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Spatio-temporal dynamics and determinants of malaria transmission in Ethiopia: a scoping review

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ADMINISTRATIVE INFORMATION

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Conflicts of interest - The authors declare that they have no known financial or personal relationship that could have influenced the conduct and outcome of this review.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 18 May 2026 and was last updated on 18 May 2026.

INTRODUCTION

Review question / Objective The aim of this scoping review is to systematically map and synthesise evidence on the spatio-temporal dynamics and determinants of malaria transmission in Ethiopia and to develop a conceptual framework linking multi-domain drivers to malaria risk patterns. Moreover, this scoping review has the following review questions: -

- How were the spatiotemporal dynamics of malaria transmission defined and mapped in Ethiopia?
- What determinants of malaria transmission are known in Ethiopia?
- What methodological approaches have been used in spatiotemporal dynamics of malaria transmission studies in Ethiopia?
- What gaps and limitations exist in the current evidence on the spatio-temporal dynamics of malaria transmission and its determinants in Ethiopia?

Background Malaria remained one of the leading causes of morbidity and mortality globally. According to the 2024 World Health Organization (WHO) malaria report, an estimated 263 million malaria cases were recorded globally, with the African region accounting for 94% of all global malaria cases and high malaria transmission rates across sub-Saharan Africa (1), including Ethiopia (2). More than half of all cases in Africa originate from just five countries: Nigeria, the Democratic Republic of Congo, Uganda, Ethiopia and Mozambique. Between 2023 and 2024, global malaria cases increased by nine million, with Ethiopia contributing to the large rise (+2.9 million) (1). This highlights the persistent regional vulnerability and emerging epidemiological shifts. Ethiopia has committed to the WHO Global Technical Strategy for Malaria from 2016 to 2030, recognizing the complexity of the situation. The country is working towards malaria control and elimination and has set ambitious but achievable

global targets. These targets aim to reduce malaria incidence and mortality rates by at least 90% by 2030 (3). To achieve these targets, the country has strategically prioritized improving surveillance and response. This includes identifying risks and focusing interventions on the most affected areas. Additionally, the country implements strategies to avoid mosquito bites through vector control, chemoprophylaxis, vaccination, early diagnosis, and treatment with adequate medications (3, 4). Despite these programmatic interventions to tackle malaria transmission, the disease persists as a significant health concern. It is still responsible for most mortality and morbidity due to its upsurge and resurgence (5, 6). Furthermore, the resurgence of malaria is linked to conflict-related access constraints, and the invasion of the Asian malaria vector An.stephensi(7-9). These challenges hinder Ethiopia's aim to achieve zero indigenous malaria cases by 2030 (10). In Ethiopia, approximately three-fourths (75%) of the population reside in malaria-risk areas (7). The transmission of malaria in Ethiopia is shaped by the complex interaction of socio-demographic and economic factors(7, 9, 11, 12); socio-political (population migration/mobility, conflict and poor security) (6, 7, 12); environmental and climatic factors (climate change/shift, high temperature, altitude, rainfall patterns, and seasonal climate variability)(9, 12-16); ecological (land use, vegetation index, irrigation, dam, and urban agriculture)(14, 15); health system/ programmatic interventions (intervention coverage and effectiveness, poor access to healthcare services, health system disruptions, and weak surveillance) (11, 17, 18); and biological factors (human behavior, travel to endemic zones, poor knowledge, nighttime outdoor exposure, vector ecology, mosquito breeding sites near households, An. stephensi invasion, insecticide/drug resistance, HRP2/3 deletions, and G6PD deficiency) (7, 9, 11, 12). Because of these features, malaria in Ethiopia frequently manifests as localized outbreaks and shifting hotspots rather than stable transmissions (6, 9, 19) The magnitude and transmission of malaria exhibit marked spatial and temporal heterogeneity, characterized by seasonal and unstable patterns with recurrent cyclic epidemics (7, 12) and substantial spatial heterogeneity. The incidence of malaria is concentrated in noticeable hotspots and time periods rather than being randomly dispersed. The transmission also had temporal and spatial clustering and space-time variation in the region at the district level (20-22). Due to the geo-ecological conditions, the malaria burden is concentrated in the western part of the country. According to the WHO 2024 report, 222 high-burden districts (woredas) or 20% of all districts in the country, accounted for 75% of the national malaria burden in 2023 and were identified for targeted intervention (23). This also highlights the potential clustering of cases in a limited number of districts in the state. Strong spatiotemporal clustering and lagged associations with climate variables have been reported from northwest Ethiopia. These insights collectively underscore the need to view the national malaria resurgence through a multi-driverlens.

