ADDIS ABABA UNIVERSITY
Faculty of Veterinary Medicine

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Fachbereich Veterinärmedizin

INTEGRATION OF TSETSE SURVEY DATA AND AGRO-ECOLOGICAL CHARACTERISTICS FROM REMOTELY SENSED AND FIELD OBSERVATIONS IN A GEOGRAPHIC INFORMATION SYSTEM IN SOUTHERN RIFT VALLEY OF ETHIOPIA.

by

Bergenie Bancha

December, 2001

ADDIS ABABA UNIVERSITY- FREIE UNIVERSITÄT BERLIN

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DEDICATION

I praise the LORD for guiding my life to this moment

In loving memory of my late grandma, Taayiile. May her soul rest in eternal peace.

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LIST OF ABBREVATIONS

APT	Automatic Picture Transmission
AVHRR	Advanced Very High Radiometric Resolution
BUL	Bush land
^{0}C	Degree Celsius
CI	Confidence Interval
C.S.A	Central Statistical Authority
CUL	Cultivated land
DEM	Digital Elevation Model
ESA	European Satellite Agency
ESRI	Environmental Science Research Institute
FFF	Forest
GAC	Global Arial Coverage
GCP	Ground Control Point
GGL	Grassland
GIS	Geographic Information System
Gp	Glossina pallidipes
GPS	Global positioning system
HRPT	High Resolution Picture Transmission
IFOV	Instantaneous field of view
km	Kilo meter
km^2	Square Kilo meter
LAC	Local Arial Coverage
m	meter
mm	millimeter
MOM	Modular Opto-elctronic Multispectral mscanner
MSS	Multispectral scanner
NDVI	Normalised Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NIR	Near infrared
Pixel	Pixel element
r	Correlation coefficient
RBV	Return Beam Vedicon
RFF	Riverine forest
RF	Rainfall
RH	Relative humidity
SIT	Sterile Insect Technique
SNNPRS	Southern Nation Nationalities and Peoples Regional State
SPOT	Systemè Porbatoir d Observation de la Terre
SRVETEP	Southern Rift Valley of Ethiopia Tsetse Eradication Project
TM	Thematic Mapper
UTM	Universal Transverse Mercater
WGL	Wooded grassland
WL	Wooded land

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ABSTRACT

A tsetse fly survey was carried out in over 100 km^2 of the study site of the Southern Rift Valley of Ethiopia Tsetse Eradication Project (SRVETEP) with the objective of integrating the remotely sensed data, ground verified agro-ecological characteristics and tsetse survey data in a geographic information system (GIS).

Field data collection on tsetse fly distribution and abundance and ground vegetation type observation was conducted in two seasons; the dry season survey (March) and the wet season survey(June and first week of July). Seventy-eight NGU traps baited with acetone and three week old cow urine was used for catching tsetse during each season. Traps were deployed in a transect in a selected 1x1 Km. UTM (Universal Transverse Mercater) grid square . A hand held receiver GPS (Garmin 48) was used for geo-referencing and spot elevation measurement of the trapping sites. Remotely sensed Landsat TM of the area taken in 1994 was analysed . The digital image processing employed the supervised classification procedure with the maximum likelihood decision rule. Tsetse survey data, ground observed vegetation type and the processed remotely sensed data were integrated into the GIS database in ArcView 3.1. Various environmental features like roads, rivers, settlement, contours and Lakes in the study area were digitised and incorporated into the GIS databse.

Only one species of tsetse fly, *G. pallidipes* was caught in the study area. There were high catches of tsetse flies, a total of 720 (70.2%) males and females, in the wet season, compared to the dry season catch ($P<0.005$). During the ground survey, four major vegetation types: bush land, wooded grassland, wooded land and cultivated land, where *G. pallidipes* can inhibit were identified in the study area. In the dry sampling season,the highest mean catch was from the wooded grassland (mean = 11.7) followed by wooded land (mean = 9.2). In the wet season, the pattern is the same except that there was an increase in the mean catch (mean = 13.7 and 12.5 respectively). Almost all the traps in bush land vegetation type caught *G. pallidipes* in different proportions during the wet season. This indicates that *G. pallidipes* is widely dispersed in the bush land vegetation type.

The classification of digital image yielded seven types of land cover/use of the study area of which the four types were the same as in ground verified vegetation type in different proportion. Over 77% of the bush land vegetation type in the image was accurately classified to the same class in the ground but the classification accuracy was lower in wooded grassland

and wooded land vegetation types (only 33.3% each). The ground vegetation type was used as the reference data. The lower classification accuracy in wooded grassland and wooded land could be attributed to the small size of the study area in order to adquately identify the representative vegetation type for these particular types during the image classification.

The Normalised Difference Vegetation Index of the area was estimated from the same satellite data and the output image of NDVI showed at least three types of vegetation cover in the area. The green areas corresponded to the wooded land vegetation type along the base and flunk of the escarpment, the bright yellow areas corresponded to the bush land of various types in the valley and the golden yellow areas corresponded to the grassland in the high land areas of the study grid.

The integration of data in the GIS database revealed a combination of different layers with each layer having a specific information of each feature integrated. This demonstrated the GIS functional capabilities to combine a geo-referenced data from different sources to study the relationship among different features, for instance, tsetse fly distribution in relation to the vegetation type which could be assessed both by ground truthing and by using a remotely sensed satellite data.

The findings of this work indicated the potential of using remotely sensed data combined with GIS to study tsetse flies in relation to the environmental factors which could explain their temporal and spatial distribution. Using the remotely sensed data, vegetation types can be determined and suitable tsetse habitat with associated environmental parameters can also be predicted. This combined with ground survey for more accuracy will facilitate the decisionmaking process on tsetse fly control.

1. INTRODUCTION AND OBJECTIVES

1.1 Introduction

Ethiopia, located in the horn of Africa between latitude from 3^0N to 15^0N of the equator and longitude from 33^0E to 48^0E, is an agrarian country with an estimated human population of about 60 million and a land area of about 1.3 million km^2. The rural agricultural sector makes up 85 percent of the total population and accounts for 95 percent of all crop and livestock production (Slingenbergh, 1992). The livestock population of Ethiopia is estimated at 30 million heads of cattle, 21.7 million sheep, 16.7 million goats, 7.02 million equines, and 1million camels (C.S.A., 1998). Livestock contributes to the national export earning, source of food, cash income, and energy and fertiliser (Ford *et al.*, 1976; Leak, 1999).

Tsetse transmitted animal trypanosomosis is a serious constraint to livestock production and agricultural development in southern and south-western Ethiopia. Various reports on the situation of tsetse and trypanosomiasis in Ethiopia revealed that tsetse flies occupy over 66,000 km^2. area (Ford *et al.*, 1976) in the valley of southern and south- western of the country. Langridge (1976) has reported that some 98,000 km^2. area in the aforementioned parts of the country is infested with five species of Glossina, namely *Glossina pallidipes, G. morsitans submorsitans, G. fuscifus fuscipes, G. tachinoides, and G. longipennis.* However, due to the advancement of tsetse flies into formerly uninfested areas, currently about 130,000 to 150,000 km^2 area is estimated to be affected. These areas posses the country's most arable land with a high potential for agricultural development as they receive high annual rainfall (Jemal and Hugh-Jones, 1995). Slingenbergh (1992) noted that at least six million of the 50 million heads of cattle that are raised under trypanosomosis risk areas in Africa are in tsetse-infested areas of Ethiopia and are exposed to infective fly bites. Recent unpublished reports also indicated that tsetse transmitted trypanosomosis has put over 10 million heads of cattle under threat in Ethiopia (Vreysen *et al*; 1999) in areas below an altitude of 2000 meters above sea level. Losses to trypanosomosis in these affected areas are attributed to mortality and morbidity of livestock, treatment and control costs, and denied access to land resources. These losses in livestock and overall agricultural development are estimated to exceed US$236 million annually (Vreysen *et al.*, 1999). This is believed to affect directly or indirectly the lives of over 5 million people in the region.

The Southern Rift Valley region of Ethiopia, located between latitude $4^0 45'$ and $7^0 15'$ N and longitude $36^0 40'$ and $38^0 20'$ E, in the south-western part of the country, is one of the areas which is severely affected by tsetse flies and the subsequent problems. About 25,000 km^2 area that is agriculturally suitable and potential land in the valley is infested by tsetse flies. This figure by far exceeds the estimate by Ford *et al.* (1976) of 5,000 km^2some 25 years ago.. 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.

There is a diversity of factors known to affect the distribution of tsetse flies in different agro-ecological zones. This includes climate, vegetation, altitude and presence of suitable host animals (Buxton, 1955; Langridge, 1976; Ford *et al.*, 1976; Leak, 1999; Vreysen *et al.*, 1999). Buxton (1955) described that effective tsetse control requires a good knowledge on the factors that are responsible for the variation in tsetse population distribution. He also emphasised that tsetse control is, for the most part, an attempt to exploit the existing knowledge of the biology of the insect. In the Southern Rift Valley of Ethiopia, variation in tsetse population densities in different vegetation types and altitudes were observed during the entomological survey carried out by the Southern Rift Valley of Ethiopia Tsetse Eradication Project (SRVETEP) as part of the base line survey in 1998 - 1999. However, in order to facilitate the decisionmaking process, which type of control techniques to employ and which priority areas to select for the control program, the knowledge of the factors associated with tsetse distribution and abundance is of paramount importance.

Technologies like Geographic Information Systems (GIS) and remotely sensed satellite data analyses have more recently been used to examine environmental factors linked with tsetse fly distribution. Nuttal *et al.* (1995) noted the importance of GIS and remote sensing to demonstrate vector/environment relationships in the analysis of vector borne diseases. GIS are map-based tools that can also be used to study the distribution, dynamics and environmental correlation with diseases and their vectors (Connor *et al.*, 1995 and Boone *et al.*, 2000). Remote sensing and GIS are most useful if disease dynamics and distribution are clearly related to environmental variables such as vegetation and physical characteristics like average precipitation (Hugh-Jones, 1991; Connor *et al.*, 1995; Boone *et al.*, 2000). Kitron *et al.* (1996) related the seasonal and spatial distribution of tsetse flies and examined the relation with satellite imagery combined with GIS. They found a high correlation of tsetse fly catch with a remotely sensed fine resolution satellite data and suggested that satellite imagery may be a useful tool for predicting local variation in fly density. They further emphasised the importance of incorporating satellite imagery into a GIS-based surveillance programme to predict favourable fly habitat in inaccessible areas. In general, GIS is an information management tool that allows the association of remotely sensed data and ground gathered (reference) data with data on fly population dynamics, host distribution, human agricultural practices, trypanosomiasis infection rate and even to select priority areas for control programs (Rogers, 1991; Kitron *et al.*, 1996; Robinson, 1998; Allsopp, 1998).

This study is aiming to integrate some selected agro-ecological features from remotely sensed and ground gathered data into a GIS in order to improve knowledge of tsetse fly distribution and abundance in relation to vegetation, altitude, climate and other correlates. It is hoped that this will contribute by expanding the knowledge base to the ongoing tsetse eradication project in the Southern Rift Valley of Ethiopia.

1.2 Objectives

1.2.1 General Objective

- Relate spatial and temporal tsetse fly distribution patterns in the study area to the remotely sensed data and directly observed ecological features using major geographic information technologies: Global Positioning System (GPS), Remote Sensing (RS) and Geographic Information System (GIS).

1.2.2 Specific Objectives

- Establish a GIS database for the integration of Landsat image and map derived geographic information (i.e. land cover types, road network, drainage, elevation, settlements) and field data (tsetse fly catches).
- Field verification and comparison of land cover classification from satellite-derived base map with the ground surveyed vegetation classification in selected 1x1km UTM grid squares in the study area.
- Assess the predictive value of satellite imagery land cover data for the identification of tsetse habitat.
- Establish GIS functions for the input, manipulation (queries and analysis) and output (visual, tabular, statistical) of data.

2. LITERATURE REVIEW

2.1 Biology of tsetse flies

The most distinctive feature of the life history of tsetse flies, shared with only a few other small families of Diptera, is retention of the single mature egg in the uterus of the female, where it hatches to a larva and nourished by the products of a pair of modified accessory glands (Jordan, 1993). This method of reproduction is referred to as adenotrophic viviparity (Langley and Weidehaas, 1986; Jordan, 1993 and Leak, 1999).

This form of reproduction involves cyclical production of eggs, which hatch in the uterus (Leak, 1999) and the insect does not feed from the time it leaves the female fly as a mature larva until the adult emerges from the pupa (Phelps and Lovemore, 1994). Females are receptive to males as soon as they start seeking food and often mate either when taking their first blood meal or soon after. They usually mate once (they actively resist mating more than once), but sometimes more than one mating can occur. Male flies may not mate soon after emergence from the pupa and they are not fully fertile until they are a few days old.

