apparent associations. Regression models are predicted to indicate a statistically significant correlation between HAT case distribution and both temperature and rainfall factors. While the relationship with rainfall may be curvilinear, with moderate levels being most advantageous, the relationship with temperature is probably positive within the vector's ideal thermal range. The ultimate goal of this research is to create prediction risk maps by combining these statistical and geographical findings. The district's areas most at risk for HAT transmission in the future under current climate patterns will be predicted by these maps, which will be the main outcome. It is anticipated that these findings will offer a solid body of evidence for developing geographically focused, climate-resilient surveillance and control plans, allowing for more effective and proactive public health initiatives in Binga District.

4 Discussion

The findings from this study might enrich the effectiveness of surveillance strategies for trypanosomiasis by identifying the changes brought about by climate variability and change in the disease distribution. Health professionals may use this knowledge to plan for targeted intervention strategies. The study might further result in a predictive map for the occurrence of the disease to be anticipated by factoring in the changes in climate, where conducive environments for the breeding of the vector are being created. However, it is anticipated that the collected data may not accurately represent the occurrence of the disease because sleeping sickness cases are underreported, especially in remote areas with limited access to healthcare.

5 Ethical consideration

The research proposal underwent examination by the National University of Science and Technology Institutional Review Board (NUST IRB) to secure approval (NUST/IRB/2024/060) for the study. Modifications to the methodology and data collection instruments were made based on the feedback received. Consent will be obtained from Binga District Hospital for the trypanosomiasis case data recorded between 2000 and 2025. The researcher will also request approval from the Ministry of Health and Child Care (MoHCC) to access records at health facilities and seek permission from local authorities to reach areas where the cases were documented to capture the coordinates. No primary data will be gathered from human subjects, and the associated risks to individuals are deemed minimal. All data collected will be treated with the utmost confidentiality. The data will be anonymized and securely stored within the Kobo Collect toolbox, granting access only to the principal investigators and supervisors, and will solely be used for the academic purposes specified in this protocol.

6 Conclusion

This study highlights how climate variability and changes influence trypanosomiasis transmission in Binga District, Zimbabwe, revealing shifts in tsetse fly habitats due to changing temperature and rainfall patterns. The findings underscore the need for adaptive public health strategies, including targeted surveillance in emerging high-risk zones, climate-informed vector control, and strengthened cross-sectoral collaboration under a One Health framework. Integrating early warning systems with localized interventions, like community-based tsetse trapping and livestock treatment, can help Zimbabwe reduce the resurgence of diseases driven by climate change. This approach combines proactive monitoring with targeted actions to effectively address the health challenges posed by environmental shifts. Additionally, improving diagnostic capacity in rural health systems and aligning efforts with WHO's 2030 elimination roadmap will ensure sustainable progress.

7 Limitations

The use of secondary data comes with inherent drawbacks, especially when it comes to capturing real-time changes in environmental and socioeconomic factors that could significantly influence disease patterns. For example, modifications in land utilization, farming practices, and inequalities in access to healthcare are vital aspects that may affect the relationship between climate variability and the occurrence of trypanosomiasis; however, these elements may not be accurately reflected in historical data. Additionally, the lack of efficient surveillance tools can impede the precise identification of cases, causing healthcare workers in Binga to rely primarily on clinical symptoms for diagnosis. This dependence on symptomatology carries the risk of misdiagnosis or missing cases, particularly in regions where diagnostic resources are limited.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

NN: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft. PM: Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing. WN: Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fitd.2026.1755154/full#supplementary-material

References

1. Organization WH. *Trypanosomiasis, human african (Sleeping sickness)* (2023). World Health Organization (WHO.

2. WHO WHO. *Zimbabwe revives sleeping sickness case detection and management - Zimbabwe*. Geneva, Switzerland: ReliefWeb. (2022).

3. Ngonyoka A, Gwakisa PS, Estes AB, Nnko HJ, Hudson PJ, Cattadori IM. Variation of tsetse fly abundance in relation to habitat and host presence in the Maasai Steppe, Tanzania. *J Vector Ecol*. (2017) 42:34–43. doi: 10.1111/jvec.12237

4. Lord JS, Hargrove JW, Torr SJ, Vale GA. Climate change and African trypanosomiasis vector populations in Zimbabwe's Zambezi Valley: A mathematical modelling study. *PloS Med*. (2018) 15:e1002675. doi: 10.1371/journal.pmed.1002675

