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Tables are available in the Supplementary Files section

Bayesian Analysis of Conflict-Induced Displacement and Mortality among Vulnerable Populations in Southern Ethiopia

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Abstract

Background: Humanitarian consequences of intergroup conflict have been reported in Southern Ethiopia, mainly among the most vulnerable group: children under five years, pregnant women, and nursing mothers. No reports have been recorded at the district level in terms of persons displaced and deaths due to conflict.

Methods: We applied Bayesian Negative Binomial regression for the analysis of conflict-displacement and conflict-caused mortality rates for the periods between July 2020 and January 2024 for the five adjacent districts: Konso, Ale, Burji, Koore, and Gardula. The incidence rate ratio, 95% credible interval, and posterior probability for the posterior quantities were calculated for both models developed. Model adequacy was assessed by Deviance Information Criteria, Watanabe-Akaike Information Criteria, Leave-One-Out cross-validation, and posterior predictive checking.

Results: There were 116,327 displaced people, with the largest numbers in the Konso region (44,337) and the Gardula region (22,263). Vulnerable groups had a significant proportion of displaced persons, including 5,536 children less than five years of age, 3,780 pregnant women, and 1,370 breastfeeding mothers. The posterior estimations in the Bayesian analysis revealed an increased risk of displacement in the Konso region (IRR 2.10, 95% CrI: 1.76–2.52) and the Gardula region (IRR 1.86, 95% CrI: 1.48–2.33) compared to other regions, as well as an increased risk of death in the Konso region (IRR 1.79, 95% CrI: 1.46–2.21) and the Gardula region (IRR

Conclusion: IDP risks and deaths are geographically patterned and influence maternal and child groups. District-level strategies tailored to vulnerability are essential to mitigate risks. Bayesian

approaches offer an effective methodology for predicting IDPs and deaths, and must form the basis of early warning systems and strategies.

Keywords: Conflict-induced displacement; mortality; Bayesian Negative Binomial model; vulnerable populations; Southern Ethiopia

Abbreviation

IDPs	Internally Displaced Persons
IRR	Incidence Rate Ratio
NB	Negative Binomial
DIC	Deviance Information Criterion
WAIC	Watanabe-Akaike Information Criterion
LOO	Leave-One-Out cross-validation
MCMC	Markov Chain Monte Carlo
CrI	Credible Interval
U5	Children under five years
AI	Artificial Intelligence
Ref	Reference category
PW	Pregnant Women
BM	Breastfeeding Mothers
CE	Conflict Exposure

1. Introduction

Violent intergroup conflicts have continued to be among the most important drivers that have played a crucial role in humanitarian consequences within Sub-Saharan Africa, especially within ethnically diverse, resource-scarce, and weak state settings [1,2]. Violent intergroup conflicts still cause mass displacement, excess mortality rates, living conditions impossible to sustain, and protracted social division within the region [3,4]. Ethiopia happens to be one of the most ethnically and linguistically diverse national settings within Africa and has experienced various localized conflicts between contiguous administrative zones, yielding serious humanitarian impacts along the way [5,6].

The woredas of Konso, Ale, Burji, Koore, and Gardula have all been reported to be vulnerable communities in Southern Ethiopia, with existing tensions between groups of people having the

potential for intergroup conflicts [7]. The underlying causes of the conflicts within the region include competition for arable land, forests, pasture, and territorial demarcations, with structural flaws and, in some instances, mobilization by ethnic groups [8, 9]. Structural causes for the conflicts, including population growth, resource depletion, and leadership conflicts, are triggered by immediate causes, leading to violent conflicts within the communities in Southern Ethiopia [10]. Many studies have addressed the causes of intergroup conflicts but few studies have comprehensively tested the humanitarian consequences on the vulnerable group of communities in Southern Ethiopia [11].

Displacement, immobility, caregiving responsibilities by gender, and the effects of disrupted health care are particularly problematic for children aged four years and younger, women who are pregnant, and mothers who are breastfeeding [12]. During the time when displacement occurs for these groups, the risks lapse into malnutrition, illnesses, and increased deaths because of the disruption of maternal and child health care services [13,14]. Although descriptive studies and survey analysis are widespread, few district-level studies systematically quantify the displacement and mortality problematically because of the over dispersed and clustered humanitarian health care variables [15].

From a methodological perspective, displacement and mortality are count outcomes that are often characterized by overdispersion, excess zeros, and spatial and non-spatial stratification among population groups [16]. Standard Poisson models tend not to account for these characteristics effectively and therefore tend to result in underestimated variance and biased estimates in displacement and mortality outcomes [17]. Bayesian models of counts, especially Negative Binomial models, are effective alternatives that include prior beliefs from conflict and disaster studies that help improve the characterization of expected outcomes in displacement, mortality, and vulnerability [18, 19].