Active and viable sperms can remain in the spermathecae, nourished by a secretion of layers of cells, which surrounds the cuticular lining of the lumen of each spermathecae, through out the life of the female. This is the basis for the need to mate not more than once in the female.

The whole pregnancy cycle takes approximately nine days, although the rate and development of each stage is temperature dependent. By the ninth day the third instar larva with its two conspicuous black polypneustic lobes at the posterior end is deposited through the vagina (larviposition) on the ground (Jordan, 1993; Nagel, 1995; Warners, 1997 and Leak, 1999). Leak (1999) described that the larva attempts to burrow in the soil shortly after deposition by female. The successful burrowing in the soil by the deposited larva depends on various factors, for instance, soil particle size, moisture content of the soil, and possibly the soil temperature are the most important ones.

Under favourable environmental conditions (temperature and moisture of the soil) newly deposited larva (white third–instar skin) is transformed within a few hours into a hard, almost black larva and moults to form the prepupa. But this remains within the third instar cuticle, which then hardens to form the puparium within an hour of larviposition. 30 days later adult fly emerges from puparium with the sex ratio of 1:1. The puparial period is highly dependent on temperature. For example, Jordan (1993) indicated that at a minimum temperature of 20^0C the duration of puparium period is about 47 days while at 30^0C it is about 20 days only. At temperatures below 17^0C and above 32^0C there are insufficient fat reserves within the puparium and development cannot be successfully completed.

The optimum temperature for the puparium development is 25^0C (Leak, 1999) and at this temperature males emerge after 30 days and females emerge after 27 days (Jordan, 1993).

Both sexes of tsetse flies feed exclusively on blood of vertebrates (mainly from mammals but some species take the meal from reptiles and birds). They usually search for hosts and food when they are active. It has been noted that female flies live longer (the mean life span being 8 weeks) than males (about four weeks) in the field. As a result of this, there are always more females than males in any tsetse population.

A female fly may produce about 8-10 offsprings in her lifetime. Consequently, the rate of reproduction is much lower than in any oviparous insects and in fact resembles that of small mammals (Langley and Weidehaas, 1986; Leak, 1999) and this suggests the suitability of controlling tsetse flies by the release of sterile males (SIT).

2.2 Factors affecting tsetse fly distribution

Tsetse flies occur only in Africa south of the Sahara and north of the temperate climates in the south of the continent. They are unevenly distributed within their ranges, the occurrence affected by species-specific factors (Nagel, 1995). Leak (1999) noted that even though more precise limits of distribution, particularly in low population densities are not known, the general distribution of tsetse flies is determined principally by climate and influenced by altitude, vegetation and the presence of suitable host animals.

However, recent technological advancements led to the use of current techniques like the GIS and remote sensing to understand factors associated with tsetse distribution without even being in particular place.

2.2.1 Climate

The effect of climate on tsetse distribution is often through its effect on vegetation. Buxton (1955) discussed in detail the relationship between tsetse flies and different climatic factors. However, most of these discussions were based on the results of laboratory experiments and such results might not be fully in agreement with situations in the field. But this is not far from the general truth. The effect of temperature on the ecology of tsetse flies is through its effect on the interval and puparial duration and also the influence on the activity of the flies (Buxton, 1955). In temperatures below 15^0C tsetse flies are inactive and above 35^0C they seek refuge in rot-holes in the trees and animal burrows and deep tissues in the barks, where they remain inactive (Phelps and Lovemore, 1994). Temperature greater than 40^0C has a lethal effect both to the larger and smaller species of tsetse and their puparium (Buxton, 1955 and Phelps and Lovemore, 1994).

Humidity is another important factor for both pupal and adult fly development. Tsetse flies require certain soil humidity for development (Nagel, 1995). Cumulative effects of long rainy or dry seasons are thought to have been importance in influencing advances and recession in tsetse population (Leak, 1999). Humidity has also an important effect in relation to the behaviour of the flies.

Buxton (1955) has also noted the effect of light. Tsetse flies use light for searching food and most tsetse flies are active during daytime.

The effect of altitude on tsetse distribution is through its effect on climate, mainly temperature. As temperature falls with increasing altitude the geographic limitations of different species may be due to their inactivity in lower temperatures (Vreysen, *et al.*, 1999).
In general, according to Rogers (1991), climate cannot determine the abundance directly, but only via its effect on one (or more) of the four important demographic rate- of birth, death, immigration and emigration. Climate affects these parameters and thus shifts the demographic balance in one way or another.

2.2.2 Vegetation

Different species of tsetse flies require particular vegetation type that would provide an optimal condition for growth and survival (for example, *morsitans* group in savannah, *fusca* group in forest and *palpalis* group in forest and river banks). Vegetation is not only important that provides shade for tsetse flies at lower altitude, but it also provides shelter for their hosts (Buxton, 1955; Leak, 1999; Phelps and Lovemore, 1994).

Vreysen, *et al.*, (1999) reported that the highest catches of *G.pallidipes* were in bushes (tickets) and wooded grassland in the Southern Rift Valley of Ethiopia. Different vegetation classification (like wooded grassland, forest, riverine forest, bush land, grassland and cultivated land) was available in tsetse-infested areas. However, one can classify in more detail classes and subclasses using remotely sensed data when combining with ground truth. Moreover, vegetation type in a given locality is greatly influenced by temperature and humidity and it is subject to the amount of rainfall of that particular region.

2.2.3 Host animal

The presence of host animals is very important for tsetse fly distribution. Phelps and Lovemore (1994) noted that the distribution and abundance of some species especially *G. morsitans* and *G. pallidipes*, which are often referred to as the game tsetse flies, are closely related to the numbers and habitats of certain wild animals. Nagel (1995) also described that the highest densities of certain tsetse fly species are reported from areas with very high densities of wild mammals and low human population areas.

2.3 Remote Sensing and the Geographic Information System (GIS)

2.3.1 Remote Sensing

2.3.1.1 Definition and Importance

Remote Sensing is defined as the method of acquisition of information about an object without physical contact (Colwell, 1983). It means obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Washino and Wood, 1994; Thrusfield, 1995). Thus, the use of the term remote sensing usually refers to the gathering and processing of information about the earth's environment, particularly its natural and cultural resources, through the use of photographs and related data acquired from an aircraft or satellite.

2.3.1.2 Acquiring Remote Sensing Data

Basically remote sensing is a science and an art. Washino and Wood (1994) in their description on the application of remote sensing to vector arthropod surveillance have discussed that the science of remote sensing rests on the fact that every object, area, or phenomenon reflects or emits energy at specific and distinctive wavelengths of the electromagnetic spectrum. On the other hand, the art of remote sensing lies in the ability to exploit the basic matter and energy relationships in order to identify, map or monitor features of interest. Moreover, remote sensing can also be referred to as the use of imaging devices that measure reflected and /or emitted energy from the earth's surface in the visible and infrared wavelengths.

Traditional methods of acquiring remote sensing data, as discussed by Washino and Wood (1994) and Thrusfield (1995), employ cameras or a variety of electronic sensing devices that can be mounted on platforms located anywhere from a few meters to thousands of kilometres from the object, area, or phenomenon of interest.

There are two types of gathering remote sensing data:

1. Passive sensors- are sensors which record reflected or emitted energy. They include photography and multi spectral scanners.
2. Active sensors-are sensors that transmit short bursts of microwave energy to illuminate the surface, for example, radar. These systems then record the return signal from within their field of view. They have an advantage over passive systems in that they can be used day and night under all weather conditions and most importantly they provide their own source of energy within the microwave (1mm to 1m) portion of the electromagnetic spectrum to illuminate features of interest.

2.3.2 The Satellite system

Satellite systems are of global character by nature, because they are in orbit and cover all or at least very large part of the world. Thus, there is no doubt remote sensing satellites can offer a great deal of information for all kinds of land information system.

Among the most widely used sensors for the remote sensing of data, for the assessment of the environment are, Landsat's Multi-Spectral Scanner (MSS) and Thematic Mapper (TM), the National Oceanic and Atmospheric Administration (NOAA)'s Advanced Very High Resolution Radiometer (AVHRR), and France's Systemè Probatoir d'Observation de la Terre

(SPOT) (Harris,1990; Beck et al., 2000). The Japanese system Medular Opto-electronic Multispectral Scanner (MOM) the European Satellite Agency (ESA) remote sensing satellite are also on use

2.3.2.1 Landsat

This is the American Commercial Earth Observation Satellite. Landsat imagery forms the bulk of space imagery, which is available to photogrametrists and cartographers. Landsat satellites carried 3 principal sensor packages: Return Beam Vidicon (RBV), Multi Spectral Scanner) and Thematic Mapper (TM). Of these sensors, Thematic Mapper is the most widely used. Landsat is a low orbit satellite whose TM sensor records data in six spectral channels at a 30 x 30m, and one at 120 x 120m spatial resolution with repeat time of 16 - 18 days and high resolution with 30 meters pixel size. It operates in seven bands in the visible, near infrared, short wave infrared, and thermal infrared regions of the electromagnetic spectrum (Harris, 1990) (Table 1).

Petrie (1979) has indicated that the work carried out on Landsat imagery falls in to two main categories:

- Accuracy testing
- Interpretation and mapping

The accuracy of remotely sensed data depends greatly on the clarity of atmosphere quantified in the inverse form of optical thickness (Hiernaux, 1988). While in the interpretation and mapping a simple enlargement technique is used without geometric correction, but this suffices to meet the accuracy specification at that scale (Harris, 1990).

Images from Landsat satellites were used for various studies and assessment of factors related to different environmental conditions. However, Harris (1990) emphasised that the primary emphasis of Landsat is on land application, and it has widely been used for geology, forestry, agriculture and hydrology. Wood *et al.* (1991), in the study to evaluate the use of Landsat TM imagery and GIS modelling techniques to distinguish between high and low anopheline producing rice fields in California, have also discussed the potential of Landsat TM for measuring vegetation parameters such as plant density, percent canopy cover, and leaf area that can influence anopheline larva habitat quantity.

Table 1: Wavebands and principal application of Landsat TM bands

Band	Wavelength range (Micrometer)	Application
1	0.45-0.52 (Blue)	Costal water mapping, soil/ vegetation differentiation
2	0.52-0.60 (Green)	Green reflectance by healthy vegetation
3	0.63-0.69 (Red)	Chlorophyll absorption
4	0.76-0.90 (Infrared)	Biomass survey
5	1.55-1.75 (Infrared)	Vegetation moisture, snow or cloud discrimination
6	10.4-11.7(Thermal Infrared)	Thermal mapping
7	2.08-2.35 (Infrared)	Geological mapping

Modified after Harris (1990) and Hartl et al. (1990)

2.3.2.2 The National Oceanic and Atmospheric Administration (NOAA)/ Advanced Very High Resolution Radiometer (AVHRR)

The NOAA / AVHRR satellite system has been in operation since the launch of Television Infrared Observations (TIROs) in October 1978. AVHRR is one of the main sensors of the NOAA satellite with a five channelled sensors operating in the visible, near-infrared, short-wave infrared, and thermal infrared regions of the spectrum (Harris, 1990). It is an operational, high quality, cross- track, line scanning multispectral radiometer (Huh, 1991). It acquires a day and night-time infrared measurements of the earth's surface (Malone, 1995). The digital data of AVHRR are at 1.1 km maximum spatial resolution; 2800km swath width beneath the satellite. It measures daytime reflected solar radiation in the visible and near infrared spectral bands and radiation both day (TMax) and night (TMin) in the mid-infrared portion of the spectrum (Huh, 1991 and Malone, 1995). The same authors have described that the NOAA's AVHRR satellite operational system provides imagery of the globe at least four times per day.

These data are broadcasted in two modes:

- Automatic Picture Transmission (APT) – a low-cost, low-resolution, and two channel data
- High Resolution Picture Transmission (HRPT)- full resolution, all channels and other data

Saull (1985), Harris (1990) and Huh (1991) have stated that there are four data types operationally available from the AVHRR. These are:

1. Automatic Picture Transmission (APT). This is a broadcast, low resolution, direct read-out to worldwide ground station of the APT visible and infrared data, providing two channels at 4km maximum resolution. The data are reserved only within the radio horizon of the local antenna.
2. High Resolution Picture Transmission (HRPT). Broadcasts continuously around the world to ground stations equipped with tracking antennae, receiving all five channels, at 1.1km resolution. Data are received only with in the radio horizon of the local antenna. It is available when the satellite is in line of sight of ground receiving station, however, the coverage by ground station is local and is constrained by the horizon view of the satellite;
3. Global Area Coverage (GAC). On-board spacecraft recording of 4km resolution data from spectral channels. These data are available for two complete coverage of the globe each day. The full resolution data are sampled to allow the construction of the globe image at low resolution;
4. Local Area Coverage (LAC). On-board, tape-recorded, high-resolution data from selected portions of each orbit (one equator-orbit maximum recorder time, 1.1km resolution, and all channels).

