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CONTROL OF TSETSE AND TRYPANOSOMOSIS IN THE SOUTHERN RIFT VALLEY (STEP AREA): EVALUATION OF DELTAMETHRIN APPLICATIONS

By

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LIST OF ABBREVIATIONS

µm:	micrometers
CCOHTA	Canadian Coordinating Office for Health Technology Assessment
CSA:	Central Statistical Authority
DG:	Dark Ground Phase Contrast Buffy Coat Technique
ELISA:	Enzyme Linked Immunosorbent Assay
ESTC:	Ethiopian Science and Technology Commission
FAO:	Food and Agricultural Organization
GIS:	Geographic Information Systems
HCT:	Haematocrit Capillary Tube
IAEA:	International Atomic Energy Agency
IBAR:	Inter African Bureau for Animal Resources
ICIPE:	International Centre of Insect Physiology & Ecology
ILCA:	International Livestock Centre for Africa
ILRAD:	International Laboratory for Research in Animal diseases
ILRI:	International Livestock Research Institute
ISCTRC:	International Scientific Council for Trypanosomosis Research and Control
Km:	Kilometres
MOA:	Ministry of Agriculture
NLDP:	National Livestock Development Project
NTTICC:	National Tsetse and Trypanosomiasis Investigation and Control centre
OAU:	Organization of African Unity
OSSREA:	Organization for Social Science Research in Eastern and southern Africa
PATTEC:	Pan African Tsetse and Trypanosomosis Eradication Campaign
PCV:	Packed Cell Volume
SCT:	Silicone Centrifugation Technique
SNNPRS:	Southern Nations Nationalities and People's Regional State
SIT:	Sterile Insect Technique
STEP:	Southern Tsetse Eradication Project
STRC:	Scientific and Technical Research Commission
UN:	United Nations
WHO:	World Health Organization

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ABSTRACT

A trial aimed to evaluate the efficacy of Deltamethrin (0.4% impregnated odour-baited targets and 1% pour-on formulation applied to animals) in reducing the incidence of bovine trypanosomosis and comparing the corresponding cost-effectiveness of both strategies was conducted in two selected 10X10km Universal Transverse Mercator Grids of the Southern Tsetse Eradication Project (STEP) area in the Southern Rift Valley of Ethiopia. The Grids selected were H3 & G5 designated as study Sites I & II respectively. The trial was underway from late September, 2003 to early April, 2004. The accomplishment of the trial included baseline survey (Questionnaire, Parasitology, and entomology), intervention with insecticide (Deltamethrin 0.4%) impregnated odour-baited targets at Site I(Grid H3) and Deltamethrin 1% 'pour-on' application to cattle at Site II (Grid G5) and monthly monitoring of the incidence of disease and apparent density of tsetse fly. Following the deployment of 460 targets (0.4% Deltamethrin impregnated and odour-baited) at a density of 4 targets /km^2 at the trial Site I, the relative abundance of tsetse fly (*G. pallidipes*) population declined from a pre-intervention catch of 1.35 flies/trap/day to 0.05 flies/trap/day during the final trapping time in April, 2004 with about 88.88% overall reduction achieved. The associated disease (trypanosomosis) status was monitored by monthly blood sampling from the sentinel animals established prior to the intervention and the incidence in cattle dropped from 10.75% (first monitoring) to 1.8% (last monitoring) with about 83.25%. The prevalence of the disease had also dropped to 9% ($P< 0.01$) as compared to the pre-intervention result of 23% and as a result, an overall reduction of 60% was achieved. The corresponding overall mean PCV (packed cell volume) record had shown an improvement from 21.8% of the pre-intervention to 25.5 % ($P<0.01$) after intervention. Similar assessment at Site II with Deltamethrin 1% pour-on formulation started by applying to about 409 animals at a rate of 1ml/10 kg body weight and subsequently repeated on monthly basis throughout the trial period resulted in a sharp drop of the relative abundance of tsetse fly population to nil from 0.91 flies/trap/day of the pre-intervention catch with a 94.88% ($P<0.01$) overall reduction achieved. The incidence of the disease also declined from 10% to 0.95% (about 90.5%). The reduction from 21% to 4.75% in the prevalence of the disease was observed to be significant ($P<0.01$) with a 77.4% overall drop. The associated overall mean PCV value (24.1% increased to 27.2%) had shown a gradual increase ($P<0.01$) until the third monitoring and maintained a stable state thereafter. The use of Deltamethrin 1% pour-on proved better efficacy based on the results obtained and conclusions made.

In addition to this, cost effectiveness evaluation of the intervention component was conducted. This indicated that the routine intervention cost for Pour-on formulation offered Incremental Cost-Effectiveness Ratio (ICER) ranging from 34762.54- 102927.94 USD per unit effectiveness and the use of impregnated odour-baited targets ranging from 43184.93-942652.00 USD per unit effectiveness for tsetse control and the associated disease (trypanosomosis) reduction. The ranges imply that reasonable variation is lacking between the cost-effectiveness of the two strategies. Though this uncertainty interval ruled out the difference between using targets and pour-on, it seemed that pour-on having lower ICER on average cost and average effectiveness assessments. The integrated application of both strategies was definitely relevant and thus recommended.

Keywords: Tsetse; Trypanosomosis; Deltamethrin; efficacy; intervention; cost-effectiveness; sentinel cattle; pour-on; targets

1. INTRODUCTION

1.1. Tsetse and Trypanosomosis in Africa

Trypanosomosis is one of the world's most important diseases of livestock and to man (Levine, 1985). It is caused by protozoan parasites of the genus *Trypanosoma*, transmitted cyclically by the tsetse fly (*Glossina species*), and is arguably still the main constraint to livestock production on the continent of Africa, preventing full utilization of land to feed the rapidly increasing human population (Murray *et al*., 1991). Infection by one or other of the trypanosomes in man gives rise to a disease that takes a variety of forms, one of which may correctly be called sleeping sickness and the cattle trypanosomosis are sometimes called by the Zulu name "Nagana" (Ford, 1971).

The disease in human (sleeping sickness) caused by *Trypanosoma brucei gambiense* and *Trypanosoma brucei rhodesiense* is always fatal if left untreated. It causes malaise and associated waves of parasitaemia in affected individuals (Jordan, 1986). The World Health Organization of the United Nations (WHO) reports that over 60 million people, mainly living in rural areas of sub Saharan Africa, are at risk of becoming infected with the disease. The estimated number of infected persons is between 300,000 and 500,000. The situation is rapidly deteriorating, with more than 45,000 new cases being registered in 1999, excluding the many unreported cases from inaccessible rural areas (surveillance covering only 5-7% of the people at risk)(WHO,2000).

Domestic livestock in Africa are important as a source of protein (milk & meat) to humans, as a source of animal traction, as a source of income (e.g. hides) and investment (social security) and as a source of manure for enhancing agricultural (crop) production (Erkelens *et al*., 2000). Tsetse-transmitted trypanosomosis affects 37 sub-Saharan countries; an estimate of 160 million cattle and 260 million sheep and goats are kept in this area of risk extending over 10 million km^2 of land (Erkelens *et al*., 2000).

Approximately 35 million doses of trypanocidal drugs (worth about US$35 million) is bought every year(Geerts and Holmes,1995) in futile efforts to maintain livestock free of the disease. The annual losses directly attributed to trypanosomosis, in terms of reduced meat and

milk production and in terms of the costs related to treating the disease or controlling the vector, have recently been estimated at US$1.2 billion (FAO, 2001). If the lost potential in livestock and crop production is included, trypanosomiasis is estimated to cost sub-Saharan Africa more than US$4 billion each year, equivalent to one-quarter of the area's total livestock produce(FAO, 2001; Budd, 1999; ILRI, 1995), and excludes the incalculable losses attributable to the effects of sleeping sickness in humans (FAO, 2001).

The impact of trypanosomosis on African agriculture is most obviously seen in the birth and mortality rates of young animals (Erkelens *et al*., 2000). In susceptible cattle breeds, the disease reduces calving by up to 20% and causes the death of another 20% of young stock. Even the so-called "trypanotolerant" animals such as the N'Dama cattle are affected. It strongly reduces milk off-take (reduction of 26%) and lambing and kidding rates (reduction of 37%) in the Gambia. Trypanosomosis reduces the availability and efficiency of drought animals used for preparing land for crop production (reduction of 33 %) in Ethiopia (FAO, 1998). In mixed farming systems, where trypanosomosis is so severe that it constrains the number of oxen that farmers own, it can reduce the average area planted per household by as much as 50% (FAO, 2000b).

According to MacLennan (1980) about 7 million km^2 of tsetse infested areas of Africa would otherwise be suitable for livestock and mixed agriculture if trypanosomosis could be controlled. Those areas, had they been free of tsetse, could support another 140 million cattle and an equivalent number of sheep and goats (FAO, 1984). The situation with regard to sheep, goats, pigs, donkeys, horses, and camels is probably as serious but is less documented (Gu *et al*., 1999).

1.2. Tsetse and Trypanosomosis in Ethiopia

Ethiopia, located in the horn of Africa between latitude from 3^0 N to 15^0 N of the equator and longitude from 33^0 E to 48^0E, is an agrarian country (Tikubet, 1993) with an estimated human population of about 61 million and a land area of about 1.1 million km^2 (Bourn, *et al*., 2001). The rural agricultural sector makes up 85% of the total population and accounts for 95% of all crop and livestock production (Slingenbergh, 1992). Climate and temperature are largely dependent on elevation, but rainfall patterns are highly variable. Three distinct seasons are

recognized. From February to May, South-easterly winds usually bring moisture from the Indian Ocean to produce the short rains ('Belg' in Amharic). From the June to September, South-westerly and South-easterly winds carry winds from both the Atlantic and Indian oceans to produce the generally more reliable main rains ('Kiremt' in Amharic). The dry season ('Bega' in Amharic) lasts from October to January (Bourn et al., 2001). The livestock population of Ethiopia is estimated at 35.1 million heads of cattle, 22 million sheep, 16.95 million goats, 8 million equines and 1million camels (FAO,2000 a). Livestock contributes to the national export earnings, sources of food, cash income and energy and fertilizer (Ford *et al*., 1976; Leak, 1999).

The devastating disease, trypanosomosis, had relatively little impact on the economy of the country or it had little consideration before 1960's. However, the magnitude of the problem has increased enormously and still it is increasing (NLDP, 1997). This is due to a number of factors which include mainly, overpopulation and overstocking of the highlands which forces people to use the tsetse infested lowlands, the advance of tsetse flies into previously un-infested areas and the development of a widespread drug resistance by trypanosome parasites over the different types of trypanocidal drugs which are in use in Ethiopia (NLDP, 1997).

The potential area of tsetse infestation has been variously estimated at 66,000 km^2, based on a 1500m above sea level breeding limit (Ford *et al*., 1976); 98,025 km^2, based on a 1600 m above sea level breeding limit (Langridge, 1976); and between 135,000 – 220,000 km^2, based on maximum dispersals up to 1700 m above sea level and 2000 m (Slingenbergh, 1992 a & b).

Five species of tsetse are found in Ethiopia: *Glossina longipennis*, *G. m. submorsitans*, *G. pallidipes*, *G. fuscipes fuscipes*, and *G. tachinoides*, and are confined to Southern and South-western regions of the country (Langridge, 1976). *G. m. submorsitans* is usually found in deciduous woodland and wooded grassland, often interspersed with evergreen vegetation. *G. pallidipes* is almost invariably associated with extensive and fragmented thickets, including evergreen species. *G. longipennis* is found in dry acacia, thorn-bush and is very active after sunset and before nightfall. *G. fuscipes fuscipes* and *G. tachinoides* inhabit gallery forest, thickets and fringing vegetation on streams, rivers and lake shores (Ford *et al*., 1976; Langridge, 1976).

Four tsetse-borne trypanosome species, *T. congolence, T. vivax* and *T. brucei brucei* of livestock and *T. brucei rhodesiense* of humans were identified and their distribution and frequency in hosts recorded. *T. vivax* was detected in almost all regions of the country below the 2500m above sea level altitudinal limits (Lemecha, 1994).

In tsetse infested regions of Ethiopia, the problem of trypanosomosis is the main cause of decline in the number of cattle and particularly draught oxen (Abebe and Jobre, 1996; NLDP, 1997). And therefore, draught animals can not be used for ploughing and other purposes, the situation forces the farmers to cultivate manually, as the majority of peasant farmers can not afford costly machinery. The end result is that only a small fraction of potential agricultural land is cultivated for crop production (Tikubet, 1993). Annual losses to the national economy are estimated to exceed US$200 million due to mortality and morbidity of livestock, denied access to land resources and the costs of controlling the disease (Vreysen *et al*., 1999).

The Southern Rift Valley, situated in the South-western part of the country, is one of the areas, most severely affected with the disease and annual losses to the livestock industry amount to more than US$12 million. This is believed to affect directly or indirectly the lives of over 5 million people in the region (Vreysen *et al*., 1999). About 25,000 km^2 areas that is agriculturally suitable and potential land in the valley are infested by tsetse flies. In this part of the country nearly one million heads of cattle are currently at risk of trypanosomosis, and almost all domestic animals in and adjacent areas of the valley are at risk of acquiring the disease at any time (Bancha, 2001). Thus, priority for tsetse control has been given by Ethiopian Government and a programme has been launched in 1997; the then 'Southern Rift Valley of Ethiopia Tsetse Eradication Project' (SRVETEP) 1988-2000(currently named as 'Southern Tsetse Eradication Project' STEP). The programme is jointly supported by the Ethiopian Federal Government and Southern Nations, Nationalities and People Regional State and the International Atomic Energy Agency and is coordinated by the Ethiopian Science and Technology Commission. A phased dynamic approach with the Sterile Insect Technique (SIT) as the final eradication component is in use, as this area is regarded sufficiently isolated from other tsetse belts (Muturi, *et al*., 1999). An area-wide integrated tsetse eradication programme with the eventual aim to eliminate by sequential releases of male tsetse flies sterilized by ionizing radiation, the project is in operation engaged in suppression of tsetse fly in areas of high fly population densities. This activity is undertaken by the use of conventional tsetse control methods especially insecticide impregnated and odour-baited targets or traps,

applying insecticide to cattle (pour-on technique) by creating living, moving targets with built-in odour attractants.

A wide scale use of these methods where appropriate, appeared technically fairly simple and found efficient and relatively cost effective according to the trial made by Keno and Mengistu (1995) in the Upper Didessa valley in western Ethiopia for the control of *G. m. submorsitans* and *G. tachinoides*. Emphasis must be put on acceptable levels of effective suppression of disease and tsetse with methods that are appropriate, efficacious and cost-effective. And thus the same approaches have to be applied in the Southern Rift Valley STEP. Therefore, this work is planned to investigate the advantages and disadvantages of the strategies being implemented and verify the most effective methodology to facilitate the control activity with the following objectives.

1.3. Objectives

1. To conduct a comparative evaluation of the efficacies of Deltamethrin application as 'pour-on' or insecticide impregnated targets as currently employed available technique for the tsetse and trypanosomosis control and then determine the best method for further utilisation.
2. To assess and determine the cost-effectiveness of both strategies which might aid in suppressing the wild fly in the field in the shortest possible time before the release of sterile male flies.

2. LITERATURE REVIEW

2.1. The parasite and disease

2.1.1. Trypanosomes

Trypanosomes are flagellated protozoa which belong to the family *Trypanosomatidae*. The family consists of several genera and many species; all are parasitic in habit. The species which parasitize vertebrates require a vector for transmission (Adam *et al*., 1979). Trypanosomes live and multiply in the bloodstream, lymphatic vessels, and tissues, including the cardiac muscle and the central nervous system. The most common form of *Trypanosomatidae* is the bloodstream form of the mammalian parasites (Itard, 1989).

2.1.2. Classification and Morphology

Trypanosomes are microscopic, elongated& flattened cells, which move with the help of a single flagellum directed towards, at the base of which is found a characteristic structure, the kinetoplast (Itard, 1989). The length and position of the trypanosome's flagellum is variable. In trypanosomes from the blood of a host, the flagellum originates near the posterior end of the cell and passes forward over the cell surface to extend freely at the anterior end. Where the flagellum is adherent to the cell surface, its sheath is expanded and forms a wavy flange, called the undulating membrane (Adam *et al*., 1979).

Based on this grouping, the systematic position of *Trypanosoma* among the protozoa and revised classification of the mammalian trypanosomes was made by arranging related species into subgenera corresponding to the two sections (i.e. Stercoraria & Salivaria)(Mulligan,1970). Pathogenic trypanosomes in the genus *Trypanosoma* are divided according to their development in the vector and transmission by either the saliva (inoculative) (Salivarian group) or transmission by faecal contamination (Stercoraria) (Adam *et al*., 1979; Losos, 1986; Mulligan, 1970). The Salivarian consists of species of veterinary and medical importance (Adam, 1979; Mulligan, 1970) and can be separated into four groups or sub genera (Duttonella, Nannomonas, Trypanozoon and Pycnomonas) according to their

morphology in the blood and their pattern of development in the tsetse fly (Adam *et al*., 1979; Mulligan 1970).

2.1.2.1 Subgenus Duttonella: Trypanosoma (Duttonella) Vivax, Ziemann, 1905

Trypanosoma (Duttonella) vivax has a mean length of 20-26µm, a long free flagellum and a large terminally placed kinetoplast, distinguishing it from the other pathogenic salivarian trypanosomes. *T. vivax* is a very mobile and "lively" parasite. It crosses the field of a microscope rapidly, which makes it difficult to follow its movement under microscope (Stephen, 1986).

2.1.2.2 Subgenus Nannomonas: T. (Nannomonas) Congolense Broden, 1904

The subgenus Nannomonas is represented by relatively small trypanosomes measuring between 8-24µm in total length. They are typically devoid of a free flagellum and possess a medium-sized kinetoplast usually occupying a marginal position, while the undulating membrane is in most cases inconspicuous. The posterior end of the body is either rounded (in the smaller forms) or obtusely pointed (in the longer ones). The nucleus is situated near the middle of the body (Mulligan, 1970). *T. congolense* is one of the smallest trypanosomes with a mean length of 12-17µm. *T. simiae* is more pleomorphic in its characteristic and slightly longer than *T. congolense*. Nannomonas trypanosomes are very active in fresh blood films but do not tend to move far across the microscope field. They also demonstrate agglutinating properties by tending to adhere to each other as well as to host tissues in vivo (Stephen, 1986).

2.1.2.3 Subgenus Trypanozoon: T. (Trypanozoon) Brucei Plimmer & Bradford, 1899

The Subgenus Trypanozoon is the most homogenous group of salivarian trypanosomes in that it contains a number of species which are morphologically indistinguishable but differ only in biological and nosological features. In Africa, there are about five species, three of which (*T. brucei*, *T. rhodesiense* and *T. gambiense*) are tsetse-borne and develop in the mid gut and salivary glands of the vector while the remaining two are transmitted directly, one (*T. evansi*) by mechanical inoculators (Tabanid flies) and the other (*T. equiperdum*) by contact between

the mammalian hosts. The blood forms of Trypanozoon measure from 11µ to 42µ (Mulliga, 1970) in total length. They are typically polymorphic, being represented by three forms:

a) Slender trypanosomes (mean length 23-30µ)(Mulligan,1970) possessing a length free flagellum and a well-developed undulating membrane, elongated nucleus, sub terminal kinetoplast and narrow posterior end drawn out to a blunt point or sometimes truncated; b) Stumpy trypanosomes (mean lengths 17-22µ) which are stout and usually without a free flagellum, undulating membrane well developed, nucleus rounded (displaced to the posterior end in posteronuclear forms), kinetoplast near broadly rounded or obtusely pointed posterior end; and c) intermediate forms (mean lengths 20-25) in which the flagellum is shorter, the posterior end blunter and the kinetoplast nearer to this extremity than in the slender forms. The kinetoplast in Trypanozoon is smaller than in any of the other salivarian Trypanosomes. Animal and human infective *T. brucei* are morphologically indistinguishable (Mulligan, 1970; Stephen, 1986).

2.1.2.4 Subgenus Pycnomonas: Trypanosoma (Pycnomonas) Suis Ochmann, 1905

The subgenus Pycnomonas is represented by a single species, *Trypanosoma suis*, which is characterized by stout monomorphic forms with a free flagellum and a small sub terminal kinetoplast. It develops in Glossina like the tsetse-borne species of Trypanozoon, viz. in the mid gut and salivary glands. Pigs are the only domestic mammalian hosts. *T. suis* is the least known pathogenic trypanosome (Mulligan, 1970).

2.1.3. Epidemiology

Tsetse-transmitted trypanosomes occur in Africa according to the distribution of vector. Mechanically transmitted trypanosomes can occur elsewhere in Africa (Hall, 1985) large areas of Asia, Middle East and South America (ILRAD, 1987). Among the Salivarian group only *T.vivax* is considered to be spread beyond the confines of tsetse fly belt by mechanical transmission (Hall, 1985).

Tsetse-transmitted trypanosomosis infects various species of mammals but, from an economic point of view, it is particularly important in cattle. It is mainly caused by *T. congolence*, *T. vivax*, and to a lesser extent, *T. brucei brucei*. *T. uniforme*, *T. simiae* and *T. suis* are other, less common tsetse-transmitted species (OIE, 2000). The occurrence of trypanosomosis within the

overall tsetse infested area is irregular because of differences in animal husbandry practices which affect the nature of the contact between tsetse flies and livestock and because of variation in the distribution and density of particular groups and species of tsetse flies which differ in their capacities to transmit the pathogenic trypanosomes. The pattern of the disease is also affected by differences in the distribution of the pathogenic trypanosomes; *T. congolence, T. vivax* and *T. brucei* are always found within tsetse infested areas. *T. simiae, T. uniforme,* and *T. suis* occur less frequently (Robertson, 1976). Beside the tsetse flies, the appearance of game is of great importance for the persistence of the disease within an infested area. Highly resistant wild ruminants harbour the trypanosomes and being alternative hosts for the tsetse fly become a reservoir of infection for the tsetse fly and contribute to its survival (Seifert, 1996).

The infection with *T. vivax* is widespread: if transmitted by *G. palpalis*, it shows a light and chronic course, but if as in east Africa, *G. pallidipes* becomes the vector or if it is *G. morsitans* or *G. tachinoides* as in West Africa, the disease occurs with high fever, oedemas in the sub cutis and causes death after 3-4 weeks. The *T. congolence* infection shows the most severe course. High fever is a symptom for the heavy multiplication of these, the smallest pathogenic *Trypanosoma* species within the blood up to 3 weeks after natural infection (Seifert, 1996). Multiple infections are also of the most important features of trypanosomosis in cattle (Losos, 1986). *T. vivax* causes major losses in cattle in West Africa; whereas in east Africa, the disease is usually characterized by low mortality and morbidity (Hoare, 1972) however, there have been outbreaks of haemorrhagic disease caused by *T. vivax* in Kenya (Olubayo *et al*., 1985). On the other hand *T. congolence* is most important in east Africa causing serious economic loss (Losos, 1986).

There is also a difference in host susceptibility to trypanosomes, which is best exemplified by the small West African breeds of cattle such as the N'Dama and West African short horn. These animals are less susceptible to the disease than zebu or the European breeds and are commonly found in endemic areas of trypanosomosis. They are referred to as 'trypanotolerant' breeds (Morrison *et al*., 1981). There are few data on trypanosomosis in small ruminants, which have received much less attention from scientists and veterinary researchers compared with cattle. This may be due to their smaller size and lesser apparent importance, but may also be because they are less susceptible to trypanosomosis (Leak, 1999).

2.1.4. Life Cycle of Trypanosomes

According to Seifert (1996), the transmission and interchange of hosts of African trypanosomosis which is transmitted by tsetse fly can be summarized as follows:

- The tsetse fly gets infected with the trypomastigote blood form which loses its surface coat in the goitre of the fly and, while remaining there at least one hour, restructures its mitochondrion.
- The trypanosomes enter the mid gut where they transform through lengthwise division into the epimastigote form in the cardia.
- The trypanosomes penetrate the haemocoel via the peritrophe membrane and the mid gut epithelium and move from there to the saliva gland of the tsetse fly where they develop into the metacyclic infectious trypomastigote form which has now got its surface coat; the trypanosomes are haploid.
- After the vertebrate host has been infected by the tsetse fly, syngamy takes place; the trypanosomes become diploid and multiply through lengthwise division.

According to Putt *et al*. (1980), *T. brucei* develops in the tsetse mid gut, proventriculus and salivary glands, while *T. congolence* develops in the mouth parts in addition to mid gut and proventriculus, and *T. vivax* develops entirely in the mouth parts (Ford, 1971; Putt *et al*., 1980).

2.1.5. Pathogenesis

The pathogenesis of the disease caused by the African trypanosomes differs according to the species causing the infection. *T. vivax* and *T. congolence* appear to be strictly parasites of the blood plasma and produce tissue injury primarily by the anaemia associated with infection. *T. brucei* is more widely distributed in the host affecting the intercellular fluids of the body cavities (Robertson, 1976). Here, although anaemia occurs, it is considered to be of secondary importance to the extensive degenerative, necrotic and inflammatory changes. The pathogenesis of trypanosomosis includes: chancre, lymphadenopathy, anaemia, and tissue damage (Mulligan, 1970).

2.1.5.1 Chancre

The fly bite deposits metacyclic trypanosomes in dermal connective tissue of skin and here a local inflammatory reaction, the 'chancre' develops. All three cyclically transmitted species eventually undergo a chancre (Vickerman and Barry, 1982) although the local skin reaction is less severe with *T. vivax* infections (ILRAD, 1986). From the chancre, the trypanosomes enter the draining lymphatics and then the bloodstream. *T. congolence* multiplies in the tissue of the chancre as a morphologically distinct phase before it invades the bloodstream (Vickerman and Barry, 1982). The chancre phase completed, *T. congolence* and *T. vivax* remain largely intravascular parasites (Losos and Ikede, 1972), the former localizing in small blood vessels where it attaches to the endothelium. Both species are now known to occur also in the lymphatics. *T. brucei* may secondarily escape from the bloodstream into the soft connective tissues and multiply in the tissue fluid (Vickerman and Barry, 1982).

2.1.5.2 Lymphadenopathy

Following enlargement of the lymph nodes draining the chancre, generalized enlargement of lymph nodes and splenomegally develop. This is associated with marked proliferation of lymphoid cells in these organs. Numerous large active germinal centres are present and there is a marked increase in the number of plasma cells in the medullary cords of the lymph nodes and in the splenic red pulp. Marked hypergammaglobulinaemia accompanies these changes (Morrison *et al*., 1981).

2.1.5.3 Anaemia

Anaemia plays the major role in the pathogenesis of bovine African trypanosomosis. The development of anaemia is a well recognized sign of trypanosome infection in cattle (Losos and Ikede, 1972). In most early cases, there is an acute onset of anaemia corresponding clearly with the detection of parasites in the bloodstream (ILRAD, 1987). The initial fail in packed cell volume (PCV) value is associated with the first wave of parasitaemia in the blood. During this period the anaemia is extravascular and is possibly the result of increased red cell destruction by erythrophagocytosis in the spleen, lungs, haemal nodes and bone marrow as a result of direct traumatic effect on red cells thereby increasing red cell fragility (Mamo and Holmes, 1975; ILRAD, 1984). In cattle subjected to a single needle or fly challenge, the

packed cell volume (PCV) progressively decreases by about 40-50% over the first 4-6 weeks (Morrison *et al*., 1981). During this period the anaemia is haemolytic due to production of toxins like haemolysins (lytic factor associated with protein of low molecular weight which has anaphylatoxin activity and the release by autolysing trypanosomes of endogenous phospholipases (Holmes and Jennings, 1976; Morrison *et al*., 1981).

