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Review Article

Review on Epidemiology and Economic Impact of Tsetse Transmitted Bovine Trypanosomiasis in Ethiopia

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Abstract
Most vector-borne human diseases worldwide are spread by arthropod disease vectors, including mosquitoes, ticks, tsetse flies, and sandflies, which are greatly impacted by environmental factors. The tsetse-transmitted animal Trypanosomiasis severely hampers animal production and agricultural development in Ethiopia. The southern portion of the Rift Valley, the southwest corner of the nation, the western lowlands and escarpments, and the Blue Nile are the only areas in Ethiopia where tsetse flies are found. These areas are limited to longitudes 33° and 38° E and latitudes 5° and 12° N. The three Trypanosoma species that have the most impact on cattle in Ethiopia are *Trypanosoma brucei*, *Trypanosoma vivax*, and *Trypanosoma congolense*. Particularly in the "tsetse belt," which includes the Omo, Borena, and Metekel zones of the Benishangul Gumuz region, the illness is extensively spread throughout the western and southwest regions of the nation. Ethiopia's main river systems, including the Abay/Didessa, Omo/Gibe, Baro/Akobo, and southern Rift Valley, are linked to the prevalence of tsetse fly infestations and the Trypanosomiasis they cause. Mixed livestock and crop production is the major farming style in Ethiopia's highlands and plays a crucial role in agricultural activity. The bioclimatic threshold for tsetse flies in Ethiopia has not been met. Since it has long been typical for the peasantry in general and livestock owners, in particular, to avoid tsetse-infested areas to reduce their chance of contracting Trypanosomiasis, the impact of tsetse-borne Trypanosomiasis on development efforts in rural Ethiopia is becoming increasingly significant. This review examines the economic impact and epidemiology of tsetse-transmitted bovine trypanosomiasis in Ethiopia.
Keywords: Bovine, Distribution, Epidemiology, Trypanosomiasis, Tsetse fly

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Introduction

African animal trypanosomiasis (AAT) is a disease complex caused by tsetse-transmitted *Trypanosoma brucei*, *Trypanosoma congolense*, *Trypanosoma vivax*, and occasionally *Trypanosoma evansi*, a non-tsetse-transmitted species in cattle. While simultaneous infections of cattle with one or more of these trypanosomes have been reported (1), *Trypanosoma congolense* is considered less pathogenic to cattle than *Trypanosoma vivax* and *Trypanosoma brucei*, but it is never the less important cause of AAT in West Africa. Although the disease primarily affects cattle, it can also seriously harm pigs, camels, goats, and sheep. There are five economically significant animal trypanosome species in Ethiopia. According to (2), these are *Trypanosoma congolense*, *Trypanosoma vivax*, *Trypanosoma brucei*, *Trypanosoma evansi* in livestock, and *Trypanosoma equiperdum* in horses.

There are five species of tsetse flies distributed along the lowlands of the western, southern, and southwestern parts of Ethiopia. *Glossina morsitans submorsitans*, *Glossina pallidipes*, *Glossina fuscipes*, and *Glossina tachinoides* are the most important tsetse flies, while *Glossina longipennis* is of minor economic importance (2). Out of the 12 regions of Ethiopia, five (Amhara area, Benishangul-Gumuz, Gambela, Oromia, and Southern Nations Nationalities and Peoples' Regional States) are infected with more than one species of tsetse flies (3). The most prevalent trypanosome species in tsetse-infested areas of the southern region of Ethiopia and southwest Oromia are *Trypanosoma congolense* and *Trypanosoma vivax* (4).

Ethiopian tsetse and trypanosomiasis situations share many characteristics with the rest of African countries occupied by different species of tsetse flies. Until 1976, a total area of 98 000 km^2 in Ethiopia was infested by five

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species of tsetse flies. In more recent years, tsetse flies have progressively invaded productive agricultural areas in the west, south, and southwest parts of Ethiopia. In Ethiopia, the vector fly occupies some 220 000 km^2 of areas of fertile land, and about 23.15 million livestock populations are at risk of contracting the disease (2). The presence of tsetse-transmitted trypanosomiasis is a major obstacle to the introduction of highly productive exotic dairy cattle and draft oxen to land settlements and resettlement areas of the country for the utilization of large land resources (5). In Ethiopia, the disease is economically important, and livestock found below 2000 m above sea level (M.a.s.l.) are exposed to various levels of trypanosome risk (3). The major impact of this disease is associated with mortality, a retarded growth rate, reduced reproductive performance, low milk production, and poor draft power (6). The epidemiology and economic impact of tsetse-transmitted Trypanosomiasis on livestock, especially cattle production, are determined largely by the prevalence and distribution of the disease and its vectors in the affected area (7).