Collectively, these data from NOAA/AVHRR are arguably the most comprehensive set short repeat time remotely sensed imagery. Such high temporal frequency is the main virtue of the NOAA/AVHRR system in relation to other systems such as Landsat/TM or Landsat/MSS. It increases the sequential cloud free imagery that is necessary for application in various fields, for example, agricultural and hydrological monitoring systems (Saull, 1985).

Table 2: Wavebands of the NOAA-AVHRR

Channel	Wavebands (micrometer)
1	0.58-0.68
2	0.725-1.1
3	3.55-3.93
4	10.3-11.3
5	11.5-12.5

Source: Harris (1990)

2.3.2.3 SPOT

This is a French Commercial Earth Observational satellite. It carries High-Resolution Visible (HRV) sources with two modes. The satellite has a narrow swath (60x75km) and fewer bands: two in the visible and two in the infrared with a resolution of 20 meters. On the other hand, SPOT has an extra, which is broad panchromatic band with a 10 meters resolution. The data are ideal for mapping applications including stereoscopic coverage (Harris, 1990).

Table 3: Data collection interval, resolution of each pixel (picture element) and swath width for data from polar-orbiting satellite commonly used for remote sensing and geographic information systems.

Satellite/sensor	Interval	Resolution	Swath
NOAA/AVHRR	12 hours	1.1km	2800km
Landsat MSS	18 days	79 meters	185 km
TM	16 days	30 meters	185km
SPOT	26 days	20 meters (Infrared)	60km
		10 meters (visible)	60km

Source: Malone (1995)

2.3.3 Image processing and analysis

The digital image is a representation of any real scene formed from a regular (two-dimensional in x-y space) arrangement or array of picture elements (Pixels) in columns and rows. Each pixel corresponds to an equivalent area on the Earth's surface. The ground area represented by the pixel is related to the effective resolution of the sensor system. The size of this ground segment is determined by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time (Hartl *et al.*, 1990). Any given pixel is composed of integrated single value reflection collected from all the various reflecting objectives, including clouds, with in that segment of the surface encompassed in the IFOV. The detected radiation from one ground element is encoded in digital numbers. The values in a range of 0 to 255 of one element or pixel is called its grey value (0 is dark, 255 is bright). These digital numbers represent measured intensities. The intensity value represent the measured physical quantity such as the solar radiance in a given wavelength band reflected from the ground, emitted infrared radiation or back scattered radar intensity.

Prior to data analysis, initial processing on the raw data is usually carried out to correct for any distortion due to the characteristics of the imaging system and the imaging condition. These correction procedures include radiometric correction (to correct for uneven sensor response over the whole image) and geometric correction (to correct for geometric distortion due to Earth's rotation and other imaging conditions such as oblique view). Furthermore, if accurate geographic location of an area on image is needs to be known ground control points (GCP) are used to register the image to a precise map (geo-referencing).

Different land cover types in an image can be discriminated using some image classification algorithms using spectral features, i.e. the brightness and "colour" information contained in each pixel. There are two classification procedures, the supervised and unsupervised classification.

In supervised classification, the spectral features of some areas of known land cover types are extracted from the image. These areas are known as the training areas. Every pixel in the whole image is then classified as belonging to one of the classes depending on how close its spectral features to the spectral features of the training areas.

In unsupervised classification, the computer program automatically groups the pixels in the image in to separate clusters, depending on their spectral features. Each cluster will then be assigned a land cover type by the analyst.

Each class of land cover is referred to as a theme and the product of classification is known as a thematic map. The accuracy of the thematic map derived from a remote sensing images should be verified by field observation.

2.3.4 Normalised Difference Vegetation Index (NDVI)

The amount and composition of solar irradiance that strikes the surface and the reflectance properties of the surface determine the amount of light reflected from a surface. However, this solar irradiance is variable depending on the time and atmospheric conditions. Because of this variability it is not possible to characterise the surface in a repeated manner from a single measure of light reflected from a surface. Jackson and Huete (1991) explained that this problem can be circumvented somewhat by combining data from two or more spectral bands to form what is commonly known as vegetation index. Vegetation index can be calculated by rationing, differencing, rationing differences and sums, and by forming linear combination of spectral data. NDVI is calculated in order to identify and estimate the greenness and health of foliage. Normalised Differences Vegetation Index (NDVI) can be calculated by rationing the differences between near infrared (NIR) and visible wavelength (R) bands:
NDVI=NIR-R/NIR+R (Hiernaux, 1988; Harris, 1990; Jackson and Heute 1991; Rogers, 1991; Cihlar, *et.al.*,1991).

Because vegetation has low visible (red) reflectance and a high near infrared (NIR) reflectance, by applying the above equation high vegetation amounts are distinguishable from bare areas and areas of low vegetation (Harris, 1990). Vegetated areas will have higher ratio Vegetation Index values compared to non-vegetated areas. Rogers (1991) discussed the reason for combination and rationing the differences of radiances over their sum for obtaining NDVI. According to the discussion, the active photosynthetic tissue absorbs the visible red and reflects infrared and rationed in order to diminish the variation introduced into the raw waveband information by varying atmospheric absorption and view-angle differences.

Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production (Jackson and Huete, 1991). However, the same authors have warned that the successful use of these indices requires knowledge of units of input variables used to form indexes, and an understanding of the manner in which the external environment and the architectural aspect of one vegetation canopy influences and alters the computed index value. They also have expressed that the index value can also be altered by several factors such as the soil background, moisture condition, solar zenith angle, view angle, as well as the atmosphere, even though the vegetation indices were developed to extract plant signal only.

In most cases, the images for the analysis of NDVI are obtained from the advanced very high resolution radiometer (AVHRR) sensor of the National Oceanic and Atmospheric Administration (NOAA) series of the meteorological satellites and processed to provide normalised differences vegetation index or NDVI (Hiernaux, 1988; Harris, 1990; Jackson and Huete, 1991; Rogers, 1991; Malone, 1995) but it is also possible to obtain satellite image for NDVI determination from Landsat TM (Wood, *et al.* 1991).

Rogers and Randolph (1991) have related measurements of vegetation types, derived from AVHRR data, to field measurements of saturation deficit and tsetse fly population. In their study, the vegetation measurements were derived from NDVI, which were considered as the integral picture of environmental factors that determine tsetse fly survival. They found a significant correlation fly mortality rates and fly sise with the mean NDVI values. Rogers (1991) has also found significant correlation between vector mortality rates and mean monthly NDVI values. Using TM images to to remotely specify habitat of tick, *Amblyomma variegatum*, for which ground survey was carried out regarding tick density and habitat, Hugh-Jones (1998)described the importance of satellite imagery for differentiating fields with heterogenous vegetation type and high tick densities from fields with a single vegetation type and low tick density. High tick density to be correlated with high variance in NDVI bands.

2.3.5 Limitations of using Satellite imagery

Even though there are a great diversity of application of remotely sensed data, there also exists certain limitation for using them. Harris (1990) and Lessard *et al.* (1990), noted some of the limitations; The use of high resolution satellite imagery is limited by its cost, poor temporal resolution is a serious limitation as cloud cover may obscure a scene (area of image) frequently enough to allow one good image of the region and infrequent occurrence of high images for use in large scale.

Particularly on the utility of NOAA/AVHRR data for Earth surface application Huh (1991) discussed five categories of limitations:

1) Spatial resolution and its time variability;

2) Atmospheric effects on the measurements (basically the cloud cover);

3) Problem of in-flight calibration of visible and near- infrared sensor;

4) Special problem with mid- infrared sensor;

5) The wide spectral sensitivity bands of the data channel.

2.3.6 Geographic Information Systems (GIS)

2.3.6.1 General Consideration

A Geographic Information System (GIS) is an organised collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information (Environmental System Research Institute, 1994). A GIS is computer-based system for entering, storing, accessing, analysing, and presenting spatially referenced data from various sources. The GIS can therefore create a link between spatial data and their related descriptive attributes. A GIS is combination of hardware (computers, digitising table, scanner, Global Positioning System (GPS), plotter, printer, and so on) and specific software (IDRISI, Arc View, ARC/INFO etc) (Colwell, 1983; Lessard *et al.*, 1990; Nuttal *et al.*, 1995; Robinson, 1998). Boone *et al.* (2000) have also described GIS as a data management system that organises and displays digital map data from remote sensing and other sources and facilitates the analysis of relationships between mapped features.

2.3.6.2 GIS Functions

GIS represents a system, commonly computer-based, for handling spatial data. According to Colwell (1983), a complete or full GIS perform the following major functions.

- Data input: normally consists of mixture of manual and automatic digitising operations together with associated data clearing and edit activity;
- Data storage and retrieval: initial creation of the spatial database together with subsequent update operations and query handling;
- Data manipulation: Creation of composite variables through processed activities directed toward both spatial and non spatial attributes;

- Report generation: creation of both tabular and cartographic reports reflecting selective retrieval and manipulation of entities within the database.

2.3.6.3 Source of data for GIS

Information for GIS use can be obtained from many sources including standard maps, aerial photographs, satellite images, text files, recording instruments (Lessard et.al.,1990). Colwell (1983) also noted that the most common source of data for GIS has been the analogue map that is oriented toward the creation of digital files from map documents. Hoever, currently geo-refenced data using GPS fro the ground survey has also been a goog source of data for integration in the GIS.

- GPS (Global Positioning System) is a system of 21 satellites in unique orbits such that four satellites are above the horizon at all places. These satellites contain atomic clocks, and transmit encoded signals containing time and orbital information. GPS receivers receive and decode these signals, and use the information to compute the location of the receiver.

GPS is one of the tools for capturing data for use in GIS. Discussing the use of remote sensing and GIS in the control of tsetse in Botswana, Allsopp (1998) described GPS as an important tool, which increased the ability to navigate in the Okavango delta, Botswana. Furthermore, GPS used in the GIS would enable the data layers geographically registered and thus target location can accurately overlay a map.

2.3.6.4 Handling of Data in a GIS

GIS permits computer database management, storage and manipulation of spatial data including standard maps, aerial photographs, satellite images, climate zones and ground survey maps (Yilma & Malone, 1998). Basic types of entities considered in computer handling of spatial data are points, lines and polygons. All entities in Earth space can be viewed as being represented by one of these three forms (Colwell, 1983). Basically, the GIS stores geographically referenced data (where by the position of that particular element is known by the use of the co-ordinate system), in a database management system in a form that can be geographically queried and summarised. When using cartographic data, they must be stored in digital form on computers.

Colwell (1983) and Thrusfied (1995) described the two basic formats for storing spatial data.

- Vector -Base: Stores points, lines and polygons. The cartographic entities are translated line- for –line, point –for –point into digital form. More or less this is direct translation of the map. Points and lines (arcs) are used to represent geographical feature, the lines being composed of their straight-line segments. Areas enclosed by the lines are termed polygons. This format of storing spatial data have inherently high resolution but are complex to implement.

- Raster-Base: stores map features in grids or raster formats. Information is stored uniformly in relation to each cell that forms the grid. The grid or matrix data structure is uncompacted raster form. The smallest logical unit is called a pixel (picture element) or single grid cell.

Grid systems store and manipulate regional and remotely sensed data more conveniently, but data processing is relatively slow if high resolution is required. Many current systems can analyse both vector and raster data (by converting one in to the other format).

3. MATERIALS AND METHODS

3.1 The project Area

The study was carried out in a selected site in the block one of the Southern Rift Valley of Ethiopia Tsetse Eradication Project (SRVETEP). Most of the SRVETEP area is located within the administrative boundary of Southern Nations Nationalities and Peoples Regional Administration (SNNPR) and only a small part in the east falls within the Oromia Administrative Region. The project area in block one lies between latitude $6^{0}02'$ and $7^{0}15'$ N and longitude $37^{0}40'$ and $38^{0}20'$ E in the Ethiopian Southern Rift Valley. This area is composed of 105 10x10 km, UTM grid squares thus representing approximately 10500 km^2, according to the tsetse survey of 1998 to 1999. The ongoing project, SRVETEP is aiming to eradicate tsetse from the Valley by implementing the Sterile Insect Technique (SIT).

