

Bovine Tuberculosis (BTB) in selected areas of Northwestern Tigray, Northern Ethiopia: Prevalence, Risk Factors, and Public Health Implication

Negasi Arefayne

Shire Agricultural Technical and Vocational Education and Training (ATVET) College

Biruk Mekonnen Woldie

`biruk.mekonnen@mu.edu.et`

Mekelle University

Hailay Kidanu Gebreselassie

Mekelle University

Nigus Abebe Shumuye

Mekelle University

Melat Elias Wubu

Mekelle University

Solomom Gebre Dufe

Animal Health Institute (AHI)

Tadesse Teferi Mersha

Mekelle University

Habtamu Taddele Menghistu

Mekelle University

Gebrehiwot Tadesse Mewcha

Mekelle University

Yishak Tsegay Redda

Mekelle University

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Abstract

Background

Bovine tuberculosis (BTB), caused by *Mycobacterium bovis*, is a chronic zoonotic disease that remains endemic in Ethiopia, where it adversely affects livestock productivity and poses a significant public health risk. This study aimed to estimate the prevalence of BTB in and around Shire Indasilase, Northern Ethiopia, identify the major associated risk factors with the disease, and evaluate the level of public awareness regarding its transmission and prevention.

Methods

A cross-sectional study was conducted from December 2022 to May 2023 involving 382 dairy cattle from 109 farms. The prevalence of BTB was determined using the comparative intradermal tuberculin test (CIDT). In addition, structured questionnaires were administered to 109 dairy cattle owners and 29 patients with tuberculosis lymphadenitis (TBLN) to assess awareness and potential risk factors associated with BTB. Univariate and multivariate logistic regression analyses were used to identify potential risk factors and determine independent predictors of BTB. Statistical significance was assessed at the 5% level.

Results

The animal- and herd-level prevalence of BTB was 10.2% (39/382) and 26.6% (29/109), respectively. Crossbred cattle (OR = 2.36, 95% CI: 1.14–4.89), pregnant cows (OR = 4.33, 95% CI: 1.46–12.86), and animals with poor body condition were more likely to be at higher risk of tuberculin positivity. The questionnaire survey revealed a low level of awareness of BTB among respondents, with fewer than 20% recognizing its zoonotic importance and transmission routes. Furthermore, high-risk practices, including the consumption of raw milk and raw meat, were commonly reported. Human tuberculosis cases were reported in 13% of households owning purified protein derivative (PPD)-reactor cattle, suggesting a possible epidemiological association between bovine and human tuberculosis.

Conclusion

BTB remains an important animal and public health concern in the study area. Several host- and herd-level factors were associated with infection, while limited awareness and risky consumption practices may facilitate zoonotic transmission. Strengthened BTB surveillance, improved public awareness, enhanced biosecurity, and integrated One Health interventions are recommended.

Introduction

Ethiopia has the largest livestock population in Africa, with cattle playing a significant role in agricultural production, food security, and the national economy (Shapiro et al., 2017; FAO, 2022; CSA, 2023). However, livestock productivity remains below its potential due to multiple constraints, including poor genetic potential, inadequate nutrition, traditional management practices, and the high burden of infectious diseases (Shapiro et al., 2017; Berhanu and Pavanello, 2019). Among these diseases, Bovine Tuberculosis (BTB) remains one of the most important chronic bacterial infections affecting cattle dairy farming. The disease compromises animal productivity, imposes considerable economic losses on dairy farms, and poses potential public health concerns (Ameni et al., 2007; Vordermeier et al., 2012; Sibhat et al., 2017; Tessema et al., 2024).

BTB is a chronic zoonotic disease caused by *Mycobacterium bovis*, a member of the *Mycobacterium tuberculosis* complex, with a broad host range that includes domestic livestock such as cattle, wildlife, and humans (WOAH, 2024; Khairullah et al., 2024). The disease is characterized by the formation of granulomatous lesions, primarily in the lungs and associated lymph nodes. Cattle serve as the primary reservoir and shed the pathogen through respiratory secretions, milk, feces, urine, and saliva. Transmission occurs predominantly via inhalation of infectious aerosols, although oral transmission through contaminated feed or milk may also occur (Palmer et al., 2023; WOA, 2024). In addition to its adverse effects on animal health, BTB has important economic implications through reduced milk production, weight loss, reproductive inefficiency, premature culling and trade restrictions while simultaneously constituting a significant zoonotic hazard (WHO, 2024; Singh et al., 2024).