In Ethiopia, the direct loss (mortality) due to trypanosomiasis is estimated to amount to 1.5 to 2 billion Birr annually (8). Animal trypanosomiasis is estimated to reduce cattle density by 37%-70%, offtake by 50%, reduce the calving rate, and increase calf mortality by 20% (9). Vector-borne trypanosomiasis excludes some 180 000-200 000 km^2 of agriculturally suitable land in the Western, Northwestern, and Southwestern parts of Ethiopia. Over 15 million livestock, including cattle, goats, and equines, are at risk of contracting trypanosomes every year in Ethiopia (10).

The objectives of this review are:

- To review the epidemiology and status of tsetse-transmitted bovine trypanosomiasis in Ethiopia and
- To review the economic impact of the disease in the country.

Literature Review

African Animal Trypanosomiasis

Trypanosomes

Trypanosomes are single-celled, flagellated protozoan parasites that are spread by the bite of a vector fly. They reside and reproduce extracellularly in their mammalian hosts' blood and tissue fluids. Because of their corkscrew-like motion, the Greek terms trypano (borer) and soma (body) are the origin of the name Trypanosoma (11). Trypanosomes range in size from 8 to 50 µm and are composed of a single cell. Trypanosome species can be distinguished from one another by their distinct morphological traits, which include differences in size, shape, and appearance (12).

Mode of Transmission

Most trypanosomes must develop for one to a few weeks in tsetse flies (Glossina species), which act as biological vectors before being transmitted to susceptible hosts. The tsetse fly becomes infected with trypanosomes when feeding on an infected animal. When an infected tsetse fly bites an animal, the parasites are transmitted to a susceptible host in the saliva (13). Trypanosome species that commonly infect cattle in Ethiopia, such as *Trypanosoma congolese*, *Trypanosoma vivax*, and *Trypanosoma brucei*, are transmitted to cattle biologically via the bite of infected tsetse flies. Cattle whose residences were near major river systems such as the Abay, Didessa, Dabus, Baro/Akobo, and Gibe rivers had been infected more frequently (14). Other studies in different parts of Ethiopia revealed that, in addition to Glossina spp., other biting flies such as Tabanus, haemtopota, and Stomoxys are responsible for the mechanical transmission of trypanosomes to susceptible animals (15).

Life Cycle of Trypanosome

The trypanosome life cycles of tsetse involve cyclical development that takes different amounts of time, depending on the species and temperature of the environment. Most tsetse transmission starts when a tsetse fly consumes blood from an animal with a trypanosome infection. After losing its surface coat and multiplying inside the fly, the trypanosome regains its coat and starts to spread. The complete cycle for *Trypanosoma vivax* occurs in the proboscis, but the cycle for *Trypanosoma brucei* species ends at the hypopharynx and does not invade the salivary glands. *Trypanosoma brucei* species migrate from the gut to the proventriculus, the pharynx, and the salivary glands. The term "metacyclic form" refers to the animal-infective form found in the salivary gland of tsetse. According to (16), the life cycle of a tsetse can last anywhere from a week for *Trypanosoma vivax* species to several weeks for *Trypanosoma brucei* species (Figure 1).