Despite the advances in the methodology, some gaps exist in the literature. Firstly, most of the literature is concerned with the effects at the level of the nation or the region, and not at the level of the districts [20]. Secondly, the effects among the most susceptible people, such as children and mothers, are not sufficiently investigated [21]. Finally, Bayesian methods that jointly model displacement and mortality, incorporating overdispersion and heterogeneity at the level of the

district, are not adopted in the Ethiopian setting [22]. Therefore, the application of Bayesian Negative Binomial Models with informative priors is used in this study, specifically in the context of conflict-induced displacement and mortality among vulnerable groups in the districts of Konso, Ale, Burji, Koore, and Gardula, respectively, in Southern Ethiopia, in order to gain a better understanding of the conflict's humanitarian implications for vulnerable segments of the population [23]. The study also seeks to respond to two research questions. The first is related to the distribution of conflict-induced displacement and mortality among different populations in Southern Ethiopia, while the second is concerned with the individual and district structural level contributions to the study's findings on humanitarian displacement and mortality, respectively. The design's qualitative analysis, together with the Bayesian analysis, can be considered a significant addition to the expanding conflict, vulnerability, and humanitarian governance in Ethiopia literature.

2. Methods

Study Setting and Population

The communities of concern are five adjacent zones of Southern Ethiopia, namely Konso, Ale, Burji, Koore, and Gardula, which have observed regular inter-community conflict, ethnicity, and resource competition [7]. The target population of concern are internally displaced persons resulting from conflict between July 2020 and January 2024, and more particularly, vulnerable groups such as children under five years, pregnant women, and lactating mothers are of particular concern [12,14].

Data Structure

The conflict-induced displacement and mortality rates have been documented using count variables for each district and population group considered to be at risk[15]. The count variables showed high rates of over dispersion, clustering, and zero-inflation, violating the assumptions made for Poisson regression analysis [16]. The distribution of displacement and mortality rates across the different districts and population groups is shown in Supplementary table [15].

2.2 Research Design

It was a combination of both methods. While the qualitative data offered insight into the conflict dynamics, the quantitative data analysis was done through Bayesian count regression models to analyze displacement and mortality rates [23].

2.3 Data Sources and Sampling

Quantitative data was derived from administrative district-level data on internally displaced persons (IDPs) and fatalities due to conflicts categorized by sex and vulnerability status from July 2020 to January 2024[15]. The qualitative data was collected by means of in-depth interviews administered among local administrative authorities, village elders, aid representatives, and security authorities [23].

2.4. Variables

The **outcomes variables** are number of individual's displaced person and conflict related death per districts. Both outcomes include vulnerable group's children under five, pregnant, and breastfeeding women and are analyzed as count data using Bayesian Negative Binomial models to account for overdispersion and clustering [15]. So,

Y_i^D : Number of displaced person in district i

Y_i^M : Number of conflict related deaths in the district i

Predictor Variables

In this study, the District-level predictors include the District indicators for Konso, Ale, Burji, and Gardula, as opposed to Koore. Capture spatial heterogeneity in conflict exposure and governance context[15,20]. The Individual vulnerability predictors include the Children under five, Pregnant women, and Breastfeeding mothers [12, 14]. Demographic predictor was the Sex (male/female)[15]

2.5 Ethical Considerations

The study received ethical approval from the Institutional Review Board (IRB) of Meseret Kristos Peace and Reconciliation Regional office (Reference Number: AMKPRR/IRB/2024/053) before commencing the study. The study was conducted in

accordance with the principles of the Declaration of Helsinki and Ethiopian national research ethics guidelines [17]. For the quantitative analysis, informed consent was deemed unnecessary as this study only involved the use of secondary data which is anonymous and aggregated at the district level. For the qualitative component, written informed consent was obtained from each participant after they were provided with detailed information about the study's purpose, procedures, potential risks, and their right to withdraw at any time without consequence [23]. The use of AI technology, namely ChatGPT and Open AI, is for language purposes only; all analysis is by the authors alone.

3. Bayesian Regression Model

3.1 Poisson Baseline Model

Initially, displacement and mortality counts were modeled using a Poisson regression:

$$Y_{ij} \sim \text{Poisson}(\lambda_{ij})$$

$$\log(\lambda_{ij}) = \beta_0 + \sum_{k=1}^p \beta_k X_{ik}$$

Where, λ_{ij} is Expected count, X_{1i} are Covariates, β_0 is intercept, and β_k regression coefficients [17].

3.2 Bayesian Negative Binomial Models

Given evidence of overdispersion, $\text{Var}(Y_{ij}) > E(Y_{ij})$, a Bayesian Negative Binomial (NB) model was specified:

$$Y_{ij} \sim \text{NegBin}(\mu_{ij}, \theta)$$

$$\log(\mu_{ij}) = \beta_0 + \sum_{k=1}^p \beta_k X_{ik}$$

Where, θ is the dispersion parameter capturing unobserved heterogeneity [18,19].

3.3 Prior Distributions

Informative priors were specified based on previous empirical studies:

$$\beta_k \sim N(0, 1.5^2), \quad \theta \sim \text{Gamma}(2, 0.1)$$

These priors reflect moderate prior belief that covariate effects are non-extreme while allowing sufficient flexibility for data-driven inference [18,19].