The public health burden of zoonotic tuberculosis caused by *M. bovis* is significant in low-and middle-income countries, due to close human–animal interactions, inadequate disease surveillance and control measures, and the widespread consumption of unpasteurized milk and inadequately cooked animal products (WHO, 2024; Khairullah et al., 2024). Humans may acquire infection through the consumption of contaminated milk and dairy products, ingestion of undercooked meat, or inhalation of infectious aerosols from infected animals (WOAH, 2024; Singh et al., 2024). As a result, BTB remains an important One Health challenge requiring integrated interventions across the veterinary and public health sectors.

In Ethiopia, BTB is endemic and has been documented in both extensive and intensive dairy production systems, with prevalence varying considerably across regions and management systems (Sibhat et al., 2017; Tessema et al., 2024; Weldegebriel et al., 2025).

However, epidemiological information on BTB in northwestern Tigray is scarce. Therefore, this study aimed to determine the animal- and herd-level prevalence of BTB, identify associated risk factors, and assess dairy farm owners' awareness of the disease's zoonotic importance in and around Shire Indasilase, northwestern Tigray, Ethiopia.

Materials and Methods

Study Area and Period

The study was conducted from December 2018 to May 2019 in selected areas of northwestern Tigray: Shire Indaselassie town and Tahtay Koraro district, Northern Ethiopia (Fig. 1). The study area is predominantly characterized by a subtropical climate, intensive and semi-intensive dairy production in Shire Indaselassie, and mixed crop–livestock farming in Tahtay Koraro.

Shire Indaselassie, the administrative center of Northwestern Tigray, Northern Ethiopia, is situated at an altitude of 1,600–2,200 m above sea level and has a subtropical (Woina Dega) climate. Livestock production, mainly under intensive and semi-intensive systems, is a key economic activity in the area (Tahtay Koraro Agricultural and Development Office, 2018).

Tahtay Koraro, located in the Northwestern Zone of Tigray, Northern Ethiopia, is characterized by a subtropical climate and a mixed crop–livestock farming system. The district lies at an altitude ranging from 1,800 to 2,398 m above sea level. Livestock production is a major agricultural activity, while intensive dairy farming is practiced in some areas, particularly Semema and Beles (Tahtay Koraro Agricultural and Development Office, 2018).

Study Animals

The study was conducted on dairy cattle managed under intensive and semi-intensive production systems in Shire Indaselassie and Tahtay Koraro, Tigray Region, Northern Ethiopia. The study animals consisted primarily of Holstein Friesian, local Zebu, and their crossbreeds kept on selected dairy farms. Study animals of varying sex, age, and origin were recruited from smallholder dairy farms with owners' consent to participate. Calves younger than six months and cows in advanced pregnancy (> 7 months) were excluded from the study. For the human component, 109 dairy farm owners were interviewed to assess risk factors and awareness related to BTB, while 29 acid-fast bacilli (AFB)-positive tuberculosis lymphadenitis (TBLA) patients were recruited from local health facilities to evaluate public health knowledge and practices.

Study Design, Sample Size Determination, and Sampling Strategy

A cross-sectional study was designed and implemented to estimate the prevalence of BTB and identify associated risk factors in the study area using the comparative intradermal tuberculin test (CIDT) (WOAH, 2022). The minimum sample size was computed using Thrusfield's formula (Thrusfield, 2018), based on an assumed BTB prevalence of 11.7% from a previous study in Tigray Region (Zeru et al., 2014), a 95% confidence level, and 5% absolute precision. The calculation produced an initial sample size of 109 animals. However, to account for the clustered sampling design (animals nested within herds) and to mitigate the potential reduction in statistical power due to intra-herd correlation, a design effect of 2.4 was applied, yielding a final sample size of 382 cattle recruited from 109 dairy farms.