There is evidence that immune sensitizations of red cells occur in animals infected with trypanosomes. The trypanosomal antigens can attach to red cell membranes and thereby make them susceptible to phagocytosis. The contribution of splenomegally to red cell membrane was suggested that pooling of red cells which may occur in the enlarged extra-sinusoidal compartments having detrimental effect leading to increased osmotic fragility and secondly, enhanced phagocytic activity of reticulo-endothelial system (RES)which may lead to clearance of both sensitized and normal red cells (Holmes, 1987). Haemodilution also contributes to the anaemia of African trypanosomosis by a disproportionate increase in the plasma volume as demonstrated in cattle (Mamo and Holmes, 1975) and laboratory animals (Holmes and Jennings, 1976). This phenomenon was commonly observed to occur during acute phases of the disease. Death may occur within 4-12 weeks after infection (Morrison *et al*., 1981).

Cattle that survive the acute process, progress into a chronic anaemia. This may still result in death, or in either spontaneous recovery or survival with persisting low grade anaemia. This chronic phase is characterized by low and transient parasitaemia or complete absence of detectable parasites in the blood. Death results from congestive heart failure (Morrison *et al*., 1981).

Bleeding disorders are commonly associated with trypanosome infections and may become a major aspect of the pathogenesis of trypanosomosis in cattle with a haemorrhagic syndrome associated with *T. vivax* infection (Holmes, 1987; Wellde *et al*., 1983). In this type of infection, the trypanosomes rapidly reach high numbers in the bloodstream and there is a severe drop in the number of red blood cells and platelets, a dramatic enlargement of the spleen and extensive haemorrhaging, both of the external mucous surfaces and the internal viscera and especially of the gut. Cattle may die of this disease in two weeks (ILRAD, 1984; Wellde *et al*., 1983; Olubayo *et al*., 1985).

2.1.5.4 Tissue Damage

As might be expected from the blood-borne nature of trypanosome infections, most tissues and organs are damaged during the course of infection although some are more consistently and severely infected than others. While necrosis is not a major feature of the disease in cattle, tissue cell damage and degeneration may be marked. The nature of the cellular infiltrate and possibly the mechanisms involved in cell injury would appear to depend on the difference in tissue invasiveness between species of trypanosomes. One vital organ which is consistently damaged by all three species of trypanosomes is the heart. The changes which occur in the heart also reflect to some extent what occurs in other tissues and organs. Other vital organs which are commonly affected include the skeletal musculature, central nervous system, endocrine organs and the reproductive tract (Morrison *et al*., 1981; Robertson, 1976; Olubayo *et al*., 1987; Hall, 1985; Abebe, 1991).

2.1.6. Clinical Features

Acute infections may be seen occasionally in all domestic animals notably with *T. vivax* in cattle leading to death after 1-3 weeks (Robertson, 1976). Regardless of the species of trypanosomes and the species of the host, the principal clinical signs are intermittent fever, an increasing degree of anaemia and progressive loss of condition and the disease is seen more commonly as a chronic form (Hall, 1985; Robertson, 1976). Infected animals are dull, have a staring lustreless coat, lose weight and are easily exhausted, lagging behind the herd, superficial lymph nodes are enlarged and prominent, cattle infected with *T. vivax* often show photophobia and excessive lacrimation (Hall, 1985; Losos, 1986; Murray *et al*., 1983; Robertson,1976).

2.1.7. Pathology

Post-mortem examination of animals after acute trypanosomosis may show extensive small haemorrhages involving mucous and serous surfaces, areas of emphysema in the lungs and mild gastroenteritis. After more chronic infections, the carcase may be anaemic and emaciated with an enlarged spleen and lymph nodes (Robertson, 1976) subcutaneous oedema and accumulations of pericardial and thoracic fluid containing trypanosomes are found particularly in horses and dogs infected with *T. brucei* (Seifert, 1996). Degenerative changes

have been observed in testis and epididymis of sheep, goats, and cattle infected with *T. congolence, T. brucei* and *T. vivax* (Morgan, 1990). Pathological changes of pituitary and adrenal glands with associated endocrine dysfunction have been observed in Boran (*Bos indicus*) cattle infected with *T. congolence* (Abebe, 1991).

2.1.8. Diagnosis

The history of the affected animals, the geographical incidence of the disease and the clinical signs of infection may arouse suspicions of trypanosomosis, but definitive diagnosis depends on the demonstration of trypanosomes of pathogenic species. In the field, reliance is placed on the examination of blood smears and occasionally, on lymph node biopsy (Mulligan, 1970; Losos, 1986; Robertson, 1976; Wilson, 1969). It can be accomplished through direct and /or indirect demonstration of the parasite. In spite of certain differences between the different species, direct demonstration of the parasite can generally be accomplished with a blood smear in the form of a wet film with or without concentration, e.g. by centrifugation in a haematocrit capillary (HCT), dark ground buffy coat technique (DG) or by separating trypanosomes from blood by anion-exchange chromatography (e.g. diethylaminoethyl cellulose), stained (Romanowski or Giemsa stain) blood smears as either thick or thin films; a lymph node biopsy may be useful (*T. vivax*) and transmission of blood to splenectomized calves or small laboratory animals. Since, depending on the species of trypanosomes, the pathogens are either found in the peripheral blood (*T. congolence*) or in the blood of the large vessels, collecting the blood has to be done accordingly (Seifert, 1996).

A large number of serological tests have been used to indicate infections with trypanosomes indirectly. However, few of them have found practical application. The most commonly used techniques are: immunoflourescence agglutination test (IFAT), enzyme-linked immunosorbent assay (ELISA), card agglutination test (CAT) (*T. evansi*). With use of the mentioned serological techniques, the responsible *Trypanosoma* species may be identified within certain limitations (Seifert, 1996). Interpretation of the results is made difficult because antigens from different trypanosome species show considerable cross-reactivity, and antibodies persist for several months after trypanocidal drug treatment. The most promising test apparently is the ELISA. Species-specific monoclonal antibodies are currently being developed which should allow preparation of defined antigens for use in assays for antibody detection. In addition, monoclonal antibodies can be used in a sandwich-ELISA to detect

trypanosomal antigens and thus the presence of active infections (Brown *et al*., 1990). An antigen-detection enzyme-linked immunosorbent assay (antigen-ELISA) for trypanosomosis has been described (Nantulya and Lindquist, 1989) and is now available for the diagnosis of *T. vivax, T. congolence and T. brucei* infections in cattle. However, field evaluations of the test have given inconsistent results. Works done in various countries have shown unexpected results such as high prevalence of *T. brucei* infections which is not usual. Therefore, additional work is needed to discover and overcome the cause of those inconsistencies before the test can be used in the routine diagnosis of trypanosomosis (OIE, 2002). Specific circulating antigens can be detected in cattle from 8-14 days after infection, but within 14 days of treatment they are not longer detectable. Therefore, this test seems to be an important tool for controlling the efficiency of trypanocidal treatment, or whether or not a treatment has eliminated premunity (Nantulya, 1990; Nantulya *et al*., 1989).

New tools developed by molecular biologists now make it possible to characterize trypanosomes both in the vectors and the hosts. The use of molecular biological tools, and in particular the Polymerase Chain Reaction (PCR), introduced an exceptional sensitivity and especially the possibility of characterization at the specific or infra-specific level, which had been impossible previously (Solano *et al*., 2000).

2.2. The Vector, Tsetse Fly

2.2.1. Classification and Distinguishing Characteristics

The vector, tsetse fly, can be classified in the order *Diptera* (the two-winged flies), family *Glossinidae*, and within the genus: *Glossina*. There are bout 23 species and 8 sub- species of *Glossina* identified so far (Moloo, 1993; Leak, 1999). From morphological point of view, tsetse flies are elongated and robust, of various shades of brown ranging from yellowish to greyish to dark or blackish brown in colour and about 6 to 16mm long excluding the proboscis. Males are usually smaller than the females (Itard, 1989). Useful features for identification include: wings being held closed over the abdomen fully overlapping one another; a piercing proboscis which sticks out horizontally from the front of head; widely separated compound eyes; the discal medial cell of the wing is shaped like a butcher's cleaver and is sometimes referred to as the 'hatchet cell' and the hairs on the arista of antenna have

further hairs branching off them (Robertson, 2004). The genus is further subdivided into well marked species groups (subgenera) identified based on differences from ecological characteristics (Leak, 1999). These are the subgenus *Glossina* (the *Glossina morsitans* group), the subgenus *Nemorhina* (the *Glossina palpalis* group) and the subgenus *Austenina* (the *Glossina fusca* group). The *G. morsitans* group is typically found in savannahs and thicket habitats. The *G. palpalis* group are riverine flies requiring a higher humidity; this group, however, is also capable of adapting to peri-domestic habitats in West Africa or lantana thickets in Uganda. The *Glossina fusca* group is found in high forest habitats or in more humid relict forests on the periphery of the rain forest belts (Cox, 1993). Within the subgenera, males of the palpalis group are identified mainly from the morphology of the inferior claspers, males of the morsitans group from the superior claspers and fusca group females most easily from the signum, which is a chitinized plate at the anterior of the oviduct (Leak, 1999).

2.2.2. Distribution and Diversity

Tsetse flies (genus *Glossina*) are the principal vectors of African trypanosomosis, which infect humans and their domestic animals over some 10 million km^2 (Green, 1994). They occur exclusively in the sub-Saharan Africa over an area extending on both sides of the equator from 15^0N to 29^0S latitude (Ford, 1971).According to Moloo (1985), most of the *fusca* and *palpalis* group of tsetse are concentrated in west and central Africa, while most of the morsitans group of tsetse species are found in eastern and southern Africa. *Glossina brevipalpis* and *G. longipennis* seem to be the only fusca group species found in eastern Africa.

Evidence of an earlier, wider distribution of tsetse and of their evolutionary age, arose from the discovery of fossil flies in Florissant shales in Colorado, USA, where four species of fossil Glossina, have been found and thought to date back to the Oligocene (at least 40 million years a go), indicating that Tsetse flies once had a much wider distribution (Leak, 1999).

2.2.3. Factors Affecting the Distribution of Tsetse Flies

The most favourable temperature for Glossina is between 21and 24^0c for the adult stage while too high (>35^0c) or too low temperature (<14^0c) hinder puparia from completing their development (Glasgow, 1963). The influence of humidity and rainfall can be partly seen in the relatively high mortality rates of the end of the dry season and the low mortality rates during the rainy season. However during the onset of the dry season changes in host distribution, amount of available shade, number and kind of predators, changes in temperature (^{0}c) and changes in hours of sunshine must also be taken in to account (Leak,1999).

The general distribution of tsetse flies, determined principally by climate and influenced by altitude, vegetation and the presence of suitable host animals, has been known for a long time (Leak, 1999). Each of these factors may directly affect the birth, death or migration rates of the vector and thus the population size (Hay *et al*., 1996). The limit of distribution is closely correlated with the tropical savannah (summer rain) climate, which follows the 508mm annual isohyet. Climate, though dependent on latitude, is modified by altitude and of course has a great effect on the vegetation, which is vital for providing shade and maintaining a suitable microclimate for tsetse as well as a habitat for their vertebrate hosts. As a generalization, the tropical rain forest (equatorial) climate controls the habitats of the *fusca* and *palpalis* groups, and the surrounding woodlands are the habitats of the *morsitans* group. Altitude influences tsetse distribution through its effect on climate, particularly temperature (Leak, 1999). In Ethiopia, 1600m above sea level was considered the rough upper altitudinal limit to tsetse distribution according to Langridge (1976). Subsequently, however, *G. pallidipes* was found at 1700m altitude and *G. morsitans submorsitans* at altitudes up to 2200m (Tikubet and Gemetchu, 1984).

Generally, the habitat of livestock is directly related to the presence of human settlements. The most important factor to develop an optimum habitat for the disease is the direct interaction between host, vector and parasite each with their own optimum habitat (Glasgow, 1963).

2.2.4. Biology of Tsetse Flies

Tsetse flies have a form of reproduction called adenotrophic viviparity where the egg hatches within the female and the larva develops in the female by feeding on food from modified

accessory glands (Robertson, 2004; Leak, 1999). Females live longer than males in the field. During her life-span a female can theoretically give birth to only a maximum of 8-10 offspring (in reality much lower), so tsetse flies are rather like human beings in that they make a large investment per offspring so that juvenile mortality is low. However, this means that they can't produce many offspring (Robertson, 2004). Consequently, tsetse flies have a very low rate of reproduction and therefore, termed as k-strategists and they differ from most insect species which produce large numbers of eggs and termed as r-strategists (Leak, 1999).

In most instances, mating seems to take place on or near the host, but this is not the case in *G. pallidipes*. There is no evidence of volatile sex pheromones being produced but females do have species-specific cuticular hydrocarbons which induce a copulatory response in males of the same species. Mating takes an hour or two during which time a spermatophore is formed within the female's uterus using secretions from the male. Just before copulation ends, the male ejaculates sperm into the spermatophore. Within the subsequent few hours, the sperm moves from the spermatophore up the paired spermathecal ducts into the paired spermathcae. These sperm serve the female throughout her life so she doesn't have to mate again. Males are able to mate a number of times with different females (Robertson, 2004).

Eggs develop sequentially in the female, alternating between the four ovarioles: after the female is about 9 days old, the first egg passes into the uterus from one of the two ovarioles in the right ovary. After 9-10 days, there is the second ovulation from one of the two ovarioles in the left ovary, and so on. In the uterus the egg is fertilized by a sperm from the spermatheca (gained during earlier mating with a male). After 3.5 days of development in the egg, the 1^{st} instar larva breaks out of the egg case (Robertson, 2004). Then the larva develops in the female's uterus by feeding on food from modified accessory glands. It passes through two moults to reach the 3^{rd} instar larva and it is then 'larviposited' by the female. The female finds a suitable place to lay the larva. In the wet season or wet regions such as rain forest, where there is general dampness everywhere, females tend not to concentrate their larviposition in particular areas. However, in dry areas larviposition takes place mainly in well-shaped spots so that there is an aggregation effect in these places (Robertson, 2004). The freshly-laid free-living larva is fully fed, and after expelling the waste- products it gained while developing in its mother, it burrows into the soil where its skin hardens and blackens into a puparium and within the puparium, pupation and metamorphosis take place. The puparial period can range from 20days (at 30^0c) to 47 days (at 20^0c) (on average 30 days at 24^0c). Development in the

puparium is generally unsuccessful below about 17^0c and above about 32^0c. The entire life cycle from egg to adult usually takes about 30days (Leak, 1999; Robertson, 2004).

All tsetse flies feed on blood, mainly from mammals but also reptiles and birds. Infected tsetse are vectors all their lives (Seifert, 1996). Analysis of blood meals has demonstrated that species of *Glossina* have different food preferences, *G. morsitans* and *G. fusca* groups feed mainly on *Bovidae* and *Suidae*, whereas members of the *G. palpalis* group have less well-defined host preferences and are capable of feeding on most available hosts (Cox, 1993). Trypanosomes can be transmitted during feeding (Robertson, 2004). Species of *Trypanosoma* transmitted by tsetse cause diseases of economic importance in humans and domestic animals they infect. Biting flies can also transmit trypanosomes mechanically, both in Africa and in other parts of the world (Leak, 1999).

2.3. Control

Programs to control trypanosomosis have been in operation for nearly 100 years (ILRAD, 1984). The different options currently in use for trypanosomosis control, with particular reference as to their suitability for control and/or eradication, amenability to community participation, suitability for large scale use and a general appraisal of their advantages and disadvantages were briefly indicated as follows.

- Parasite control
- Vector control
- Use of innate resistance of the host (trypanotolerance)

2.3.1. Parasite Control

In many parts of Africa where bovine trypanosomosis is a serious constraint to development, trypanocidal drug treatments constitute the principal method of controlling the disease. Despite the availability of effective vector control methods, it is very likely that in the foreseeable future, chemotherapy and chemoprophylaxis will continue to contribute significantly to the control of bovine trypanosomosis (Van den Bossche *et. al*., 1999). Certain compounds have specific effects on some enzyme system or block essential metabolic

pathways and thus kill trypanosomes or inhibit their development (Uilenberg, 1998). Drugs currently recommended for chemotherapy of animal trypanosomosis come from only three closely related groups. These are the phenanthridines, isometamidium, and homidium, and the aromatic diamidine, diminazene. Only isometamidium and homidium are recommended for prophylaxis (Peregrine, 1994). Chemoprophylaxis against bovine trypanosomosis has been in widespread use in tropical Africa for many years and isometamidium chloride (Samorin®) has been marketed since 1961 as a prophylactic and therapeutic drug. Because of the cost of developing new trypanocides, and the relatively small commercial market, there have been no new drugs for about 30 years and there is little prospect of new ones being developed in the near future. The use of the same drugs over such a long period has resulted in the widespread development of drug-resistant stains of trypanosomes (Leak, 1999; Peregrine, 1994). In Ethiopia, presences of moderate to high prevalence of trypanosomes resistant to drugs were reported in different sites (Afework *et al*., 2000; Codjia *et al*., 1993; Tewolde *et al*., 2004).

Resistance in trypanosomes to the available trypanocides is a constant and, in some areas, increasing threat. Drugs are not always available and their purchase consumes valuable foreign exchange (Erkelens *et al*., 2000). Resistance to mainly chemoprophylactic trypanocides used in cattle has been reported at sites in west, central, east and southern Africa (Peregrine, 1994). The only alternative for circumventing the problem of drug resistance is the alternating application of products which should not have a chemical relationship and thus are not subject to a cross-resistance. However, known prophylactic products do not fulfil this prerequisite, and therefore Diminazene aceturate offers itself as a secondary "sanative" trypanocide (Seifert, 1996). 'Sanative pairs' of drugs, by means of which induction of resistance to one drug can be eliminated by use of the other that can effectively be used (Seifert, 1996; Leak, 1999). In addition to this, it is widely accepted that the best way to delay the development of drug resistance is to reduce selection pressure on parasite populations. This is best achieved by using the correct dose, decreasing the treatment frequency and reducing the number of animals treated (Geerts and Holmes, 1998).

In view of the increasing prevalence of drug resistance, it is important to know how effective tsetse control would be in alleviating trypanosomosis in livestock in situations where trypanocidal drugs alone have become ineffective. Studies carried out at Ghibe, in southwest Ethiopia, where a high prevalence of multiple drug resistance was detected (Codjia *et al*., 1993), showed that tsetse control , in combination with trypanocidal drug use, can effectively reduce the apparent trypanosome prevalence in cattle (Leak *et al*.,1996).

2.3.2. Vector Control

Vector control is the most reliable means of disease control since it removes the threat of trypanosomosis on a permanent basis. Many vector control methods including woody vegetation clearance to remove tsetse shelter, and large scale application of insecticides by air (non-persistent and persistent formulations) and ground spraying (only persistent insecticides) and large wild life elimination (to deny tsetse its source of food i.e. blood), could be applied (SIT, 1996).

With regards to removal of vegetation in savannah areas, larviposition occurs in shaded places, so one control method is to remove trees and bushes so one is just left with grass. This method was used quite extensively with success in the past but is labour intensive and requires that there be reslashing of vegetation on an annual basis. The method fell into disuse with the advent of insecticides. However, removal of vegetation for firewood and urbanization has sometimes achieved the same effect. Also, killing of wild animals with the objective to remove reservoirs of infection in the wild animal populations was used extensively in the past (Robertson, 2004). However, these methods are now unpopular on environmental and on biodiversity grounds (SIT, 1996).

Persistent insecticides like organochlorine compounds were used until the mid 1970s during which environmental considerations led to a search for alternative insecticides. Ground spraying technique was used in the first attempts at control of tsetse with such insecticides. It was widely used in Nigeria, Uganda, Zambia, Zimbabwe, Kenya, and Botswana in different ways. Over 200,000km^2 of tsetse infested land was cleared by ground spraying in West Africa, mainly in Nigeria, and proved particularly successful and cost-effective. However, the technique was highly labour intensive, demands high level of supervision and allowed limited areas to be covered during the spraying season, difficult to cover inaccessible areas of possible tsetse resting sites, mechanical difficulties and high cost restricts their use (Leak, 1999).

In the 1970s and 1980s there were many advocates of spraying of tsetse habitats from the air, which apparently offered a high technology solution requiring little organization on the ground. Aerial spraying has, however, proved highly expensive, especially in foreign currency, and is also polluting (although less so than ground spraying) (Green, 1994). Nevertheless, aerial spraying is appropriate for the need to control tsetse over large areas and

inaccessible sites infested. Apart from the use of air craft to control tsetse successfully in South Africa in the 1940s, the technique was developed largely at the then Colonial Pesticides Research Institute in Tanzania in the early 1970s and large-scale control was carried out in Zambia, Zimbabwe, and Botswana in southern Africa, in Nigeria, and more recently in Somalia (Leak, 1999).

A family of techniques of tsetse control has recently been coming to the fore which offers some important advantages over those previously practiced: the so-called 'bait systems'. Instead of the destruction or contamination of the environment of the tsetse, they depend on the attraction of the fly from its surroundings to some introduced object, which may be insecticidal, but which can if necessary be removed later; this may be an artefact (e.g. trap), or a live host, treated with insecticide. Although not new, several developments have come together over the last 10-15 years to render bait techniques more practicable, over a wider range of tsetse habitats, than ever before. Bait systems are inherently of low environmental impact, and are relatively low-technology. It is also claimed that they are logistically less demanding than other approaches, and are capable of being adopted by local communities on self-help basis and seems increasingly likely that these techniques will form the basis for tsetse fly control in the short to medium term (Green, 1994).

Although attempts were made to control tsetse using targets impregnated with insecticide many years ago, successful application of this technique followed the production of the second-generation synthetic Pyrethroid insecticides (Deltamethrin, Cypermethrin, Cyfluthrin etc.) and the development of potent odour attractants in the last 10-20 years (Leak, 1999).

There have been important advances in the production of synthetic attractants, and various phenol mixtures in use either in trials or for practical control operations against several tsetse species. Traps and targets are a more acceptable means of controlling tsetse than either ground or aerial spraying of insecticides in terms of the direct ecological and environmental impact they might have (Leak, 1999). These approaches offer the prospect of cheaper alternatives, although they are not a simple panacea as competent supervision and management are still essential (Jordan, 1986). Most development of this method of tsetse control has concentrated on improved and cheaper designs of the target and odour attractants in order to attract as many tsetse as possible and to increase the number of tsetse actually landing on a target. Synthetic Pyrethroids are now widely used for tsetse control on impregnated traps, screens and targets (Leak, 1999). Deltamethrin impregnated odour-baited targets have efficiently

controlled *G. m. submorsitans* and *G. tachinoides* in a heavily infested area of over 1000 km^2 of the upper Didessa Valley (Keno, 1994).

The development of long-lasting formulations of Pyrethroids for use on artificial baits eventually led to these being directly applied to the surface of domestic animals, where they were shown to have a long-lasting knock-down effect on tsetse which fed on the animals under controlled conditions. One such approach has been to substitute Deltamethrin for the acaricide in regular cattle-dipping programmes, such as those in parts of Zimbabwe where substantial control of trypanosomosis in cattle was achieved over 2500km^2 without the use of other techniques (Green, 1994).

Another approach is to use a 'pour-on' (or spot-on) formulation, in which the insecticide is applied to the back of the animal and spreads over the body surface. This has been tested successfully in Kenya, Cote d'Ivoire, Zanzibar, and Burkina Faso where in the later two, *G. austeni* and *G. palpalis gambiensis* were completely eliminated from localized habitats for a time, without other control measures being applied (Green, 1994). Likewise, control trials of *G. pallidipes, G. f. fuscipes, G. m. submorsitans* and other biting flies with Cypermethrin pour-on insecticide was carried out in Ethiopia at a site with a high prevalence of multi-drug resistant trypanosomes resulted in a 98% decrease in apparent density of the main vector, *G. pallidipes*, and a 70% reduction in trypanosome prevalence in cattle (Leak *et al*., 1995). Similarly the application of Deltamethrin spot-on appeared to effectively control *G. morsitans submorsitans* and *G. tachinoides* in the upper Didessa Valley where reinvasion pressure was not high (Lemecha, 1994).

One of the latest methods of control is the Sterile Insect Technique (SIT) involving continuous release of sterile insects among the indigenous insect population at rates sufficient to result in a reduction in biotic potential of the target population. The mating of released sterile male insects with indigenous fertile female insects causes infertility in the target population (SIT, 1996).

The sterile insect technique (SIT) has been used successfully against insect pests for many years; for example, the screw-worm fly (*Cochliomyia hominivorax*) was eradicated from the south-eastern United States by the 1960s. The technique requires large numbers of tsetse of the target species to be reared in laboratory colonies and sterilized with a source of radiation while in puparia and the sterile males emerging from the puparia are released in large

numbers, over a long period, into the area from which tsetse are to be eradicated(Leak, 1999). *G. austeni* has been successfully eradicated from Zanzibar using this method. During this campaign, 60,000 irradiated male flies were being released per week. From 1995-1996, 5.5 million sterile males were released in total (Robertson, 2003). In practice, number of wild tsetse have to be reduced by other means, such as insecticide-impregnated traps or targets, before the release of sterile males so that the numbers of sterile males required are within acceptable limits (Leak,1999).

2.3.3. Use of Innate Resistance (Trypanotolerance) of Animals

Innate resistance, or trypanotolerance, has been recognized since 1906 when the ability of indigenous taurine cattle in West Africa to survive and be productive under trypanosomosis risk was observed. Both acquired and innate resistance to African trypanosomosis can occur in cattle. The two most important trypanotolerant breeds are the *Bos taurus* subtypes, N'Dama and Baoule, whilst a degree of trypanotolerance has also been shown to occur in some *Bos indicus* zebu breeds- for example, the Orma Boran (Leak,1999). The use of trypanotolerant cattle had it not been limited in availability (account only for 17% of the total cattle population of the continent), was a potential alternative strategy for coping with the problem (Erkelens *et al*., 2000).

2.4. Cost-effectiveness analysis

Cost-effectiveness analysis (CEA) is a technique of evaluation of health interventions to assist in decision making. It involves assessing the gains (effectiveness) and resource input requirements (costs) of alternative ways of achieving a given objective (Creese and Parker, 1999). Broadly, cost-effectiveness analysis is any analytic tool designed to assist a decision maker in identifying a preferred choice among possible alternatives (Dixon *et al*., 1994; Mishan, 1988; Quade, 1967; Winpenny, 1993). Whenever cost-benefit analysis which allows aggregation of all benefits expected from a programme in a monetary form becomes impossible, since the benefits can not be valued or when a unique effectiveness criterion would be used, it is useful to compare the costs of providing the beneficial outcome in different ways. The basic concepts inherent in cost-effectiveness analysis are now being applied to a broad range of problems in defence, public health and the environment (Dixon *et*

al., 1994; Layard and Glaister 1994). CEA provides a way to optimize technical efficiency of intervention.

Specifically, cost-effectiveness analysis involves comparison of alternative courses of action in terms of their objective. In cost-effectiveness analysis, we address both cost and effectiveness at the same time to rank alternatives based on cost-effectiveness ratio (i.e. cost per unit of effectiveness). In applying cost-effectiveness, three requirements must be satisfied. First, the systems being evaluated must have common goals. Second, alternative means for meeting the goals must exist. Third, the capability of bounding the problem must exist (Fabrycky and Tuesen 1974).

2.4.1. Cost concepts

Describing the economic aspects of a livestock production system essentially involves the determination of the costs and quantities of the various resources and all consequences of that system. Two distinctions can usefully be made in the analysis of resources or costs. Firstly, costs can be listed by item and the various factors of production (resources) they apply to and, secondly, they can be classified by their degree of variability into variable and fixed costs. Variable costs vary in the short run and directly with the amount of output produced, declining to zero if the output is zero. While fixed costs (capital costs) vary only in the long run and are still incurred if output is nil. They cover such annual cost items as permanent labour, rent and rates, maintenance and running, and depreciation on durable goods which last for more than 1 year. Sometimes an intermediate category of items is defined. These are integer costs, which vary with output in the medium term, such as large capital items (Putt *et al*., 1988).

Distinguishing between the variable and the fixed costs of production is important in the analysis of disease control projects, because changes in production level due to disease losses or the removal of production constraints affect costs at different levels as well as output. Usually, a reduction in mortality and morbidity will affect only the producer's variable costs, since these vary with the levels of output and thus usually with the number of animals. The variable costs most often affected are feed and veterinary costs (Putt *et al*., 1988).