The climate of the area is modulated by altitude (ranging from 900 meters above sea level in the Deme River gorge to above 2900 meters at Mount Damota near Soddo Town). There are three agro-climatic zones in the project area: Highland (areas over 2400 masl), mid altitude (areas between 1600 and 2400 masl) and lowland (areas below 1600 masl). The area experiences a bimodal rain fall pattern, with a short rainy season starting from late January to late March or early April and a long rainy season starting from June to mid September or October. The lowland areas receive on average 700 to 800 mm of rainfall annually while the average amount of rainfall in the higher altitude areas exceeds 1200mm. The average monthly maximum temperature goes up to $35^{0}C$ in some of the project areas (meteorological data at Arba Minch) and the monthly minimum temperature below $7^{0}C$ (at Yirgachefe). Basically the people living in the project area practise mixed farming (agropastoralism) whereby they keep domestic animals and cultivate crop plants (map).

3.2. The Study area

The study area, which approximates 100 km², is situated in the project area between the shores of Lake Abaya and the western escarpment of the Rift (Figure 1) around the town of Mirab Abaya. It has been selected because of its suitability for the study as assessed on the basis of its accessibility, geographic and agro-ecological diversity and structure, Landsat image and topographic map coverage, and the presence of tsetse flies (*Glossina pallidipes*) from previous surveys.

The study area falls into the two 100 km² UTM grids internally coded F9 and E9 (Figure 1).

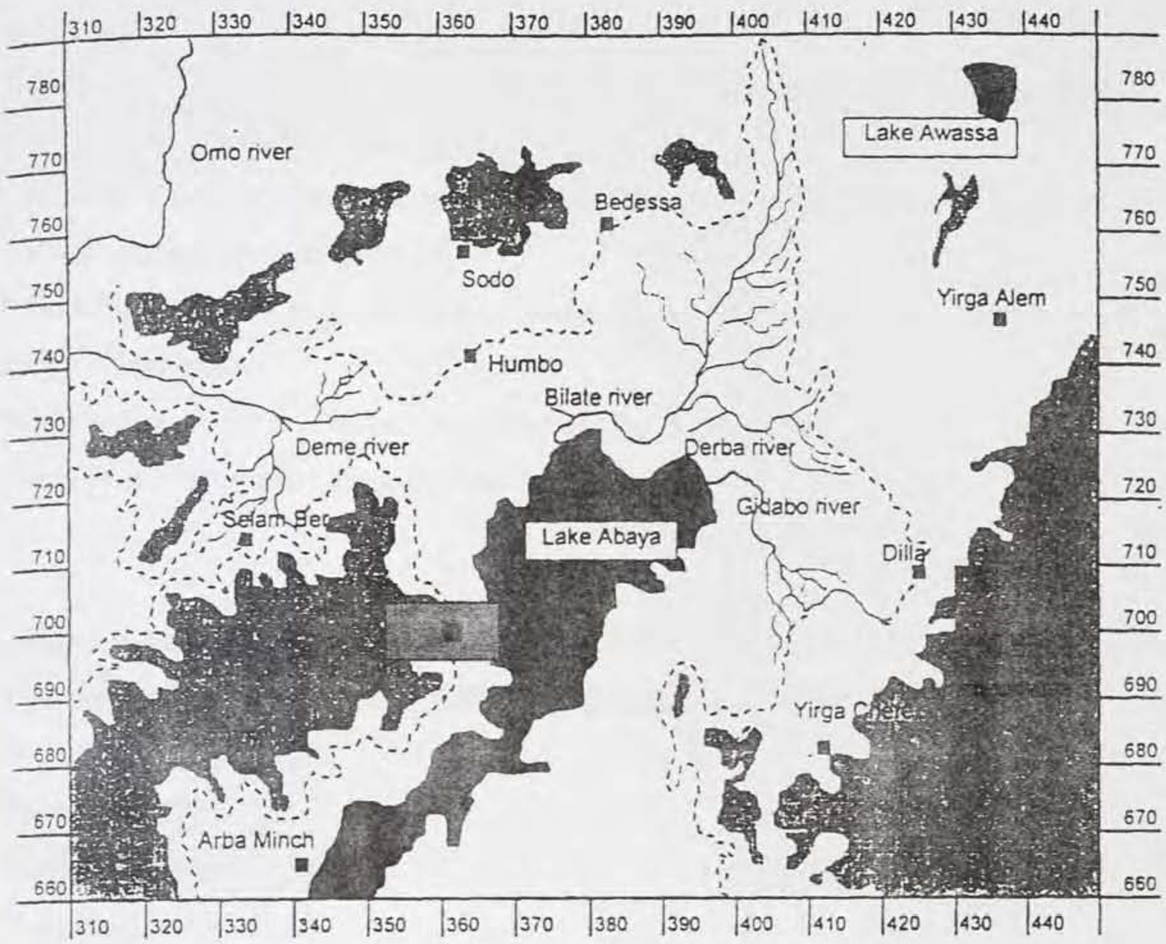

Figure 1: Map of the study site with the surrounding areas in the block one of the project site.

Study area — Mirab Abaya (town) — Lake
Areas above 2,000m — ----- 1,600m contour lines — ______ River

3.2.1 Vegetation (Tsetse habitat types)

Classification of vegetation types was carried out according to the following definitions.

- Bush land(BUL)- If the habitat was dominated by trees and shrubs with the total canopy cover greater than 20% and the single canopy was not more than 10 meters.
- Wooded grassland (WGL)- If the habitat was dominated by grass with trees in groups or scattered. Trees are common and the canopy cover was greater than 2% but did not exceed 20%.
- Wooded land (WL)- If the habitat was dominated by long trees that can be up to 20 meters in height or with an open or continued canopy cover greater than 20%. Shrubs if exist contribute less than 1% of the total canopy cover.
- Cultivated land (CUL)- habitat dominated by man-made cultivated crops (could be perrenial, annual or mixed cultivation types).
- Grassland (GGL)- a field dominated by grass and occassionally with trees or shrubs often with the canopy cover less than 2%.
- Forest (FFF)- habitat that consisted of evergreen and some semideciduous trees usually with a closed canopy
- Riverine forest (RFF)- Forest or bush habitat along the river banks.
- Shrub thicket- extremely dense thicket.

The classification of the satellite raster image (pixel size 28.5x28.5m) of the study area taken in 1994 displayed the following land cover/use types (Figure 2) in the study area:

- Wooded grassland (WGL)
- Bush land (BUL)
- Grassland (Open)
- Cultivated land (CUL)
- Water bodies (Lake Abaya and Ella)

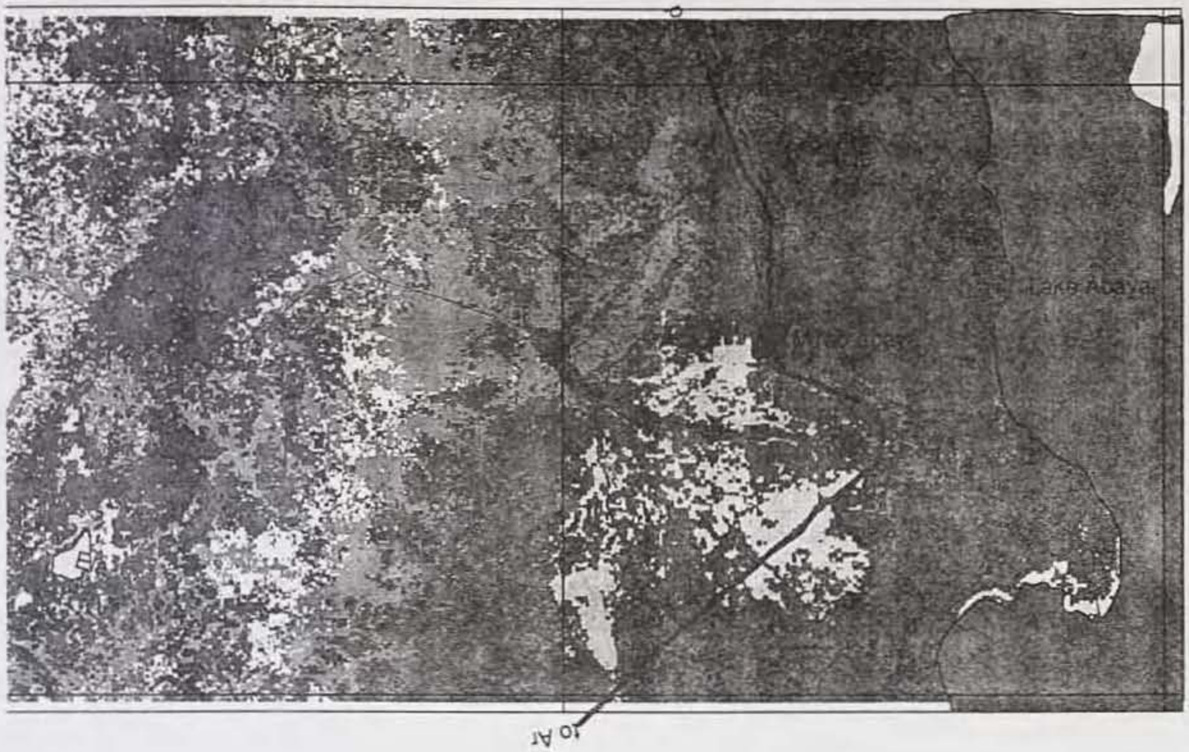

Figure 2: Landsat TM Scene of the study area (1994).

3.3. Employed GI-Technologies and Programs

The following geographic information technologies were used:

RS -Remote Sensing/Satellite Imagery for Land cover classification (based on 1994 Landsat Thematic Mapper scene) and determination of the NDVI.

GPS – Global Positioning System for position and altitude measurements in the field using Garmin 48 hand held receiver.

GIS- Geographic Information System for data entry, analysis and output (map layers, spatial data analysis):

Software: IDRISI 2.05 for raster-based data (the digital image) and ArcView 3.1 for vector-based data and for overall integration. CartaLinx, The Spatial Data Builder for digitising different environmental features. Surfer for creating Digital Elevation Model (DEM) after contour digitisation.

Excel, d-Base (Access) and Statigraphics were used for statistical analysis.

3.4 Data collection (Ground Survey)

3.4.1 Tsetse fly sampling

Tsetse fly sampling was carried out in two seasons, the dry and wet season. The dry season survey was done in March 2001 and the wet season survey was carried out in June and the first week of July 2001.

3.4.1.1 Selection of UTM Sampling Grids

Thirty 1-km² UTM grid squares (sampling grids) were selected in six transects. Each transect had five sampling grids. The sampling grids were evenly distributed over the study area. Each sampling grid was interspersed by one alternate grid in horizontal and in diagonal direction (Figure 3). An exploratory survey was made to locate each selected grid after identifying them and their co-ordinates in the topographic map. A reference feature in the selected grid was identified and co-ordinate of that reference point was recorded and saved in the GPS, to help locate the sampling grids easily during the actual tsetse fly sampling.

X		X		X		X		X	
	X		X		X		X		X
X		X		X		X		X	
	X		X		X		X		X
X		X		X		X		X	
	X		X		X		X		X

Figure 3: Schematic presentation of grids for vegetation classification. NDVI and the placement of traps
X = Randomly sampling selected UTM Grid squares

3.4.1.2 Trap deployment

NGU traps baited with acetone and three-week-old cow urine were used for sampling tsetse flies. Three traps were deployed in each selected grid approximately 200 meters apart. Sampling grids were selected systematically but deployment of traps within the sampling grids was knowledge based, thus traps were deployed in locations where tsetse flies were likely to occur. This vegetation type was identified and registered for each trapping site.The traps remained in position for 72 hours before fly collection was made.

Tsetse flies were sampled in twenty-seven of the sampling grids. Because of the accessibility problem, deployment of traps was not possible in the rest of the three sampling grids identified before. A total of 156 (78 in the dry and 78 in the wet season) traps baited with acetone and three week-aged cow urine were positioned throughout the survey period in twenty-seven sampling girds in six transects. In each transect, an average of 13 traps (the number ranging from 9 to 15) were deployed.

The co-ordinate of every trapping site (geo-referencing) and as well as spot elevation was recorded using a handheld receiver, GPS (Garmin 48) for further incorporation of tsetse fly catch and distribution and vegetation types in the GIS database.

3.5 GIS Laboratory work

The GIS laboratory work was carried out in collaboration with Department of Geology and Geophysics, Faculty of Science, Addis Ababa University in the GIS and Remote sensing (RS) laboratory. The following activities were performed:

1) Digitizing of various features like roads, settlement, rivers, lakes and contours from the topographic map (scale 1: 50,000), Ethiopian Mapping Authority, 1979. The digitizing tablet and CartaLinx, The Spatial Data Builder, version 1.04 were used for digitizing the features.

2) Processing of the satellite image for the study of land cover/ use of the area.