A two-stage cluster sampling approach was employed (Dohoo et al., 2009). First, districts and selected kebeles/tabias were purposively chosen based on dairy cattle population, accessibility, and logistical

considerations. Subsequently, dairy farms were randomly selected from lists obtained from local agricultural offices, and eligible animals within each farm were selected using a random sampling technique.

Study Methodology

Tuberculin Skin Testing

The Comparative Intradermal Tuberculin Test (CIDT) was performed following World Organization for Animal Health (WOAH/OIE) guidelines for the diagnosis of BTB (OIE, 2018). Two sites approximately 12 cm apart on the mid-neck region were shaved and cleaned, and the initial skin thickness was measured using a digital caliper. Subsequently, 0.1 mL of bovine PPD (2,500 IU/mL) and 0.1 mL of avian PPD (2,500 IU/mL) were injected intradermally at separate sites. Bovine and avian purified protein derivatives (PPDs) for this test were obtained from the Animal Health Institute (AHI), Sebeta, Ethiopia. Seventy-two hours (72hrs) later, skin thickness was measured again. The CIDT reaction was calculated as the difference between the increases in skin thickness at the bovine and avian PPD sites 72 hours after inoculation: CIDT reaction = Δ bovine PPD – Δ avian PPD. Animals were classified as positive when the bovine reaction exceeded the avian reaction by ≥ 4 mm, doubtful when the difference was between 1mm and 4mm and negative when the difference was ≤ 1 mm (Awah-Ndukum et al., 2016).

Questionnaire Survey

A pre-tested, structured questionnaire comprising both closed- and open-ended questions was administered to 109 cattle owners/farm attendants recruited during farm visits (Annex I) and 29 patients with tuberculosis lymphadenitis (TBLA) recruited from collaborating local health facilities (Annex II). The questionnaire was designed to collect information in three main domains: (i) respondents' awareness and knowledge of bovine tuberculosis (BTB) and its potential zoonotic transmission; (ii) potential exposure practices, including consumption of raw milk, close contact with cattle, and shared human–animal housing; and (iii) animal- and herd-level risk factors, including herd size, management practices, and housing conditions.

Prior to enrollment, all participants were provided with comprehensive oral and written information detailing the study's objectives, procedures, potential risks, and their rights. Written informed consent was obtained from each literate participant; for non-literate individuals, witnessed verbal consent was documented. Participants were explicitly assured of their right to withdraw from the study at any stage without consequence or prejudice. To guarantee strict confidentiality, all personal identifiers were removed and replaced with unique alphanumeric codes, and all collected data were securely stored in password-protected databases accessible only to the principal investigators.

All interviews were conducted in the local language (Tigrigna) to facilitate clear communication and minimize misunderstanding. Furthermore, animal handling during the comparative intradermal tuberculin test (CIDT) strictly adhered to standard veterinary welfare protocols to minimize stress and discomfort.

Concurrently, universal biosafety and hygiene precautions were rigorously maintained throughout all human and animal interactions to protect both participants and field personnel.

Data Management and Statistical Analysis

The data collected during the study were recorded in Microsoft Excel spreadsheets and subsequently analyzed using STATA statistical software, version 17.0. Animal-level prevalence was calculated as the proportion of positive reactors among the total animals tested, while herd-level prevalence was determined as the proportion of herds with at least one positive reactor among all herds examined.

Potential risk factors associated with BTB were initially assessed using univariable logistic regression analysis. Variables showing associations with the outcome were subsequently included in a multivariable logistic regression model to evaluate the effects of factors such as species, age, and sex, and to estimate odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Descriptive statistics were used to summarize questionnaire data. Associations between BTB prevalence and potential risk factors were considered statistically significant at $p < 0.05$.