2.4.2. Effectiveness and Its Indicators

Effectiveness refers to how much the result is achieved (Hornby, Cownie, and Gimson 1987). The indicators of outcome of an intervention will be changes in capacity, activity, behaviour or health of the population (which represents the final impact measurement of the programme). Ultimately, through these intermediate outputs and effects, an intervention may have a final impact on disease, health, production and well-being (Lwasa and Mwanje, 2002). Ordinarily, it is easier to establish criteria for cost than for effectiveness because costs are certain, while effectiveness more uncertain. Costs may include research and development, engineering, test, prediction, operation and maintenance. Effectiveness, on the other hand, may be measured by numerous indicators reflecting various dimensions like utility, merit, worth, benefit and gain or mobility, availability, maintainability, and reliability, which are all difficult to determine (Lwasa and Mwanje, 2002).

In general, CEA is a powerful tool in order to optimize the use of resources although it has to be applied carefully. Sensibly applied, CEA can be very helpful in providing economic evidence (criteria) towards appropriate planning of environmental protection while allowing development activities to continue (Dixon *et al*., 1994).

Cost-effectiveness can be used to determine most effective alternative. Therefore, there must be more than one alternative of achieving the required change (Mishan, 1988). CEA is appropriate for social programmes dealing with health and population as well as for the analysis of environmental effects (Dixon *et al*., 1994; Winpenny 1993). The standardized approach to cost-effectiveness evaluation involves many steps, the most important being establishing evaluation criteria for costs and effectiveness. Both fixed and variable costs will be included (Derbetin 1989).

In Cost-effectiveness ratio (CER), we rank the programmes by CER that the best is the one having lowest CER. A guideline by CCOHTA (1997) indicates that in cost-effectiveness analysis, when comparing two programmes, the incremental costs[1] are compared to the incremental outcomes[2] as measured in physical or natural units.

[1] Incremental cost (ΔC) is the difference in cost between the two programmes compared.
[2] Incremental outcome or effectiveness (ΔE) is the difference in effectiveness between the two programmes.

Natural units could range from clinical measures such as millimetres of mercury blood pressure reduction, through disability days averted, to lives saved, or life years gained. Incremental cost is the difference between the costs of two options. The ICER would help to understand how much it cost to shift (at a point) from one programme to other programme. Therefore, costs and effects must be reported as increments (i.e. the differences between two alternatives). This guideline further states that the treatment under study must be compared to one or more relevant alternative treatments, which may include a 'doing nothing' alternative (whenever relevant).

3. MATERIALS AND METHODS

3.1. The Project area

3.1.1. Location and Topography

The first block of the STEP area is situated in the Southern Rift Valley and most of the area lies within the administrative boundary of the Southern Nation Nationalities and Peoples Region. Only a small part in the east falls within the Oromiya Administrative Region. The area is bordered in the north-east by the town of Awassa and in the north-west by the town of Sodo. The mountain chain located immediately east of the towns of Yirgalem, Dilla and Chelelektu, constitutes the eastern border of the area. The area is bordered in the west by the line drawn from Sodo to the Deme River and the town of Arbaminch. The altitude ranges from below 900m above sea level in the Deme River system to above 3,000 m above sea level. Lake Abaya, with a total surface area of 1,160km^2, is situated in the middle of the survey area (Annex 12).

3.1.2. Vegetation

Vegetation in the highlands is dominated by intensively cropped fields and occasionally some coniferous trees while lowlands are characterized by acacia trees (high and low) and grasslands. Gully forests are also encountered around permanent surface waters (rivers and lakes).

3.1.3. Climate

As the climate is mainly influenced by altitude, meteorological data recorded from 1987 to 1997 at four towns located at different altitudes in the survey area Arbaminch (1,170 masl), Dilla (1,600 masl), Yirga Cheffe (1,820 masl), and Sodo (2,000 masl) are considered for this purpose. The highest values for the average monthly maximum temperature were 33.2^{0}c and 28^{0}c, recorded in the period January- March at Arbaminch and Sodo, respectively. The lowest average monthly minimum temperature recorded was 6.8^{0}c in Yirga Cheffe (January) whereas 15.9^{0}c was the lowest value recorded in Arbaminch (December) (no minimum data for Sodo).

The lowest values for the relative humidity were 33.8% in Arbaminch and 43.8% in Sodo. The amount of rain received varied likewise with the location and fluctuated between on average 908mm per year for Arbaminch to 1,450mm for Yirga Cheffe. Most of the rain was received in March and April and the driest period occurred during the months of December, January and February.

3.1.4. Human Population

According to a population census of 1994, the human population in the survey area amounts to 3.7 million (or730, 000 households) of which 91% live in rural areas. The distribution is highly influenced by environmental and climatic factors with the highlands being the most densely populated areas. Agriculture is the main occupation of the people in the project area.

3.1.5. Land use

The land use pattern is roughly 15% cultivated land and 26% cultivable land, 30% grazing and browsing, 12% shrubs and trees and 17% others. The major food crops grown in the area include maize, sorghum, teff, barley, wheat, horse bean, haricot bean, field pea, fruits, vegetables, and root crops such as Enset (false banana), potato, etc. some cash crops like coffee and cotton are also grown in some parts.

3.1.6. Livestock Population

The livestock population in the project area is estimated at close to 1 million cattle, 490,500 sheep, 371,000goats and 1.3 million poultry. Fish is also abundant in the lakes and rivers of the project area. Livestock plays an important role in the area serving as draught animal and as a source of milk, meat, cash and other uses.

3.1.7. Animal Health

Tsetse-borne trypanosomosis has been the major cause for the large land resource in the southern rift valley to remain under utilized. Almost all the livestock populations in and adjacent to the valley are at risk of acquiring the disease at any one time. The prevalence of

trypanosomosis in the project area (block 1) is found to be about 12% (Muturi *et al*. 1998) with *T. congolence*, *T. vivax*, and *T. brucei brucei* being the parasites encountered in decreasing order in the area. Trypanosomosis, therefore ranks first in causing livestock production losses and is the most feared livestock disease by the local animal rearing communities.

3.1.8. Wildlife

There is one national park in the project area, namely the Nech-sar national park. Elephant, lion, giraffe, leopard, zebra, warthog, crocodile, etc are some of the wild life found in the park.

3.2. The Trial area

The trial was carried out in an approximate area of about 10x10km (100km^2) grids selected at two sites located in two districts (Woredas) of Wolaita Zone of the Southern Nations Nationalities and Peoples' State within the Southern Tsetse Eradication Project area. The centers of the study were peasant associations (PAs) contained within the specified grids in both cases. The PAs selected were Tora-Sedebo & part of Adecha (regarded as Site I) in Damot Woyde district situated at about 36 kilometers eastward from Soddo close to Bilate river at low altitude and Abela-Mareka PA of Humbo Woreda (Site II) some 40 kilometers far South of Wolaita Soddo town on the way from Soddo to Arba Minch in the area near the great lake of rift valley (Lake Abaya) (Annexes 12-15). The coordinates of the area for site1 (Tora-Sedebo& Adecha) is $6^0$47'50"N-$6^0$52'30"N and $37^0$55'00"E or Grid H3 whereas that of Abela-Mareka is $6^0$32'00"-$6^0$37'00"N and $37^0$49'44"-$37^0$55'00"E or Grid G5. Abundance of tsetse flies, frequency of trypanosomosis cases, altitude category, vegetation type, cattle grazing land and watering point were taken as criteria to determine the ideal habitat of tsetse flies for study site selection. This was accomplished with the assistance of the project technical personnel. According to the information, supplied by the respective agricultural offices, cattle population for Site I was estimated at 1754 and that of Site II was nearly 1500. Livestock keeping is traditional type with mixed farming. All cattle encountered were East African zebu type.

Monthly weather data (total rainfall, mean monthly minimum and maximum temperature and relative humidity) for the year 2003 obtained from the nearby meteorological station at Mirab Abaya, a site considered to represent the trial places (grids), in the same lowland area indicate that; the total rainfall for the dry season months (January, February, March, April) was 7.9 mm, 8 mm, 79.8 mm and 84.7 mm respectively and for the months of wet season (May, June July, August) was 182.2 mm, 45 mm, 72 mm and 89 mm respectively. The subsequent rainfall record for months of September, October, November and December was 68 mm, 54 mm, 12 mm and 29 mm respectively. The mean monthly minimum temperature for the dry season months was 17.2^0c, 16.8^0c, 18.2^0c, and 18.5^0c. For the months of wet season it was 18.8^0c, 18.9^0c, 19.2^0c and 18.4^0c. It was also 18.30c, 17.90c, 18.20c and 18.50c for the months September, October, November and December respectively. The mean monthly maximum temperature for the dry season months was 31.3^0c, 33.3^0c, 32.1^0c, and 31.0^0c and it was 29^0c, 28^0c, 28.3^0c and 29.6^0c in the months of wet season. The record for the months of September, October, November and December was 29^0c, 29.5^0c, 30.5^0c and 30^0c respectively. The relative humidity was lowest during dry season, 45.3% in January and increased with the increasing rain fall in May, 63%.

3.3. Study methodology

3.3.1. Sampling Method:

Two strategies were applied for evaluation of tsetse and trypanosomosis control pilot trial by use of different formulations of Deltamethrin. Purposive sampling was in use as the appropriate technique employed in selecting two localities for the application of the proposed strategies while random sampling was applied to examine animals for baseline parasitological survey. Sample was determined according to Thrusfield (1995) based on the following formula.

$n = 1.96^2 \times P(1-P)/d^2$, where P is estimated prevalence, d is absolute precision and n is sample size.

3.3.2. Pre-Intervention Baseline Data Collection

3.3.2.1. Questionnaire

Before the experiment in each case, a questionnaire survey was conducted. A structured questionnaire format designed to include information about herd composition, major livestock health problems, livestock management, socio-economic profiles, sources and usage of drugs, and knowledge of control and prevention from livestock diseases, was administered to farmers in the targeted place to respond in view of that. A total of 62 household representative farmers (all male) were interviewed (i.e. 32 of them from Site I and 30 from Site II).

3.3.2.2. Entomological Data

Entomological data collection and recording had commenced with collection of baseline data on the distribution and density of tsetse before the start of the trial. Tsetse flies were sampled by deploying about 71 NG2U traps (35 at Site I & 36 at Site II) baited with three week old bovine urine and acetone in two different dispensing bottles. Traps were set at approximate intervals of 200-250 meters. All trap positions were geo-referenced (by use of hand-held GPS, Garmin 48), altitude and vegetation type recorded. It was attempted to include different vegetation types like bushland (BUL), wooded grassland (WGL), and cultivated land (CUL) for trapping. Collection of trapped flies took place after 72 hours of deployment of traps. Community was initiated to participate in trap deployment and collection to provide labour input for the proposed study. Therefore, a highly cooperating response was obtained and this collaboration was consistent throughout the course of the study.

3.3.2.3. Parasitological and Haematological Data

Parasitological data were collected from animals above one year old. A total of 323 animals (171 from site1 and 152 from Site II) were randomly sampled and examined. Records were taken with respect to age, sex and colour of the animal. Parasitological examination was conducted with blood samples collected from marginal ear veins from cattle at random using micro-haematocrit capillary tube and sealed on one side with cristaseal (Hawskely Ltd.). The capillary tube was then transferred to a haematocrit centrifuge and spun for 5 minutes at 1200 revolution per minute. The centrifuged capillary tube was examined / measured for packed

cell volume (PCV) values on the haematocrit reader and recorded to demonstrate the general health status of the animal and measure anaemia. The capillary tube was cut 1mm below the Buffy coat to include the top layer of red blood cells and the contents of the tube expressed on to a slide, mixed and covered with a 22x22 mm cover slip. This slide was then examined under x40 objective using phase contrast or dark field microscopy to examine for the presence /absence of motile trypanosomes. A total of 20 fields were examined for every slide. All sampling work was carried out in the morning 8:00 A.M. and 11:00 A.M. just before noon. Animals found positive for trypanosomes as well as showing the clinical signs were treated with curative dose of Berenil® (Diminazene aceturate) at dose rate of 3.5 mg/kg body weight intramuscularly to clear any previously contracted infections. During this time, sentinel herd of cattle (95 at site1 and 75 at Site II) were selected and ear-tagged in each site for subsequent monitoring of the disease incidence. Appropriate data was taken and recorded at every step.

3.3.3. Intervention Study

3.3.3.1. Insecticide Impregnated Odour-Baited Targets (Site I)

The control strategy applied in Site I was insecticide impregnated odour-baited targets using 0.4% Deltamethrin. For impregnation, the chemical used was Glossinex 200 Sc (200 gm/litre). This was Deltamethrin Sc 20 %(W/V %) (Appropriate Applications limited (USA)) residual insecticide for tsetse control. One litre of 20% W/V contains 200 grams of active ingredients (a. i.). According to the company's recommendation, in order to have 6-8 months residual action, the 20% Sc (Suspension concentrate) of Deltamethrin was diluted into 0.4% and used to impregnate targets (blue-black-blue) made up of 110x70 cm cotton fabric. Thus, the strength of the original concentrate (20%) is divided by the strength required for the final application (0.4%) and then by subtracting 1 from the result, the number of litres of water that should be added to 1 litre of the original would be obtained (FAO, 1992b).

Based on this, (20/0.4)-1 = **49** litres of water was added to **1** litre of original strength.

Both sides of the target were treated covering the entire area at a rate of 600ml/ target with the diluted liquid. The impregnated targets were deployed at a density of 4 targets per square kilometre where they were placed at approximately 250 m apart. A total of 460 impregnated targets were deployed by the community participation assisted by technical staff. Acetone was

the odour used in this case. Replenishment of odours for the targets was done three months after initial deployment.

3.3.3.2. Pour-On Application (Site II)

A strategy with pour-on technique was applied to evaluate its comparable efficacy at Site II. In this case, nearly one-third of the cattle in the area excluding calf below the age of 1 year were mass treated with Deltamethrin 1% W/V pour-on ready for use formulation (Appropriate Applications Ltd (USA)) at a dose rate of 10ml/100kg body weight by applying along the midline or the spine of the animal using automatic applicator. Pour-on application was subsequently repeated after a month for the first round visit and then continued on monthly basis throughout the whole monitoring period. The numbers of treated animals during the 1st, 2nd, 3rd, 4th and 5th treatment rounds were 409, 432, 350, 420 and 600 respectively.

3.3.3.3. Intervention Monitoring

Entomological monitoring was conducted every month by deploying traps (NG2G) at previous sites of catch using odours (acetone and bovine urine).

Parasitological and haematological examination was subsequently conducted every month by blood sampling from sentinel cattle for 5 months (mid October, 2003 to early April, 2004). The same methodology as to pre-intervention survey was applied for parasitological examination. Animals found positive for trypanosomes as well as those with clinical signs were treated with curative dose of Berenil® (Diminazene aceturate) at dose rate of 3.5 mg/kg body weight intramuscularly.

3.3.4. Cost-Effectiveness of the Trial

With regards to the sources of valuation, costing was based on the preliminary assessment of the information obtained from the different sources. Data for this purpose was obtained from records and some procurement information from Ethiopian Science and Technology Commission (Southern Tsetse Eradication Project, STEP). Information was also obtained from local markets. In general, it would be worthwhile if all categories of direct and indirect cost expenses in research and intervention were included; however, there were limitations of

information sources to obtain all these components of required categories. Therefore, direct costs associated with the intervention under consideration were applied to estimate the inputs considered.

Fixed assets involved during the intervention work were associated with the monitoring of disease status such as microscope, haematocrit centrifuge, haematocrit reader, and vehicle as well. Since the intervention was underway for about six months which was a short time frame activity, it was preferred to use renting cost of a vehicle and other capital costs as equivalent to economic values of the use of the resource as recommended from the literature. It was also supposed as appropriate to obtain microscope, micro-haematocrit centrifuge and haematocrit reader by purchasing from market and considering the value of its use for six months and therefore, the cost estimation was determined for this time period considered by annualizing the purchasing cost which therefore encompasses both depreciation and opportunity cost of the capital invested. For this purpose, the methodology relied on ranking of listed items. And thereafter, cost items with relatively lower values were generally put into one category and a 10% value of their price was considered to adjust for some incidentals. The occurrence of variation in such items within a short time period wouldn't be generally anticipated to bring about a significant variation in the overall cost under consideration.

On the other hand, high ranking costs like the items being utilized for direct intervention purpose were estimated with different ranges of valuation within the market available. Falls or rises in the prices of such items might create a significant impact in the overall progress of the project be it short-term or long-term. Therefore, the prices of traps, targets, chemicals & medicines and some assets were viewed in such a way. Then, calculation of the cost took various ways i.e. taking reasonable varied outliers; minimum, maximum and average prices in conducting sensitivity analysis. In addition, great emphasis was given to the cost expenses associated with the work in both strategies to reveal the change in cost expense brought about by intervention. Simultaneously, cost expenditures to achieve the effectiveness at first monitoring was differently calculated and compared. Though costs seem to include all the cost expenses incurred (intervention and research[3]) during the period, it was intended to include the intervention component of the cost only.

[3] To measure and control effectiveness of the objective we have put a protocol in place. But when research has proven effectiveness, only routine intervention should be reproduced at very lower cost.

The unit of the cost considered was presented by converting in to the equivalent amount in USD (1 USD = 8.809 Birr). All costs incurred to one strategy are extra costs as compared to doing nothing scenario (which is comparator).

Effectiveness in the present work was regarded as the results of intervention based on reduction in the apparent density of tsetse fly population (number of flies caught per trap per day)and decline in the disease (trypanosomosis) due to intervention underwent as compared to the pre-intervention (doing nothing) results. The result obtained due to reduction in the apparent density of tsetse fly population was of course, one of the targets to be achieved; however, this does not necessarily imply to disease reduction and therefore couldn't be taken as criteria for final effectiveness. And thus, the best indicator justified was decline in the disease magnitude.

3.4. Statistical Analysis

Information was obtained by questionnaire administration using structured format just before the entomological and parasitological data collection. Descriptive statistics was used to summarize and evaluate questionnaire data. For the detailed analysis, all sorts of entomological and parasitological raw data were stored into a computer program Microsoft Excel Spreadsheet. During statistical analysis, data in the Microsoft Excel Spreadsheet was edited and then imported into the statistical software called Intercooled Stata 7.0 for Windows 98/95/NT (Stata Corporation, Texas, USA) for different ways of analysis and showing the significance of results. Relative abundance (apparent density) of tsetse was calculated as the average number of flies (males and females) caught per trap per day. The pre-intervention entomological data (trap catches) were compared by Student's t-test while parasitological data by chi-square test. Association of PCV values with regards to parasitaemic status of animals was tested by Chi-square distribution. Differences between PCV value measurements of individual animals of the pre-intervention were assessed by using one way Analysis of Variance (ANOVA).

Intervention results in the relative abundance of fly population were assessed for each study site, vegetation type using descriptive statistics as well as Student's t-test. The trends of drop in catch rate for the two sites were compared to obtain the efficacy of the strategies applied.

The data were finally presented by calculating the de-transformed means (Geometric means). From the tsetse catch data worked out using log $_e$ transformation (geometric mean), the rate at which tsetse reduction achieved was calculated by using the pre- intervention data as compared to last monitoring. This was obtained by using the formula:

Efficacy % of a strategy = ((C-T)/C) x100, Where C is the pre-trial relative abundance of vector under consideration and T is the post intervention relative abundance of the considered vector. Logarithm transformed means (geometric mean) was appropriate in so doing (Thrusfield, 1995). In this case, moving average was used as the post-intervention relative abundance in carrying out the efficacy percentage calculation.

The situation of the disease during intervention was assessed by calculating the incidence rates of each monitoring month and calculating the rate of reduction in the disease status by descriptive statistics and then the use of McNemar's test was justified. In addition to this, the mean PCV value of sentinel animals before and after intervention was evaluated by the use of Student's t-test for related samples. Animals given Diminazene aceturate (whenever parasitaemic) were considered to be protected during the subsequent two weeks, and were therefore excluded from population at risk during the next calculation of incidence. The incidence rate of trypanosome infection at each monitoring visit was calculated from the ratio of the numbers of new cases of trypanosome infections in each site of sentinel cattle to the average number of cattle (animal)-months at risk of the particular monitoring visit. Only new cases were considered when calculating the incidence rate. The prevalence corresponding to each visit was also estimated from the results of incidence rate and the duration of time (where prevalence is small) (Thrusfield, 1995).

Economic assessment based on incremental cost-effectiveness (ICER) comparison among the two strategies was carried out for the interventions. There are two steps in calculating incremental cost-effectiveness ratio (ICER). It was determined by calculating the ratio of difference in the cost of two options to the difference obtained in effectiveness (change in disease magnitude) between two options. This could either be the difference before and after intervention (i.e. intervention compared to doing nothing) or the difference between two intervention strategies being compared which help to discuss a shift from one strategy to another (the most efficient given CER ranking). The first step is calculating the change in the cost due to intervention compared to doing nothing which can mathematically be presented as follows:

$\Delta \mathbf{C} = \mathbf{Ct_5} - \mathbf{Ct_0}$, where Δ**C** is the change in cost expense (extra cost) brought about by intervention; $\mathbf{Ct_5}$ is the total cost expenditure due to intervention and $\mathbf{Ct_0}$ is the cost expense before intervention (doing nothing).

In the same way, the change in cost expenditure during the first monitoring was also calculated as:

$\Delta \mathbf{C} = \mathbf{Ct_1}\text{-}\mathbf{Ct_0}$, for all ranges and components to be assessed.

Since $\mathbf{Ct_0}$ (cost for doing nothing) was nil as far as government is concerned then the difference in the cost would be the cost which is added due to intervention and therefore represent an incremental cost due to the intervention.

On the other hand, change in effectiveness criteria can be obtained mathematically by:

$\Delta \mathbf{E} = \mathbf{Et_5} - \mathbf{Et_0}$, corresponding the first step above, where

E stands for effectiveness and t for time (before or after)

$\mathbf{Et_0}$ is the prevalence of disease before intervention (doing nothing),

$\mathbf{Et_5}$ is the prevalence of disease after intervention and

Δ**E** is the change in the prevalence of disease before and after intervention.

And also $\Delta \mathbf{E} = \mathbf{E_1} - \mathbf{E_2}$, corresponding the second step above.

Where, $\mathbf{E_1}$ effectiveness at Site I, $\mathbf{E_2}$ effectiveness at Site II and ΔE change in the effectiveness between two sites.

Finally,

ICER = Δ**C**/Δ**E**, for the first step calculation

Where, **ICER** is incremental cost-effectiveness ratio,

Δ**C** is change (increment) in cost expenditure due to intervention,

Δ**E** is change in effectiveness due to intervention.

4. RESULTS

4.1. Pre-intervention

4.1.1. Questionnaire

Substantial information was obtained from both sides with regards to the most common diseases in the area, way of transmission, and signs of the disease which could contribute to the scientific conclusion about the disease in the area. All respondents ranked trypanosomosis as a serious drawback in their livelihood. The farmers claimed trypanosomosis to cause reduced appetite, starring hair coat, diarrhoea, emaciation, coughing, weakness and loss of draught power. In addition, information obtained indicated that the average cost expense per treatment of a single mature animal (preferably cattle) was about 7.20 Ethiopian Birr at Site I while it was 5.10 Ethiopian Birr at Site II. Each family loses an average cost expense of about 298.9 Ethiopian Birr and 231.00 Ethiopian Birr per year in Sites I and II respectively. About 36 (58%) of the respondents were able to link the disease to dry season whereas 25(40%) of them answered as they did not recognize any difference in the disease magnitude between either of the seasons. Yet all respondents have agreed that the disease was getting worse throughout its occurrence history in the place. Regarding to the preference for control methods to be applied to the sustainable control of the problem, about 55(88.7%) of them demanded live bait (Pour-on) as a best strategy. Though most of them heard about insecticide impregnated odour-baited targets as a control alternative to the problem, only a small proportion recognized its importance. Related responses like important disease types occurring in the area, frequency of usage and administration of trypanocidal drugs per animal per year and cattle mortality experiences on the basis of proportion of respondents were indicated (figures 1- 4).

Figure 1. Important livestock diseases at Site I

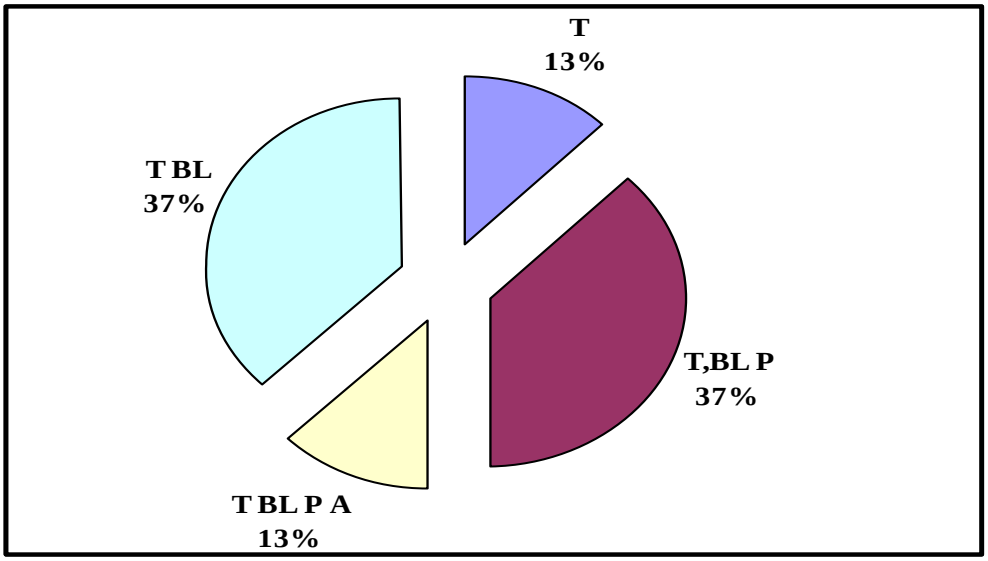
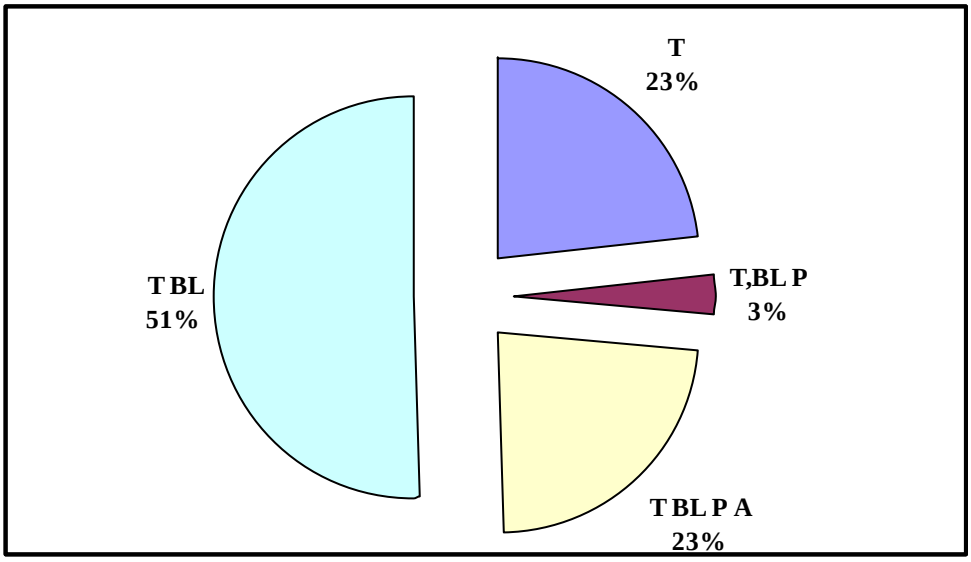


Figure 2. Important livestock diseases at Site II



T: Trypanosomosis

BL: Blackleg

P: Pasteurellosis

A: Anthrax

Figure 3. Cattle mortality due to trypanosomosis in the study areas.