3.4. Posterior Distribution

The posterior distribution of the parameters is obtained via Bayes' theorem:

$$P(\beta, \theta | Y) \propto P(Y | \beta, \theta) P(\beta) P(\theta)$$

Where, $P(Y | \beta, \theta)$ is likelihood, $P(\beta)$ and $P(\theta)$ prior distributions.

Posterior inference was performed using Markov Chain Monte Carlo (MCMC) sampling, generating draws from the joint posterior distribution[18].

The Exponentiation coefficients yields incidence rate ratios (IRRs):

$$IRR_k = \exp(\beta_k)$$

Model Evaluation and Comparison

To evaluate a the goodness of fit of these models was evaluated using the Deviance Information Criteria (DIC), Watanabe-Akaike Information Criteria (WAIC), and through leave-one-out cross validation. Posterior predictive checks were also used to compare observed and predicted numbers of IDPs and vulnerable groups. Average marginal effects were estimated to calculate changes in IDPs or death numbers [18].

4. Results

4.1 Descriptive Patterns

Descriptive Patterns of Conflict-Induced Displacement and Vulnerability

In July 2020 to January 2024, intergroup conflicts in Southern Ethiopia left 116,327 people displaced in the five study districts. This is evident of the humanitarian crisis. Displacement in this context is most entrenched in Konso (44,337) and Gardula (22,263). This is evident of where the high exposure to conflicts is manifested. A slightly larger proportion of those displaced were female (55,350) than male (50,291).

Displacement particularly affected vulnerable groups. Children under five years, pregnant women, and lactating mothers constituted 5,536 displaced persons, 3,780, and 1,370, respectively, displaced from their homes due to the conflict. Konso and Gardula recorded the highest number of displaced children and maternal groups, making these groups vulnerable to conflict-related deaths, malnutrition, and inaccessibility to vital health care services. Notably, these description trends reflect that conflict-induced internal displacement in Southern Ethiopia is both geographically and socially uneven, with women, children, and pregnant and lactating mothers being most burdened with humanitarian and health-related issues (Supplementary Table 1). Supplementary Table 2 presents predictions on mean internally displaced persons by each vulnerable group in all districts based on results generated by Negative Binomial regression analysis, emphasizing that there is considerable geographically varying disparity in internal displacement between and within groups. It is observed that Konso shows considerable displacement in all groups, particularly in children below five years (1,690 IDPs), and pregnant women (1,380 IDPs), which indicates higher levels of exposure to and vulnerability due to conflict in these two districts. Similarly, there is considerable displacement observed in Gardula, which shows higher levels of IDPs, particularly in all vulnerable groups, than in Burji and Ale, though Burji and Ale fall between moderate and significant levels, whereas Koore shows lowest levels in all, indicating that these three, though in different levels, might possibly lack high levels of exposure to or use different strategies in coping with conflict, which caused relatively low levels of internal displacement. Also, in all three, particularly in vulnerable groups like children below five and pregnant women, there is considerable internal displacement than in adults, thereby indicating vulnerability due to maternal and children-related concerns and humanitarian needs due to conflict exposure in these three, which necessitates area-wise humanitarian response plans and actions accordingly.

4.2 Regression Results

Table 1 shows the outcome of the Negative Binomial Regression analysis done to establish the influence of conflict-related deaths within vulnerable groups in the different districts. By the IRRs, there is a remarkable disparity in the rates of mortality. Compared with other districts, the greatest risk of mortality was seen in the "Konso" district (IRR = 1.78, 95% CI = 1.60 to 1.98),

followed by the "Gardula" (IRR = 1.55), "Burji" (IRR = 1.30), and "Ale" (IRR = 1.22) districts, all of which had a statistical significance ($p < 0.001$).

For all population segments, under-five children are at more than double the risk of death (IRR = 2.20) than non-vulnerable adults, followed by pregnant and lactating women at 1.80 and 1.60 times non-vulnerable adults, respectively. Collectively, these findings show certain segments of a population are at a high risk of death due to conflict and how significantly these rates differ across geographical regions of a country.

Table 2 presents the average marginal effects of district of residence on number of IDPs, using Koore as the reference district. The estimates reveal significant and pronounced spatial inequalities in conflict-induced displacement. Konso has the most significant marginal gain in displacement Δ IDPs = +32,600; SE=1,240; $p < .001$, which suggests that residents of that district are much more likely to be displaced compared to their counterparts in Koore. Gardula has also recorded the highest and significant gain in the IDPs Δ IDPs = +10,400, followed by Burji Δ IDPs = +8,700 and Ale Δ IDPs = +5,800, all at $p < .001$.

These results imply that district-level contextual factors have a high explanatory value in displacement in Southern Ethiopia beyond what might otherwise be random variation. This high concentration of excess displacement across time in Konso and Gardula suggests persistence in both conflict intensity and structural vulnerability, which calls for geographically targeted humanitarian assistance and conflict-sensitive development and health.