Results

Prevalence of Bovine Tuberculosis (BTB)

Animal-level prevalence and associated risk factors

The animal-level prevalence of bovine tuberculin positivity was 39 out of 382 animals (10.20%) (95% CI: 0.568–3.479) at cut-off ≥ 4 mm. Univariate analysis indicated that crossbred cattle were approximately 2.4 times more likely to be BTB positive than local breeds (OR = 2.36, 95% CI: 1.138–4.890). Similarly, pregnant cows showed a significantly higher prevalence of BTB positivity compared with non-pregnant cows (OR = 4.33, 95% CI: 1.461–12.857). Body condition score (BCS) was also significantly associated with tuberculin positivity. Cattle with a good BCS were less likely to test positive than those with medium (OR = 9.98) or poor (OR = 23.08) body condition scores. In contrast, no significant differences in bovine tuberculin reactivity were observed with respect to study area, sex, parity, or age group (2–4 years, 4–7 years, or >10 years) (Table 1, 2).

Herd-level prevalence and associated risk factors

Out of the 109 herds/farms examined, 29 had at least one tuberculin-reactor animal, resulting in a herd-level prevalence of 26.6% (95% CI: 0.122–0.729) using a cut-off value of ≥ 4 mm.

Univariate logistic regression analysis identified several herd-level factors significantly associated with bovine tuberculin positivity ($p < 0.05$). Herds characterized by poor management practices, larger herd sizes, intensive production systems, closed housing conditions, poor sanitation, the presence of respiratory problems, and contact with wild animals were at significantly greater risk of tuberculin

positivity. Conversely, ventilation status, mixing of cattle with other herds, and medium sanitation levels were not significantly associated with herd-level tuberculin reactivity (Table 2).

Multivariable logistic regression analysis identified breed, BCS, pregnancy status, lactation status, herd size, and management condition as significant predictors of CIDT positivity ($P < 0.05$). Crossbred cattle were more likely to be tuberculin positive than local breeds (AOR = 18.41, 95% CI: 1.91–195.83). Pregnant cows (AOR = 14.86, 95% CI: 2.34–94.37) and lactating cows (AOR = 5.20, 95% CI: 1.45–18.63) had significantly higher odds of positivity than non-pregnant and non-lactating cows, respectively. Cattle with medium and poor BCS also showed markedly increased odds of tuberculin reactivity compared with those having good BCS. In contrast, study site, sex, age, and parity were not significantly associated with CIDT positivity (Table 3).

Cattle Owners' Awareness of the Public Health Importance of BTB

Assessment of respondents' knowledge revealed generally low awareness of BTB. Out of the 109 individuals interviewed, 21 (19.27%) knew that BTB can affect animals, while 19 (17.43%) were aware that the disease is zoonotic (Table 4). In addition, out of the total interviewed households (109), 15 (13.7%) had TB cases in their families or farm attendants, which were thought to be linked to direct contact with cattle.

Tuberculosis Lymphadenitis (TBLA) Patients

A total of 35 TB patients receiving Directly Observed Treatment (DOT) or treatment outside the hospital were identified in the study area. After excluding six participants with incomplete questionnaires, 29 (82.9%) respondents were included in the analysis. Most participants were female (79.3%), aged 29–50 years (41.4%), and 31.0% had secondary education or above, while 27.6% were illiterate. Among the 29 TB-positive respondents, **48.3% (14/29)** reported consuming raw milk, whereas **27.6% (8/29)** reported eating raw meat. Raw milk (Table 6)

Discussions

The present study revealed a bovine tuberculin positivity prevalence of 10.2% at the individual animal level and 26.6% at the herd level. The individual animal prevalence was comparable with reports from several regions of Ethiopia, including Hawassa (11.6%), Mekelle (11.3%), Southern Ethiopia (14.4%), and Southwest Ethiopia (12.4%) (Regassa et al., 2010; Zeru et al., 2014; Tesema et al., 2024; and Alemayehu et al., 2024). This consistency suggests that bovine tuberculosis (BTB) remains endemic across diverse agroecological zones and production systems in Ethiopia. However, the prevalence observed in the current study was lower than the 20.3% reported by Kemal et al. (2019) in eastern Ethiopia and slightly lower than the 14.4% reported by Tesema et al. (2024) in southern Ethiopia. These differences may be explained by variations in herd management practices, cattle populations, production systems and local epidemiological conditions.