Rationale A clear understanding of spatiotemporal malaria dynamics is critical to Ethiopia's malaria elimination strategy, yet current evidence remains fragmented and methodologically heterogeneous, limiting its utility for national decision-making. In this context, evidence synthesis that supports the targeted deployment of interventions has become both a scientific and strategic necessity supporting Ethiopia's Malaria Elimination Strategic Plan (24).

This review is unique in that it summarizes where and when malaria risk concentrates and shifts (hotspots, clustering, seasonality, and trends), the multi-domain determinants proposed to drive these patterns, and the spatiotemporal methods and data practices used to generate the evidence (25-27). In addition, to improve policy relevance and pinpoint gaps in practical evidence, the review will also integrate stakeholder consultation and translate identified drivers into a country-context conceptual framework. The finding is also crucial for tackling risk factors and taking proper evidence-based decision-making that supports Ethiopia's malaria risk stratification, surveillance, and targeted interventions.

It also supports policymakers in developing more effective, evidence-based policies and practices by providing a clear understanding of the scope, diversity, and key characteristics of existing research or evidence (26, 28). Therefore, this scoping review will systematically map and synthesize evidence on the spatiotemporal dynamics and determinants of malaria transmission, describing the methodological approaches used and the existing knowledge gaps and limitations, and develop a conceptual framework of malaria transmission linking complex determinants to inform targeted, evidence-based malaria control and elimination.

METHODS

Strategy of data synthesis A systematic search of electronic databases, including Scopus, EMBASE, Web of Science, and PubMed will be undertaken in a three-step search strategy. Additionally, grey literature sources such as WHO institutional repository for information system

(WHO IRIS), Ethiopian public health institute reports, proceedings of Ethiopian Malaria Research Network, PMI/USAID document, and research repository sites of universities will be used. A comprehensive search strategy will be developed, and articles will be identified using medical subject headings (MeSH) terms and keyword combinations and truncations. During retrieval of studies, keywords will consist of spatio-temporal dynamics, drivers/determinants, and interventions of malaria in the Ethiopian context. Boolean operators such as "OR" and "AND" will be used in combination during article search and will be adapted for each included database and/or information source.

Eligibility criteria Studies fulfilling the following eligibility criteria will be included in this scoping review:
- Studies involving all age groups of individuals with malaria in Ethiopia: P. falciparum, P. vivax, and mixed infection cases
- Studies that report malaria cases/prevalence/incidence/API and their determinants
- Observational studies (cross-sectional, case-control, cohort, ecological, clinical trials, surveillance data analysis), prevalence, incidence, spatial and spatio-temporal studies, modelling and predictive studies, remote-sensing analyses
- Entomological studies with explicit spatial or temporal relevance to human malaria transmission, including those linking vector distribution, density, seasonality, or indices to human malaria risk, transmission patterns, or intervention outcomes
- Intervention impact evaluation studies reporting malaria-related outcomes of interest

Moreover, studies that align the following will be included:-
- Time: All articles published between 2000 and 2026.
- Geography: single country studies covering all geographic regions and ecological zone of Ethiopia
- Setting: urban, peri-urban, rural, highland, lowland, pastoralist, riverine
- Language of publication: Restricted to English only.

The following studies will be excluded:
- Non-human studies: studies exclusively focusing on animals and mosquitoes without explicit spatial, temporal, or epidemiological linkage to human malaria outcomes
- Studies focused only on drug resistance genetics, clinical case management, treatment efficacy trials, and molecular laboratory studies.
- Studies without prevalence or incidence of malaria and spatio temporal components
- Commentaries without empirical data, systematic review and meta-analysis, reviews, editorials, qualitative studies, case reports, and case series
- Laboratory-based vector biology or insecticide resistance studies with no relevance to human transmission dynamics
- Purely clinical, diagnostic, or pharmacological studies without a spatial or temporal analytical part
- Multi-country studies, non-English manuscripts and pre 2000studies.