Pathogenesis

The pathological impact of the disease occurs in three successive stages: acute, stabilization, and chronic. Fever and the highest peak of parasitemia, followed by the development of anemia, are the most prominent features of acute trypanosomosis. Virulence of the parasite population, age, nutritional status, host breed, etc., can influence the severity of anemia (12). Enlarged lymph nodes, weakness, lethargy, loss of condition, abortion, reduced milk production, and a high rate of neonatal mortality occur as a result of acute disease. In the chronic stage, anemia is not strictly associated with the presence of parasites in the blood. The level of parasitemia is intermittently monitored. Lymph nodes and spleens become normal, and even atrophy and sclerosis occur. Stunted growth, waste, and infertility are characteristics of cattle infected with chronic trypanosomosis. General

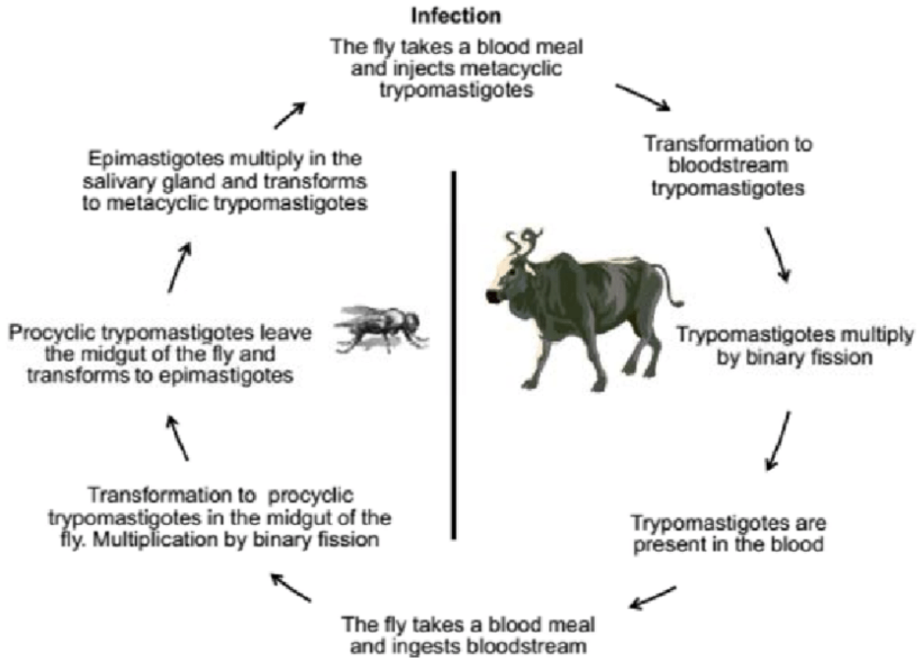

Figure 1. The Main Phases in the Life Cycle of the Trypanosome, Both in the Tsetse fly and the Mammalian Host. Source: Stein (17)

lesions are congestive, inflammatory, degenerative, and sometimes hemorrhagic. The disease affects various organs: the heart, central nervous system, eyes, testes, ovaries, and the pituitary gland. Congestive heart failure is an important cause of death in chronic cases and is related to the combined effect of anemia, myocardial damage, and increased vascular permeability (12).

African trypanosomes live in blood plasma and, in the case of *T. brucei*, lymph, cerebral fluid, and interstitial fluids. Their extracellular lifestyle poses two distinct difficulties. The first thing the parasites have to do is stay away from serum complement factors, which are a set of enzymes that can form a protein complex like a doughnut on membranes with permissive lipid bilayers, causing the membrane permeability barrier to be lost. Second, for the parasites to cause chronic infections, they need to avoid immune elimination. According to Samuel and John (18), the variable surface glycoprotein (VSG coat) mediates protection against complement activation and immunological elimination.

Tsetse Flies as Vectors of African Trypanosomes

AAT is found mainly in those regions of Africa where the tsetse fly exists (13). Tsetse flies are of primary importance in the spread and epidemiology of trypanosomosis. Tsetse flies, the vectors for AAT, belong to the family Glossinidae, order Diptera, two-winged flies. There are 31 recognized Glossina species and sub-species, divided into three groups (morsitans, palpalis, and fusca), which have been given sub-generic status (19). The morsitans group is largely found in open woodland savannahs best suited for grazing livestock and is the most important in transmitting animal trypanosomiasis (20).

The palpalis group is found mainly in the riverine galleries of West and Central Africa but sometimes extends into savannah regions between the river systems (21). The palpalis fly species are less mobile than the morsitans group, often relying on sight rather than smell to locate their hosts (22). In West Africa, important bovine trypanosomosis vectors among the palpalis group include *G. palpalis, Glossina palpalis gambiensis*, and *G. tachinoides* (19, 21, 23).