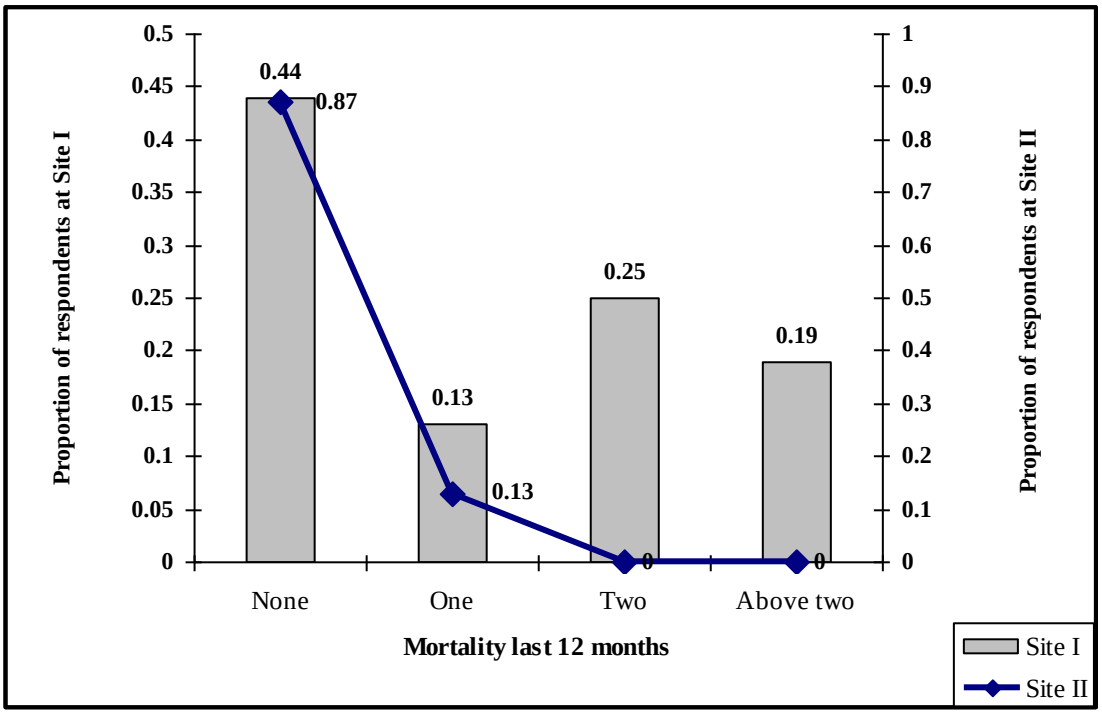
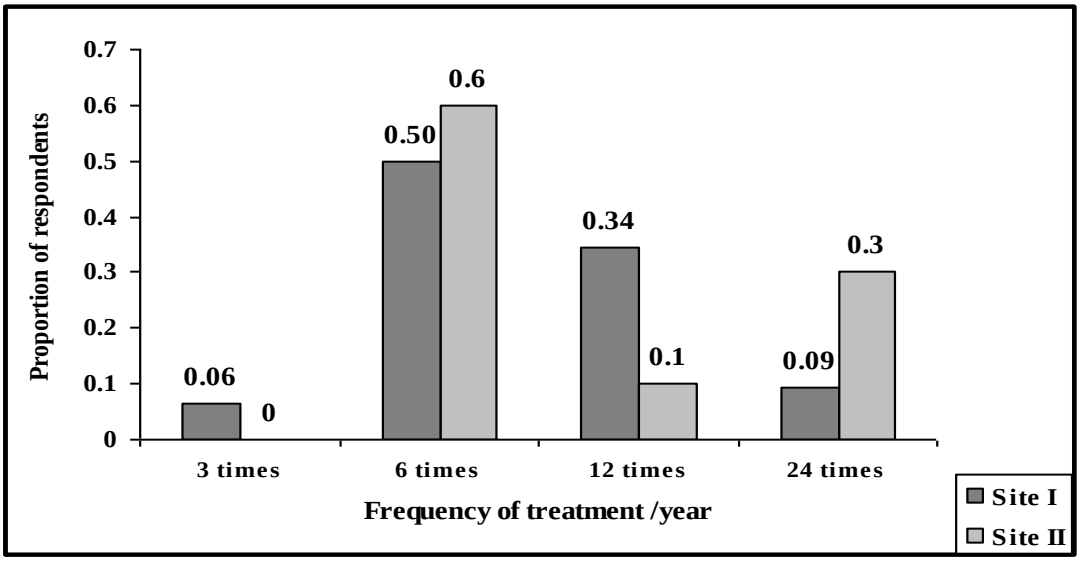


Figure 4. Frequency of treatments against trypanosomosis



About 25 (40%) of the respondents indicated that they treat their animals at home by purchasing trypanocidal drugs from local markets. This was opted because they had no way of treating their animals whenever they get illness due the greatly frightening trypanosomosis and they are placed far away from veterinary clinic.

4.1.2 Entomological Survey

Only *G. pallidipes* was the species of tsetse detected during the study. The results showed that majority of the traps deployed in both Sites caught both tsetse and biting flies. The relative abundance (apparent density) of tsetse flies in Site I was 1.35 flies per trap per day while that of Site II was 0.91flies/trap/day (Table 1).

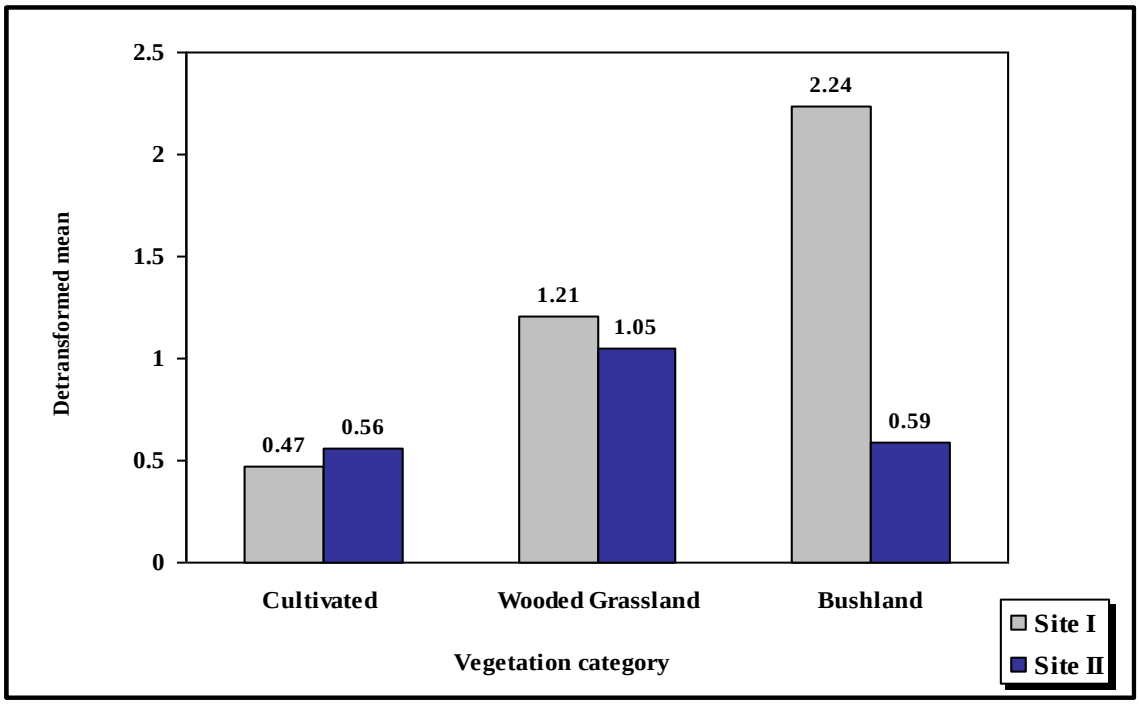
Table 1. Entomological baseline survey result recorded in both study sites.

Site	**No. of traps**	**Catch result**				
		Tsetse species	**Male**	**Female**	**Total**	**R.A. (95% CI)**
I	35	*G. pallidipes*	62	80	142	1.35 (0.909- 1.796)
II	36	*G. pallidipes*	26	72	98	0.91 (0.712-1.103)
Total	**71**		**88**	**152**	**240**	**1.12**

R.A: relative abundance of tsetse fly /trap/day; CI: 95% confidence interval

The magnitude of the catches did not show statistically significant difference (Student's t-test, Df (69); $P > 0.05$) between the two Sites of study. Higher mean catch (57.19%) was recorded in the bushland category of vegetation type in Site I followed by wooded grassland vegetation category (30.88%) while relatively more catch result was in the wooded grassland vegetation category of Site II and the rest strata having similar catch results (Figure 5).

Figure 5. Pattern of tsetse fly catch in different vegetation categories of both sites.



Of the total 240 flies caught during the pre-intervention survey, 88 (36.8%) were males and the rest 152 (63.2%) were females showing significantly higher picture than a 50:50 distribution (χ^2= 7.56; P< 0.01).

4.1.3. Parasitology

Out of 171 cattle sampled and examined from study Site I, 39 of them were positive for three kinds of trypanosome species accounting for a prevalence rate of 23% (95% CI: (0.17-0.29)) (Figure 6) whereas 32 animals out of 152 examined were positive accounting for a prevalence rate of 21% (95%CI: (0.15-0.27)) in study Site II (Figure 7).

Figure 6. Proportion of animals infected at pre-intervention baseline survey at Site I.

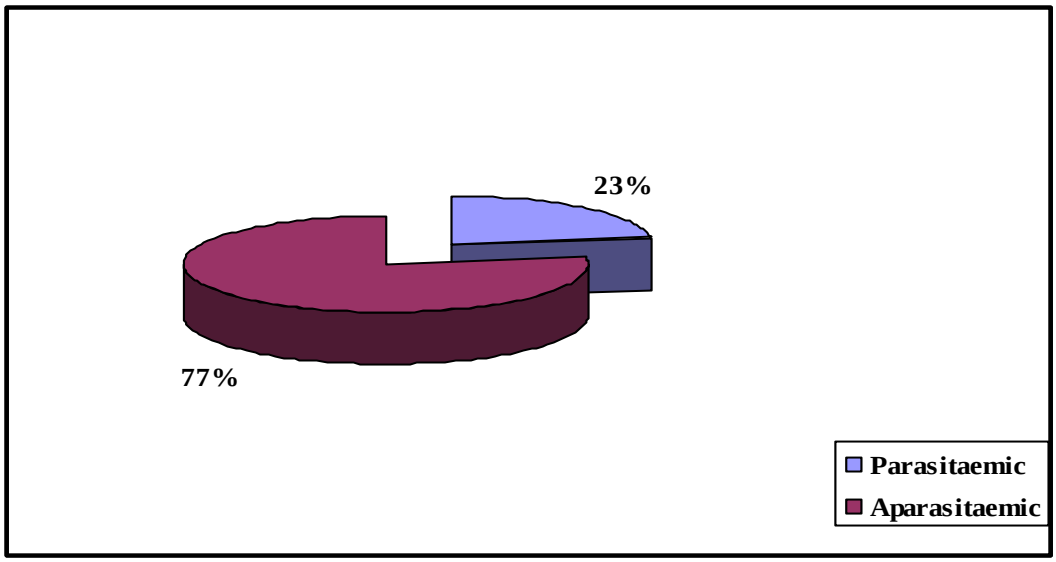
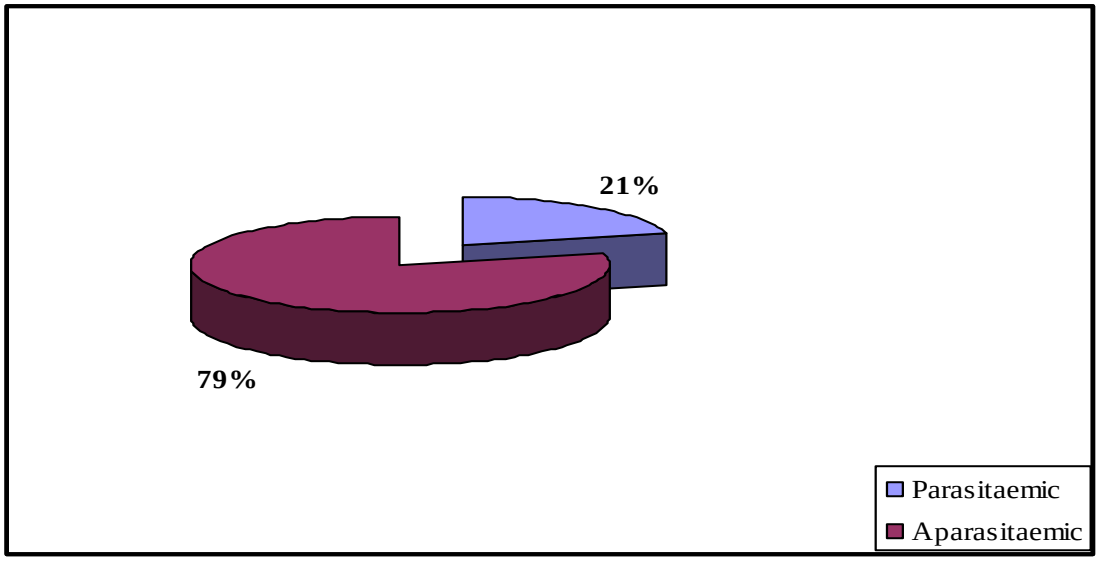


Figure 7. Proportion of animals infected at pre-intervention baseline survey at Site II



With regards to the relative abundance of the species of trypanosomes detected *Trypanosoma congolence* had a higher frequency of 49 accounting for 70% of all infections detected

keeping the highest proportion in both sites and followed by *Trypanosoma vivax* (20%), *Trypanosoma brucei* (8%) and mixed infections (2%) (Table 2).

Table 2. Infection rate recorded with different types of trypanosomes in both sites.

Trypanosome species	**Study Site I**		**Study Site II**		**Total**	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
T. congolence	29	74	20	63	49	70
T. vivax	8	21	6	19	14	20
T. brucei	2	5	4	13	6	8
T.c +T.v	0	0	1	3	1	1
T.c + T.b	0	0	1	3	1	1

T.c: Trypanosoma congolence; T.v: Trypanosoma vivax; T.b: Trypanosoma brucei

The overall parasitaemic status of animals examined from both study sites was evaluated by the use of chi-square test and the difference in the proportion of infection between them was found to be statistically insignificant (P>0.05; OR=1.107955 , 95% CI (0.632-1.951)).

4.1.4. Haematology

In this study, a PCV measurement of 25% was regarded as a threshold value. Chi-square test was applied to evaluate the presence of association between disease and mean PCV values. For study Site1, a highly significant association was observed between mean PCV values (Table 3, Figure 8) and occurrence of parasitaemia (χ^2 =56.25; P<0.01; OR= 0.03 (CI: 0.0038-0.122)). In the same manner, a highly significant association of PCV result to the presence of infection was noticed in the similar treatment conducted for study Site II (χ^2 = 23.27; P < 0.01; OR = 0.1579(CI: 0.055-0.376)) (Table 4, Figure 8).

Table 3. Frequency distribution of PCV values with regard to the threshold value (25%) in examined animals at Site I.

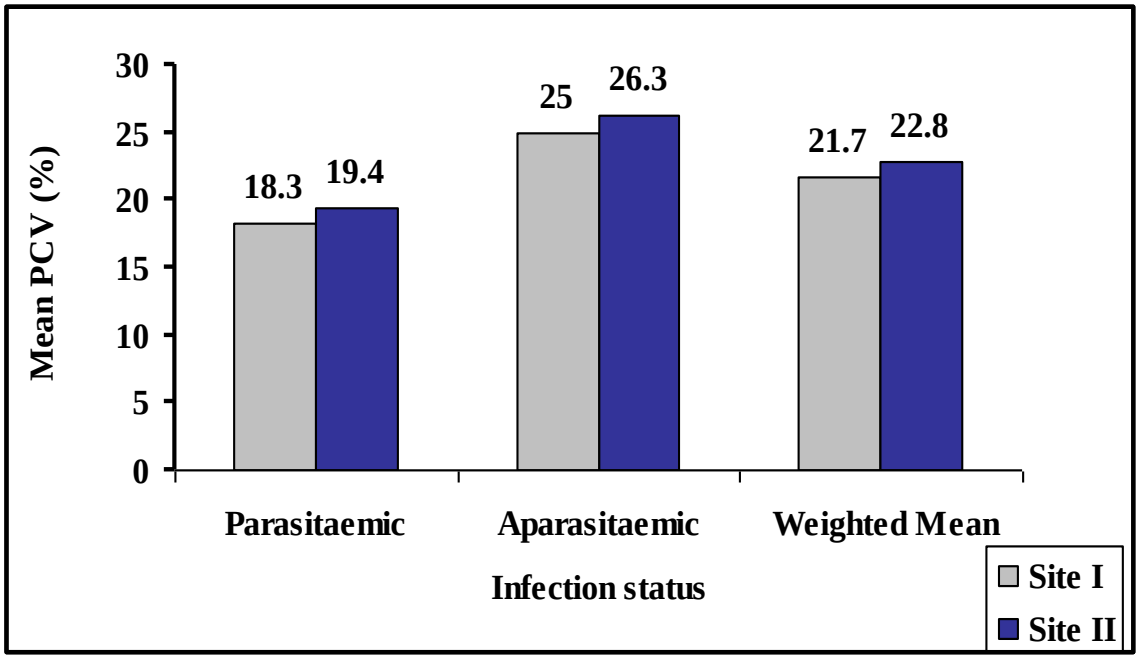
Infection status	PCV< 25%	PCV ≥ 25%	Total
Parasitaemic	37 (21.64%)	2 (1.17%)	39 (22.81%)
Aparasitaemic	61 (35.68%)	71 (41.5%)	132 (77.19%)
Total	98 (57.31%)	73 (42.69%)	171

Table 4. Distribution frequency of PCV values with regard to the threshold value (25%) in examined animals at Site II.

Infection status	PCV< 25%	PCV ≥ 25%	Total
Parasitaemic	26 (17.11%)	6 (3.95%)	32 (21.05%)
Aparasitaemic	38 (25%)	82 (53.95%)	120 (78.95%)
Total	64 (42.11%)	88 (57.89)	152

The individual animal level PCV values recorded were further subjected for statistical treatments using one way Analysis of Variance (ANOVA) and as result aparasitaemic animals had significantly higher mean PCV values (25.65% (95%CI:25.17-26.13); $F_{1,321}$=158.31; P<0.01) than parasitaemic animals (18.8% (95%CI: 17.74-19.87)) (Figure 8).

Figure 8. Mean PCV values of parasitaemic and aparasitaemic animals during pre-intervention survey.



4.2. Intervention study

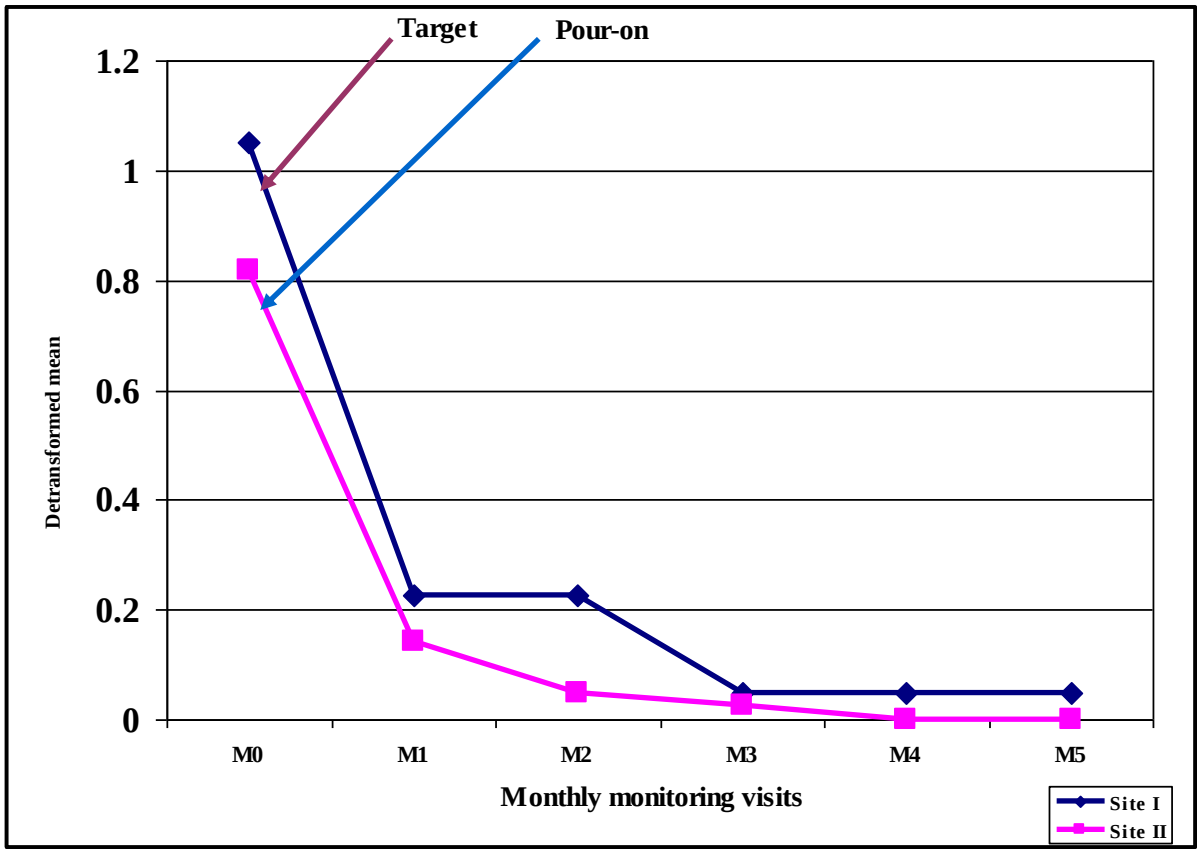
4.2.1. Entomological Results

Student's t-test was applied to evaluate the significance of decline in the catch of tsetse flies in both sites during last monitoring as compared to the pre-intervention catch. In both sites a statistically significant (i.e. Site I: $P < 0.01$ and Site II: $P< 0.01$) reduction was revealed (Figure 9). However, the difference between the results recorded at final monitoring of both cases was insignificant ($P>0.05$).

Efficacy % strategy (Site I) = ((1.051- 0.11685)/1.051)*100= **88.88%**

Efficacy % strategy (Site II) = ((0.8177-0.04185)/0.8177)*100=**94.88%**

Figure 9. Changes in tsetse fly catch record during Pre-intervention and after intervention.



4.2.2. Parasitological Results

Result assessment of the status of parasitaemia during the intervention phase indicated that there was a slow reduction pattern in the incidence rate of trypanosomosis among the sentinel animals in both study places (Site I & II).

Table 5. Sequential parasitological monitoring result of sentinel cattle recorded at Site I.

Monthly visits	Number of animals			Incidence	
	Examined	Animal months at risk	Infected	Rate	Cumulative
1	91	93	10	0.1075	0.1019
2	63	154	9	0.058	0.056
3	49	168	5	0.03	0.03
4	45	188	5	0.027	0.027
5	44	220	4	0.018	0.018

Table 6. Sequential parasitological monitoring result of sentinel cattle recorded at Site II

Monthly visits	Number of animals			Incidence	
	Examined	Animal-months at risk	Infected	Rate	Cumulative
1	65	70	7	0.10	0.095
2	58	122	3	0.025	0.025
3	45	154	3	0.0195	0.019
4	42	174	3	0.017	0.017
5	42	210	2	0.0095	0.0095

The monthly monitoring results (cumulative incidence rate of trypanosome infection) in cattle of both sites were presented in tables 5&6 above. Based on descriptive comparison applied to evaluate the magnitude of decline in the risk of infection during intervention, 83.25% reduction was achieved in the incidence rate of trypanosome infection in Site I and 90.5 % reduction in Site II throughout the intervention period. The corresponding prevalence estimated for the first and last monitoring at Site I is 11% & 9% while the same results for Site II is 10% & 4.75% respectively. Therefore, it was noticed that decline of prevalence was significantly associated with the progress of intervention when the pre-intervention

parasitaemic status was compared with the first monitoring result (χ^2 = 104.82, P< 0.01, OR=13.2 (95% CI= 6.955547-28.16911) and the final monitoring result (χ^2=120.47, P< 0.01, OR= 33 (12.5888-122.9004) at Site I (Figure 10). The same type of assessment to the results recorded at Site II revealed that there was a highly significant relationship between the decline of the status of parasitaemia and progress of intervention i.e. pre-intervention to first monitoring (χ^2= 100.54, P<0.01, OR= 17.14286, 95% CI (8.068977- 43.55224) and pre-intervention to the last monitoring (χ^2=14.13, P<0.01, OR= 60, 95% CI (16.25108 501.2231) (Figure 11).

Figure 10. Pattern of reduction in the incidence of disease during intervention at Site I.