Source of evidence screening and selection The selection process will be conducted in two stages. At the first stage, piloting of the study selection process based on title and/or abstracts will be done. Then, formal screening of the search results against the eligibility criteria will be undertaken via a full-text review of potentially relevant articles. Eligible studies for data extraction will be identified using Covidence. Discrepancies among reviewers during the inclusion of studies will be resolved through third-party adjudication (BS) to ensure methodological rigour. During the review process, standardized exclusion criteria will be applied at the full-text review, and findings will be reported using a PRISMA-ScR flow diagram. All sources of evidence will undergo a two-stage selection process i.e. (1) title/abstract screening and (2) full-text screening, which is conducted independently by two reviewers (AGB and EBE). Any discrepancies among reviewers during inclusion of studies will be resolved through the third-party adjudication (BS) to ensure methodological rigour. During the review process, standardized exclusion reasons will be applied at full-text review, and findings will be reported using a PRISMA-ScR flow diagram.

Data management The search results will be imported into Covidence and duplicates will be removed. Screening will be done by two authors (AGB and EBE) will independently screen studies and extract data using Covidence, a Cochrane Collaboration recommended web-based platform that supports streamlined screening, resolve conflicts, and data extraction (www.covidence.org) (28). Covidence will be used to track reviewer decisions, maintain an audit trail of changes, and securely store all records throughout the review process.

Reporting results / Analysis of the evidence The data collection sheet will contain study characteristics, spatial unit, malaria outcome measures, temporal granularity, determinants (environmental & climatic, socioeconomic & demographic, health system & surveillance, vector & entomological), lag structures, data source and

quality, uncertainty measures, spatial methods applied, software used, intervention coverage measures, key findings (main drivers identified, direction of association, spatial cluster/hotspots, seasonal pattern, heterogeneity noted, implications for malaria control). Two authors (AGB and EBE) will independently extract the data, followed by cross-checking and approval of the extracted data through discussion by the team will be made. The extracted data will be kept in a spreadsheet.

The findings will be thematically analysed to reflect major domains. Moreover, qualitative analysis of the scoping review will be performed using NVivo software to thematically analyze spatiotemporal dynamics and determinants of malaria. Additionally, ArcGIS Desktop software will be used to show the geographical distribution of the included study. Mapping and description of the literature to find themes, knowledge, and evidence gaps will be summarized using PRISMA-ScR guidance, including a flow diagram, descriptive tables of study characteristics, thematic grouping of spatial–temporal methods and drivers, visual syntheses, and a structured summary of methodological patterns and evidence gaps. Quantitative evidence will be synthesised according to the type of analytical methods used, direction and consistency of association, and the spatio-temporal scale of analysis.

Furthermore, each determinant or contextual drivers will be extracted from each study, and this evidence will be organized into concepts. Through inductive thematic synthesis similar concepts will be further grouped into themes, which are further organized into higher order domains. Directed acyclic graph will be used to summarize the hypothesized causal relationship among multiple determinants. The freely available online tool 'DAGitty' will be used to develop the conceptual framework.

Presentation of the results The findings of this scoping review will be presented using narratives, tables, and graphical summaries. The presentation of findings will follow the PRISMA-ScR reporting framework to illustrate a transparent study selection process. The summary table will be used to present the descriptive characteristics. Furthermore, these findings will be organized thematically to reflect major domains including classification of drivers; spatiotemporal dynamics of malaria transmission of malaria; key findings with policy implications; and evidence gaps.

Moreover, ArcGIS Desktop software will be used to show the geographical distribution of the included studies. Mapping and description of the literature to identify themes, knowledge and evidence gaps will be summarized using PRISMA-ScR guidance including a flow diagram, descriptive tables of study characteristics, thematic grouping of spatial–temporal methods and drivers, visual syntheses, and a structured summary of methodological patterns and evidence gaps.

Language restriction Yes, this scoping review will only include articles published in English language only.

Country(ies) involved Ethiopia.