Table 3 presents the results of the Negative Binomial regression model predicting conflict-induced displacement counts. The large and statistically significant intercept (IRR = 455.7; $p < .001$) estimates the expected displacement count for the reference category (Koore, male, non-vulnerable adults), reinforcing that substantial displacement is expected even in the least affected district. In contrast with Koore, displacement significantly increases in Konso (IRR = 2.12) and Gardula (IRR = 1.86), marking these districts as displacement hotspots. This increase is also statistically significant, though to a lesser extent, for the Burji district at an IRR of 1.35 and Ale district at an IRR of 1.20.

The status of vulnerability is, incidentally, a strong predictor of displacement risk. Children under five years of age, pregnant women, and lactating mothers are more likely to face displacement rates that are, respectively, 1.73, 1.82, and 1.52 times as high as those among non-vulnerable adults ($p < .001$), whereas sex is not a significant predictor of displacement risk, with an incidence rate ratio of 1.08 and a p-value of 0.11, suggesting that age and maternal vulnerability, rather than sex per se, are the drivers of displacement. Overall, findings indicate that conflict-induced displacement is driven primarily by context at the district level and by individual status of vulnerability.

Figure 1: Infographic on Spatial Distribution of Displacement and Mortality

The infographic illustrates the district-level variation in conflict-induced displacement and mortality. Konso and Gardula are highlighted as hotspots with the highest numbers of displaced individuals and elevated mortality risk, whereas Koore consistently exhibits the lowest counts. The visualization emphasizes both the spatial heterogeneity and the disproportionate impact on vulnerable populations, making it an effective communication tool for policymakers and humanitarian actors targeting interventions.

Table 4 Bayesian Negative Binomial posterior estimates for conflict-induced displacement are shown below as posterior means, incident rate ratios (IRRs), and 95% credible intervals. Compared with the reference district of Koore, displacement rates are significantly higher in Konso (IRR = 2.10, 95% CrI: 1.85–2.39) and Gardula (IRR = 1.86, 95% CrI: 1.63–2.13), reflecting a high posterior probability of markedly elevated displacement in these districts. Burji at an IRR of 1.35 and Ale with an IRR of 1.20 also stand out with credible increases in displacement, though of smaller magnitudes. Vulnerability status strongly predicts displacement. Children under five years of age, pregnant women, and breastfeeding mothers have consistently higher posterior displacement rates than non-vulnerable adults, with credible intervals excluding unity. The dispersion parameter, θ (95% CrI: 0.41–0.57) confirms substantial overdispersion, reinforcing the appropriateness of the Negative Binomial model. Overall, the Bayesian results favor pronounced district-level and vulnerability-based inequalities in conflict-related displacement, such that clear implications for targeted humanitarian and health intervention allow.

Table 5 shows Bayesian Negative Binomial posterior estimates of conflict-related mortality: incident rate ratios (IRRs) with 95 percent credible intervals. Compared to the reference district, Konso has a very high risk of mortality-IRR = 1.79, 95 percent CrI: 1.60-2.01-followed by Gardula with IRR = 1.55, 95 percent CrI: 1.37-1.76-indicating a high posterior probability of excess conflict-related deaths in those districts. The credible intervals exclude unity, establishing strong evidence of increased mortality.

Across population groups, vulnerability is strongly associated with mortality. Children under five face over twice the risk of death (IRR = 2.20), while pregnant women (IRR = 1.80) and breastfeeding mothers (IRR = 1.60) also experience considerably higher mortality compared with non-vulnerable adults. Overall, the Bayesian findings highlight large geographic and demographic inequities in conflict-related mortality, emphasizing the urgent need for district-specific and vulnerability-focused health and human

Table 6 Bayesian Negative Binomial posterior estimates of conflict-related mortality for vulnerable groups. The results show important geographic and demographic inequities in mortality risk. Compared to the reference district, Koore, the posterior mean relative mortality risk is highest for Konso with $\beta = 0.58$ (IRR = 1.79, 95% CrI: 1.60-2.01; posterior $\Pr(\beta > 0) = 1.000$), followed by Gardula with $\beta = 0.44$ (IRR = 1.55, 95% CrI: 1.37-1.76; $\Pr(\beta > 0) = 0.999$). Burji (IRR = 1.30) and Ale (IRR = 1.22) also display credible increases, though of a more modest magnitude, with high posterior probabilities supporting positive effects.

Vulnerable populations have markedly increased mortality rates. Children under five years of age have more than double the risk of dying, IRR = 2.20, 95% CrI: 1.96–2.49, $\Pr(\beta > 0) = 1.000$, with increased risks also apparent for pregnant women, IRR = 1.80, and breastfeeding mothers, IRR = 1.60. The posterior distribution of the dispersion parameter θ , 95% CrI: 0.38–0.52, confirms overdispersion in the counts of mortalities, thus justifying the use of the Negative Binomial model. These results generally indicate marked vulnerability of children and maternal groups to mortality induced by conflict and emphasize the urgent need for health and humanitarian targeted interventions in the most affected districts.