5. Mweempwa C, Chilongo K, Hayashida K, Namangala B. Effect of wing length on the prevalence of trypanosomes in Glossina morsitans in eastern Zambia. *Parasites Vectors*. (2021) 14:1–8. doi: 10.1186/s13071-021-04907-y

6. Meyer A, Holt HR, Selby R, Guitian J. Past and ongoing tsetse and animal trypanosomiasis control operations in five African countries: a systematic review. *PloS Negl Trop diseases*. (2016) 10:e0005247. doi: 10.1371/journal.pntd.0005247

7. Pielke RA Jr. What is climate change? *Energy Environ*. (2004) 15:515–20.

8. Werndl C. On defining climate and climate change. *Br J Philosophy Sci*. (2016) 67, 337–364. doi: 10.1093/bjps/axu048

9. Thornton PK, Ericksen PJ, Herrero M, Challinor AJ. Climate variability and vulnerability to climate change: a review. *Global Change Biol*. (2014) 20:3313–28. doi: 10.1111/gcb.12581

10. Ghil M, Lucarini V. The physics of climate variability and climate change. *Rev Modern Physics*. (2020) 92:035002. doi: 10.1103/RevModPhys.92.035002

11. Welburn S, Maudlin I, Simarro P. Controlling sleeping sickness–a review. *Parasitology*. (2009) 136:1943–9. doi: 10.1017/s0031182009006416

12. Moore S, Shrestha S, Tomlinson KW, Vuong H. Predicting the effect of climate change on African trypanosomiasis: integrating epidemiology with parasite and vector biology. *J R Soc Interface*. (2012) 9:817–30. doi: 10.1098/rsif.2011.0654

13. Rupasinghe R, Chomel BB, Martinez-Lopez B. Climate change and zoonoses: A review of the current status, knowledge gaps, and future trends. *Acta Trop*. (2022) 226:106225. doi: 10.1016/j.actatropica.2021.106225

14. Pagabeleguem S, Ravel S, Dicko AH, Vreysen MJ, Parker A, Takac P, et al. Influence of temperature and relative humidity on survival and fecundity of three tsetse strains. *Parasites Vectors*. (2016) 9:1–13. doi: 10.1186/s13071-016-1805-x

15. Welburn S, Fèvre E, Coleman P, Odiit M, Maudlin I. Sleeping sickness: A tale of two diseases. *Trends parasitology*. (2001) 17:19–24. doi: 10.1016/s1471-4922(00)01839-0

16. Scoones I, Dzingirai V, Anderson N, MacLeod E, Mangwanya L, Matawa F, et al. People, patches, and parasites: the case of trypanosomiasis in Zimbabwe. *Hum Ecol Interdiscip J*. (2017) 45:643–54. doi: 10.1007/s10745-017-9929-y

17. Shereni W, Neves L, Argiles R, Nyakupinda L, Cecchi G. An atlas of tsetse and animal African trypanosomiasis in Zimbabwe. *Parasit Vectors*. (2021) 14:50. Available online at: https://link.springer.com/article/10.1186/s13071-020-04555-8

18. Zoller T, Fèvre EM, Welburn SC, Odiit M, Coleman PG. Analysis of risk factors for T. brucei rhodesiense sleeping sickness within villages in south-east Uganda. *BMC Infect diseases*. (2008) 8:1–9. doi: 10.1186/1471-2334-8-88

19. Herbert Mukiibi CW, Waiswa P, Matovu E, Kabasa JD, Olet S, Khaitsa ML. Evaluation of a "Stamp Out Sleeping Sickness" campaign in Uganda to control human African Trypanosomiasis (2004 - 2009). *Pan Afr Med J*. (2017) 4. doi: 10.11604/pamj.supp.2017.27.4.12632

20. Nnko HJ, Gwakisa PS, Ngonyoka A, Sindato C, Estes AB. Potential impacts of climate change on geographical distribution of three primary vectors of African Trypanosomiasis in Tanzania's Maasai Steppe: G. *m. morsitans G. pallidipes G. swynnertoni*. *PloS Negl Trop Diseases*. (2021) 15:e0009081. doi: 10.1371/journal.pntd.0009081

21. Fèvre E, Odiit M, Coleman P, Woolhouse M, Welburn S. Estimating the burden of rhodesiense sleeping sickness during an outbreak in Serere, eastern Uganda. *BMC Public Health*. (2008) 8:96–. doi: 10.1186/1471-2458-8-96

22. CfDCaP CfDC. *Parasites - African Trypanosomiasis (also known as Sleeping Sickness) Epidemiology & Risk Factors. Global Health, Division of Parasitic Diseases and Malaria* (2025). Available online at: https://www.cdc.gov/parasites/sleepingsickness/epi.html (Accessed September, 2025).