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Comprehensive search strategy PubMed search
(Prevalence [MeSH] OR prevalence [tiab] OR incidence [MeSH] OR incidence [tiab] epidemiology [tiab] OR case* OR outbreak[tiab])
AND
(Malaria [MeSH] OR Malaria [tiab] OR Plasmodium [MeSH] OR Plasmodium [tiab])
AND
("risk factor*"[tiab] OR climat*[tiab] OR environment*[tiab] OR weather[tiab] OR "global warming"[tiab] OR temp*[tiab] OR humidity[tiab] OR precipitation[tiab] OR rain*[tiab] OR flooding[tiab] OR deforestation[tiab] OR "land cover"[tiab] OR vegetation[tiab] OR "el nino"[tiab] OR "la nina"[tiab] OR "extreme climate events"[tiab] OR urban*[tiab] OR migration[tiab] OR income[tiab] OR education[tiab] OR unemployment[tiab] OR access*[tiab] OR availability[tiab] OR healthcare[tiab] OR "health service"[tiab] OR driver*[tiab] OR indicator*[tiab] OR predictor*[tiab] OR effect*[tiab] OR impact*[tiab] OR "sociodemographic determinant*"[tiab] OR "socio-demographic determinant*"[tiab] OR "socioeconomic determinant*"[tiab] OR "socio-economic determinant*"[tiab] OR "micro-ecology"[tiab] OR "climatic factors"[tiab] OR rural[tiab] OR "peri-urban"[tiab] OR housing[tiab] OR household[tiab] OR gender[tiab] OR ecolog*[tiab] OR mobility[tiab] OR "wealth index"[tiab] OR nutrition[tiab] OR cost[tiab] OR conflict[tiab] OR "insecticide resistance"[tiab] OR vector[tiab] OR "drug resistance"[tiab] OR "antimalarial drug resistance"[tiab] OR "diagnostic resistance"[tiab] OR "antimalarial resistance"[tiab] OR "HRP2/3 deletions"[tiab] OR "gene deletion"[tiab] OR mosquito[tiab] OR control[tiab] OR "long lasting insecticidal nets"[tiab] OR LLIN[tiab] OR "indoor residual spraying"[tiab] OR IRS[tiab] OR "larval source management"[tiab] OR LSM[tiab] OR IPTp[tiab] OR iptsp[tiab] OR PMC[tiab] OR "post-discharge malaria chemoprevention"[tiab] OR pdmc[tiab] OR "mass drug administration"[tiab] OR

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AND
("Ethiopia"[MeSH] OR "Ethiopia" [tiab] OR "Ethiopia [tw]")
AND
Filter: language (English) and Year (since 2000)

Web of Science
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AND
TS= ("malaria" OR “plasmodium”)
AND
TS=("risk factor*" OR climat* OR environment* OR weather OR global warming OR temp* OR humidity OR precipitation OR rain* OR flooding OR deforestation OR "land cover" OR vegetation OR "el Nino" OR "la Nina" OR "extreme climate events" OR urban* OR migration OR income OR education OR unemployment OR access* OR availability OR healthcare OR "health service" OR driver* OR indicator* OR predictor* OR effect* OR impact* OR "sociodemographic determinant*" OR "socio-demographic determinant*" OR "socioeconomic determinant*" OR "socio-economic determinant*" OR "micro-ecology" OR "climatic factors" OR rural OR "peri-urban" OR housing OR household OR gender OR ecolog* OR mobility OR "wealth index" OR nutrition OR cost OR conflict OR "insecticide resistance" OR vector OR "drug resistance" OR "antimalarial drug resistance" OR "diagnostic resistance" OR "antimalarial resistance" OR "HRP2/3 deletions" OR "gene deletion" OR mosquito OR control OR "long lasting insecticidal nets" OR LLIN OR "indoor residual spraying" OR IRS OR "larval source management" OR LSM OR IPTp OR iptsp OR PMC OR "post-discharge malaria chemoprevention" OR "mass drug administration" OR MDA OR "targeted drug administration" OR TDA OR "seasonal malaria chemoprevention" OR SMC OR IPTi OR RDT OR "artemisinin-based combination therapy" OR ACT OR "case notification" OR "foci investigation" OR "annual parasite index" OR surveillance)
AND
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AND
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AND
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AND
TITLE-ABS-KEY ((Ethiopia OR Ethiop*)))

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AND
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AND
Ethiopia:ab,ti OR ethiop*:ti,ab,kw

Keywords Determinants, Evidence Mapping, Ethiopia, Malaria, Scoping Review, Spatio-temporal dynamics, Transmission Dynamics.

Dissemination plans Upon the completion of the scoping review, the preliminary results will be shared with stakeholders and key implementing partners in Ethiopia. This consultation will be undertaken remotely by inviting them to the preliminary scoping review findings via email and virtual meetings within 4–to-6-week period using a standardised virtual meeting discussion guide to validate our findings and identify additional evidence. Key stakeholders from the Ethiopian Ministry of Health, the National Malaria Control Program (NMCP), the Ethiopian Public Health Institute (EPHI), the Regional Health Bureaus, the President's Malaria Initiative (PMI), academic institutions, and malaria researchers will be engaged in the remote consultation using a structured debrief session. This can validate our findings, identify missing evidence, and refine policy implications. Then, the feedback will be incorporated into the final synthesis. Finally, the scoping review will be published in a reputable open access journal, and conference presentations will be made available.

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