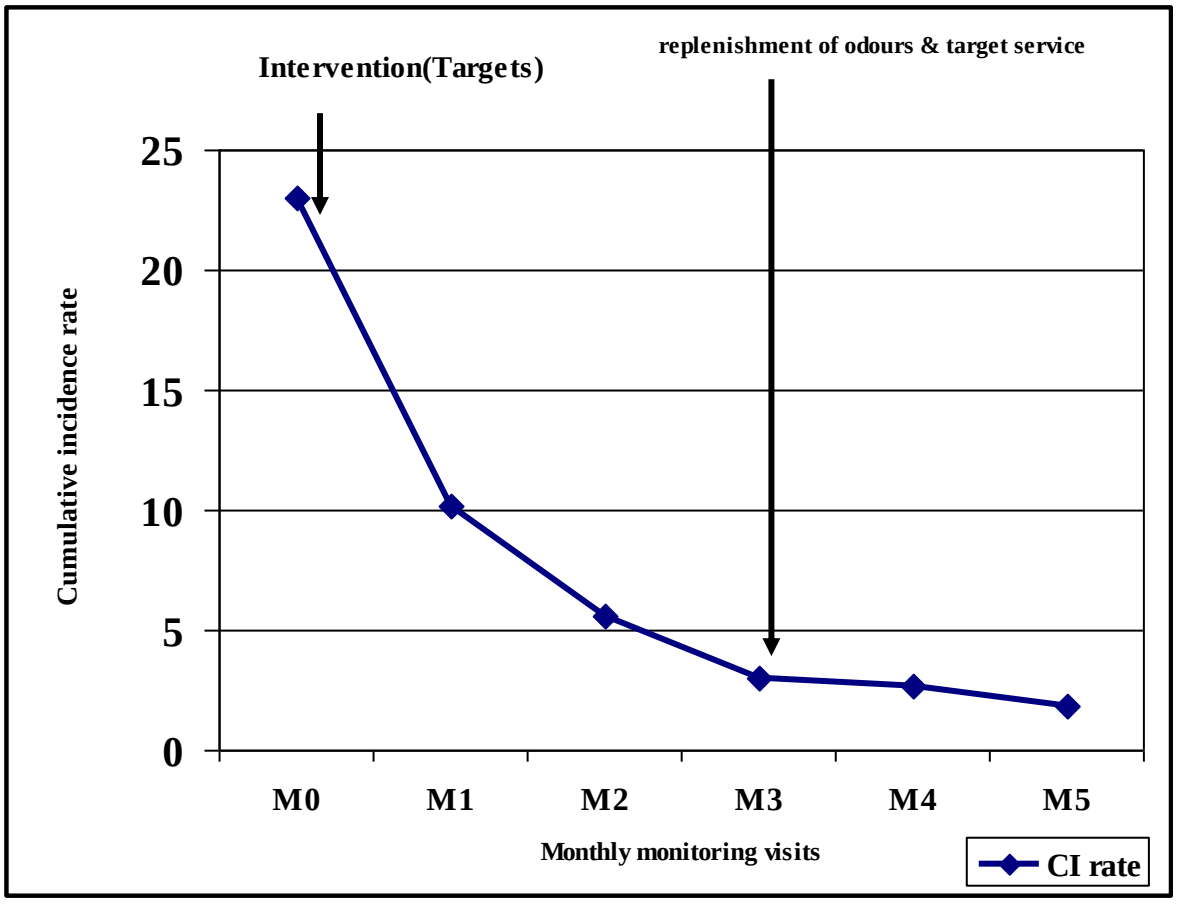
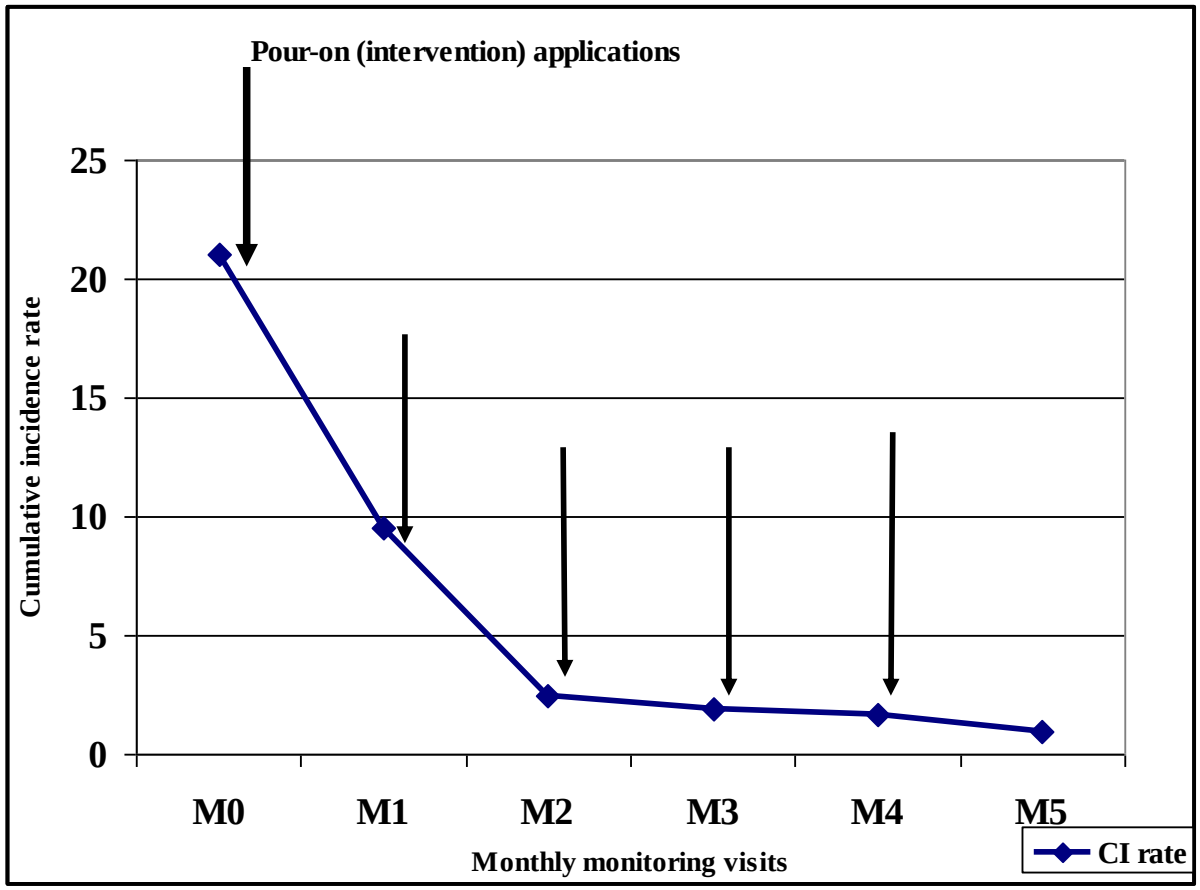
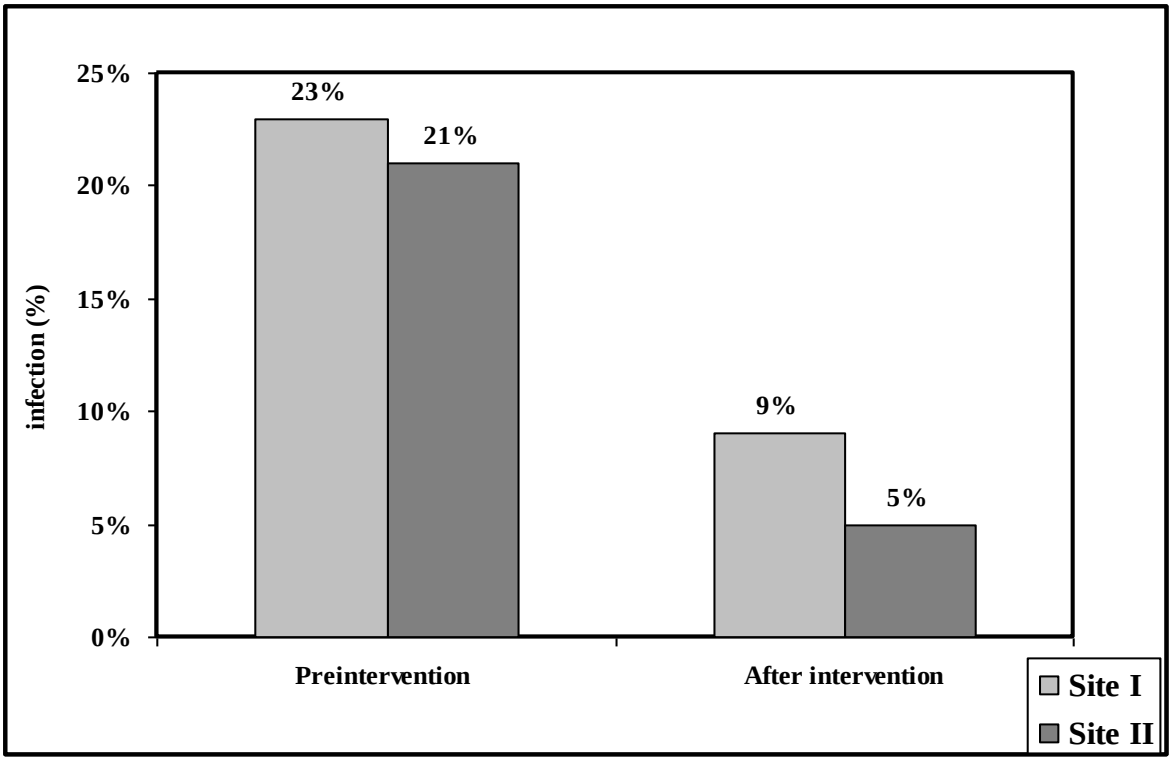


Figure 11. Pattern of reduction in the incidence of disease during intervention at Site II



From the result, the pre-intervention trypanosomosis prevalence of 21% had dropped to 4.75% at post intervention with a 77.4% overall reduction attained in study Site II (Figure 12). Even, this reduction was evident as compared to first monitoring visit result (10%) which had almost declined by half finally dropping to 4.75%(52.5% reduction). While, the same treatment of the results from study Site I have shown an apparent reduction in the proportion of animals becoming parasitaemic i.e. 23% prevalence rate of the pre-intervention study declined to 9% at post intervention monitoring (60% overall reduction).

Figure 12. Comparison of prevalence rates before and after intervention.



4.2.3. Haematological Results

Application of paired t-test to assess the magnitude of change occurred in the mean PCV value of animals examined at site I showed an obvious difference (paired $t_{(213)}$, $P<0.01$) with a statistical significance, and Site II had also proved a highly significant increment in the monthly mean PCV value (paired $t_{(192)}$, $P<0.01$).

Figure 13 below shows the increment in the mean PCV value at Site I which has followed nearly continuous pattern, while the mean PCV values recorded at Site II (Figure 14) had shown continuous increment only until the third month of monitoring visit and then after maintained a slightly stable situation during the rest visits as compared to Site I.

Figure13. Comparison of mean PCV values showing improvement during the intervention period at Site I.

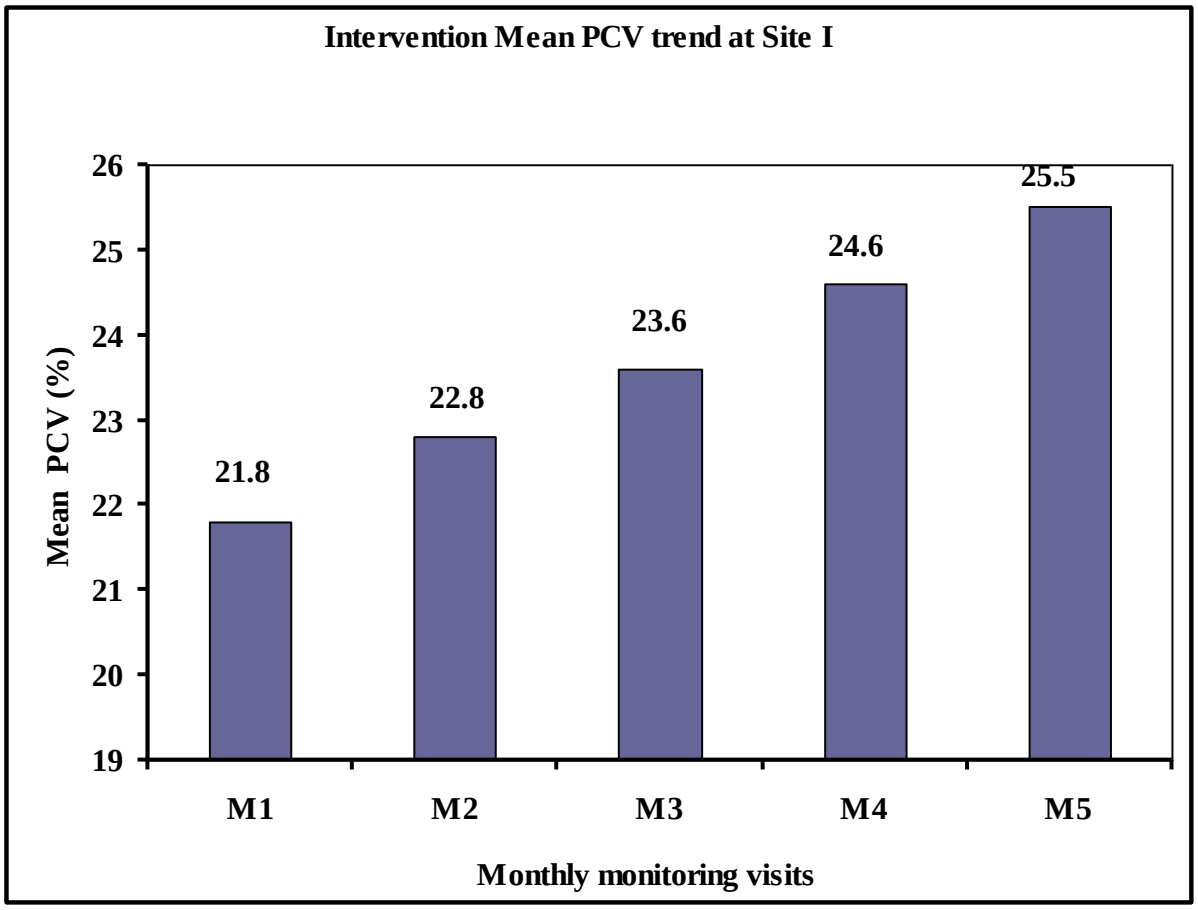
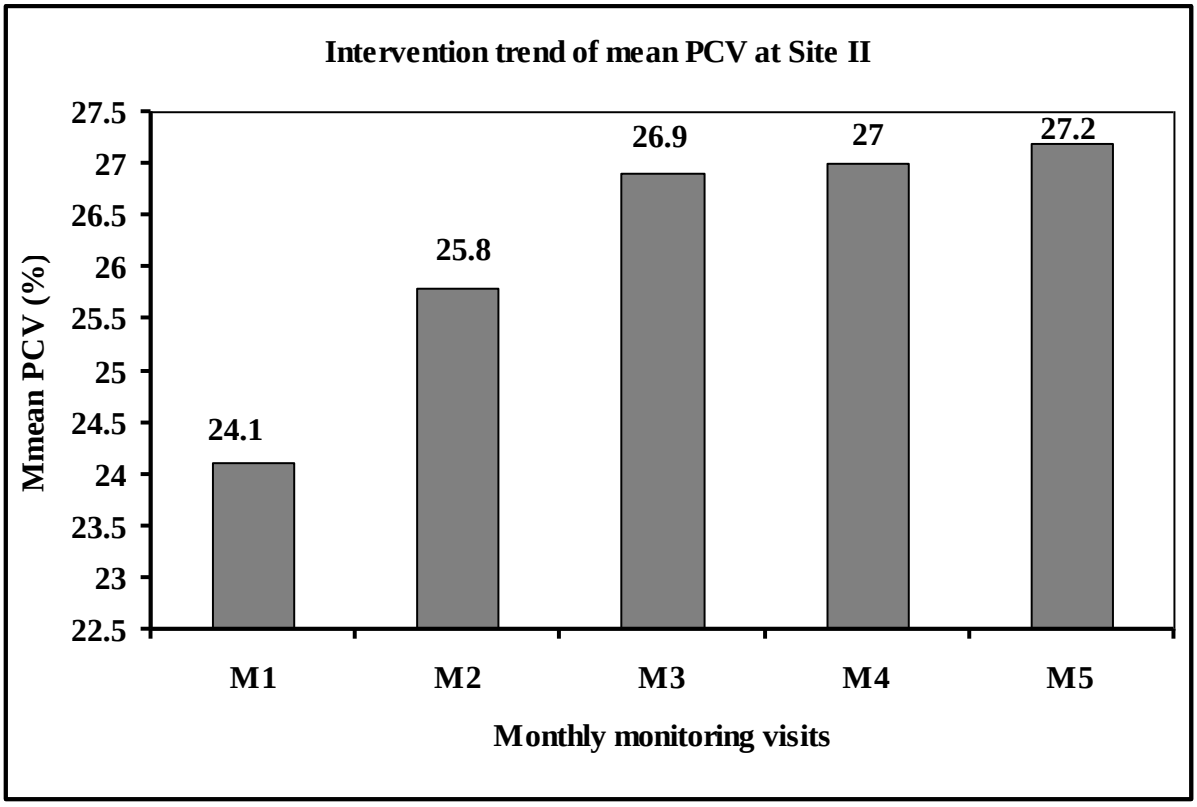


Figure 14. Comparison of mean PCV values showing improvement during the intervention period at Site II.



4.3. Cost-effectiveness analysis for the intervention

4.3.1. Costs

I) From the Governments perspective

Overall cost estimation (Annex 16):

Table 7 Cost range estimation for the whole activities undertaken at Site I

Items	Unit	Quantity	Unit price/Birr		Minimum /Birr	Maximum /Birr	Average /Birr
			Min	Max			
Target**	Pcs	460	17.62	21.14	8,104.28	9,725.14	8,995.75
Trap*	Pcs	50	40	100	2,000.00	5,000.00	3,500.00
Acetone**	litre	38	125	150	4,750.00	5,700.00	5,225.00
Deltamethrin 20%SC**	litre	6	1761.8	1850	10,570.8	11,100.00	10,835.4
Diminazene aceturate*	sachet	269	5	8	1,345.00	2,152.00	1,748.50
Vehicle rent*		46days	500.00	1000.00	23,000.00	46,000.00	34,500.00
Equipments*					2,258.70	2,484.57	2,371.64
Assets used *					1,604.00	1,916.00	1,760.00
Total					**53,632.38**	**84,077.7**	**68,936.29**
In USD* **					**6,088.36**	**9,544.52**	**7,825.67**

(*): Local market price information

(**): imported items;

(***):1USD = 8.809 Birr

Table 8 Cost range estimation for the whole activities undertaken at Site II

Items	Unit	Quantity	Unit price/Birr		Minimum value/Birr	Maximum value/Birr	Average /Birr
			Min.	Max.			
Trap*	Pcs	50	40	100	2,000.00	5,000.00	3,500.00
Acetone**	litre	8	125	150	1,000.00	1,200.00	1,100.00
Diminazene Aceturate*	sachet	146	5	8	730.00	1,168.00	949.00
Deltamethrin 1% **	litre	44	390	405	17,160.00	17,820.00	17,490.0
Vehicle rent*		37days	500.0	1000.00	18,500.00	37,000.00	27,750.0
Equipments*					2,575.20	2832.72	2,703.96
Assets*					1,604.00	1916.00	1,760.00
Total					**43,569.2**	**66,936.7**	**55,252.9**
In USD* **					**4,945.99**	**7,598.67**	**6,272.33**

(*): Local market price information used

(**): imported item;

(***): (1USD= 8.809Birr)

Table 9 Costs breakdown for strategy at Site I

Items	Minimum expense		Maximum expense		Average expense	
	Research	intervention	Research	intervention	research	intervention
Trap	2,000.00	-	5,000.00	-	3,500.00	-
Target	-	8,104.28	-	9,725.14	-	8,995.75
Acetone	1,000.00	3,750.00	1,200.00	4,500.00	1,100.00	4,125.00
Deltamethrin 20%SC	-	10,570.8	-	11,100.00	-	10,835.4
Diminazene aceturate	-	1,345.00	-	2,152.00	-	1,748.50
Vehicle rent	15,000.0	8,000.00	16,000.0	30,000.00	15,500.0	19,000.00
Equipments	2,258.70	-	2,484.57	-	2,371.64	-
Perdiem†	3,220.00	8,906.00	3,542.00	9,796.60	3,381.00	9,351.30
Labour ±	555.00	-	610.50	-	582.75	-
Fuel & lubricants	3,416.58	843.00	3,758.24	927.30	3,587.41	885.15
Assets	1,604.00	-	1,916.00	-	1,760.00	-
Grand total	**29,054.3**	**41,519.08**	**34,511.3**	**68,201.04**	**31,782.8**	**61,019.31**
In USD	**3,298.25**	**4,713.26**	**3,917.73**	**7,742.2**	**3,607.99**	**6,926.93**

(†): Scale of Ethiopian Government

(±): Wage rate Birr 5.00 at Study Sites

Table 10. Costs breakdown for strategy at Site II

Items	Minimum expense		Maximum expense		Average expense	
	Research	intervention	Research	intervention	research	intervention
Trap	2,000.00	-	5,000.00	-	3,500.00	-
Acetone	1,000.00	-	1,200.00	-	1,100	-
Diminazene aceturate	-	730	-	1,168.00	-	949.00
Deltamethrin 1% pour-on	-	17,160.00	-	17,820.00	-	17,490.00
Vehicle rent	12,500.00	6,000.00	25,000.00	12,000.00	18,750.0	9,000.00
Equipments	2,475.20	300.00	2,502.72	330.00	2,388.96	315.00
Perdiem	2,590.00	5,432.00	2,849.00	5,975.20	2,719.50	5,703.60
Labour cost	75.00	-	82.50	-	78.75	-
Fuel& lubricants	2,225.96	1,205.49	2,448.60	1,326.04	2,337.26	1,265.76
Assets	1,604.00	-	1,916.00	-	1,760	-
Grand total	**24,470.00**	**30,827.49**	**40,998.82**	**38,619.24**	**32,634.5**	**34,723.36**
In USD	**2,777.86**	**3,499.55**	**4,654.20**	**4,384.06**	**3,704.67**	**3,941.8**

4.3.2. Effectiveness

The effectiveness determined in both of the study sites is as follows.

Effectiveness for Site I

The prevalence of trypanosomosis recorded before the intervention was 23% (0.23). The corresponding prevalence estimated from incidence rate during the final monitoring at this site was 9% (0.09). The difference was calculated with the confidence interval.

$$\Delta \mathbf{E_1} = \mathbf{Et_5}\text{-}\mathbf{Et_0}$$
$$= 0.09\text{-}0.23$$
$$= 0.14\ (0.005\text{-}0.27)$$

Effectiveness for Site II

The prevalence of trypanosomosis recorded before the intervention was 21% (0.21). The corresponding prevalence estimated from incidence rate during the final monitoring at this site was 4.8% (0.048). The difference was calculated with the confidence interval.

$$\Delta \mathbf{E_2} = \mathbf{Et_5}\text{-}\mathbf{Et_0},$$
$$= 0.048\text{-}0.21$$
$$= 0.162\ (0.034\text{-}0.29)$$

4.3.3. Incremental Cost-Effectiveness Ratio (ICER) determination

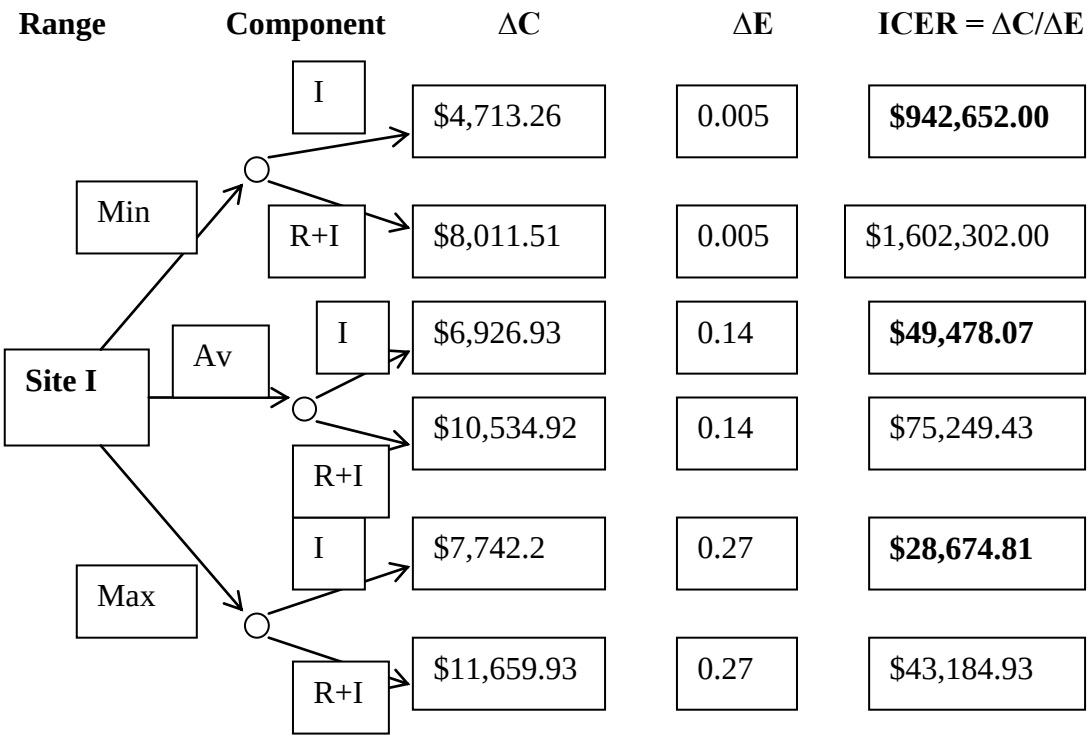
This applies to both strategies for comparison in the following way based on Scenario analysis. The calculation follows the steps described in the methodology part (i.e. intervention strategies of Site I and II compared to doing nothing as first step; shift from one strategy(I) to another (II) as second step).

Scenario I

This Scenario would assess the strategy conducted in Site I under varied assumptions where situations might hold one of these. The strategy of this site is best described in the methodology section.

a) minimum, average and maximum market prices were considered
b) with and without research cost consideration in the calculation was applied
c) Effectiveness (prevalence) : lower and upper limits considered

Figure 15. The different ways of comparing ICER calculation based on decision tree analysis (sensitivity analysis) at Site I.



I: intervention cost component alone

R+I: research and intervention costs

Min: minimum value considered

Av: average value considered

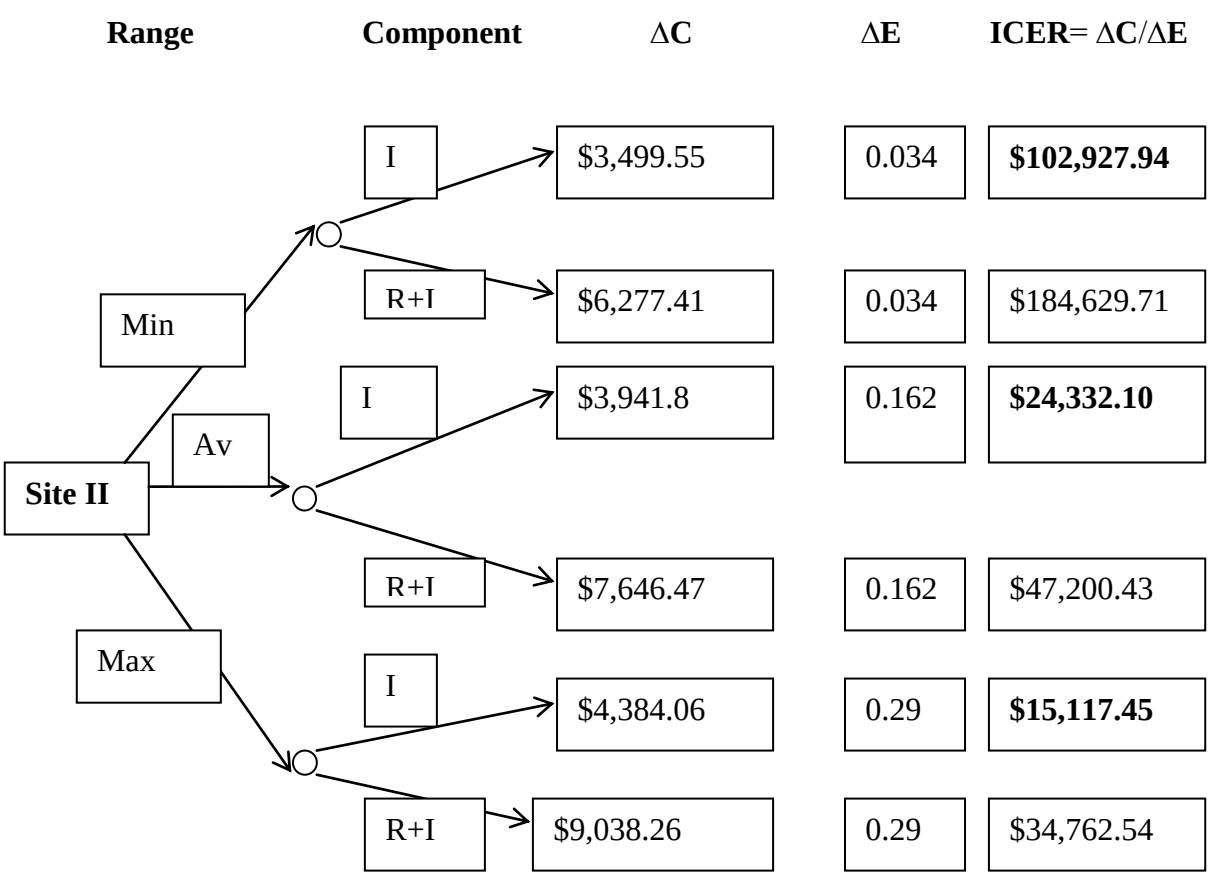
Max: maximum value

Scenario II

This Scenario again assesses the strategy at Site II (pour-on application to cattle) under various assumptions.

a) Minimum, average and maximum market prices were considered.
b) With and without research cost included in cost consideration
c) Effectiveness (prevalence) : lower and upper limits considered

Figure 16. The different ways of comparing ICER calculation based on decision tree analysis (sensitivity analysis) at Site II.



I: intervention cost component alone

R+I: research and intervention costs

Min: minimum value considered

Av: average value considered

Max: maximum value

The sensitivity analysis for both Scenarios depending on the minimum and maximum value was calculated. Results of the above sensitivity analysis indicated the uncertainty interval that, the ICER lies between 43,184.93 – 942,652.00 USD for Site I (impregnated targets) and 34,762.54-102,927.94 USD for Site II (pour-on) when the cost of intervention as an overall effect was considered. The average ICER for Site II was 24,332.1USD per unit effectiveness while that of Site I was 49,478.07 USD per unit effectiveness. The uncertainty interval obtained here shows an overlapping and thus the difference between the two strategies is insignificant.