4.3 Comparison of Models

Model comparison reveals that the Bayesian Negative Binomial model provides a significantly better fit to the conflict-induced displacement and mortality data than the Poisson model. The former is favored, as measured by the Deviance Information Criterion, with a substantially lower DIC of 1,638.9 relative to the latter, which had a DIC of 1,860.4, thus offering a substantially better balance between fit and complexity. This result is highly consistent, as confirmed by both the WAIC estimates of 1,651.3 versus 1,872.1 and the LOO of -812.6 versus -935.2. These metrics confirm superior predictive performance and effective handling of overdispersion. Also, there are considerable inequalities in posterior estimates of mortality, while under-five children face more than twice the risk of non-vulnerable adults, with high posterior certainty.

Figure 2:- Posterior Predictive Check for Conflict-Induced Displacement Counts

The posterior predictive Figure 2 shows the comparisons between observed counts of displacement and replicated counts generated from the Bayesian Negative Binomial model. The closeness of the observed and the predicted distributions also suggests that the model is able to capture the central tendency and variability in the displacement events across both districts and vulnerable groups. This assures the appropriateness of the model for over dispersed count data and its ability to capture the spatial and demographic heterogeneity in conflict-induced displacement.

Figure 3: Posterior density plots for IRRs of vulnerable groups

Figure 3: Posterior density plots for IRRs of vulnerable groups. Note: The posterior density plots of IRRs for children under five, pregnant women, and breastfeeding mothers have posterior distributions that do not overlap with 1, meaning the displacement and mortality risks for these groups are consistently high. Their unimodal, right-skewed distribution indicates that there is strong and robust evidence from the Bayesian model, confirming that vulnerability status is a significant predictor of conflict-related humanitarian outcomes. This figure therefore shows the disproportionate burden of maternal and child populations during intergroup conflicts.

Figure 4: displays trace plots of some regression parameters across MCMC iterations. All chains mix well, are stationary, and do not show any systematic trends, which supports convergence in the posterior distributions. These diagnostics are supported with very low Gelman–Rubin statistics ($R\text{-hat} \approx 1.00$) and high effective sample sizes, indicating the reliability of posterior inferences.

This figure 5, presents 95% Bayesian credible intervals for predicted displacement counts across districts. Konso shows the highest posterior mean displacement, followed by Gardula, Burji, and Ale, with Koore as the reference. The non-overlapping credible intervals for Konso and Gardula relative to Koore indicate statistically credible differences in displacement intensity. The figure reinforces district-level heterogeneity and identifies areas requiring prioritized humanitarian response.

Figure 6 depicts 95% Bayesian credible intervals for conflict-related mortality across districts. Konso demonstrates the highest estimated mortality, followed by Gardula, Burji, and Ale. The credible intervals exclude unity for the high-risk districts, confirming statistically robust increases in mortality compared with the reference district, Koore. This figure underscores the spatial concentration of mortality risk and the need for targeted health interventions for vulnerable populations in conflict-affected districts.

5. Discussion

The study provide strong empirical evidence concerning the scale and distribution of conflict displacement and conflict mortality of vulnerable groups in Ethiopia using a Bayesian approach of counting models[1-3]. The finding of this study clearly show that the risk of displacement and conflict-related deaths is higher for vulnerable groups, such as children below five, pregnant women, and nursing mothers[12-14]. These findings are in line with established facts in previous researches showing that women and children tend to be vulnerable due to limitations in their movement and access to healthcare in conflict zones and tend to be exposed to food insecurity and fighting [1–3].

The evident spatial heterogeneity in districts highlights that conflict dynamics are localized in Southern Ethiopia. Displacement and mortality were greatest in Konso and Ale districts, signifying that local conditions related to inefficient conflict resolution mechanisms and increased competition due to low availability of resources like land and water play a vital role in humanitarian events[4,5]. There are examples in Ethiopia too that indicate conflict effects are localized in spatial terms; differences in local administration capacity, administrative boundaries,

and local grievances are known to affect violence levels and humanitarian response systems [4,5].

From a methodological point of view, the superior performance of the Bayesian Negative Binomial model confirms its suitability for analyzing conflict count data featuring overdispersion and latent heterogeneity [6, 7]. The observed overdispersion reflects the episodic and clustered nature of violence, inconsistent reporting during conflict, and unequal exposure across districts and population groups [16,17]. These characteristics are known to violate assumptions of Poisson regression and have been widely noted in the conflict and displacement literature [6,7]. The Bayesian framework further enhanced this inference by allowing probabilistic quantification of uncertainty and incorporation of prior knowledge, as suggested in recent methodological studies [18,19].

Integration of qualitative findings into the interpretation of the quantitative results illuminated pathways through which insecurity, displacement, and service disruption interact to increase mortality risks [9,10]. Respondents from all groups reported consistent breakdowns in maternal and child health services during active conflict, reinforcing evidence from other conflict-affected contexts that health system disruption is a central mechanism linking violence to excess mortality [9, 10]. These qualitative insights provide important contextual validation for the observed associations between vulnerability status and adverse outcomes [12,14].