At the herd level, the prevalence of bovine tuberculin positivity (26.6%) was comparable with previous reports from Mekelle City (20%), Southwest Ethiopia (28%), and Southern Ethiopia (19.4%) (Zeru et al., 2014; Alemayehu et al., 2024; Tesema et al., 2024). In contrast, it was substantially lower than the herd-level prevalences reported from central Ethiopia (48.7%) and Addis Ababa (43.4–53.6%) (Regassa et al., 2008; Elias, 2008; Tsegaye et al., 2010). Such variation in BTB prevalence is likely attributable to differences in herd size, production systems, management practices, stocking density and biosecurity measures. The relatively lower prevalence observed in the present study may be associated with the predominance of smallholder farms characterized by smaller herd sizes and good to medium ventilation housing conditions, which may limit opportunities for transmission of *Mycobacterium bovis* (Alemayehu et al., 2024).

The present study also identified several factors significantly associated with bovine tuberculin positivity, including age, breed, lactation status, herd size, production system, housing type, farm management practices, and study site ($P < 0.05$). These findings highlight the multifactorial epidemiology of BTB and emphasize the importance of both host- and management-related factors in disease transmission.

Age was significantly associated with bovine tuberculin positivity, with cattle older than seven years having 4.4 times higher (OR = 4.4) of testing tuberculin-positive than younger animals. This finding is consistent with previous reports (Mekonnen et al., 2019; Alemayehu et al., 2024; Tesema et al., 2024). The increased risk among older cattle may be attributed to prolonged cumulative exposure to *Mycobacterium bovis* throughout their lifetime and the chronic nature of the disease, which increases the probability of developing detectable tuberculin reactivity over time. In addition, age-related changes in immune competence may increase susceptibility in older animals (Srinivasan et al., 2018; Robi et al., 2024).

Breed was another significant determinant of bovine tuberculin positivity. Crossbred cattle had higher odds of testing positive (OR = 2.36) than local zebu breeds, consistent with previous findings from Ethiopia (Zeru et al., 2014; Nuru et al., 2015; Alemayehu et al., 2024; Robi et al., 2024; Tesema et al., 2024). The higher susceptibility observed in crossbred cattle may reflect the greater innate resistance of indigenous zebu cattle to *Mycobacterium bovis* infection. In addition, crossbred cattle are more commonly managed under intensive production systems, where higher animal density and more frequent animal-to-animal contact facilitate disease transmission (Ameni et al., 2007; Vordermeier et al., 2012; Robi et al., 2024).

Lactating status of cows was also significantly associated with BTB infection. Lactating cows were more likely to be tuberculin positive than non-lactating animals. This increased risk may be due to the physiological and metabolic demands of milk production, which can impair immune function and increase susceptibility to infection. Similar findings have been reported in recent studies in Ethiopia, where lactation and reproductive status were identified as significant risk factors for BTB (Hussen et al., 2024; Robi et al., 2024). The immunological and metabolic stress during lactation may reduce resistance, thereby increasing susceptibility to *Mycobacterium bovis* infection and subsequent tuberculin reactivity.

At the herd level, both herd size and production systems were significantly associated with BTB prevalence. Compared with small herds, medium- and large-sized herds had 6.52 and 4.27 times higher odds of BTB positivity, respectively. These findings are in agreement with previous studies (Robi et al., 2024; Alemayehu et al., 2024; Hussein et al., 2024), highlighting herd size as an important epidemiological factor of BTB. Similarly, cattle managed under intensive production systems had significantly higher odds of BTB infection (OR = 10.45) than those reared under less intensive systems.

The increased risk observed in larger herds may be attributed to higher animal density, increased frequency of animal-to-animal contact, and the increased likelihood of introducing infected replacement animals. Likewise, intensive production systems often involve close confinement, shared feeding and watering facilities, and reduced ventilation, all of which facilitate the transmission of *Mycobacterium bovis*. These management conditions increase the opportunities for pathogen transmission and contribute to the persistence and spread of infection within and between herds.