- Extraction of the appropriate bands for land cover/ land use (bad 1, band 3 and band 4)
- Colour composition of the selected bands
- Rectification (image registration)
- Image enhancement
- Georeferencing
- Image classification – the supervised classification procedure was used

- Image interpretation
- A Digital Elevation Model (DEM) was created for the study area at 50 meters interval using Surfer (win 32 version 6.01, 1995, Surfer Mapping System) after digitising the contours.

3) Linking the tsetse distribution data with other features (altitude, land cover/ land use, settlement and drainage systems)

4) Integration of the digitised, processed and geo-referenced map features and satellite image into a GIS, IDRISI 2.05 for raster data, Arc/View 3.1 for vector data. Finally establishing the GIS database for the study area in ArcView GIS and produce map output.

The land cover/use classification (Supervised classification of the land cover/use) of the area derived from Landsat TM image was verified by ground-truthing in selected 1-km^2 UTM grid squares.

3.6 Data Analysis

Microsoft Excel 97 and Statgraphics Plus 2.1 were the main computer softwares for the statistical analysis of tsetse catch data. Total fly catches in relation to variables measured (transect, season, vegetation type, altitude level, and climate) were analysed using Krukal-Wallis Test. Prior to the application of this test, an attempt was made to normalise the catch data using $\log_{10}(x+1)$ transformation. However, this transformation did not achieve the expected normal distribution. This was confirmed using probability density plot. Therefore, Kruskal-Wallis, a non-parametric procedure, was used.

4. RESULTS

4.1 Fly catch by transect

Trap locations were geo-referenced using GPS. These locations were incorporated in a GIS database and were well matched to the coordinates of selected sampling grids. The location and distribution of traps in the sampling grids in each transect is shown in figure 5.

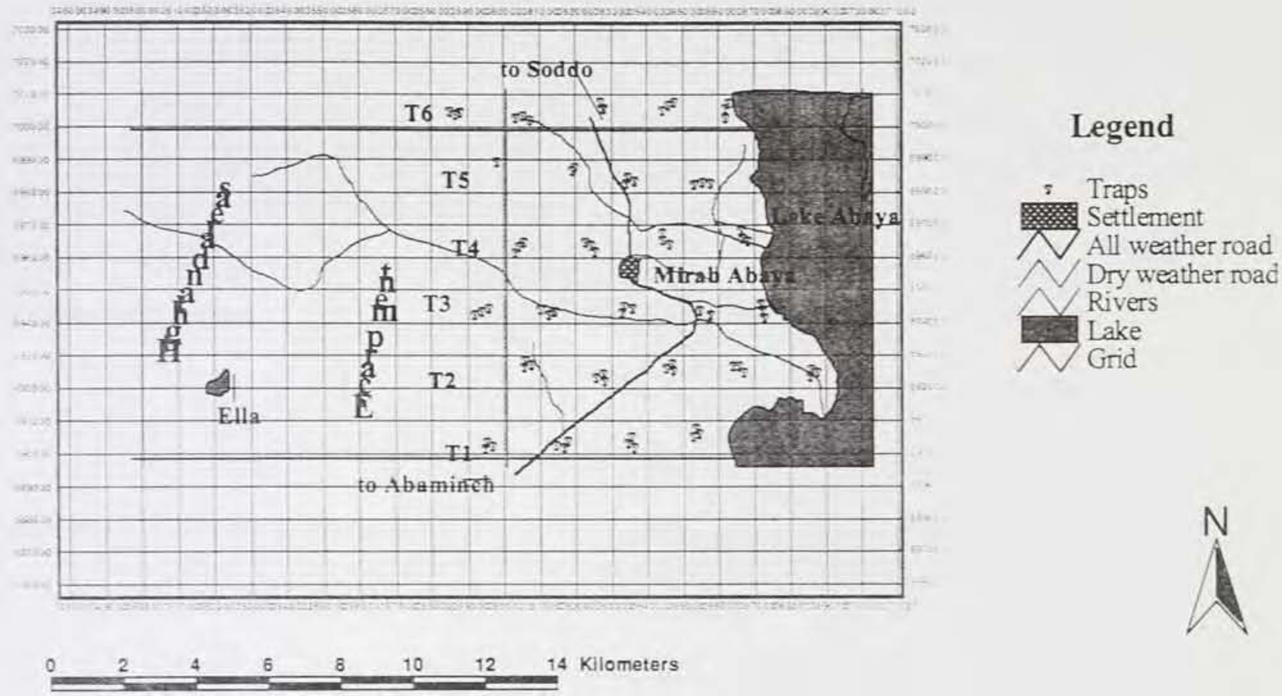

Figure 4: Location and distribution of traps in the sampled UTM Grid Square by transect (T1-T6) in a GIS generated map of the study area.

Three NGU traps were deployed in each sampling UTM grid square along the transect (T1-T6), except in two sites in transect five (only one and two traps were deployed) where access was denied. Each transect begins from east by the Lake (Lake Abaya) to the west up to the foothill of the escarpment (Figure 4).

56% of the traps deployed in the dry season and 93.6% of the traps deployed in the wet season caught tsetse flies (Table 4). Of all the traps in the six transects, the highest percentage of traps that caught tsetse flies were in transect four in both seasons (91.67% in the dry season and 100 % in the wet season). Also all the traps deployed in transect five-caught tsetse during the wet season. However, average catches were not significantly different from transect to transect in both seasons, in the dry season (W = 6, P = 0.31) and in the wet season (W =10.92, P = 0.053 (Table 5).

Table 4: Distribution of traps in transect and percentage of traps that caught tsetse flies

Dry Season				Wet Season	
Transect	Number traps	Number Gp +ve	% +ve	No. Gp +ve	%+ve
1	12	5	41.7	11	91.7
2	15	8	53.3	14	93.3
3	15	9	60	15	100
4	12	11	91.7	12	100
5	9	4	44.4	8	88.9
6	15	7	46.7	13	86.7
Total	78	44	**56.4**	73	**93.6**
%	100	56.4		93.6	

Gp = Glossina pallidipes

Table 5: Ranking of average catches of *G. pallidipes* by transect in the dry and wet seasons, using Kruskal-Wallis procedure (W = 6, P = 0.31) in the dry season and (W =10.93, P = 0.053) in the wet season.

Dry season			Wet season		
Transect	Sample Size (No. traps/transect)	Average Rank	Transect	Sample Size (No. traps/transect)	Average Rank
1	12	35.4	1	12	35.4
2	15	35.9	2	15	26.9
3	15	40.13	3	15	44.0
4	12	52.6	4	12	53.25
5	9	33.4	5	9	45.0
6	15	38.9	6	15	36.6

Altitude of the surveyed area varied form 1197 meters above sea level by the lake (Lake Abaya) to 1480 meters above sea level at the base of chain of mountains. Forty six percent of the traps (95% CI = 34.8-57-82) were deployed in altitude up to 1250m, 27% (95% CI = 17.5-38.2) between 1251-1300m, 9% (95% CI = 3.7-17.6) between 1301-1350m, 13% (95% CI = 6.3-22.3) between 1350 -1400m and 5% (95% CI=1.4-12.6) of the traps were deployed in an altitude above 1400m (Figure 5).

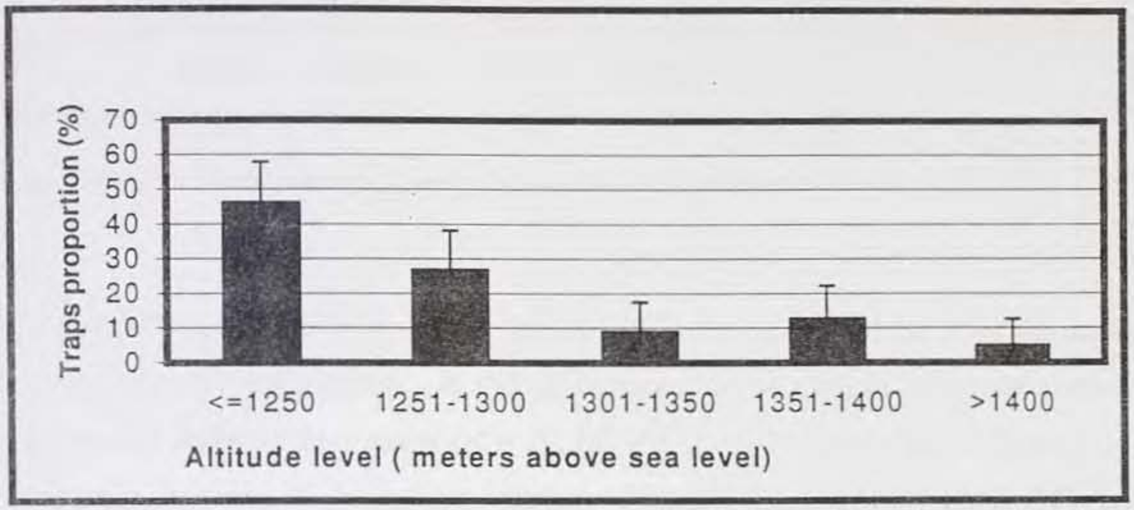

Figure 5: Proportion of distribution of traps by altitude level in the study area (with 95% CI).

Traps were not equally distributed over the major vegetation types present in the study area. The traps were positioned in vegetation, which was judged predominant in a specific sampling grid and supposed to be the most suitable habitat for tsetse flies. Therefore, about 60.3% (95% CI= 48.5-71.2) of the traps were deployed in bush land (BUL), 20.5% (95% CI = 12.2-31.2) in cultivated land (CUL), 11.5% (95% CI = 50.4-20.8) in wooded land (WL) and 7.7% (95% CI =2.9-15.9) in wooded grassland (WGL) (Figure 6).

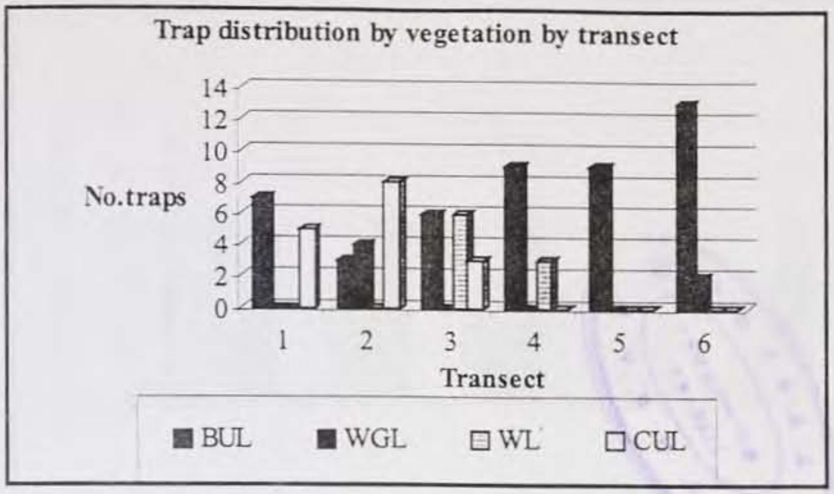

Figure 6: Distribution of traps by vegetation and transect

Catches of female *G. pallidipes* were always higher than males almost in all the transects in both the dry and wet seasons. In the dry season, the proportion of female catches were significantly different from males ($\chi^2 = 38$, DF = 5, P = 0.000) by transect (Figure 7). In the wet season, however, the proportion catches of female were not significantly different from male ($\chi^2 = 5.9$, DF = 5, P = 0.31) by transect (Figure 8).

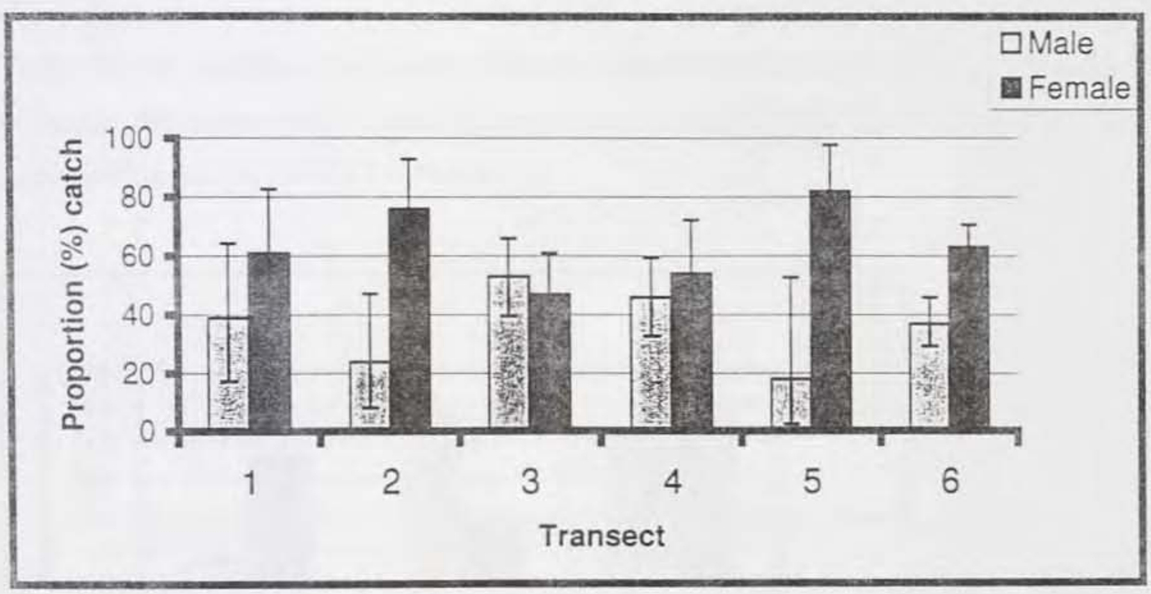

Figure 7: The proportion of male and female *G. pallidipes* catches by transect during the dry season (with 95% CI).