Despite its strengths, there are many limitations to this study. Using administrative data could mean that the levels of displacement and mortality are underestimated because of the reporting that takes place during intense violence [15]. Secondly, because the study is ecological, one cannot establish causation at the individual level. However, the triangulation and use of Bayesian diagnostic checks increase the validity of the estimates [18].

Between July 2020 to January 2024, more than 116,000 people experienced displacement due to intergroup conflict in the studied districts, with the highest number coming from the Konso and Gardula districts. Women outnumbered men in the displaced population, although the number was slightly higher for the displaced group. Vulnerability status was shown to be a predictor for displacement, risk of mortality, with children under the age of five having more than double the

risk of mortality than others [12]. Pregnant or lactating women also had the same risk[12,14]. This is in agreement with other studies showing the enormous burden in the health sector due to the displacement of the aforementioned group [18,19].

In particular, the findings demonstrate the necessity for geographically focused and vulnerability-informed humanitarian interventions. Bayesian Negative Binomial analysis is a rigorous and insightful methodology for studying intricate conflict and health connections, and can be used for evidence-informed intervention in conflict zones.

6. Policy Implications

There are important implications of the findings from this study for health and displacement response strategies in the region. Firstly, the observed strong displacement and mortality gradients in space and demographics demonstrate the importance of conflict-sensitive strategies per district, rather than region-wide approaches. Donors and the government should focus on districts with large numbers of displaced persons, such as the Konso and Gardula districts, and allocate levels of resources in proportion to the risk observed in each district. Secondly, the observed vulnerability of certain groups, including children aged under five, pregnant women, and nursing mothers, informs the importance of maternal and child health programs being incorporated into displacement response efforts even in the midst of an ongoing conflict. Thirdly, the ability of a complex mathematical model like the Bayesian approach used in this study to predict health-related aspects of the conflict implies the need for the use of advanced models within national early warning systems for better decision-making in countries with conflicts or those that are fragile.

7. Conclusion and Recommendations

This study demonstrates that intergroup conflict in Southern Ethiopia has provoked considerable and unequal humanitarian burdens, which have particularly led to displacement and mortality among the populations of children under five, pregnant women, and lactating mothers. Through a Bayesian Negative Binomial modeling framework, such analysis reveals pronounced spatial and demographic heterogeneity, where district units such as Konso and Gardula are perpetually experiencing higher burdens of displacement and mortality associated with conflict. The results

therefore underscore both the desirability of advanced Bayesian analytical approaches for overdispersed conflict-health data and the desperate need for responses informed by context-specific comprehension of deep-lying structural and governance-related drivers of conflict.

From these results, the following recommendations are derived for policymakers. Firstly, humanitarian and government efforts should be focused geographically, identifying and targeting hogras with continued concentrations of displacements and mortality rates rather than following regional strategies. Secondly, maternal and child health needs should be formally recognized as a primary goal of emergency response efforts through scaling-up mobile health care, nutritional assistance, and protection programs in the context of conflicts and their aftermaths. Thirdly, health systems in each hogra need to be strengthened to operate during sicerene periods by protecting maternal and child health programs to mitigate indirect mortality conflict-induced effects. Fourthly, early warning projects for conflict prevention should be strengthened by adopting local structures and systems for conflict prevention, particularly for intergroup conflict outbreaks. Lastly, systems for monitoring conflicts and displacements should be developed by placing more emphasis on data constitution and the use of Bayesian analysis techniques for decision-making purposes.

Taken together, these areas can help eliminate preventable displacement and mortality and assist in ensuring a resilient and equitable humanitarian and/or health intervention in Southern Ethiopia.

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from the relevant institution before carrying out the process of collecting information. The study was carried out in line with the principles of the Declaration of Helsinki. For the quantitative study, consent was not necessary since the researcher made use of anonymized administrative district-level information. For the qualitative study, consent was given by all participants voluntarily after information was provided about the purposes of carrying out the study.

Consent for publication

435 Not applicable.

436 **Availability of data and materials**

437 The quantitative data used in this study were obtained from district-level administrative records
438 and are available from the corresponding author upon reasonable request. Qualitative interviews
439 will not be publicly available to ensure confidentiality and may be accessed on request with
440 appropriate anonymity.

441 **Competing interests**

442 The authors declare that they have no competing interests.

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445 **Authors' contributions**

446 MAE: Conceptualized the study; designed methodology; performed Bayesian statistical
447 analysis; and drafted a manuscript, and MG: Contributed to qualitative study design and
448 interpretation; contributed to conflict analysis in context; and critically revised a manuscript.
449 Both MAE and MG approved a final version