23. Lord JS, Torr SJ, Auty HK, Brock PM, Byamungu M, Hargrove JW, et al. Geostatistical models using remotely-sensed data predict savanna tsetse decline across the interface between protected and unprotected areas in Serengeti, Tanzania. *J Appl ecology*. (2018) 55:1997–2007. doi: 10.1111/1365-2664.13091

24. Ndlovu I, Nunu WN, Mudonhi N, Dube O, Maviza A. Land use– land cover changes and Mopani worm harvest in Mangwe District in Plumtree, Zimbabwe. *Environ Syst Res*. (2019) 8:1–9. doi: 10.1186/s40068-019-0141-5

25. Nunu WN, Ncube B, Dube O, Mpofu C, Ndlovu B, Dzinomwa T, et al. Nutritional factors associated with distribution of Mopani Worms in Mopani woodlands in Tsholotsho and Gwanda Districts, Zimbabwe: A comparative survey. *Sci Rep*. (2019) 9:17320. doi: 10.1038/s41598-019-53923-7

26. Dlamini W, Nunu WN, Ndlovu V, Nleya N, Mudonhi N, Sibula M. Molecular detection of Imbrasia belina proteins associated with allergic reactions on harvesters and consumers from selected districts in Matabeleland: a comparative study. *Mol Biol Rep*. (2023) 50:8025–34. doi: 10.1007/s11033-023-08678-w

27. Mubaya CP, Njuki J, Mutsvangwa EP, Mugabe FT, Nanja D. Climate variability and change or multiple stressors? Farmer perceptions regarding threats to livelihoods in Zimbabwe and Zambia. *J Environ management*. (2012) 102:9–17. doi: 10.1016/j.jenvman.2012.02.005

28. Chapungu L, Nhamo G. Interfacing vector-borne disease dynamics with climate change: Implications for the attainment of SDGs in Masvingo city, Zimbabwe. *Jàmbá: J Disaster Risk Stud*. (2021) 13:1–12. doi: 10.4102/jamba.v13i1.1175

29. Ramirez B. Support for research towards understanding the population health vulnerabilities to vector-borne diseases: increasing resilience under climate change conditions in Africa. *Infect Dis poverty*. (2017) 6:1–7. doi: 10.1186/s40249-017-0378-z

30. Kmet LM CR, Cook LLS. *Standard quality assessment criteria for evaluating primary research papers from a variety of fields*. Alberta Canada, Alberta Heritage Foundation for Medical Research (2004).

31. Chigonda T. More than just story telling: A review of biodiversity conservation and utilization from precolonial to postcolonial Zimbabwe. *Scientifica*. (2018) 2018:6214318. doi: 10.1155/2018/6214318

32. Pollock J. *Ecology and behavior of tsetse training manual for tsetse control personel*. Rome: Food and Agriculture Organization of the United Nations (1996). p. 2

33. Singh B, Sharma R, Gill J, Aulakh R, Banga H. Climate change, zoonoses and India. *Rev Scientifique Technique-OIE*. (2011) 30:779. doi: 10.20506/rst.30.3.2073

34. Ashaq Ashraf MMD, Wani BM, Shah SA, Shabir M, Shafi M. Climate change and infectious diseases of animals: A review. *J Entomology Zoology Stud*. (2017) 12:51. doi: 10.1186/s40249-023-01102-2

35. Longbottom J, Caminade C, Gibson HS, Weiss DJ, Torr S, Lord JS. Modelling the impact of climate change on the distribution and abundance of tsetse in Northern Zimbabwe. *Parasites vectors*. (2020) 13:526. Available online at: https://link.springer.com/article/10.1186/s13071-020-04398-3

36. Nnko HJ, Ngonyoka A, Salekwa L, Estes AB, Hudson PJ, Gwakisa PS, et al. Seasonal variation of tsetse fly species abundance and prevalence of trypanosomes in the Maasai Steppe, Tanzania. *J Vector Ecology*. (2017) 42:24–33.

37. Nunu WN, Ndirangu J, Tsoka-Gwegweni J. Effects of COVID-19 on malaria elimination initiatives in sub-Saharan Africa: a scoping review protocol. *BMJ Open*. (2023) 13:e076140. doi: 10.1136/bmjopen-2023-076140

38. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. (2016) 5:210. doi: 10.1186/s13643-016-0384-4

39. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Internal Med*. (2018) 169:467–73. doi: 10.7326/M18-0850