The fusca group flies settle mainly in forests and are less important vectors of bovine trypanosomosis. *Glossina longipennis and Glossina brevipalpis* found in the drier areas of Kenya are exceptions among the fusca group, as they have been demonstrated to transmit trypanosomes effectively (24). In addition to tsetse flies, other hematophagous insects like tabanids and *Stomoxys* species also transmit trypanosomosis mechanically, as demonstrated by (25).

Epidemiology of Trypanosomosis

The distribution of trypanosomes of veterinary importance varies with locality and depends on the interaction between tsetse flies, parasites, and domestic and wild animals (26). Since the parasite infects a wide range of animals, including wild animals, which constitute the reservoirs of the disease, the epidemiology of trypanosomosis is extremely complex (27).

Trypanosomosis is a cyclically and acyclically transmitted disease caused by different species of tsetse flies and other flies (28). Transmission by tsetse fly is a complex mechanism in which the fly remains a lifelong carrier. In the vector, the trypanosome changes through several morphologically distinct stages (amastigotes, promastigotes, and epimastigotes) until it reaches the trypomastigote (metacyclic stage), which is infective for mammals (27). The tsetse fly becomes infected with trypanosomes when feeding on an infected animal. Once the trypanosomes are ingested, they lose the surface coat, develop a mitochondrion, and undergo several developmental stages before becoming infective for the mammalian host. Although the developmental stages are similar for the three species of trypanosomes, the sites within the tsetse in which they occur are different (29).

Distribution of Bovine Trypanosomosis in Ethiopia

Trypanosomosis is an important disease of livestock in Ethiopia. Six pathogenic species of trypanosomes exist in Ethiopia, namely *Trypanosoma vivax*, *Trypanosoma congolense*, *Trypanosoma brucei*, *Trypanosoma evansi*, *Trypanosoma equiperdum*, and *Trypanosoma rhodesiense*. But the most important trypanosomes in the country are *T. vivax* and *T. congolense*. Both species affect a great number of cattle, which are the most important species of domestic animals in Ethiopia. Due to its extensive distribution, *T. vivax* is more important than *T. congolense*. Most of the above-listed species of trypanosomes are limited in distribution to Africa, which is the home of the cyclical vector. However, the mechanically and generally transmitted trypanosomes have a cosmopolitan distribution (30).

Trypanosoma vivax is found in the entire country except in the highlands, which are 2500 m above sea level. The wide spread of *T. vivax* is due to its adaptation to mechanical transmission by biting flies in areas outside the Tsetse fly belt. The distributions of *T. congolense* and *T. brucei* have been limited nearly to the area of the cyclical vector, the Ethiopian tsetse fly belt (Table 1). This is because both species of trypanosomes are not adapted to acyclical transmission. Therefore, the diseases that T. congolense and T. brucei cause are limited to the southern and western areas of the country (30).

Distribution of Tsetse Flies in Ethiopia

The epidemiology of AAT depends on three factors: the vectors' distribution, the parasite's virulence, and the host's response. When dealing with tsetse-transmitted trypanosomosis, much depends on the distribution and capacity of the vectors. *Glossina* spp. is responsible for the biological transmission of the disease to susceptible hosts. Tsetse flies are classified into (*i*) savannah woodland, (*ii*) the water courses and drainage systems (riverine type), and (*iii*) dense-forest groups (31).

In Ethiopia, trypanosomosis is widely spread in domestic livestock in the western, south, and southwestern lowland regions and the associated river systems (Abay, Ghibe, Omo, and Baro/Akobo) (32). Out of the nine regions of the country, five (Oromia, Amhara, Southern Nations Nationalities and People's Region (SNNPR), Benishangul Gumuz (BG), and Gambela) are infested with more than one species of tsetse flies (3).