Furthermore, significant geographical differences in BTB prevalence were also observed between the two study sites. Shire Indaslassie showed higher prevalence at both the individual animal (14.89%) and herd (39.58%) levels compared with Tahtay Koraro (7.48% and 16.40%, respectively). Similar spatial variations have been documented in Ethiopia and other countries, where agroecological factors, herd management practices, housing conditions, animal movement, and production systems influence the epidemiology of BTB (Ameni et al., 2007; Robi et al., 2024; Hussein et al., 2024). The higher prevalence observed in Shire Indaslassie may be associated with greater dairy intensification, larger animal density, and management practices that facilitate the transmission of *Mycobacterium bovis*.

The present study also revealed a low level of awareness of BTB among cattle owners. Only 19.3% (21/109) of respondents were aware that cattle can be infected with tuberculosis, while 17.4% (19/109) recognized its zoonotic importance. Furthermore, only 19.3% and 11% of respondents identified raw milk and raw meat consumption, respectively, as potential routes of transmission. These findings are consistent with previous studies conducted in Ethiopia and other developing countries, where limited knowledge regarding BTB transmission, zoonotic significance, and preventive practices among livestock owners remains a major challenge for disease control (Ameni et al., 2007; Mohammed et al., 2012; 2014; Zeru et al., 2014; Ciaravino et al., 2021). Poor awareness of BTB, coupled with high-risk practices such as consumption of unpasteurized milk, raw animal products, as well as inadequate farm biosecurity measures, may increase the likelihood of *Mycobacterium bovis* transmission between cattle and humans (WHO, 2017; OIE/WOAH, 2019; Olea-Popelka et al., 2017; Ciaravino et al., 2021; Torres-Gonzalez et al., 2020).

In humans, BTB caused by *Mycobacterium bovis* poses important clinical and public health challenges because the pathogen is intrinsically resistant to pyrazinamide, one of the first-line anti-tuberculosis drugs used in standard treatment regimes. Consequently, treatment often requires prolonged and more complex therapeutic regimens, which can increase healthcare costs, extend recovery time, and contribute to productivity losses among affected individuals (Biruk et al., 2019; Michel et al., 2021;

Mersha et al., 2021). Therefore, improving community awareness of BTB and promoting safer food consumption should be integral components of BTB control programs within a One Health framework.

Consistent with previous reports from Ethiopia (Ameni et al., 2001; Ameni et al., 2003; Zeru et al., 2014), this study identified human tuberculosis cases in 13% (15/109) of households that owned tuberculin-positive cattle, suggesting a possible epidemiological association between BTB and TB in humans. Although the cross-sectional nature of the study precludes establishing a causal relationship, this finding underscores the need for integrated surveillance of animal and human TB.

Risky food consumption behaviors were commonly observed among respondents. Nearly half of the respondents (46.8%) reported consuming raw milk, 42.2% eating raw meat, and 96.3% regularly consuming traditionally fermented yogurt. Similarly, among the 29 tuberculosis lymphadenitis (TBLN) patients interviewed, 48.3% (14/29) reported raw milk consumption and 27.6% (8/29) reported consuming raw meat. These practices may increase the risk of zoonotic transmission of *Mycobacterium bovis*, particularly through consumption of contaminated, unpasteurized animal products and inadequately cooked meat (Olea-Popelka et al., 2017; WHO et al., 2017; Ciaravino et al., 2021). The continued preference for raw milk in Ethiopia, influenced by cultural practices, perceived nutritional value and taste, as well as its availability and affordability, remains an important public health concern (WHO et al., 2017). At the policy level, the substantially higher odds linked to intensive systems and larger herds indicate that control efforts should pivot toward targeted biosecurity audits and routine screening in commercial dairies, rather than applying uniform measures across all production types. Furthermore, the 13% household-level co-occurrence of animal and human TB, viewed alongside pervasive raw milk consumption, strongly justifies the urgent establishment of integrated, cross-sectoral One Health surveillance platforms and the promotion of pasteurization or bulk-milk testing in high-prevalence districts as pragmatic, high-impact interventions to curb zoonotic *M. bovis* transmission. These findings highlight the need for public health education aimed at improved awareness of the zoonotic risk associated with BTB.