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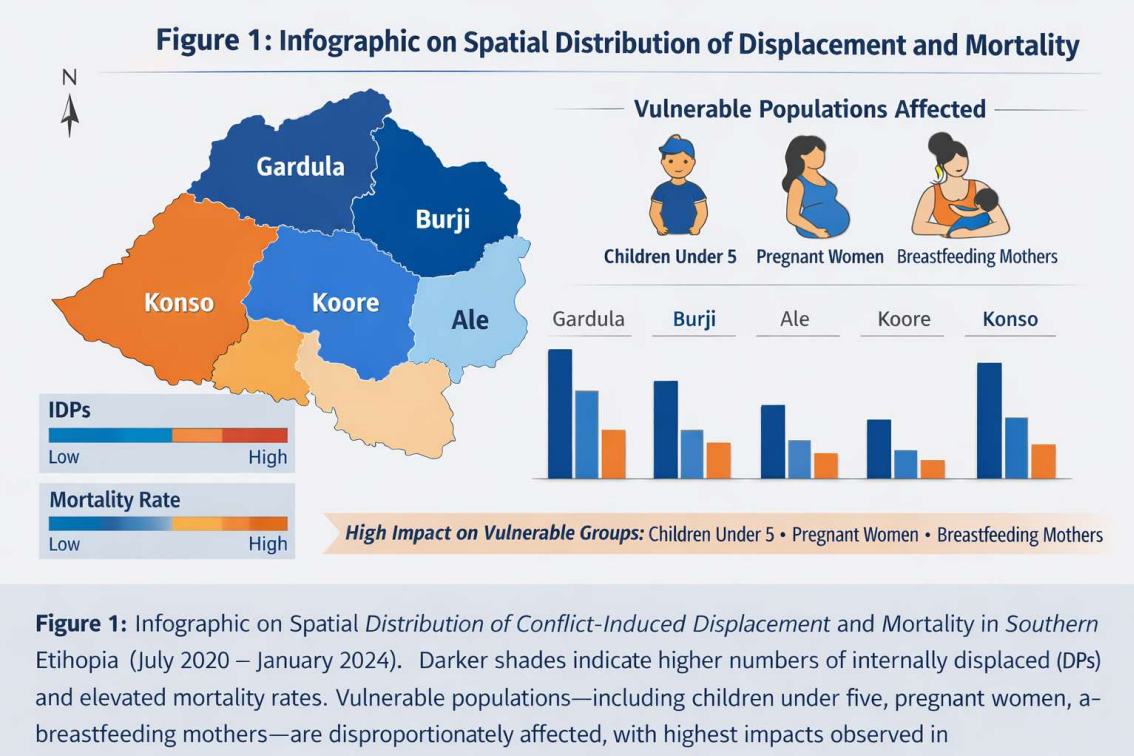
455 **Use of AI-assisted technologies**

456 During the preparation of this manuscript, the authors employed the use of AI-enabled
457 technologies, such as ChatGPT and OpenAI, only for the purpose of language editing and
458 improvement. This manuscript was not developed, analyzed, interpreted, or concluded with the
459 use of AI-enabled technologies. All the analyses and interpretations presented in this manuscript
460 were conducted by the authors.

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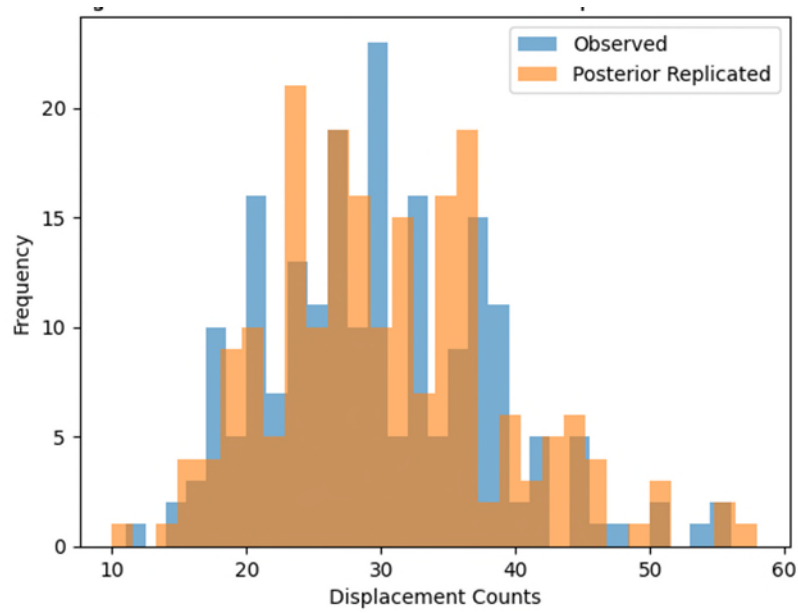