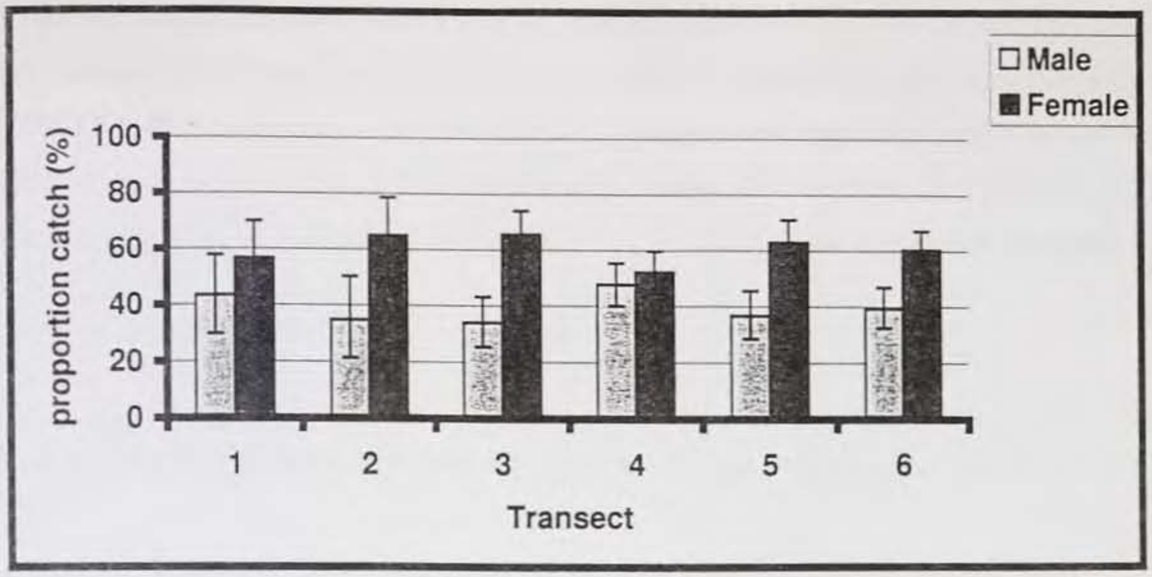

Figure 8: Proportion of male and female *G. pallidipes* by transect in the wet season (with 95% CI).

4.2 Fly species

A total of 4620 (all the fly species) flies were caught during the dry season and 1969 flies during the wet season. Only one species of tsetse fly (*G. pallidipes)* was caught during both the dry and the wet seasons. Biting flies like Tabanids and non-biting flies (Muscids) were also caught during the survey period (Figure 9).

Tsetse fly (*G. pallidipes*) accounted only for 6.6% (95% CI = 5.9-7.3) of the total fly catch during the dry season while Tabanids accounted for 52.2% (95% CI =50.6-53.4) and the rest accounted for 41.2% (95% CI = 39.8-42.7).

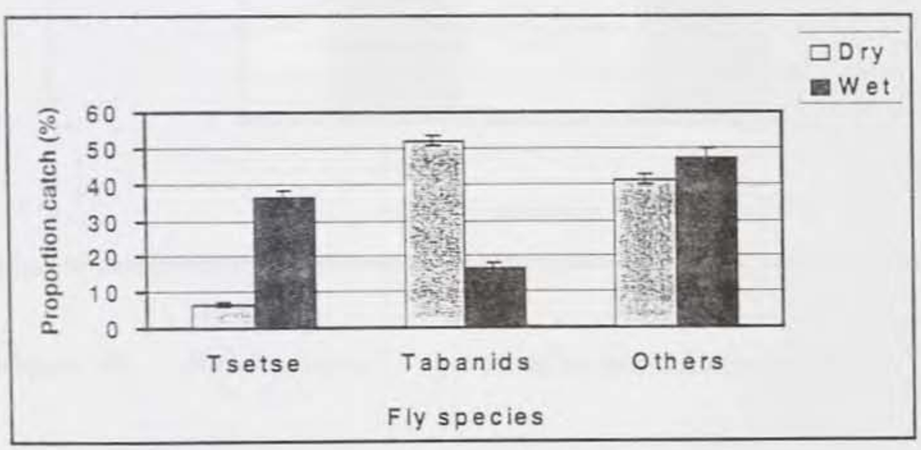

Figure 9: The proportions of distribution of fly species caught in the dry and wet seasons (with 95% CI)

In the wet season, the above figure was increased to 36.4% (95% CI = 34.4-38.7) for tsetse fly catches and that of Tabanids declined to 16.6% (95% CI =14.9-18.3) and other flies was 47% (95% CI = 45.6-50) (Figure 10). The overall fly catches were higher in the dry season, 69.9% (95% CI = 68.1-71) compared to the wet season catches, 30.1% (95% CI = 28.9-31-2). These were significantly different ($\chi^2 = 71.77$, DF = 2, P = 0.000) in the dry season compared to the wet season.

4.3 Seasonal Distribution of Tsetse flies (*Glossina pallidipes*)

A total of 1025 tsetse flies (*G. pallidipes*) were sampled during the two survey periods. Of these 305 *G. pallidipes* were sampled during the dry season and 720 *G. pallidipes* were sampled during the wet season. The catches were 29.8% (95% CI = 26.9-32.6) in the dry season and 70.2% (95% CI = 67.3-73) in the wet season (Fig. 10). The mean catches of *G. pallidipes* during the wet season were significantly different ($P < 0.05$) compared to the dry season (mean = 9.24, 95% CI = 7.4-11.1 during the wet season and mean = 3.91, 95% CI = 2.1-5.75 during the dry season).

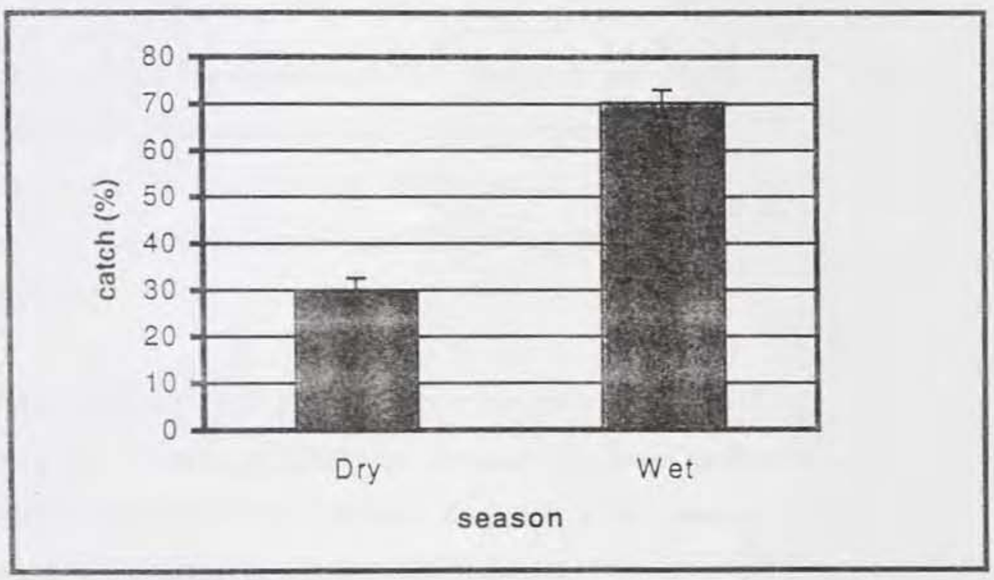

Figure 10: Distribution of *G. pallidipes* by season in the study area

60% of *G. pallidipes* caught in each season were females. However, the overall mean catches (pooled data) of female flies were not significantly different ($P > 0.05$) from males (means =

2.64, 95% CI =1.96-3.32 for males and mean = 3.93, 95% CI = 3.24-4.6 for females). χ^2 test also showed no significant difference (χ^2 = 0, DF =1 and P = 0.9621) between female and male fly catches in the two seasons.

Tsetse apparent density as calculated as mean tsetse fly caught per trap per day was estimated from the catch. The apparent density was about two times (3.1 flies/trap/day) greater in the wet season than in the dry season (1.3 flies/trap/day) (Table 6).

Table 6: Apparent density and distribution of male and female tsetse flies in the dry and wet season.

Season	Total catch (Three days catch)	Male Gp (%)	Mean catch (male Gp)	Female Gp (%)	Mean catch (Female Gp)	Total mean catch	Fly/trap/day (Apparent density)
Dry	305	123 (40)	1.6	182 (60%)	2.3	3.9	1.3
Wet	720	289 (40)	3.7	431 (60%)	5.5	9.23	3.1
Total	1025	412		613			

Gp = Glossina pallidipes

Glossina pallidipes distribution and abundance per trapping site was integrated in a GIS database and presented in the GIS generated map (Figure 11-12). Figure 11 shows distribution of tsetse flies in the sampling UTM grid squares in transects. The diameter of the circles shows the amount of *G. pallidipes* caught in each trapping site, which ranged from 0 to 57 in dry season.

Settlement shows the only township in the study area. The town Mirab Abaya was digitized and integrated in the GIS database because the other settlement areas were too many and scattered. Therefore, it was difficult to digitize every point of all the settlement areas in the study area and incorporate into GIS database. The all-weather and dry weather roads and rivers in the study area are digitized and incorporated into a GIS database, as shown in the figure (Figure 11 and 12).

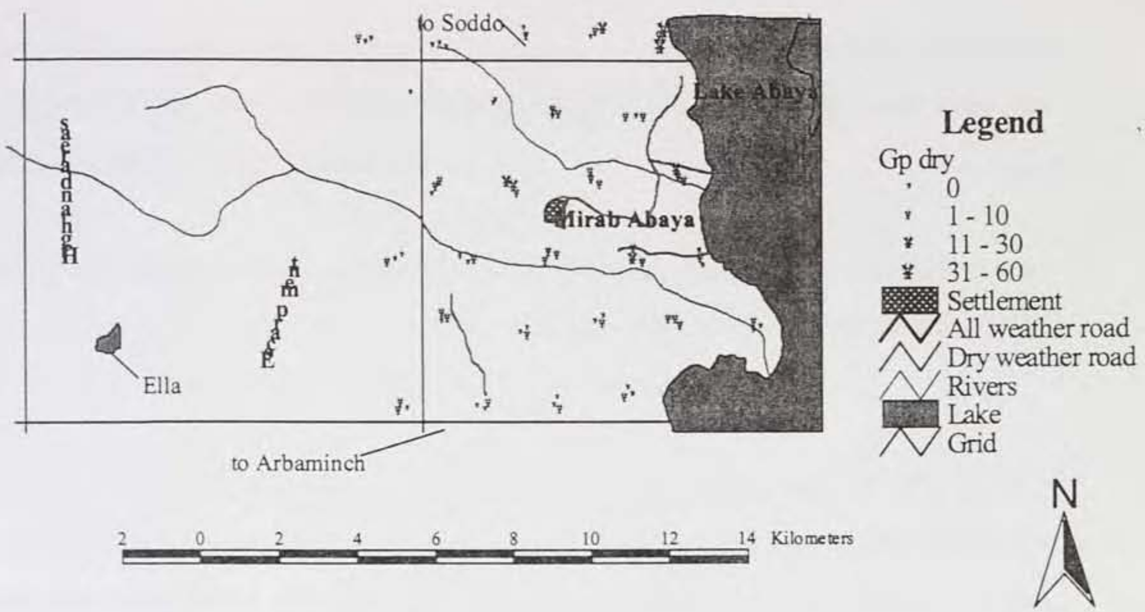

Figure 11: A GIS generated map showing the distribution and density of *G. pallidipes* at every sampling site in the dry season.
Gp dry- *G. pallidipes* catches in the dry season

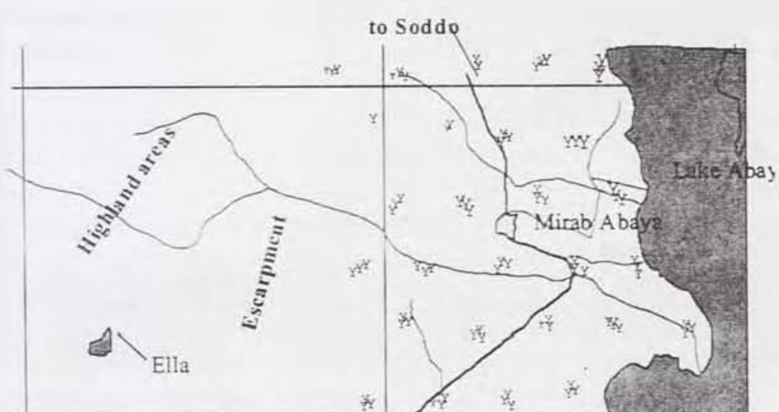

Figure 12: A GIS generated map showing the distribution and density of *G. pallidipes* at every sampling site in the wet season.