Limitation of the Study

This study relied solely on the Comparative Intradermal Tuberculin Test (CIDT) for bTB screening. While CIDT is a key surveillance tool, its sensitivity may be reduced by factors such as infection stage, anergy, immunosuppression, and late pregnancy, potentially leading to false-negative results (WOAH, 2022; Palmer et al., 2023; Conteddu et al., 2024). The study was also constrained by logistical challenges and restricted field accessibility due to security problems, which prevented the inclusion of some dairy-producing areas. Such limitations may affect the representativeness and generalizability of findings, particularly in regions where livestock production systems and bTB risk factors vary considerably (Sibhat et al., 2017; Tessema et al., 2024; Alemayehu et al., 2024). In addition, confirmatory post-mortem examination, mycobacterial culture, and PCR were not performed due to resource limitations. The absence of these reference diagnostic methods may have reduced the detection of subclinical

infections, affected prevalence estimates, and limited characterization of circulating *Mycobacterium bovis* strains (WOAH, 2022; Palmer et al., 2023; Conteddu et al., 2024).

Conclusion and Recommendations

Bovine tuberculosis remains a significant animal health and public health challenge in and around Shire Indasilase, with animal- and herd-level prevalence of 10.2% and 26.6%, respectively. Geographical variation was evident, with Shire Indasilase exhibiting a markedly higher prevalence than Tahtay Koraro. Older age (≥ 7 years), crossbred breed, poor body condition, lactation status, larger herd size, and intensive production systems were identified as important risk factors for tuberculin positivity. The low level of public awareness regarding the zoonotic nature of BTB, coupled with the widespread consumption of raw animal products, may increase the risk of *Mycobacterium bovis* transmission between cattle and humans. The observed co-occurrence of human TB cases in 13% of households owning tuberculin-positive cattle further emphasizes this zoonotic risk.

These findings underscore the need to strengthen BTB surveillance and control programs, improve community awareness and milk safety practices, and enhance farm biosecurity. However, given the substantially elevated odds associated with intensive systems and larger herds, control strategies should be context-specific, prioritizing targeted biosecurity audits and routine screening in commercial dairies rather than applying uniform measures. Furthermore, the high prevalence in Shire Indasilase and the evidence of household-level animal–human TB association strongly justify the urgent establishment of integrated One Health surveillance platforms and the promotion of pasteurization or bulk-milk testing in high-prevalence districts as pragmatic, high-impact interventions. Further longitudinal and molecular epidemiological studies are warranted to better understand transmission dynamics and support evidence-based BTB control strategies.

Declarations

Declarations

Ethical considerations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki to uphold ethical standards and protect participants' rights. Ethical approval was obtained from the Institutional Review Board of the College of Veterinary and Animal Sciences, Mekelle University. Participation was voluntary, and informed consent was obtained from herd owners/managers and Sehul Hospital. Confidentiality was maintained using unique participant codes. Skin testing was performed by a veterinarian following OIE guidelines, and owners of BTB-positive animals were informed of the results

and advised on appropriate prevention, control, and follow-up measures. The study received MTB PPD kits and related materials from the National Animal Health Institute (AHI).

Consent for publication

Not applicable.

Competing interests

The authors declare no conflicts of interest related to this study.

Clinical trial

Not applicable

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Author Contribution

Negasi Arefayne conceived the study, collected the data, and drafted the original manuscript. Biruk Mekonnen, Solomon Gebru, Habtamu Tadelles, Tadesse Teferi, Gebrehiwot Tadesse, and Yishak Tsegay contributed to the study methodology. Habtamu Tadelles conducted the data analysis. Biruk Mekonnen, Habtamu Tadelles, Tadesse Teferi, and Yishak Tsegay supervised the study. Biruk Mekonnen, Solomon Gebru, Habtamu Tadelles, Tadesse Teferi, Gebrehiwot Tadesse, Hailay Kidanu, Nigus Abebe, Melat Elias, and Yishak Tsegay critically reviewed and edited the manuscript. All authors approved the final version of the manuscript.