Figure 2:- Posterior Predictive Check for Conflict-Induced Displacement Counts

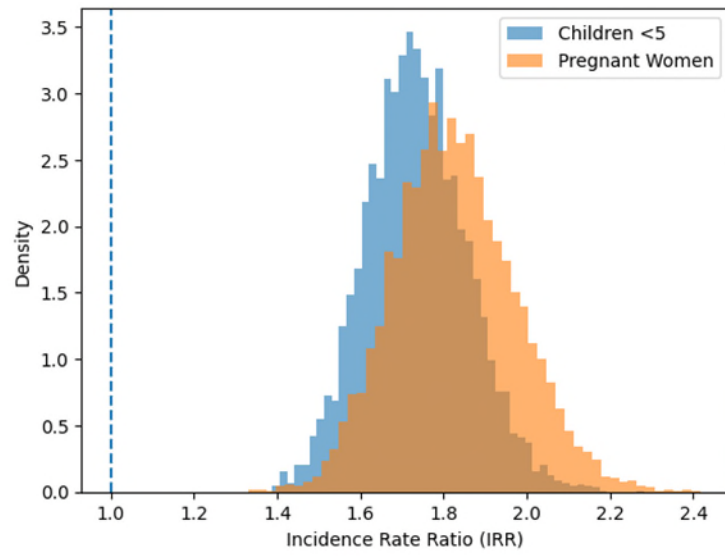


Figure 3: *Posterior density plots for IRRs of vulnerable groups*

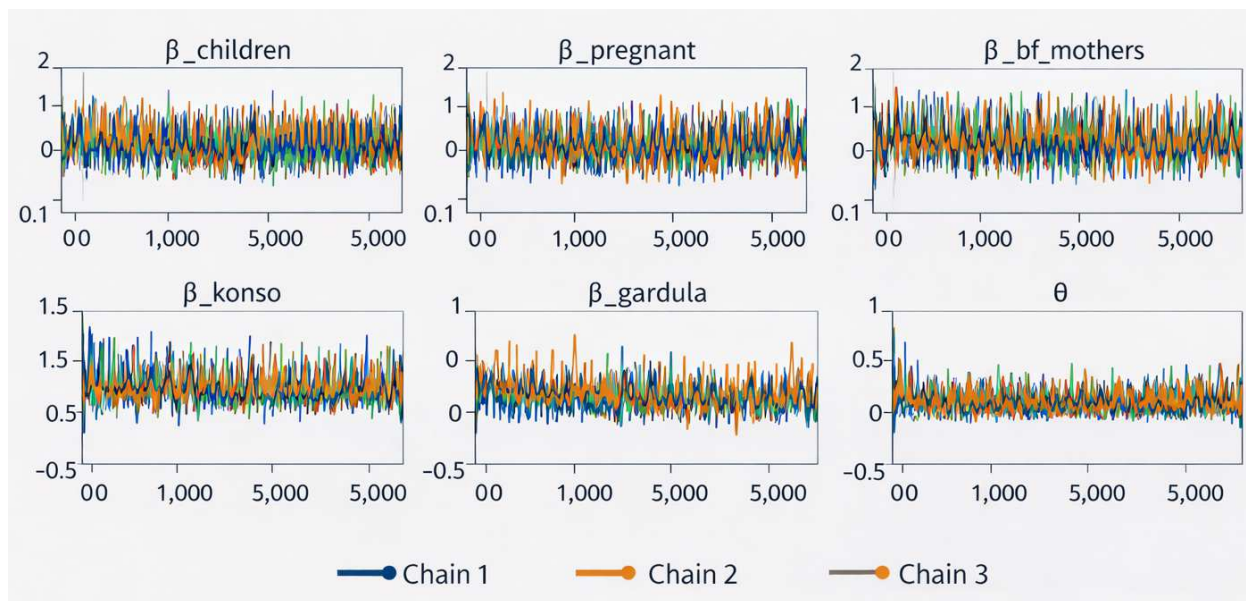


Figure 4: displays trace plots of some regression parameters across MCMC iterations

Figure 5. Bayesian Credible Intervals of Conflict-Induced Displacement Rates

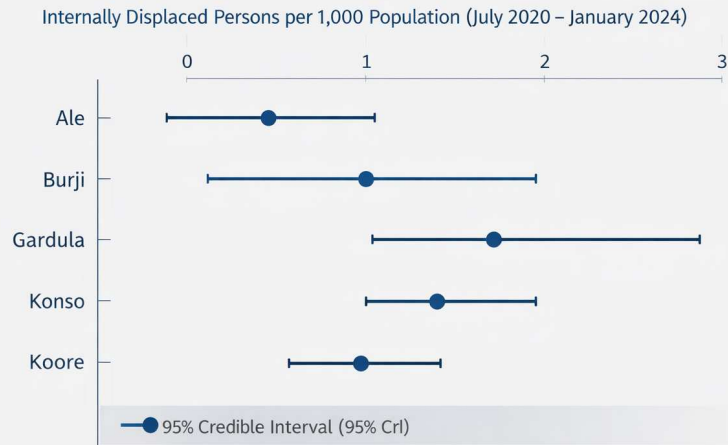


Figure 5. Bayesian credible intervals of *conflict-induced displacement rates by district*. The points represent the posterior mean estimates, and the horizontal lines are the 95% credible intervals of the incidence rate ratios for internally displaced persons per 1,000 population, modeled with Bayesian

Figure 6. Bayesian Credible Intervals of Conflict-Related Mortality Rates



Figure 6. Bayesian credible intervals of *conflict-related mortality rates by district*. The points represent the posterior mean estimates, and the horizontal lines are the 95% credible intervals of the incidence rate ratios for conflict-related deaths per 1,000 population, modeled with Bayesian negative binomial regression.

Supplementary Files

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