Four tsetse fly species (*G. pallidipes, G. m. submorsitans, G. fuscipes,* and *G. tachinoides*) are found in Ethiopia, of which *G. tachinoides* has been observed in the Amhara region, and *G. m. submorsitans* has been registered in the Benishangul Gumuz region, while more than one species of tsetse flies has been observed in the Oromia region. The distribution of tsetse fly species is significantly influenced by altitude; for example, regions below or equal to 1200 meters above sea level had a higher average tsetse fly density (17.1 catches/trap/day) than did regions above 1500 m above sea level (12 catches/trap/day) (14,15). According to a study done in the Mao-Komo special term of the Benishangul Gumuz region, there are G. fuscipes and G. pallidipes in addition to the previously known presence of *G. m. submorsitans* (Table 2).

Economic Impact of Bovine Trypanosomosis

Trypanosomosis has a wide range of complicated and varied economic repercussions in Africa. These effects include direct implications on human health and animal output, as well as indirect effects on land usage, farming, draught power use, animal husbandry, and settlement patterns (33). Young animals' birth and mortality rates are the most visible indicators of trypanosome impact (34). According to Gechere et al study (35), the disease can result in a 20% decrease in productivity and the mortality of 16%-20% of the young stock in susceptible cattle breeds. The disease has devastating effects on the livelihoods of local farmers, for whom cattle represent not only the source of food (meat and milk), manure, and draught power but also fundamental social roles as "living banks" and are used for social obligations such as dowry and ritual use (36). The overall negative impact extends to the access and availability of cultivable areas, changes in land use and exploitation of natural resources, and restraint of opportunities for diversification and intensification of agricultural activity (37).

Table 1. Trypanosomes Species Reported in Ethiopia

Species of *Trypanosome*	Vector	Host Affected	Regional Distribution
T. congolense	Tsetse	Cattle	Amhara
T. vivax and T. brucei			Benishangul-Gumuz Gambela, Oromiya, SNNPR
T. vivax	Biting flies	Cattle	All over Ethiopia
T. evansi	Biting flies	Camel	Afar, Amhara, Oromia, Somali, Tigray
T. equiperdum	Via coitus	Horses and donkeys	Oromia

Table 2. Tsetse-Infested Regions and River Basins of Ethiopia

Region	Major River Basin	Tsetse fly
Oromiya	Abay/Didessa Upper Ghibe/Omo Baro/Akobo	*G. m. submorsitans, G. tachinoides G. pallidipes, G. fuscipes*
Benishangul-Gumuz	Abay (Blue Nile)	*G. m. submorsitans, G. tachinoides*
Amhara	Abay (Blue Nile)	*G. m. submorsitans, G. tachinoides*
Gambela	Baro/Akobo	*G. m. submorsitans, G. tachinoides G. pallidipes, G. f. fuscipes*
SNNPR	Ghibe/Omo Rift valley	*G. pallidipes, G. f. fuscipes, G. longipennis, G. pallidipes*

Source: Abebe (2).

In Ethiopia, a study conducted on the socioeconomic impacts of trypanosomosis on cattle in the Girja district of southern Oromia indicated that the total household expenditure on trypanocidal drugs was increasing occasionally. The estimated annual expenditures on preventive and curative drugs were about 480 Ethiopian birrs (ETB) per household (US$ 28.23) and 320 ETB (US$ 18.2) per household, respectively. The finding also indicated that trypanosomosis has a direct impact on livestock productivity by reducing 23% meat and milk off-take, 5% increase in calving rate, 13.5% mortality, and livestock management, especially the number of livestock kept by farmers, the breed and species composition of the herd, 12% loss of draft power, 3% abortion, and 28% cost of trypanocidal drugs and insecticides in the district (7).

The estimated mean annual financial loss due to cattle mortality as a result of bovine trypanosomosis in the study districts (Gimbo from Gojeb and Gurafreda from Baro/Akobo river basins) was about 3502 ETB (US$ 200; "according to the National Bank of Ethiopia, 1 US$ is equivalent to 17 ETB) per household. Draft power loss due to sickness of oxen, treatment cost, production losses (milk and growth reduction), interference with agricultural activities, disease-induced mortalities, and replacement cost were considered the important impacts of bovine trypanosomosis and accounted for 68.3%, 53.7%, 48.8%, 45.15%, 35.4%, and 25.6% of the respondents, respectively, in the study districts (38-40).