In figure 12 all the features are the same as in figure 11 except that the number of *G. pallidipes* caught in the trapping site was different (increase in total catch) in the wet season, varied from 0 to 71.

Monthly weather data (total rainfall, mean monthly minimum and maximum temperature and relative humidity) for the years 2000 and 2001 (January to July) were received from the nearby meteorological station at Mirab Abaya.

The total rainfall for the dry season months (January, February, March and April 2001) was 7.9mm, 8mm, 79.8mm and 84.7mm respectively, and for the months of wet season (May, June and July 2001) it was 182.2mm, 45 and 72 mm respectively.

The mean monthly minimum temperature for the dry season months was 17.2°C, 16.8°C, 18.2°C and 18.5°C. For the months of wet season it was 18.8^{0}C, 18.9^{0}C and 19.2°C. The mean monthly maximum temperature for the dry season months was 31.3^{0}C, 33.3^{0}C, 32.1^{0}C and 31°C and it was 29^{0}C, 28^{0}C and 29.6°C in the months of wet season. The relative humidity was lowest during dry season, 45.3% in January and increased with the increased rainfall in May 63%.

Pattern of weather records in the study area during the study period is presented in figure 13.

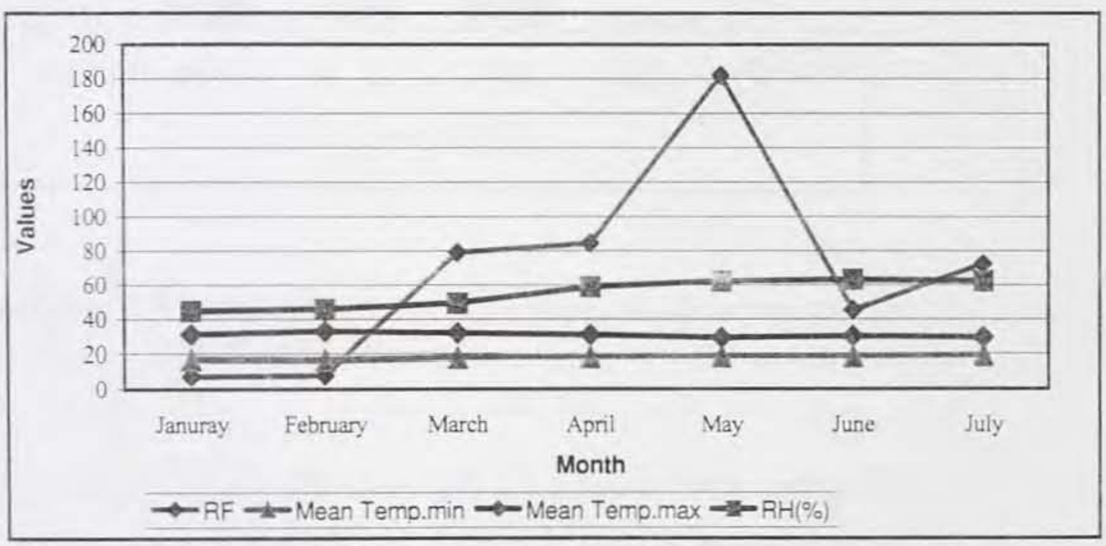

Figure 13: Mean monthly climate data at Mirab Abaya meteorological station in 2001. RF= Monthly total Rainfall (in mm), Mean Temp.min. = Mean monthly minimum temperature (°C), Mean Temp.max. =Mean monthly maximum temperature (°C), RH= Relative humidity (%)

4.4 Tsetse flies Distribution and Vegetation Types

4.4.1 Analysis of *G. pallidipes* catches by vegetation

Four major vegetation types namely, Bush land (BUL), Wooded grassland (WGL), Wooded land (WL), and cultivated land (CUL) was used to classify the study area during the field survey.

In the dry season, *G. pallidipes* catch was 46% (95% CI = 40.5 - 52) in BUL, 22% (95% CI = 17.4-27) in WGL, 27% (95% CI = 21.9-32.) in WL and 5% (95% CI = 2.7-7.9) in CUL (Fig.14). However, these proportions were not significantly different (W = 6.9, P = 0.075) from one vegetation type to another In the wet season, catches were 68.3% (95% CI = 64.7-71.1) in BUL, 15.7% (95% CI = 13.1-18.6) in WGL, 11.4% (95% CI = 9.2-13.9) in CUL and 4.6% (95% CI = 3.2-6.4) in WL. The catches were significantly different from one vegetation type to another (w = 16.05, P = 0.0012).

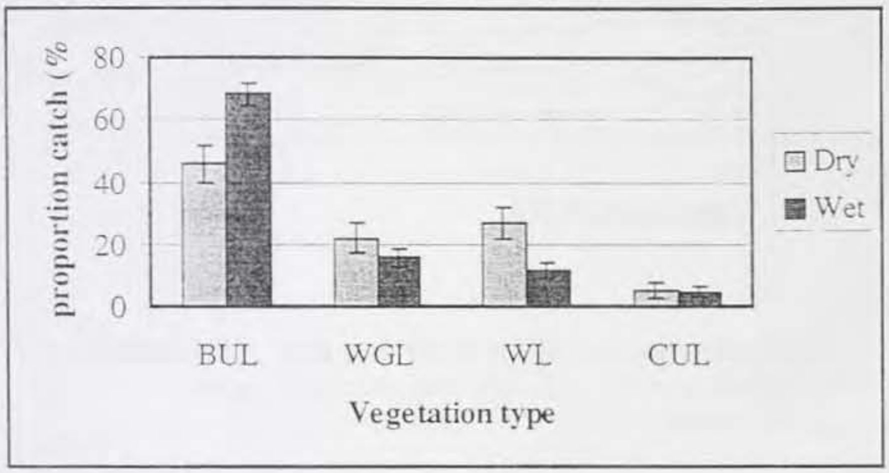

Figure 14: Percentage catches of *G. pallidipes* in vegetation type during the dry and wet seasons (with 95% CI).

Tsetse apparent density (Flies/trap/day) was higher in WGL vegetation type in both seasons. In the dry season, it was 3.72, 3.2, 1 and 0.27 flies per trap per day in WGL, WL, BUL and CUL respectively and it was 4.6, 4.2, 3.5, and 0.7 flies per trap per day respectively in the wet season.

Mean catches of female *G. pallidipes* were higher in all the vegetation types compared to male flies in both the dry and wet seasons. However, mean female fly catches were not significantly different from males in each vegetation type in the dry season ($\chi^2 = 0.82$, DF = 3, P = 0.8) and the wet season ($\chi^2 = 0.11$, DF = 3, P = 0.98).

Average catches in different vegetation types were ranked. The average ranking catches in each vegetation was analyzed using the Kruskal-Wallis procedure. Differences in ranks between the catches amongst the vegetation types were significantly different (w =14.8, P = 0.0019) from one level of vegetation type to another. The highest mean catches were in WGL followed by WL, BUL and CUL respectively in dry and wet season (Figure 15).

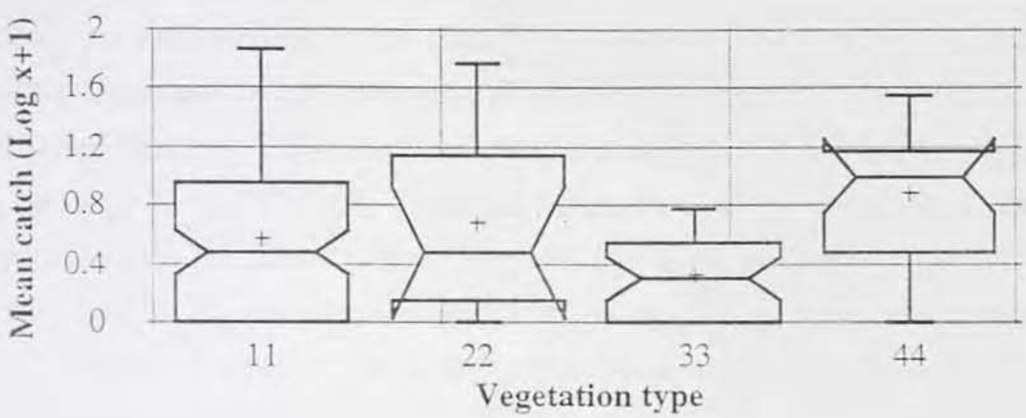

Figure 15: Box-and Whisker of *G.pallidipes* by vegetation type (pooled data) in the study area with 95% CI (w = 14.87, P = 0.0019)
11=BUL, 22= WGL, 33 = CUL and 44 = WL

Figure 15 shows Box -and -Whisker of *G. pallidipes* (for the pooled data). In the figure, the central box covers the middle 50 percent of the data. The sides of the box are the upper and lower quartiles and the vertical line drown through the box is the median. The whiskers extend out to the lower and upper values of the data (the range). The mean is plotted as a single point (+).

Catches of female *G. pallidipes* remained high in all the vegetation types in both the dry and wet seasons compared to male flies. In the dry season, female *G. pallidipes* catches were significantly different ($\chi^2 = 8.49$, DF = 3, P 0 0.038) from male *G. pallidipes*. In the wet season, however, female catches were not differed significantly (χ^2=0.45, DF = 3, P0 0.93) from male flies. The average ranking in each vegetation type for male and female *G. pallidipes* in the dry and wet seasons were analysed using the Kruskal-Wallis procedure (Table7). Differences in ranks amongst the catches in each vegetation type were significant ($w = 8.4$, $P = 0.038$) for male *G. pallidipes* and ($w = 8.11$, $P = 0.044$) for female *G. pallidipes*. In the wet season, the differences were also significant ($w = 14.49$, $P = 0.002$) for males and ($w = 15.92$, $P = 0.0012$) for females.

4.4.2 Comparison of vegetation classification from satellite image with vegetation type in the field (ground survey)

Comparison was made between the vegetation type classification in digital image (supervised image classification using a maximum likelihood procedure) with vegetation types classified in the field. Field vegetation type of a specific trap location was used as a reference data. In the image, the vegetation type in a pixel where trap is located was compared to the vegetation type in the same location in the ground. As a result, the vegetation classification in the satellite image was in agreement with the field classification. 77% (95% CI = 62-87.7) of BUL vegetation type in the image was classified as BUL. CUL was classified as CUL about 62.5% (95% CI = 35.4-84.8). However, in some cases the comparison resulted in low accurate classes. i.e., below 50 %. 33.3% (95% CI = 4-77) was classified as WGL and 33.3% (95% CI = 7.5-70) was also classified as WL in satellite image. (Table 7). Relatively most WL, about 44.4% was classified as BUL. The overall classification accuracy was 64% with lower CI limit of 63.8%.

Table 7: Comparison of vegetation type classification in the field observation to satellite Landsat TM image

Vegetation type at every trapping location				
Field classification (Reference data)	Satellite Image classification (%)			
	BUL	WGL	WL	CUL
BUL	77	17	6	0
WGL	16.7	33.3	33.3	16.7
CUL	12.5	6.25	18.75	62.5
WL	44.4	22.2	33.3	0

Figure 16: Thematic Mapper (TM) Landsat false-colour image of the study area (SRVETEP site, around Mirab Abaya).

Legend

Bush lands (shrubs)	Perennial Cultivation
Bush land (trees)	Mixed cultivation
Wooded land	Annual cultivation
Wooded grassland	Lake Abaya
Open grassland	Lake Ella

Figure 16 shows the supervised classification of land cover/use of the study area. This is the view of the two 10x10km UTM square grids selected for the study with Lake Abaya in light green in the eastern border.