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Data Availability

The corresponding author can provide the datasets used in this study upon reasonable request.

Tables

Tables 1-6 are available in the Supplementary Files section.

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Figures

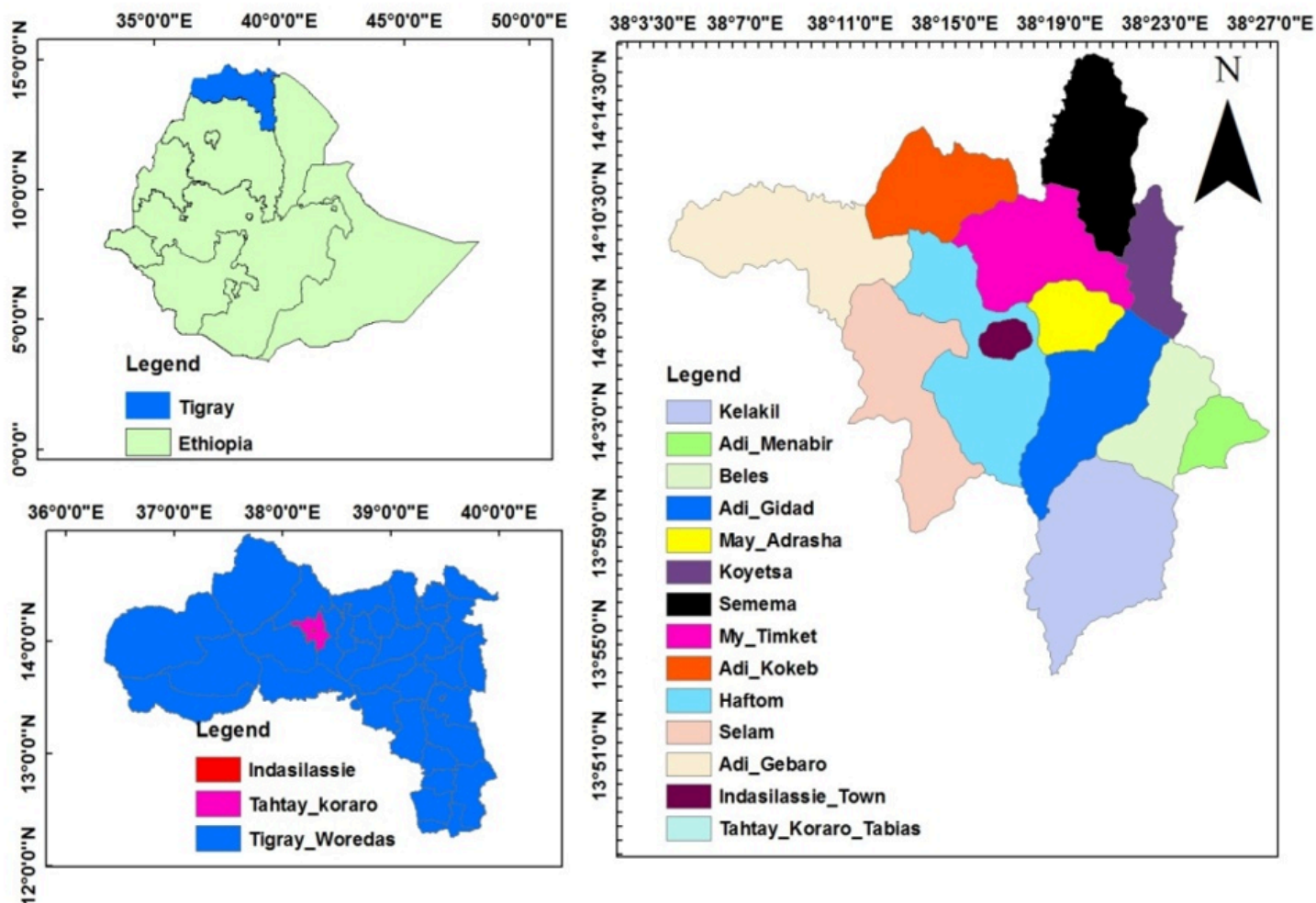


Figure 1

Map of the Study Area

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