Due to its extremely large livestock density and the significance of animal traction, Ethiopia stands to gain much from intervention against bovine trypanosomosis. It is projected that eradicating trypanosomiasis and tsetse flies on every square kilometer of land in the afflicted area will save US$ 10 000 annually. Therefore, treating bovine trypanosomosis in Ethiopia might yield annual benefits of up to US$ 1 billion (41,42). Trypanosomosis lowers agricultural production by 2% to 10% (roughly speaking, a 50% increase in animal numbers would result in a 10% rise in total agricultural output) (43,44). Moreover, sleeping sickness poses a risk to around 50 million individuals in Africa (45-47).

Trypanosomiasis and Vector Control Practices in Ethiopia

Trypanocidal Drug Use

Trypanocides are the main method of controlling bovine trypanosomosis in most sub-Saharan African nations where tsetse and trypanosomosis are present (48-51). Historically, for the past 50 years, the three trypanocide compounds — isometamidium chloride, homidium (bromide and chloride), and diminazene aceturate — have been marketed. However, recent data suggests that diminazene and isometamidium are likely to be extensively used (52,53). Isometamidium protects for roughly six months and is primarily used prophylactically. In contrast, diminazene aceturate is applied as a therapeutic agent. Nonetheless, extended usage, subpar brands, and underutilization of the available trypanocidal medications have persistently jeopardized their effectiveness (54,55). According to multiple studies, trypanocidal medication resistance is a common occurrence in various regions of Ethiopia (44-46).

Tsetse Fly Control

The main control strategy is based on tsetse fly suppression and eradication, using pour-on traps and insecticide-impregnated targets and releasing sterile male tsetse flies. In the 1980s and early 1990s, insecticide-treated targets and monoclonal and biconical traps were used in the Didesa River Valley and the Omo-Gibe Valley. This greatly reduced the number of tsetse flies and cases of trypanosomiasis in large parts of the Chelo, Limu Shay, Bedele, and Dembi-Toba intervention sites (47). Different methods of tsetse control, including insecticides in the form of areal spray, animal spray, or pour-on, have been used to suppress the tsetse population (56,57).

Conclusion and Recommendations

Notwithstanding years of efforts to suppress them, tsetse flies and trypanosomes are still extremely common and spread throughout Ethiopia. These pests' abundance is affected by several factors, including altitude, river drainage systems, game reserves, and land usage and encroachment. *G. pallidipes, G. m. submorsitans, G. fuscipes,* and *G. tachinoides* are the species of tsetse flies that cause the cyclic transmission of trypanosomosis to cattle in Ethiopia. Cattle that are vulnerable to *T. congolense, T. vivax,* and *T. brucei* are bitten by infected tsetse flies, which can have a detrimental effect on animal productivity and production. Despite the disease's enormously high economic impact, there isn't a comprehensive document on the financial losses brought on by the disease's presence in the nation.

Thus, the following suggestions can be sent out in light of the foregoing conclusion:

- Farmers and livestock keepers in all areas impacted by trypanosomiasis and tsetse should receive education regarding the disease's financial consequences.
- To persuade policymakers during the development of preventative and control policies, the economic impact of the disease should be thoroughly researched and documented at the national level.
- To eliminate the disease and the tsetse fly vectors from the afflicted areas and make them safe for livestock production, sustainable community-based integrated control measures must be developed and implemented.
- Ethiopia's epidemiological position on bovine trypanosomosis: more research may be required to determine the disease's present state.

Authors' Contribution

Conceptualization: Tesfaye Rebuma, Motuma Regassa.
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Project administration: Motuma Regassa, Firaol Tariku.
Resources: Firaol Tariku, Wondesen Girma.
Software: Tesfaye Rebuma, Motuma Regassa, Firaol Tariku, Wondesen Girma.
Supervision: Tesfaye Rebuma, Motuma Regassa.
Validation: Tesfaye Rebuma, Motuma Regassa.
Visualization: Motuma Regassa, Firaol Tariku.
Writing–original draft: Tesfaye Rebuma.
Writing–review & editing: Tesfaye Rebuma.

Competing Interests

The authors declare no conflict of interest.

Ethical Approval

Not applicable.

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