Cost estimation to see the effect of first monitoring (i.e. 1 month after intervention):

Table 11. Cost range estimation of items at first monitoring at Site I

Variable items	Unit	Quantity	Unit price/Birr		Min. value	Max. value	Average value
			Min	Max			
Target	Pcs	400	17.62	21.14	7,048.00	8,456.00	7,752.00
Trap	Pcs	50	40	100	2,000.00	5,000.00	3,500.00
Acetone	Litre	32.8	125	150	4,100.00	4,920.00	4,510.00
Deltamethrin 20% SC	Litre	6	1,761.8	1,850	10,570.8	11,100.00	10,835.4
Diminazene	Sachets	76	5	8	380.00	608.00	494.00
Vehicle rent	Days	20	500	1000	10,000.0	20,000.00	15,000.0
Equipments					2,050.83	2,506.57	2,278.7
Total					**36,149.63**	**52,690.57**	**44,370.1**

Table 12. Cost range estimation of items at first monitoring at Site II

Variable items	Unit	Quatity	Unit price/Birr		Min. value	Max. value	Average value
			Min	Max			
Trap	Pcs	50	40	100	2,000.00	5,000.00	3,500.00
Acetone	Litre	2.8	125	150	350.00	420.00	385.00
Diminazene	Sachet	49	5	8	245.00	392.00	318.50
Deltamethrin 1% pour-on	Litre	7	122.45	134.80	857.15	943.60	900.38
Vehicle rent	Days	17	500	1,000	8,500.00	17,000.00	12,750.00
Equipments					2,317.68	2,832.72	2,575.20
Total					**16,142.68**	**28,479.72**	**22,311.2**

Table 13. Cost breakdown estimated to see the effect of intervention up to the first monitoring at Site I

Items	Minimum cost/Birr		Maximum cost/Birr		Average cost/Birr	
	Research	Intervention	Research	Intervention	Research	Intervention
Target	-	7,048.00	-	8,456.00	-	7,752.00
Trap	2,000.00	-	5,000.00	-	3,500.00	-
Acetone	350.00	3,750.00	420.00	4,500.00	385.00	4,125.00
Deltamethrin 20% SC	-	10,570.8	-	11,100.00	-	10,835.40
Diminazene aceturate	-	380.00	-	608.00	-	494.00
Vehicle rent	4,000.00	6,000.00	8,000.00	12,000.00	6,000.00	9,000.00
Equipments	2,050.83	-	2,506.57	-	2,278.7	-
Perdiem	1,400.00	3,790.00	1,400.00	3,790.00	1,400.00	3,790.00
Labour	30.00	525.00	30.00	525.00	30.00	525.00
Fuel & lubricant	1,020.03	834.57	1,020.03	834.57	1,020.03	834.57
Assets	267.30	-	319.33	-	293.33	-
Total / Birr	**11,118.16**	**32,898.37**	**18,695.93**	**41,813.57**	**14,907.03**	**37,355.97**
In USD	1,262.14	3,734.63	2,122.40	4,746.69	1,692.25	4,240.66

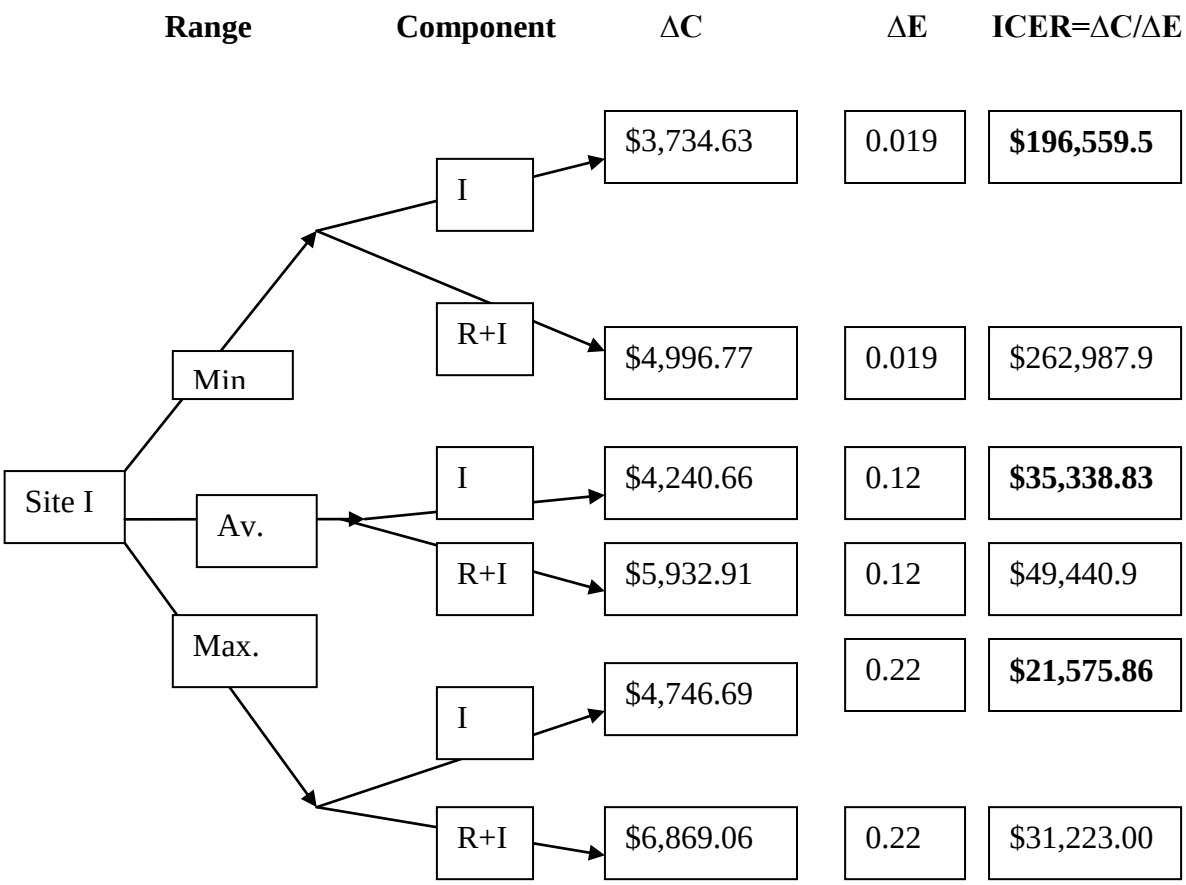
1USD= 8.809 Birr

Effectiveness achieved at first monitoring at Site I:

$$\Delta \mathbf{E} = \mathbf{Et_1 - Et_0} = 0.11 - 0.23 = 0.12\ (0.019 - 0.22)$$

Therefore, ICER would be determined to each of the costs categorized as range of minimum and maximum as follows.

Figure 17. Incremental Cost-Effectiveness at varied cost level at first monitoring at Site I



I: intervention cost alone

R+I: research and intervention costs

Min: minimum value considered

Av: average value considered

Max: maximum value

Table 14. Cost breakdown estimated to see the effect of intervention up to the first monitoring at Site II

Items	Minimum cost/Birr		Maximum cost/Birr		Average cost/Birr	
	Research	Intervention	Research	Intervention	Research	Intervention
Trap	2,000.00	-	5,000.00	-	3,500.00	-
Acetone	350.00	-	420.00	-	385.00	-
Diminazene	-	245.00	-	392.00	-	318.00
Deltamethrin 1% pour-on	-	2,730.00	-	2,835.00	-	2,782.50
Vehicle rent	3,000.00	5,500.00	6,000.00	11,000.00	4,500.00	8,250.00
Equipment	2,317.68	-	2,832.72	-	2,575.20	-
Perdiem	1,190.00	3,232.00	1,190.00	3,232.00	1,190.00	3,232.00
Labour cost	75.00	-	75	-	75	-
Fuel& lubricants	1,112.76	463.65	1,112.76	463.65	1,112.76	463.65
Assets	267.33	-	319.33	-	293.33	-
Total /Birr	**10,312.77**	**12,170.65**	**16,949.81**	**17,922.65**	**13,631.29**	**15,046.45**
In USD	1,170.71	1,381.62	1,924.15	2,034.58	1,547.43	1,708.08

1USD= 8.809 Birr

Effectiveness achieved at first monitoring at Site II

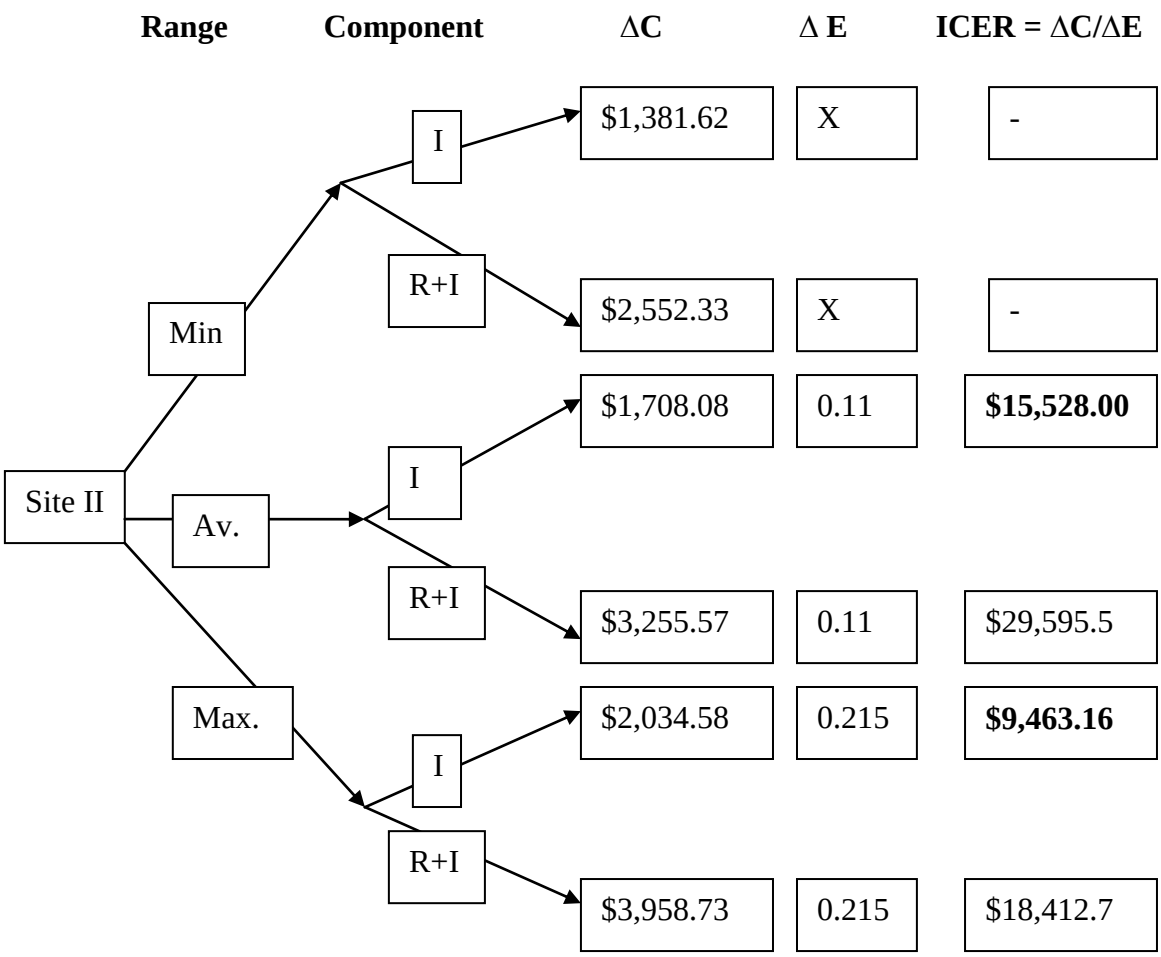
$$\Delta \mathbf{E} = \mathbf{Et_1} - \mathbf{Et_0} = 0.1 - 0.21 = 0.11 \ (-0.009 - 0.215)$$

Cost is also calculated as difference i.e.

$$\Delta \mathbf{C} = \mathbf{Ct_1} - \mathbf{Ct_0},$$ for all ranges and components to be assessed.

Since $\mathbf{Ct_0}$ (cost for doing nothing) was nil as far as government is concerned then the difference in the cost would be the cost which is added due to intervention.

Figure 18. Incremental Cost-Effectiveness at varied cost level at first monitoring at Site II



I: intervention cost alone

R+I: research and intervention costs

Min: minimum value considered

Av: average value considered

Max: maximum value

X: Lower limit for the Prevalence difference not applicable for calculation

Based on the average calculation, ICER for Site II was 15528.00USD per unit effectiveness whereas that of Site I was 35338.83 USD per unit effectiveness.

II) **From farmers' perspective**

A) Overall effect

Cost:

Labour cost was the input added by farmers into the intervention (opportunity cost is evaluated at wage rate of 5 Birr/day in the trial area)

Labour cost at Site I= 1610.00 Birr (182.8USD) = $\Delta\mathbf{C}$

Labour cost at Site II = 1445.00 Birr (164.04 USD) = $\Delta\mathbf{C}$

$$\Delta\mathbf{C} = \mathbf{Ct_5 - Ct_0}$$

No variation has occurred in the labour cost during the study period.

Effectiveness:

The overall change in the effectiveness ($\Delta\mathbf{E}$) was determined as

$\Delta\mathbf{E} = \mathbf{Et_5 - Et_0} = 0.09 - 0.23 = 0.14$ (for Site I)

$\Delta\mathbf{E} = \mathbf{Et_5 - Et_0} = 0.0475 - 0.21 = 0.162$ (for Site II)

Incremental Cost Effectiveness (ICER) = $\Delta\mathbf{C}/\Delta\mathbf{E}$:

ICER for Site I = 182.8/0.14 = 1305.7 USD per unit effectiveness

ICER for Site II = 164.04/0.162 = 1012.6 USD per unit effectiveness

B) Effect due to intervention at first monitoring

Site I:

Labour cost = 650.00Birr (73.8USD) => $\Delta\mathbf{C} = \mathbf{Ct_1 - Ct_0}$

Effectiveness: $\Delta\mathbf{E} = \mathbf{Et_1 - Et_0} = 0.11 - 0.23 = 0.12$

ICER= $\Delta\mathbf{C}/\Delta\mathbf{E}$ = 73.8/0.12 = 615 USD/unit effectiveness

Site II:

Labour cost = 400.00 Birr (45.41USD) => $\Delta C = Ct_1 - Ct_0$

Effectiveness: $\Delta E = Et_1 - Et_0 = 0.1 - 0.21 = 0.11$

ICER $= \Delta C/\Delta E = 45.41/0.11 = 412.82$ USD/ unit effectiveness

From farmer's perspective, the cost of intervention provided was labour. The result of ICER calculated was 1,305.7 USD per unit effectiveness for Site I and 1,012.6 USD per unit effectiveness for Site II. This indicates that Site II seems lower than site I, but still if sensitivity analysis was implemented to this section it would have closer results.

III) **From society's perspective**

The calculation was based on the average cost only and the overall effect of intervention was assessed.

Site I

Cost:

Table 15. Cost from Society's perspective at Site I

Cost component	Average cost by government	Labour cost by farmers	Total
Research	5,607.99 USD	-	5,607.99USD
Intervention	5,696.89 USD	182.8 USD	**5,879.69** USD
Total	9,304.88 USD	182.8 USD	1,1487.68 USD

Since the intervention cost is required for calculation, the ΔC would be 5879.69 USD.

Effectiveness: $\Delta E = Et_5 - Et_0 = 0.09 - 0.23 = 0.14$

Incremental Cost-effectiveness (**ICER**) = $\Delta C/\Delta E$= USD 5879.69/ 0.14 = 41.997.8 USD/effectiveness

Site II

Cost:

Table 16. Cost from society's perspective at Site II

Component	Average cost by government	Labour cost by farmers	Total
Research	3,704.67 USD	-	3,704.67 USD
Intervention	2,598.74 USD	164.04 USD	**2,762.78** USD
Total	6,303.41 USD	164.04 USD	6,467.45 USD

Since the intervention cost is required for calculation, the ΔC would be 2762.78 USD

Effectiveness: $\Delta \mathbf{E} = \mathbf{Et_5}\text{-}\mathbf{Et_0} = 0.0475 - 0.21 = 0.16$

Incremental Cost-effectiveness (**ICER**) = $\Delta \mathbf{C}/\Delta \mathbf{E}$= 2762.78 USD/0.16 = 1726.4 USD/unit effectiveness

From society's perspective, it was only the average cost which was considered for calculation and therefore, a lower ICER of 17,267.4 USD per unit effectiveness was obtained at Site II than Site I with ICER of 41,997.8 USD per unit effectiveness.

5. DISCUSSION

According to the farmers' response to the questionnaire administered, farmers were able to rank trypanosomosis as the most widespread disease, familiar with the signs of the disease & ways of transmission, and traced its history of occurrence in the area, estimated the frequency of therapeutic treatment required to care for their animals with the average cost incurred per family per year, how the disease was getting worse and also majority of the respondents linked the disease to dry season. However, a comparable proportion of them indicated that there was no difference between seasons. There was no as such reasonable difference among the farmers of the two sites with regards to the response to the questions administered. All these reality together prove the seriousness of the disease in the trial sites under consideration.

According to respondents of Site II (Abela-Mareka PA), cattle graze in thicketed vegetation sites along the course of Hammasa River where it joins the lake of Abaya. This occurs during dry season when there is shortage of feed in the vicinity of cultivated farm and stall feed could not be found. Those at Site I (Sedebo & Adecha PA) also responded the same phenomenon that their animals were usually herded in the thicketed vegetation alongside to Bisare River. The facts obtained from both sites could offer evidence that animals were continuously challenged by the disease vector whenever they were at grazing site where they could congregate with the fly, let the prospect and run into infection. A similar survey conducted earlier by Muturi *et al*. (1999) in the same project area agrees with these facts with regards to the seriousness of the disease and its major economic impact upon the community. Treatment of cattle by farmers themselves was a common phenomenon and most of them were under dosing their cattle. Such non-professionals handling of trypanocidal drugs would result in errors of administration. And also, as the drugs are relatively expensive, farmers tend to over dilute the drug and hence treat animals with sub therapeutic doses. This would result in selective pressure for the emergence of resistant clones that pre-exist in the trypanosome population. So, the trial areas were likely to have risk of trypanocidal drug- resistance. This would require further investigation.

In the present study, the apparent densities of tsetse flies caught were 1.35flies/trap/day in Site I and 0.91flies/trap/day in Site II. These findings correspond well to the results obtained during a study by Muturi *et al*. (1999) where they had caught about 1.4 flies/trap/day in the Southern rift valley of Ethiopia and also with the findings of Leak *et al*. (1993) over 50

months observation period reported 1.42 flies/trap/day. Msangi (1999) reported that he had caught *G. pallidipes* in all low land areas under 1600 m above sea level in the area. Entomological data (transformed) analysis of the pre-intervention survey revealed that the challenge for both sites showed insignificant difference. This has been related to the similarity in the categorisation of the ecological situations and the similarity in habitat classification in both sites. On the other hand, difference had occurred in the mean catch of tsetse flies with respect to classification of vegetation types in which bush land type had higher results. Such result of higher catch was also reported by Bancha (2001) where he indicated the highest total catch to bush land vegetation classification (46% in dry season and 68% in the wet season) and followed by wooded grass land (26% and 15% respectively in dry and wet season). Msangi (1999) also stated that this species was widespread being detected in all types of vegetation, the highest relative density being detected in the bush land vegetation. According to Leak (1999) vegetation is vital for providing shade and maintains a suitable microclimate for tsetse as well as a habitat for their hosts. Higher catches of flies during this work at bush land class of vegetation could be related to the wide dispersion of flies to this area as a result of the transition from rainy season to early spring. Catching of female flies showed a greater degree of deviation from the expected 50:50 ratio with a significant relationship. Females accounted for 63.2% catch during this study. The result is similar to the study reports of Bancha (2001) where he indicated about 60% catch; Msangi (1999) reported 71% and Vreysen *et al*. (1999) reported the catch of female *G. pallidipes* to account more than 62% in the same area under concern. Leak (1999) described this as in unbiased sample female would comprise between 70-80% of an average population. Phelps and Lovemore (1994) associated such higher catches of female *G. pallidipes* to be attributable to their longer life span (average of 8 weeks) than males living about 4 weeks, so that more catch of females could appear.

Baseline survey conducted in both study sites showed that the magnitude of the infection was high (i.e. 23% in Site I and 21% in Site II). This finding was of course higher than the result of the study made by Muturi *et al*. (1999) which reported an average of 12% prevalence for the three categorized altitude strata of the rift valley. On the other hand, the present result better satisfies the previously estimated 20-40% prevalence range for the project area and even nearly similar to the prevalence (25.9%) reported by Muturi *et al*. (1999) in the low altitude strata (<1600m above sea level) as the current study sites were in the lower altitude strata. The detection of a high proportion of *T. congolence* in both sites of this study (70%) appear to be consistent with previous reports of such by Abebe and Jobre (1996) in South west Ethiopia where they reported *T. congolence* (59%) and *T. vivax* (31%) infection, Muturi

et al. (1999) who reported 66.86% *T. congolence* and 20.57% *T. vivax* infection in the same project area in the Southern rift valley and the findings of Van den Bossche *et al*. (2004) indicating most of the trypanosome infections (90.9%) due to *T. congolence* and the remainder to *T .vivax* infection. In the present study the *T. congolence* to *T. vivax* ratio was determined to be 3.5:1 and is nearer to the work of Muturi *et al*. (1999) which had shown a ratio of 3.35:1. The two sites of the current study have shown insignificant difference in trypanosome prevalence suggesting relationship with regards to the constant challenge of the vector of the disease as well as other epidemiological and ecological risk factors. Similarity with respect to such stated features was the prerequisite to be fulfilled ahead of time while proceeding with the intervention phase activity in order to attain the proposed results.

Measurements of PCV value for each animal sampled in the pre-intervention survey in both sites was analysed and marked difference was noticed according to the infection status of animals where parasitaemic animals had generally lower mean PCV value than the corresponding aparasitaemic ones. And in addition to this, about 94.87% of the parasitaemic animals had their PCV below 25% in Site I and also 81.25% in Site II falls into this category. Again parasitaemic animals of Site I had significantly lower mean PCV than the same class of animals in Site II. This could be attributed to either the difference in constant challenge of animals by tsetse or management factors associated with widespread use of trypanocidal drugs which was more frequent at Site II than in Site I observed during questionnaire survey.

Overall, the mean PCV of animals from both sites didn't show marked difference however, majority of the animals had relatively low PCV value in both cases. The appearance of parasitologically negative animals with PCV values of less than the threshold value set (25%) may be due to the inadequacy of the detection method used (Murray *et al.*,1977) or delayed recovery of the anaemic situation after current treatment with trypanocidal drugs. And also the occurrence of positive animals with PCV of greater than 25% might be thought of recent infections of the animals. Trypanosome infection and mean PCV values obtained in the present study in the parasitaemic animals was found to be highly associated. Similar result was reported from the work of Rowlands *et al*. (2001) at Ghibe valley in South-western Ethiopia that as PCV increased the proportion of samples detected parasitaemic correspondingly decreased. Hence the mean PCV could better be an indicator of the health status of cattle population under study. It was generally accepted that mean PCV value is affected by many factors other than trypanosomosis. However, these factors are likely to

affect both trypanosomosis positive and negative animals (Van den Bossche and Rowlands, 2001).

During the intervention study, the population of tsetse flies decreased over the trial period. The apparent density of tsetse flies caught during last monitoring time was particularly low as compared to the pre-intervention catch result. The overall reduction in the tsetse population (Site I) was 88.8%. The result could be attributable to the use of effective odours i.e. bovine urine and acetone with frequent follow up to the site to manage some associated problems. Consequently, subsequent replacements of lost and damaged targets and replenishment of odours was accomplished promptly.

On top of these, the relative abundance of tsetse flies caught at every month visit at Site II has dropped to nil starting right at 4^{th} month of trapping. The efficacy determined in this case was about 94.88 % reduction in the overall fly population attributable to the pour-on intervention. This substantiates the relative superiority of Deltamethrin 1% pour-on when used to control tsetse flies by knock down effect in obtaining a good result with in a short period of time as compared to 0.4% Deltamethrin impregnated odour-baited targets. The efficacy of insecticide-treated cattle in controlling trypanosomosis hinge on the importance of cattle in the diet of the tsetse, the proportion of the total cattle population treated at regular intervals and the invasion pressure from tsetse. According to Van den Bossche *et al*. (2004), the importance of cattle in the diet of tsetse varies spatially but is usually high in areas where people and cattle have encroached into a tsetse-infested game area and where, because of cultivation, the density of large game animals has subsequently declined. This phenomenon is true in the study area under thought and might be defined in a similar way.

Tsetse intervention activity and subsequent five month monitoring showed that the incidence rate of trypanosomosis in sentinel animals of Site I declined from 10.75% to 1.8% during 1^{st} and 5^{th} monitoring visits respectively. The result of this finding shows that there was a reduction of about 83.26% in the incidence of trypanosomosis and the trend of reduction was slow. Such slow rate of reduction in the incidence of disease could partly be due the time taken for the intervention was shorter than the average required, as it was seen comparatively with the experience in other places. Study conducted in Zambia by Lumamba *et al*. (1997) and Zimbabwe by Chamisa and Mweempwa (1997) proved that tsetse control using insecticide impregnated odour-baited targets could take not less than 9 months to show a marked drop in the disease incidence as well as achieve scanty fly catch result. Additionally,

the sensitivity of the diagnostic method used under such a field condition, could also play some role. However, the final result obtained (i.e. drop of incidence rate to 1.8%) should not be held in low esteem as compared to the pre-intervention time point prevalence obtained at Site I (i.e. 23%). And therefore, a 60 % overall reduction in the parasitaemic status was achieved. This change, could be attributed to the intervention underwent in the area (Site I). Livestock owners of the site had appreciated the reduction in the disease recurrence as they had thought of the previous worsening situation to their animals. And they were also able to observe the reduction in the fly population and the subsequent avoidance of harassment to the animals while grazing. This was because they found that their animals were able to graze the whole day after intervention which was previously regarded as impossible phenomenon.

No matter how the status of parasitaemia progress, gradual improvement was confirmed in the monthly mean PCV value of the sentinel animals in Site I. The PCV improvement shows a strongly positive correlation with intervention time but negatively correlated with mean tsetse catch and monthly incidence rate of trypanosomosis. The mean PCV values of the sentinel animals at this site have followed a constant increment throughout the intervention time. Afework *et al*. (2000) and Tewolde *et al*. (2004) reported similar results from their work in the North-west and South-western Ethiopia respectively where they observed PCV increment in Isometamidium chloride protected animals.

The intervention parasitological status in study Site II, on the other hand, resulted in a subsequent decline of trypanosome incidence falling to 0.95% at final monitoring visit as compared to the 1st monitoring result (10%) obtained just after 1 month of the start of pour-on application. An overall reduction in the incidence rate was 90.5%. Together with the drop of parasitaemia, a marked increase with relatively stable pattern of mean PCV was noticed. This result agrees with the report of Van den Bossche *et al*. (2004) where the monthly incidence of trypanosomosis was negatively correlated with the time elapsed since the start of Cyfluthrin applications in the control of *G. m. morsitans* in two districts of the Eastern province of Zambia. They were able to view a period of slow decline in incidence of trypanosomosis from November 1998 to June 1999 which was followed by a dramatic fall to 0.8% in August from where onwards no trypanosome infections were detected in sentinel animals. The overall reduction in the corresponding prevalence was estimated by computing (Thrusfield, 1992) from the incidence rate result and compared with the pre-intervention prevalence. This has showed a 77.4% reduction. This result was much higher than that reported by Mulatu *et al*. (1997) from tsetse control campaign using an insecticidal Cypermethrin ‘pour-on’ application

to village zebu cattle in Ghibe in South west Ethiopia where trypanosomosis in adult cattle has been reduced from 41% to 16% (a reduction of 61%) and the number of curative trypanocidal treatments per animals has been reduced by 50% despite very high levels of drug resistance detected in the area. Again this overall prevalence reduction result achieved is far higher than the result obtained in Site I i.e. 60% and signifies the relatively better effectiveness attained.

Attempts were made to analyse mean PCV values of herds monitored during intervention in both sites and compare the value using analysis of variance (ANOVA). However, the results recorded at different monitoring months were not independent from one another and therefore comparison was made between the mean PCV value of the pre-intervention and last monitoring visit to evaluate the difference before and after intervention. For this purpose, the use of paired t-test was found appropriate (Thrusfield, 1992). The significant increment noticed in the mean PCV value of sentinel cattle could be attributed to the reduction in the incidence of trypanosomosis due the intervention and the subsequent improvement in the health status of the sentinel animals. This result agrees with the work of Leak *et al*. (1995) in which the mean PCV of cattle rose from a mean of 23.8% of pre-control period to 26.8% following the start of the tsetse control trial with Cypermethrin and monthly mean PCV values were negatively correlated with monthly trypanosome incidence. Similar result was obtained by Van den Bossche *et al*. (2004) in which the increase in the average PCV of the herd is also best explained by a decline in the incidence of trypanosomosis although consistently high average PCV were only observed after the incidence of trypanosomosis was reduced to zero in their work. Yet, this was reached from third monitoring onwards in the current study. Though an immediate effect on the incidence of trypanosome infections were not noticed, the use of Deltamethrin pour-on in the current study seem to have resulted in an immediate improvement in the monthly mean PCV of the sentinel cattle in the study Site II. Such an increase in the herd mean PCV has been observed by Van den Bossche *et al*. (2004), Bauer *et al*. (1995) and related to the effect of the Pyrethroid insecticidal applications on the abundance of other vectors , such as ticks and biting flies.

In general, it was accepted that seasonal fluctuations might occur. Whenever this phenomenon is considered, the study was conducted in the period during which trypanosomosis is normally anticipated to occur, associated with poor pasture in the surrounding and thus animals being forced to move in to bushes and riverine forests where they could get contact with tsetse flies and acquire infection. This was a usual incident noticed in both of the study areas.

Furthermore, seasonal reduction in the tsetse fly population does not assume a rapid fall phenomenon, but rather shows gradual tendency to reduce. In spite of this fact, a sharp drop in the tsetse fly population density to nil (Site II) and a comparable decline (Site I) together with the resultant falling in the disease status was observed from both interventions. To this effect, a markedly significant improvement in the PCV of sentinel animals in both study sites was noticed and this would be most likely attributed to the interventions underwent.

Additionally, a relatively faster rate of reduction was achieved in the relative density of tsetse population in Site II as compared to such trials undertaken in areas like Ghibe valley by Leak *et al*. (1995). This could be attributable to the long lasting persistence (residual effect) of Deltamethrin due to the chemical nature or the formulation type resulting in its advantage over others.

The disease situation in livestock is the product of many factors affecting the transmission and establishment of infection in the mammalian host and its duration including susceptibility to infection, the attractiveness of different hosts to tsetse and tsetse feeding success, and pattern of tsetse-livestock contact (Snow, 1996). Therefore, result which was obtained due to reduction in the population density of tsetse flies could only reflect an intermediate effectiveness. On the other hand, disease decline in prevalence or reduction in the number of new cases (infection) occurring (a criterion of final effectiveness expected from any health programme) would be the best measurement criterion to be considered as final effectiveness. Since the parameter of concern preferred was incremental cost-effectiveness ratio (ICER), the calculation was based on the change in the cost expenditure to control the problem by intervention to the change attained by reducing the disease prevalence as compared to the pre-intervention status. Incremental cost-effectiveness ratio (ICER) is advantageous whenever one has no full information about costs. However, due to the reluctance of livestock owners to allow their animals to be followed up without an intervention taking place in the area and/or difficulty of establishing sentinel herd of animals in such cases ‘doing nothing’ was not attempted. Therefore, the data obtained by baseline survey was regarded as the situation with ‘doing nothing’ and thus comparison was performed as the difference before and after intervention.

From the Scenario analysis, it would be straightforward for decision makers to selecting the appropriate one. According to the results of analysis made, use of pour-on seemed better cost-effective than the use of impregnated targets on average.

The Incremental Cost-Effectiveness (ICER) obtained (24,332.1USD per unit effectiveness) was lower than the corresponding ICER calculated for Site I (49,478.07 USD per unit effectiveness) on average market cost basis disbursed for intervention. However, there appeared an overlapping in the uncertainty intervals of the two scenarios analysed, which implies lack of justifiable difference between both strategies based on the present intervention conducted. Similar assessment of average costs and effectiveness one month after intervention shows that the ICER for Site II is 15,528.00 USD /unit effectiveness lower than Site I with ICER of 35, 338.83 USD /unit effectiveness.

Economic analysis conducted by Budd (1999) indicated that the cost of monthly treatments of cattle using a Pyrethroid pour-on at a cattle density of 15 cattle per square kilometre was estimated as 120 USD/km^2. A cost of 70 USD/km^2 for tsetse control using pour-on was reviewed and presented by Green (1994). All the information regarding cost of tsetse control using insecticide treated cattle indicate that pour-on technique is the cheapest of the options. The cost in the current study at Site II (pour-on) when computed in a similar way offers about 43.84 USD /km^2 (4384.06/ 100) which is by far better than the information above.

A more specific comparative cost analysis was indicated by Barrett (1991) that different tsetse control techniques used against *G. pallidipes* in Zimbabwe under conditions of flat and rugged inaccessible terrain was 55-71 USD/km^2 and 161-213 USD/km^2 respectively at 1 target /km^2 density. The corresponding intervention cost calculated was 77.42 USD/ km^2 (7742.2/100). This is comparatively less cost-effective than study results regarding tsetse control with similar strategy in other countries of Africa.

The cost-effectiveness results obtained in the present trial could be good evidence for tsetse and trypanosomosis suppression be achieved with a relatively lower cost than the average costs estimated by different workers in other African countries. Sustainability of such work results conducted within a portion of the project area (STEP) would depend on the continuity of the activity of the project itself. Of course, the project is now carrying out activities of massive suppression of tsetse fly by applying pour-on and impregnated targets involving the community for labour- intensive activities like deploying of targets. Therefore, the risk of the tsetse suppressed sites being re-invaded by tsetse flies would be minimal.

The present trial was conducted within a short period of time. In this work, costs involving overheads were not considered since this applies similar for both sites in comparison (sites

I&II). So, great attention was given to variable costs which were directly applied in the intervention. The results were also found indicative of the status of cost expenses required to be covered in using the two alternatives based on the changes (increments) in the cost due to intervention. Similarly these results proved indicative of tsetse control or suppression in the project area by use of the methods applied more economical than what was observed in other parts of Africa. It is further more economical doing in such a way in the strategy towards eradication of tsetse flies by finally applying sterile male flies (SIT technique). This was of course thought of highly expensive as it was estimated at 45 million USD for the proposed STEP programme covering 25,000 km2 to be cleared of tsetse (Budd, 1999). However, the cost is once-off budget expenditure while the benefit expected is far greater and therefore the feasibility of the work results and the project at large would be well appreciated.

There has been a complicating opinion that modern tick & tick-borne disease control policy in many areas is to encourage the development of enzootic stability between the animal hosts and the diseases and the vectors in their environment (Budd, 1999). Conserving enzootic stability essentially depends on maintaining tick populations above a certain minimum threshold. This implies that tsetse control measures need to reduce their impact on tick populations which include increasing the interval between applications, applying insecticides to a subset of a cattle population and /or avoiding the treatment of tick attachment sites (Eisler *et al*., 2002). Great attention was given to treating sub population of animals in the Site II of the current trial and as a result only about one-third of cattle above one year of age were allowed for the application of Deltamethrin 1% pour-on.

There is a further issue of thought that use of Pyrethroids on such a low doses of application to control tsetse population, might conversely favour ticks be exposed to sub lethal doses and thus there is a general veterinary concern that Pyrethroids will be the last shot in their armoury in cases where tick populations develop a resistance to all other usable insecticides (Budd, 1999). Since it may assist the evolution of resistant strains, it is better that wherever trypanosomosis and tick-borne diseases are to be controlled by use of treated cattle, this should be considered on the relative importance basis and be resolved ahead.

Moreover, Vale (2002) from studies conducted in Zimbabwe reported that recommended doses of Pyrethroid insecticides such as Decatix® spray or spot-on ®/ pour-on/ produced detectable residues in the dung dropped up to about two weeks after treatment at concentrations sufficient to cause substantial deaths among dung fauna. According to him, it

seemed that risks for dung fauna are likely to vary greatly according to the treatment regime, the type of fauna, the size and shape of the treated area, and the frequency of cattle treatment. So, restricted application of such insecticides to the legs at the interval of one or few weeks was recommended to eliminate the potential threat to dung fauna while still killing many tsetses. Moreover, this limited use of insecticide might lessen the impact on the enzootic stability of tick-borne disease and also give substantial savings in the cost of tsetse control (Vale, 2002). Further research is required to establish to what extent restricted spraying can kill tsetse under various climatic conditions. Similarly, Torr *et al*. (2002), showed that effective tsetse control could be achieved by treating only the larger cattle, leaving the younger ones exposed to ticks. The fact behind was that older animals were found to be bitten more likely than younger ones.

The effects of Pyrethroid treatment on many creatures other than tsetse and ticks was demonstrated by Vale (2002) using network of effects. This network of effects was developed by placing insecticide treated cattle at central place. It was further suggested that cattle treatment would provide a universal spanner suitable for tackling different aspects of development. In the network, it has been shown that treatment of cattle would result in the effects on nuisance flies and mosquitoes. In the current study places, people generally keep their animals in their house overnight and thus insecticide treatment could possibly have an effect on mosquitoes thereby reducing rate of cases in the occurrence of malaria. This evidence was supported by the feedback information from people in the trial place where they were able to appreciate an apparent reduction in the population of house flies and mosquitoes.

6. CONCLUSION AND RECOMMENDATIONS

The initial baseline survey of the current trial site indicated that tsetse and trypanosomosis is endemic to these sites as well as to the region. The interview results from the questionnaire survey well supported the situation prevailing in the area. The prevalence of the disease was higher being in the lowland category in both cases and the tsetse fly catch together indicating the seriousness of the problem.

According to the current work result, the application of both insecticide impregnated (0.4% Deltamethrin) odour-baited targets at a density of 4 targets /km^2 and pour-on formulation (Deltamethrin 1% at a rate of 1ml/ 10kg body weight to cattle) sufficiently reduced the relative abundance of tsetse fly population and trypanosomosis incidence with the resultant improvement in the overall mean PCV value of sentinel animals.

The application of pour-on has resulted in the decline of tsetse fly catch (relative density) and in the incidence of trypanosomosis faster than the use of insecticide impregnated odour-baited targets and therefore proved to be better efficacious. The incremental cost-effectiveness ratio (24,332.1 USD per unit effectiveness) of Site II (Scenario II) seems lower than the corresponding ICER (49,478.07 USD per unit effectiveness) of Site I (Scenario I) based on average calculation. However, the uncertainty interval rules out the overall effect of this result given significance consideration.

The trial confirmed that the use of the pour-on formulation of Deltamethrin is better efficacious but did not prove cost-effective than target. Furthermore, it was found easy to apply, requires less labour and highly appreciated by user community. However, this advantage would be maintained if and only if a sufficient number of cattle were allowed within the environment to be cleared of tsetse by applying pour-on. Otherwise, it would be difficult to have the anticipated result. On the other hand, the use of targets impregnated with insecticide (0.4% Deltamethrin) is generally known to be labour-intensive, offers a slow reduction rate of trypanosomosis and associated with accessibility risks (such as irregular topography and wild animals). In spite of these facts, the technique is still regarded as an alternative wherever tsetse fly pocket areas exist in the absence of cattle. And also, a substantial result could be obtained by applying targets if community participation is initiated in the control scheme with the associated training of how to deploy and maintain targets.

Therefore, in the current activity of Southern Tsetse Eradication Project (STEP), the integrated use of both methods in the suppression of tsetse fly population for the subsequent application of sterile male flies (*G. pallidipes*) is recommended as none of them could achieve its goal independently.

Moreover, further study is recommended to assess the situation with regards to the cost and benefits acquired by the society from the suppression programme underwent in the period of the project life.

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8. ANNEXES

Annex 1. Questionnaire format

1. Farmer's identity and location

   Date_____ Name_____

   Age _____ Peasant association_____

2. Herd composition

   2.1 Do you have any animal? (yes, no)

   2.2 If yes, which species and number?

   Cattle_____ Camels_____

   Sheep& goats_____ Others_____

   Equines_____

3. Major health problems

   3.1 What are the most common diseases affecting your livestock?

   _____

   _____

   3.2 Does trypanosomosis occur in this area? (Yes, no, other) if yes, would you rank trypanosomosis with regard to cattle loses compared to other diseases?

   _____

   _____

   3.3 What signs do you commonly observe when your animals get sick with trypanosomosis?

   _____

   _____

   3.4 In which season/ month do livestock most often get the disease (trypanosomosis)?

   _____

   _____

   3.5 When did trypanosomosis start to occur in this area? _____

   3.6 Is trypanosomosis getting worse, better or unchanged in this area since you first entered in the area? _____

   3.7 How do you think is trypanosomosis transmitted? _____

   3.8 In which season / month does trypanosomosis most occur? _____

4 Livestock management

4.1 How do you manage cattle?

Free grazing _____ Stall feed_____

Tethering_____

4.2 when do cattle graze_____

4.3 Where is the location of livestock watering point? _____

4.4 In which season / month of the year is livestock feed most available?

_____

4.5 In which season is it least available? _____

5. Socio-economic activities

5.1 What are your main sources of income? _____

5.2 What is the importance of keeping cattle?

For milk production_____

For meat production_____

For draught power_____

For manure Production_____

For paying of dowry _____

Others (specify) _____

6 Sources and usage of trypanocidal drugs

6.1 Where do you commonly treat your animals when they get sick with trypanosomosis?

At home_____

In veterinary clinic_____

Others (specify) _____

6.2 Where are the common treatment sources?

Veterinary clinic_____

Local farmer _____

Others (specify) _____

6.3 Which trypanocidal drugs are you commonly using to treat your animals?

_____

_____

6.4 Since when have you been using each of these dugs? _____

Since last 20 years_____

Since last 10 years_____

Since last 5 years_____

6.5 How much many do you pay to get a single mature ox treated? _____

6.6 How many times did each animal get veterinary treatment against trypanosomosis since last year? (One, two, three, or more than three times)

6.7 Can you tell how much expense is incurred in payment for treatment against trypanosomosis since last year? _____

6.8 Of your cattle treated last time:

- How many are healthy at present? _____
- When was these animals lastly treated? _____
- Could you tell the days between treatments? _____

6.9 How many cattle have you lost due to trypanosomosis since last year? _____

6.10 Do you know any other control or prevention methods from the disease? (yes/no)

6.10.1 Which methods, do you think are most effective to prevent your animals from trypanosomosis? _____

6.11 Whom do you think should cover the expenses required in the application of these alternative methods?(Government/ community / others (specify))

6.12 What would you suggest the better action be taken towards sustained controlling of the problem? (treatment/ prophylaxis/live bait treatment/ artificial bait treatments)

6.13 Are you willing to participate in these activities? (yes/no)

6.14 State the possible contributions you can provide (labour, finance, materials, other)

7. Comments (if any):

_____

_____

_____

_____

Thank you

Annex 2. Entomological baseline data at Site I (Tora-Sadebo Pa)

Trap No.	X-coordinate (UTM)	Y-coordinate(UTM)	Altitude	Vegetation	Deployed date	Collection date	Tsetse spp.	No. of flies Caught		
								M	F	Total
C1T1	6 49 57.9	37 57' 67.1"	1433	CUL	10/10/2003	13/10/03	*G. pallidipes*	0	1	1
C1T2	6 49 75.6	37 57' 81.0"	1426	WGL	10/10/2003	13/10/03	*G .pallidipes*	0	2	2
C1T3	6 49 84.7	37 57' 84.0"	1424	WGL	10/10/2003	13/10/03	*G. pallidipes*	2	4	6
C1T4	6 49 80.3	37 57 94.2	1428	WGL	10/10/2003	13/10/03	*G .pallidipes*	3	4	7
C1T5	6 49 75.8	37 58 09.4	1421	WGL	10/10/2003	13/10/03	*G. pallidipes*	1	2	3
C1T6	6 49 72.9	37 58 31.6	1423	WGL	10/10/2003	13/10/03	*G .pallidipes*	0	0	0
C1T7	6 49 79.5	37 58 47.2	1415	WGL	10/10/2003	13/10/03	*G .pallidipes*	4	2	6
C1T8	6 49 81.1	37 58 73.9	1404	WGL	10/10/2003	13/10/03	*G. pallidipes*	2	1	3
C1T9	6 49 80.3	37 58 83.8	1397	CUL	10/10/2003	13/10/03	*G .pallidipes*	3	5	8
C1T10	6 49 66.3	37 58 76.2	1402	CUL	10/10/2003	13/10/03	*G .pallidipes*	2	2	4
C1T11	6 49 55.3	37 58 85.7	1398	WGL	10/10/2003	13/10/03	*G. pallidipes*	1	1	2
C1T12	6 49 51.0	37 58 73.6	1407	WGL	10/10/2003	13/10/03	*G .pallidipes*	5	7	12
C1T13	6 49 33.6	37 58 74.1	1399	BUL	10/10/2003	13/10/03	*G .pallidipes*	4	9	13
C1T14	6 49 35.5	37 58 63.1	1407	BUL	10/10/2003	13/10/03	*G .pallidipes*	3	4	7
C1T15	6 49 45.6	37 58 55.3	1405	BUL	10/10/2003	13/10/03	*G .pallidipes*	1	5	6
C1T16	6 49 43.8	37 58 43.3	1407	WGL	10/10/2003	13/10/03	*G .pallidipes*	2	4	6
C1T17	6 49 43.2	37 58 31.3	1413	WGL	10/10/2003	13/10/03	*G .pallidipes*	0	2	2
C1T18	6 49 51.0	37 58 26.3	1424	BUL	10/10/2003	13/10/03	*G .pallidipes*	1	1	2
C1T19	6 49 54.8	37 58 17.0	1423	WL	10/10/2003	13/10/03	*G .pallidipes*	0	2	2
C1T20	6 49 61.4	37 57 96.7	1429	WL	10/10/2003	13/10/03	*G .pallidipes*	0	1	1
C1T21	6 49 43.9	37 57 72.4	1428	WGL	11/10/2003	14/10/03	*G. pallidipes*	1	0	1
C1T22	6 49 52.2	37 57 87.4	1424	CUL	11/10/2003	14/10/03	*G .pallidipes*	1	0	1
C1T23	6 49 51.3	37 58 00.4	1420	CUL	11/10/2003	14/10/03	*G. pallidipes*	0	0	0
C1T24	6 49 45.0	37 58 17.7	1418	CUL	11/10/2003	14/10/03	*G. pallidipes*	0	0	0
C1T25	6 49 31.5	37 58 25.3	1413	CUL	11/10/2003	14/10/03	*G. pallidipes*	1	2	3
C1T26	6 49 15.6	37 58 22.9	1410	CUL	11/10/2003	14/10/03	*G .pallidipes*	1	0	1
C1T27	6 49 01.5	37 58 26.9	1407	WGL	11/10/2003	14/10/03	*G .pallidipes*	3	4	7
C1T28	6 48 86.0	37 58 24.8	1406	CUL	11/10/2003	14/10/03	*G. pallidipes*	1	1	2
C1T29	6 48 77.6	37 58 11.2	1412	WGL	11/10/2003	14/10/03	*G. pallidipes*	5	7	12
C1T30	6 48 81.6	37 57 99.0	1411	BUL	11/10/2003	14/10/03	*G .pallidipes*	4	3	7
C1T31	6 48 88.3	37 57 83.1	1418	BUL	11/10/2003	14/10/03	*G. pallidipes*	2	1	3
C1T32	6 49 03.5	37 57 69.9	1423	WGL	11/10/2003	14/10/03	*G. pallidipes*	10	2	12
C1T33	6 49 13.9	37 57 61.3	1426	WGL	11/10/2003	14/10/03	*G .pallidipes*	0	0	0
C1T34	6 49 34.0	37 57 78.6	1433	CUL	11/10/2003	14/10/03	*G. pallidipes*	0	0	0
C1T35	6 49 28.2	37 57 91.2	1423	CUL	11/10/2003	14/10/03	*G. pallidipes*	0	0	0

Annex 3. Entomological baseline data collected at Site II (Abela- Mareka Pa)

Trap No.	X-coordinate (UTM)	Y-coordinate(UTM)	Altitude	Vegetation	Deployed date	Collection date	Tsetse spp.	No. of flies Caught		
								M	F	Total
C2T1	6 34 25.0	37 49 34.1	1284	CUL	13/10/03	16/10/03	*G .pallidipes*	0	0	0
C2T2	6 34 19.1	37 49 34.3	1292	WGL	13/10/03	16/10/03	*G .pallidipes*	0	3	3
C2T3	6 34 11.7	37 49 34.6	1287	WGL	13/10/03	16/10/03	*G .pallidipes*	1	5	6
C2T4	6 34 04.4	37 49 34.5	1280	WGL	13/10/03	16/10/03	*G. pallidipes*	0	1	1
C2T5	6 33 58.0	37 49 34.5	1277	WGL	13/10/03	16/10/03	*G. pallidipes*	1	3	4
C2T6	6 33 46.8	37 49 40.9	1294	WGL	13/10/03	16/10/03	*G. pallidipes*	2	5	7
C2T7	6 33 39.9	37 49 48.2	1288	WGL	13/10/03	16/10/03	*G .pallidipes*	1	2	3
C2T8	6 33 33.7	37 49 57.5	1286	WGL	13/10/03	16/10/03	*G .pallidipes*	1	2	3
C2T9	6 33 43.0	37 50 09.6	1292	CUL	13/10/03	16/10/03	*G. pallidipes*	0	1	1
C2T10	6 33 50.7	37 50 14.3	1297	CUL	13/10/03	16/10/03	*G. pallidipes*	0	0	0
C2T11	6 37 34.5	37 51 00.5	1311	WGL	13/10/03	16/10/03	*G .pallidipes*	0	4	4
C2T12	6 37 22.9	37 50 55.4	1304	CUL	13/10/03	16/10/03	*G. pallidipes*	0	1	1
C2T13	6 37 07.5	37 50 45.3	1303	CUL	13/10/03	16/10/03	*G .pallidipes*	2	2	4
C2T14	6 36 58.3	37 50 28.4	1309	WGL	13/10/03	16/10/03	*G .pallidipes*	1	3	4
C2T15	6 37 42.8	37 51 00.2	1317	CUL	13/10/03	16/10/03	*G. pallidipes*	0	1	1
C2T16	6 37 39.9	37 51 06.5	1311	BUL	13/10/03	16/10/03	*G .pallidipes*	2	1	3
C2T17	6 37 32.7	37 51 05.9	1306	CUL	13/10/03	16/10/03	*G. pallidipes*	1	0	1
C2T18	6 37 25.2	37 51 13.8	1309	WGL	13/10/03	16/10/03	*G. pallidipes*	1	3	4
C2T19	6 37 08.9	37 51 02.2	1305	WGL	13/10/03	16/10/03	*G. pallidipes*	0	2	2
C2T20	6 37 02.7	37 51 00.0	1315	WGL	13/10/03	16/10/03	*G. pallidipes*	1	3	4
C2T21	6 34 26.7	37 50 21.9	1302	WGL	14/10/03	17/10/03	*G. pallidipes*	1	0	1
C2T22	6 34 18.2	37 50 16.5	1306	WGL	14/10/03	17/10/03	*G .pallidipes*	1	3	4
C2T23	6 34 33.1	37 50 24.4	1311	WGL	14/10/03	17/10/03	*G .pallidipes*	1	1	2
C2T24	6 34 41.4	37 50 24.8	1312	CUL	14/10/03	17/10/03	*G .pallidipes*	1	3	4
C2T25	6 34 50.4	37 50 27.4	1301	CUL	14/10/03	17/10/03	*G .pallidipes*	2	2	4
C2T26	6 34 59.2	37 50 29.9	1297	CUL	14/10/03	17/10/03	*G. pallidipes*	0	4	4
C2T27	6 35 08.0	37 50 33.7	1294	WGL	14/10/03	17/10/03	*G .pallidipes*	0	4	4
C2T28	6 35 15.0	37 50 27.3	1298	BUL	14/10/03	17/10/03	*G .pallidipes*	1	2	3
C2T29	6 36 08.3	37 50 25.5	1297	BUL	14/10/03	17/10/03	*G .pallidipes*	0	0	0
C2T30	6 36 14.7	37 50 25.1	1301	WGL	14/10/03	17/10/03	*G .pallidipes*	0	2	2
C2T31	6 36 15.0	37 50 31.5	1303	WGL	14/10/03	17/10/03	*G .pallidipes*	0	2	2
C2T32	6 36 09.1	37 50 30.2	1306	CUL	14/10/03	17/10/03	*G. pallidipes*	0	0	0
C2T33	6 36 03.6	37 50 28.1	1311	CUL	14/10/03	17/10/03	*G .pallidipes*	2	3	5
C2T34	6 35 58.5	37 50 27.7	1314	CUL	14/10/03	17/10/03	*G .pallidipes*	0	1	1
C2T35	6 35 53.4	37 50 29.8	1298	WGL	14/10/03	17/10/03	*G .pallidipes*	2	1	3
C2T36	6 35 48.6	37 50 25.8	1304	WGL	14/10/03	17/10/03	*G .pallidipes*	1	2	3

Annex 4. Intervention time entomological Data showing tsetse fly catch and apparent density (different vegetation types) at two sites.

Site	Monitoring round	Vegetation Type			Total	No. traps	A.D.
		CUL	WGL	BUL			
I	1	9	12	6	27	35	0.77
	2	3	6	13	22	35	0.63
	3	0	3	3	6	35	0.17
	4	0	3	3	6	35	0.17
	5	0	6	0	6	35	0.17
II	1	6	6	6	18	36	0.50
	2	0	0	6	6	36	0.17
	3	0	0	0	3	36	0.08
	4	0	0	0	0	36	0.00
	5	0	0	0	0	36	0.00

CUL: Cultivated land

WGL: Wooded grassland

BUL: Bushland

A.D. Apparent density

Annex 5. Intervention phase parasitological monitoring data at Site I

S.No.	ID of animal	Sex	Age	Monitoring 1		Monitoring 2		Monitoring 3		Monitoring 4		Monitoring 5	
				PCV	Parasite	PCV	parasite	PCV	Parasite	PCV	Parasite	PCV	Parasite
1	DDRF3	F	1	18									
2	DDRF6	F	2	19									
3	FTRM6	M	2	22		18.5	2	21		25	2	23	2
4	HHWF6	F	2	19		22							
5	HHRF5	F	2	19		19		23		24		23	
6	HHRF6	F	2	14		16.5	2	15.5		19		20	
7	HHRM6	M	2	16		20		22		21		20	
8	HHM6	M	2	11	2	17.5		20.5		23		25	
9	HHRM5	M	2	19		22							
10	HHBF4	F	2	28		21		26		27		29	
11	HHBM6	M	2	20		22							
12	HHrF6	F	2	22		24		24		25		26	
13	HHrf4	F	2	21		25		30		30		29	
14	HHRF2	F	1	20.5									
15	HHrf6	F	2	22									
16	HHRF5	F	2	31		28		30		30		31	
17	HHBF5	F	2	16.5		23.5		24		26		28	
18	MMF5	F	2	23	2	20		19		21		21	2
19	MMRF4	F	2	20.5		23		28		27		26	
20	MMRF3	F	1	18		20		22		26		27	
21	MMrF3	F	1	25									
22	MMRF6	F	2	15.5		18		21		24		30	
23	MMrf3	F	1	22									
24	BKRM6	M	2	23	1	20		23.5		20		23	
25	BKRF5	F	2	21		32		31		35		32	
26	MH6F6	F	2	16		18		0		0		0	
27	KMRM4	M	2	25		26		29		27		28	
28	KMRF5	F	2	29									
29	KMBF5	F	2	19.5									
30	BWrM6	M	2	14	2								
31	BWrF3	F	1	15									
32	BWLF6	F	2	18									
33	BWLM7	M	3	18.5									
34	BWRF5	F	2	18									
35	BWRM7	M	3	22.5									
36	DDBF4	F	2	18	2								
37	MJRM5	M	2	25		27		27		28		29	
38	BBLF4	F	2	23		21	2	25.5		19	3	20	
39	BBWE5	F	2	26		20	2	19		19	1	22	
40	BBLF5	F	2	21		18.5	2						
41	MMRWF3	F	1	26									
42	FARM6	M	2	21									
43	DGRM7	M	3	30		33		35		32.5		33	
44	DGRM6	M	2	26.5		17		31		30		29	
45	DGRF5	F	2	21		19		22	1	21.5		28.5	
46	DGRF8	F	3	30		27.5		29		27.5		26	
47	DGRF3	F	1	23		31		27		31		30	
48	DGRM5	M	2	27		21	2	20		18		21	
49	DGRM2	M	1	16.5		23		20.5		22		23	
50	DGRM4	M	2	19		23		18		24		25	
51	DGLF6	F	2	30		35		28		20	2	26	
52	DGBF6	F	2	31		34							
53	DBWM6	M	2	18		24		17	1	20		0	
54	BBLM2	M	1	20		22		21		27		26	
55	BBLBF5	F	2	31		33		26		25		27	
56	BBRF6	F	2	20		21		28		31		29	
57	OOWF7	F	3	18		21		17		22		23	
58	OORF6	F	2	20		21		21		24		25	
59	OORF5	F	2	27									
60	AGRM4	M	2	27.5									
61	AGBM5	M	2	27.5									
62	AGWF8	F	3	29									
63	AGRM3	M	1	26									
64	FArF4	F	2	12.5	1	16		16.5					

Annex 5 continued

65	TMrM5	M	2	9	2	14							
66	TMRF6	F	2	20		21							
67	TMrF5	F	2	13	2	16							
68	AB6F5	F	2	23	2	22		24					
69	ABrM4	M	2	18.5		22		18.5	3	19		22	2
70	ABrF7	F	3	27		25		25		23		23	
71	ABrM2	M	1	22.5		26		25.5					
72	FFRM4	M	2	20									
73	HBr6	F	2	28.5		17		15.5	2	18.5	2	20	
74	HBrM5	M	2	26		25		28		29		31.5	
75	HBLF5	F	2	30		28		27		30		28	
76	MBRM3	M	1	16	2	21.5							
77	EDrM6	M	2	16.5									
78	EErF5	F	2	20									
79	ALRF5	F	2	28.5									
80	ABRM2	M	1	22									
81	ABRF2	F	1	16									
82	TKBM4	M	2	18.5		22							
83	MHRF6	F	2	17		17							
84	MHrF3	F	1	18.5		18		20		22		21	
85	HHBF6	F	2	21		20		24		25		26	
86	HhRF5	F	2	35		33	2	21	2	22		20	
87	HhrF4	F	2	24		25		30		30		29	
88	HHRM7	M	3	21		20		16		18		17	2
89	HHBF7	F	3	21		22		24					
90	HhRF4	F	2	29		26.5	2						
91	DgRM5	M	2	30		29	2						

Trypanosome species

1: *Trypanosoma vivax*

2: *Trypanosoma congolence*

3: *Trypanosoma brucei*

Age Category code

1. Animals in the range of 1-3yrs
2. Animals above 3 but up to 6yrs

3 Animals above 6years old

Annex 6. Intervention phase parasitological monitoring data at Site II

S.No.	ID of animal	Sex	Age	Monitoring 1		Monitoring 2		Monitoring 3		Monitoring 4		Monitoring 5	
				PCV 1	**Parasite 1**	**Pcv**	**Parasite**	**PCV**	**Parasite**	**PCV**	**Parasite**	**PCV**	**Parasite**
1	EDLM 7	M	3	21		31		32		28		27	
2	EDWM6	M	2	26		27		27		25		26	
3	EDLF6	F	2	32		29		30		29		27	
4	EDBM2	M	1	24		24		26	2	28		29	
5	EDWM3	M	1	16		21		23		24		25	
6	AKRM2	M	1	13		20		24		18		24	
7	AKWF2	F	1	13.5		17							
8	AKRF3	F	1	23		25		27		24		27	
9	AKRF2	F	1	18		21							
10	DFRF2	F	1	18.5		22		26		24		25	3
11	DFRM2	M	1	22		21							
12	YCLM7	M	3	28		29		30		31		30	
13	TTBM2	M	1	26		26							
14	TT6m5	M	2	21		23							
15	TTRF5	F	2	29		30							
16	TTRF6	F	2	28		28							
17	BBRF7	F	3	24	3	26		26		25		24	
18	BBBM6	M	2	30		31		26		29		30	
19	BBLF8	F	3	25		28	3	30		29		36	
20	BBRF2	F	1	22	1	21		24	3	28		24	
21	BBWF3	F	1	26		28		31		28	3	32	
22	BBRM6	M	2	22		23	3	27	1	29		28.5	
23	TBWM6	M	2	25	3	27		28		28	3	25	
24	TBRF3	F	0	21	3	24		24		33		30	
25	TBRM3	M	1	21		22		23					
26	TBRm4	M	1	28		28		27					
27	TBrm6	M	1	25		25							
28	TBRF2	F	0	21									
29	BBLF5	F	0	27		28		34		28		32	
30	AWRF2	F	0	18									
31	AWRM2	M	1	26									
32	AWLF2	F	0	17.5									
33	ESRF5	F	0	19		21							
34	IARM4	M	2	27		27		28		29		30	
35	AARF5	F	2	32		32		30		31		30	
36	AABF7	F	3	21		22		27		25		25	
37	SSWF4	F	2	20.5		21		21		24		27	
38	SSRM6	M	2	22		25		23		19		26	
39	SSWM6	M	2	23		24		25		26		25	
40	MTRF2	F	1	20		26		28		30		24	
41	MTRM2	M	1	26	1	28		25		22		27	1
42	MTRF5	F	2	25		30		27		25		27	
43	MTRM5	M	2	26		32		30					
44	MTBM5	M	2	27		32		31		33		30	
45	SLRF7	F	3	32		30		29		27		29	
46	DDRM5	M	2	33		33		29		27		28	
47	DDWF6	F	2	26		28		30		28		29	
48	TGRF2	F	1	26		28							
49	TGRF3	F	1	12		17	2						
50	DSRM6	M	2	34		34		30		31		30	
51	DSKF4	F	2	25		26		26		29		27	
52	EWRF2	F	1	17.5		21		21.5		23		23	
53	GSBF6	F	2	24	2	26							
54	TSBM3	M	1	24		25		25		20	1	23	
55	TSRM3	M	1	23		22		27		27		19	
56	TSRF5	F	2	33									
57	TSRM2	M	1	18.5	2								
58	TSRM5	M	2	28.5		30		31		30		24	
59	TSRF2	F	1	21		21		18		26		25	
60	DORF4	F	2	28		28		29		32		29	

Annex 6 continued.

61	SLWF3	3	F	1	25		24							
62	MGWF6	3	F	2	27.5									
63	ESLM5	4	M	2	30		31		29		30		27	
64	ESRM2	2	M	1	24		23		21		24		29	
65	EDLP7	4	F	3	27		27		25		29		27	

Trypanosome species

1: *Trypanosoma vivax*

2: *Trypanosoma congolence*

3: *Trypanosoma brucei*

Age Category code

1. Animals in the range of 1-3yrs
2. Animals above 3 but up to 6yrs

3 Animals above 6years old

Annex 7. Field and laboratory equipments utilized at Site I

No.	Description	Unit	Unit Price	Quantity	Total cost/Birr	Perspective		Component	
						Farmer	Government	Reaearch	Intervention
1	Lancet	pack	55	0.5	27.50		27.50	27.50	
2	Haematocrit cap. Tube	pack	55	7	385.00		385.00	385.00	
3	Sealant	Pcs	31	2	62.00		62.00	62.00	
4	Microscopic Slide	pack	46	4	184.00		184.00	184.00	
5	Cover slide	pack	15	4	60.00		60.00	60.00	
6	Mesh	m2	3.5	13	45.50		45.50	45.50	
7	Alcohol	litre	11	0.5	5.50		5.50	5.50	
8	Cotton wool	roll	26	1	26.00		26.00	26.00	
9	Grease	kg	35.2	1	38.20		38.20	38.20	
10	Nilon rope	metre			40.00		40.00	40.00	
11	Dispensers	-			50.00		50.00	50.00	
12	Wire pegs	kg			10.00		10.00	10.00	
13	Jerrycan (20litre)	Pcs	25	2	50.00		50.00	50.00	
14	Jerrycan(10litre)	Pcs	15	3	45.00		45.00	45.00	
15	Tope cone	Pcs	7	50	350.00		350.00	350.00	
16	Tope cage	Pcs	7	50	350.00		350.00	350.00	
17	Center pole	Pcs	8	50	400.00		400.00	400.00	
18	Side poles	Pcs	1	150	150.00		150.00	150.00	
					2,278.70		**2,278.70**	**2,278.70**	

Annex 8. Field and Laboratory equipments utilized at Site II

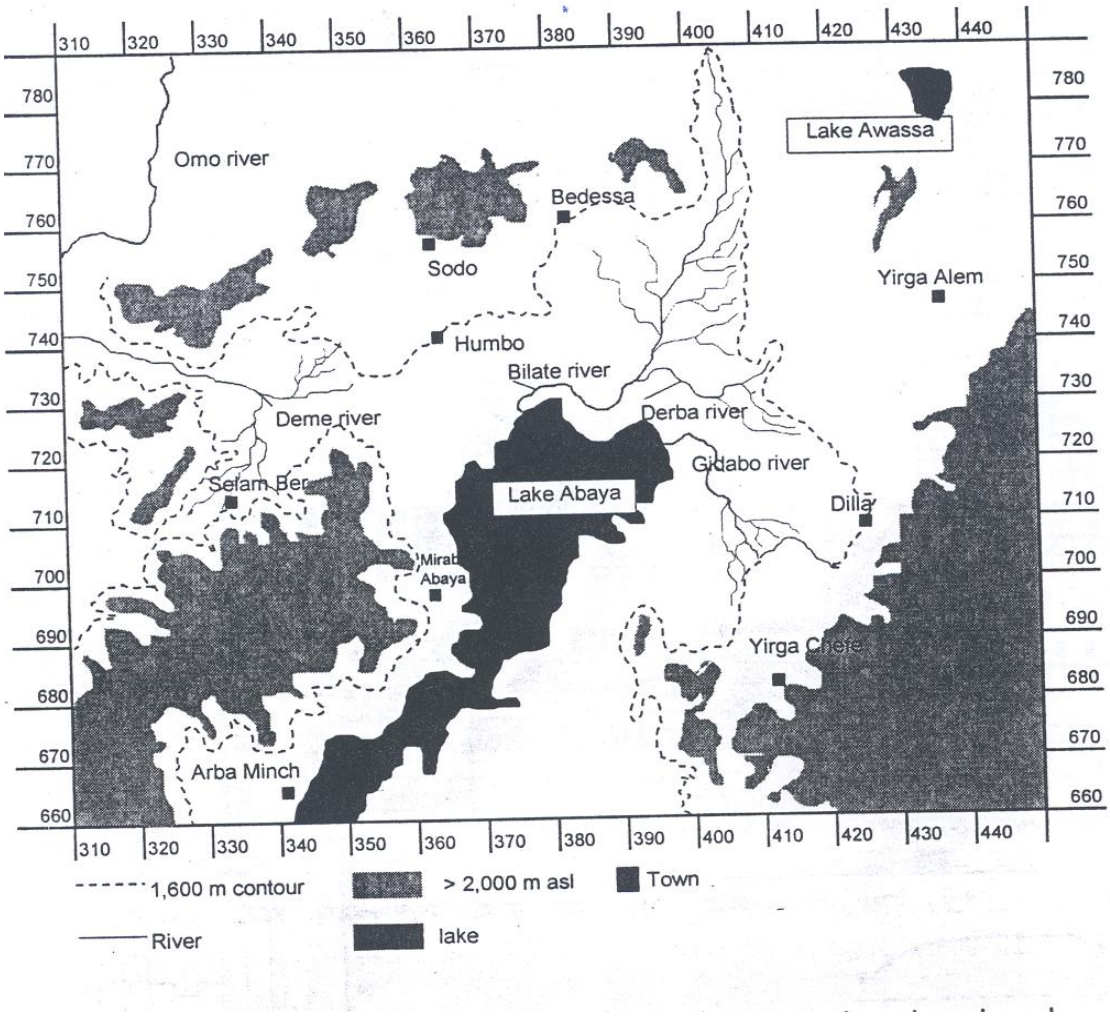
No.	Description	Unit	Unit Price	Quantity	Total cost/Birr	Perspective		Component	
						Farmer	Government	Reaearch	Intervention
4	Lancet	pack	55	0.5	27.50		27.50	27.50	
5	Haematocrit capillary tube	pack	55	5	275.00		275.00	275.00	
6	Sealant	Pcs	31	2	62.00		62.00	62.00	
7	Microscope slide	pack	46	4	184.00		184.00	184.00	
8	Cover slide	pack	15	3	45.00		45.00	45.00	
9	Mesh	m2	48	6.5	312.00		312.00	312.00	
10	Alcohol	litre	11	0.5	5.50		5.50	5.50	
11	Cotton wool	roll	26	1	26.00		26.00	26.00	
12	Grease	kg	38.2	1	38.20		38.20	38.20	
13	T-bar applicator	Pcs	300	1	300.00		300.00		300.00
14	Jerrycan	Pcs	25	2	50.00		50.00	50.00	
15	Top cone for trap	Pcs	7	50	350.00		350.00	350.00	
16	Top cage for trap	Pcs	7	50	350.00		350.00	350.00	
17	Center pole	Pcs	8	50	400.00		400.00	400.00	
18	Side pole	Pcs	1	150	150.00		150.00	150.00	
					2,575.20		**2,575.20**	**2,275.20**	**300.00**

Annex 9. NG2U trap used for tsetse catching during the study

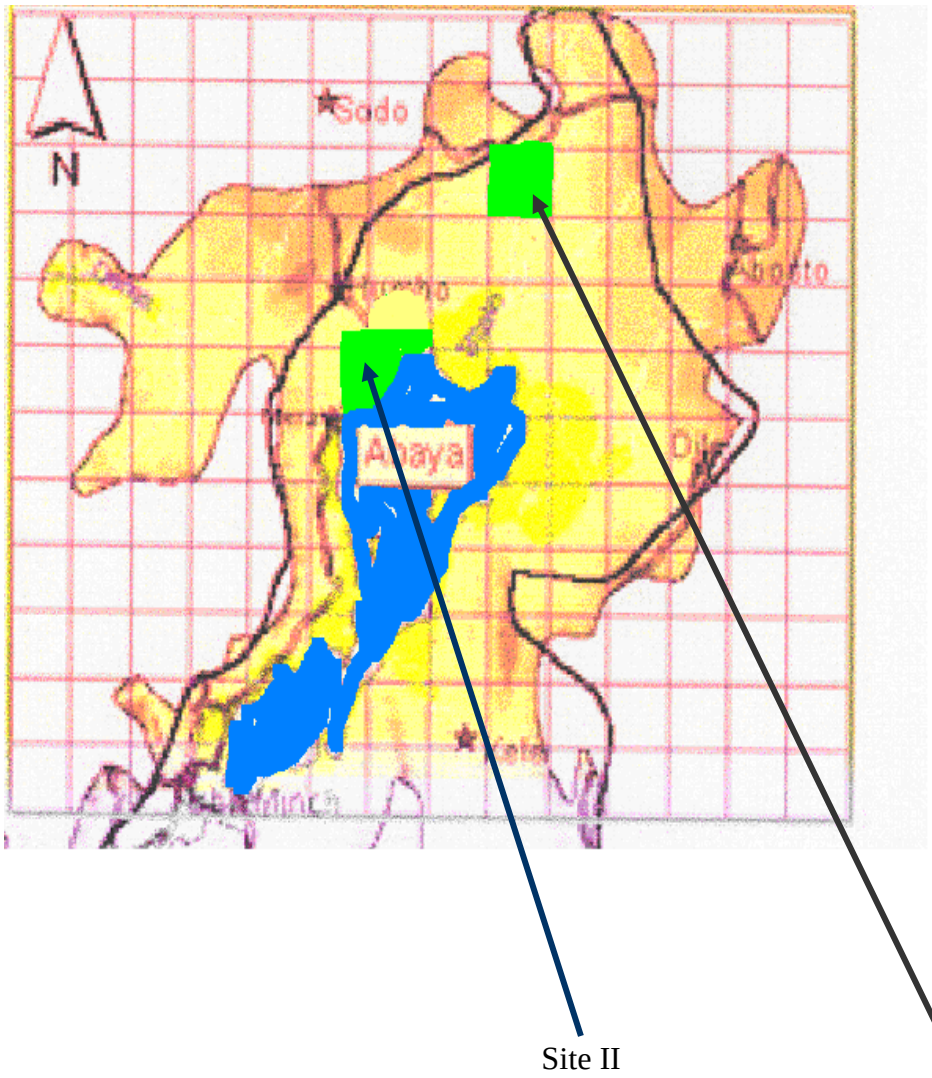
Annex 10. Target deployment activity (community)

Annex 11. A technician applying ’Pour-on’ to cattle

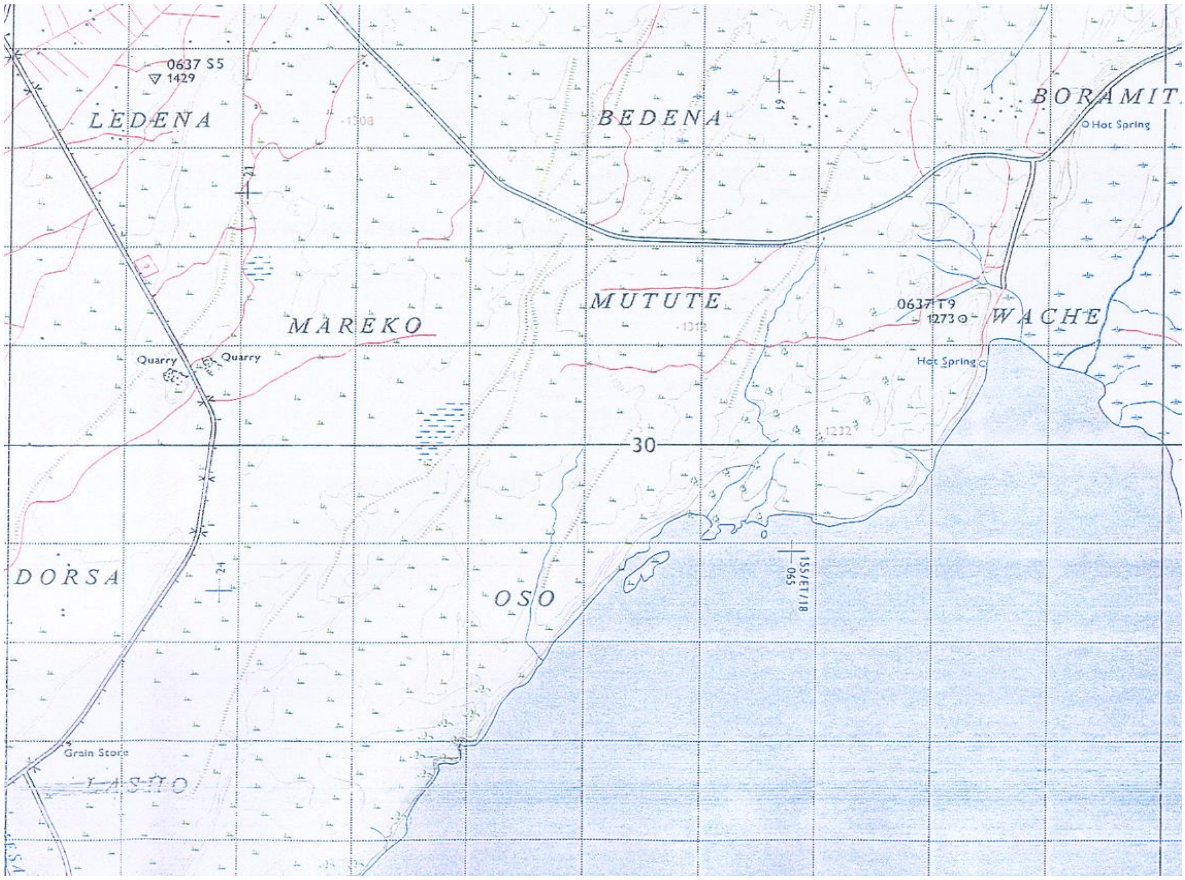
Annex 12. Map of Southern Tsetse Eradication Project (STEP) area



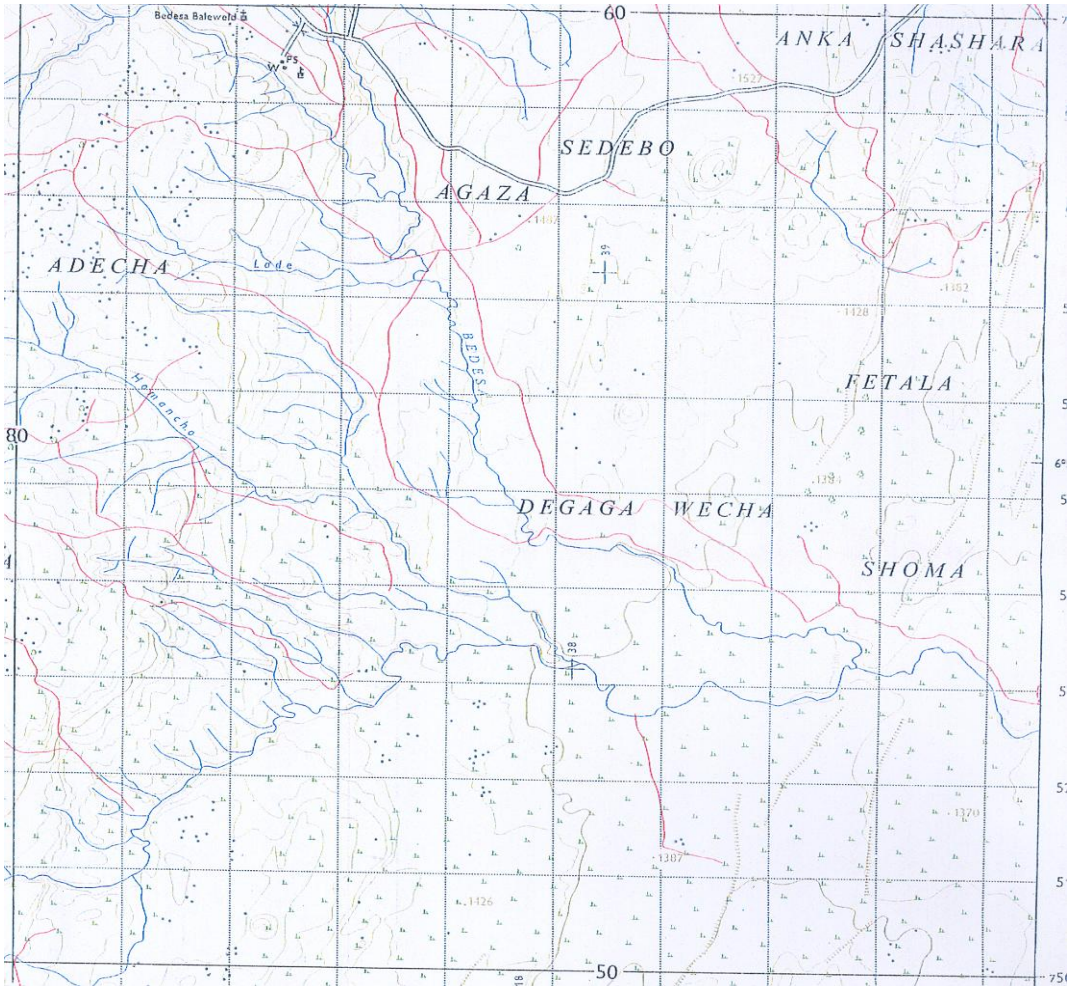
Annex 13: Map of Southern Tsetse Eradication Project (STEP) area showing the two trial Sites



Annex 14: Map of trial Site II(Abela Mareka)



Annex 15: Map of trial Site I (Sedebo)



Annex 16: Description of the strategies compared by cost-effectiveness

Time frame	1) comparing scenario doing nothing with intervention at both sites after 1 month
	1) comparing scenario doing nothing with intervention at both sites after 6 month
Cost included	1) Routine intervention (without research cost)
	2) With research cost
Perspective	1) Governments' perspective
	2) Farmers' perspective
	3) Society's perspective

9. CURRICULUM VITAE

1. Personal identification

Name:	Jemere Bekele Harito
Birth place:	Masha, SNNPRS
Birth date:	23rd December, 1966 G.C.
Sex:	Male
Marital status:	Married
Nationality:	Ethiopian
Profession:	Veterinarian
Occupation:	Team leader, veterinary service

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2. Educational Background

1974/75-1979/80:	Elementary School Keja Elementary School, Masha, Ethiopia
1980/81-1985/86	Secondary School Masha Secondary School, Masha, Ethiopia Award: ESLCE Certificate
1986/87-1991/92	Higher education attended Addis Ababa University, Faculty of Veterinary Medicine Debre zeit, Ethiopia Award: Degree of Doctor of Veterinary Medicine

3. Work experience

Year	Institution and responsibility held
1993 – 1999	Ministry of agriculture, Sheka Zone agricultural department Field veterinarian, treatment and control of animal diseases and extension service
2000- 2001	Team leader, Veterinary service, Sheka Zone agricultural department
2001- 2002	Head, agricultural department, Sheka Zone

4. Language Skills

Shekinoono:	reading, writing and speaking
Amharic:	reading, writing and speaking
English:	reading, writing and speaking
Oromifa:	reading and speaking

5. Trainings attended:

- Development project planning and appraisal by GTZ open self-help office (SNNPRS) in 1997. Certificate Awarded.
- Training programme on management, Development in the areas of management, Finance, Integrated rural development, Policy, Project and development planning organized by the office of the prime Minister of the Federal Democratic Republic of Ethiopia in collaboration with the Southern Regional Government, Awassa, Ethiopia, July 22nd – November 3rd, 1997. Award : Certificate

6. Papers / Publications

Jemere B. (1991): Review on the major reproductive characteristics of the indigenous zebu (Bos-indicus) males in the tropics. Seminar, problems in livestock development. Addis Ababa University, Faculty of Veterinary Medicine, Debre zeit , Ethiopia

Jemere B. (1992): Prevalence of bovine trypanosomiasis at different altitudes of Arjo escarpment, Wollega, Ethiopia. Addis Ababa University, Faculty of Veterinary Medicine, Debre zeit, Ethiopia. DVM Thesis.

Jemere B. (2003): An Overview of tsetse and trypanosomosis control efforts in Ethiopia: past activities and future prospects. Seminar on current topics. Addis Ababa University, Faculty of Veterinary Medicine, Debre zeit, Ethiopia.

Jemere B. (2004): Control of tsetse and trypanosomosis in the southern Rift valley (STEP) area: evaluation of Deltamethrin applications. Addis Ababa University, Faculty of Veterinary Medicine, Debre zeit, Ethiopia. MSc Thesis.

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10. SIGNED DECLARATION SHEET

I, the undersigned, declare that the thesis is my original work and has not been presented for a degree in any University.

Name _____

Signature _____

Date of Submission _____

This thesis has been submitted for examination with my approval as University advisor.

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