Figure 17 shows the land cover/use map of the study area integrated in a GIS with the vegetation type in a pixel where trap was deployed. The vegetation types on the ground are overlaid with the image to show the degree of agreement between the two classification methods (image and field verification). The vegetation type in the legend is the field observed vegetation type.

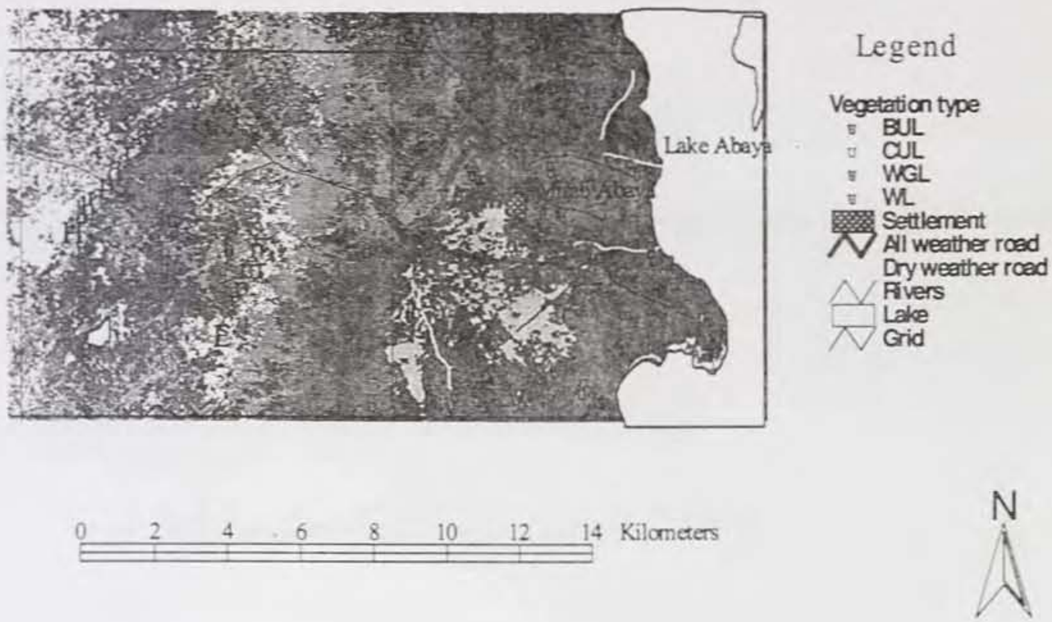

Figure 17: Overlay of vegetation type at every trapping site in the field with the imge of the study area (SRVETEP site around Mirab Abaya).

Catches of *G. pallidipes* in both seasons were overlaid with the vegetation type in the image in a GIS database. This overlay is presented in figure 18 (for the dry season) and figure 19 (for the wet serason) showing both the spatial and temporal distribution of tsetse flies in relation with the vegetation types.

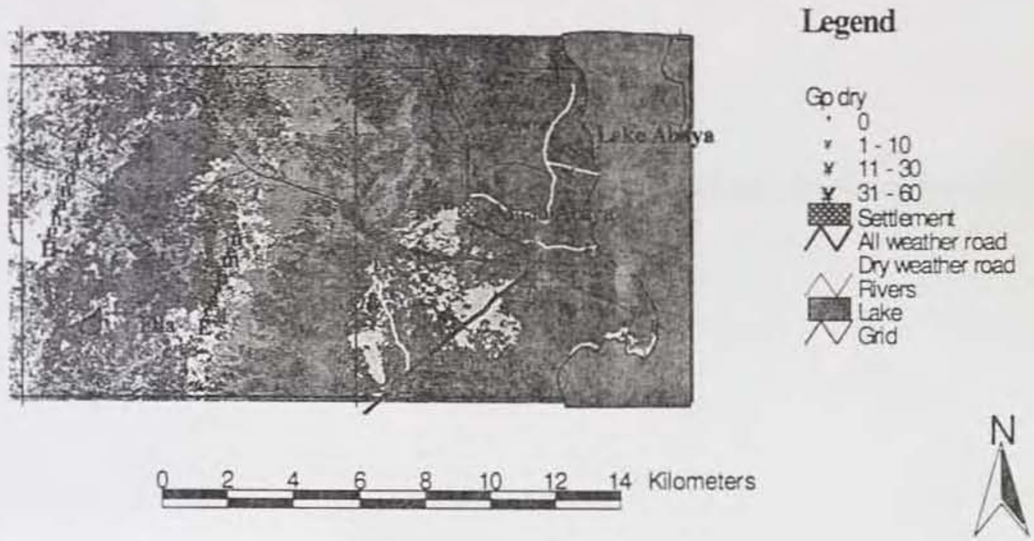

Figure 18: A GIS generated map showing the distribution of *G. pallidipes* overlaid with the image of the study area to show the distribution with respect to vegetation type. The diameter of the circles shows the number of tsetse flies caught at every sampling site (in range) during the dry season.

Gp dry- *G. pallidipes* catch during the dry season

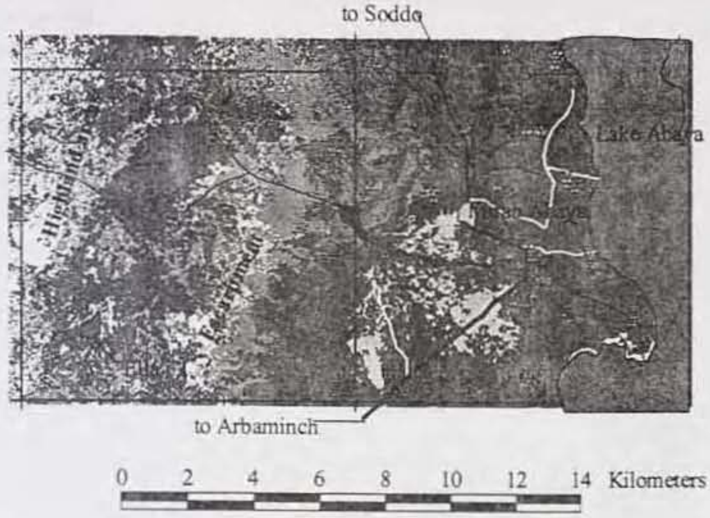

Figure 19: Overlay of *G. pallidipes* distribution at every trapping site in the wet season with the image.
Gp wet-*G. pallidipes* catch during the wet season

4.4.3 Normalised Difference Vegetation Index (NDVI).

The Normalised Difference Vegetation Index (NDVI) of the area was calculated by taking the ratio of the subtraction and summation of the two bands, the TM band 4 (near infrared) and TM band 3 (red wavelengths) from the satellite Landsat imgae. These bands of electromagnetic spectrum were used for the calculation of NDVI because the leaf tissues in the vegetated areas reflect the NIR portion but the chlorophyll present in the leaf tissue absorbs the red wavelengths. This contrast of reflection and absorption by vegetation cover can be helpful to distinguish the amount and type of vegetation present in the area.

At least three types of vegetation were identified on the colour composite image: green, bright yellow and golden yellow areas (Figure 20). The green areas consist of dense trees along the base of the escarpment and trees with closed canopy. They also consisted of some of the cultivated land areas. The bright yellow areas are covered with shrubs and less dense trees, which corresponded to the BUL vegetation type of the area. The golden yellow areas covered with grasses, which are mainly in the highland areas. Very few of these were observed along the lakeshore

The output NDVI image was integrated in the GIS database. The distribution of *G. pallidipes* was overlaid with the corresponding NDVI scene in a GIS. *Glossina Pallidipes* distribution and abundance was related with areas covered with shrubs and trees of less canopy areas (bright yellow areas) of BUL vegetation type and areas of dense trees with closed canopy (green areas) of wooded land vegetation type.

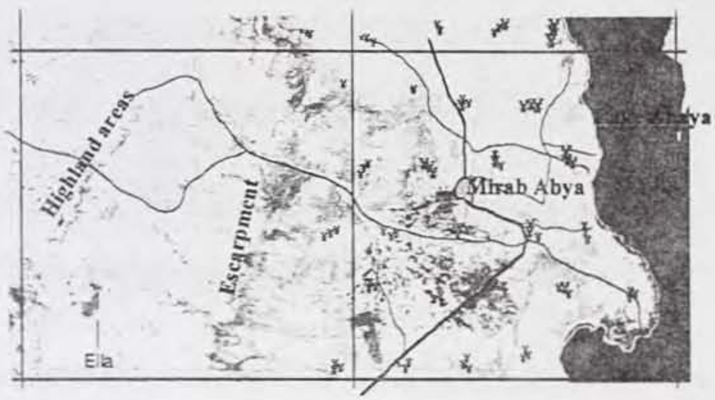

Figure 20: Distribution of *G. pallidipes* overlaid with the NDVI image of the study area in a GIS generated map (SRETEP site, Around Mirab Abaya).

4.5 Altitudinal distribution of tsetse flies (*G.pallidipes*)

The altitude of the study area ranged from 1197 to1480 meters above seas level. This altitude range was classified into five levels (intervals of 50 meters). The analysis of tsetse fly catches was based on these different altitude levels. Altitude level 1 (below 1250masl), altitude level 2 (1251-1300m), altitude level 3 (1301-1350m), altitude class 4 (1351-1400m) and altitude level 5 (above 1400m).

In the analysis of pooled data, 92% (947 flies) of the total *G. pallidipes* catch was obtained at altitude levels below 1300m. It was 7.2 % (74 flies) in altitude level between 1300 - 1400m and only 0.6 % (6 flies) in higher altitude levels. This was the basis for the classification of altitude into further detailed levels (five) as described above.

In the dry season, seventy five percent (95% CI = 69.5-79.5) of the total *G. pallidipes* catches were recorded in altitude below 1250m (altitude level 1) and 23% (95% CI = 18.4-28.1) were in altitude level 2. In altitude levels 3 and 4 the catches were almost similar and each accounted only for 1% (95% CI = 0.2-2.8) of the total catches (Figure 21). The least catches were observed in altitude level 5, accounted only for 0.32% (95% CI = 0.008- 0.02) of the total catches. The mean catches were significantly differed in all altitude levels (w = 11.4, P = 0.022).

In the wet season, the catches in altitude level 1 were as high [74.8% (95% CI = 71.7-78.1)] as was in the dry season. 15.2% (95% CI = 12.6-18) in altitude level 2, 4.7% (95% CI = 3.3-6.5) in altitude level 3, 4.4% (95% CI =3.1-6.2) in altitude level 4 and 0.7% (95% CI = 0.22-1.6) in altitude level 5 were caught (Figure21). Catches were low at higher altitude level.

Mean catches of *G. pallidipes* were also significantly different (w = 13.03, P = 0.01) from one altitude level to another in wet season.

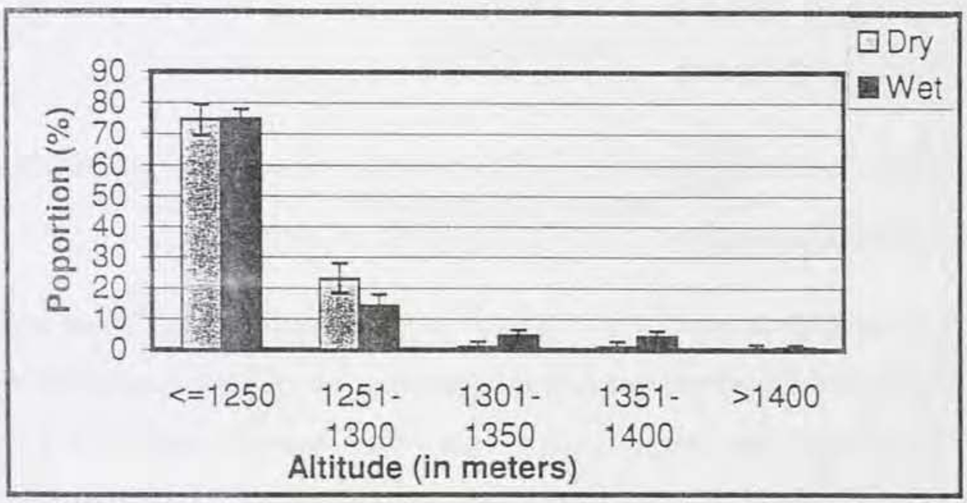

Figure 21: Distribution of *G. pallidipes* in altitude level in the dry and wet seasons (with 95% CI).

In both the dry and wet seasons there were a significant differences in the average catches of *G. pallidipes* in all the altitude levels (Figures 22 and 23 show the Box-and-Whisker of median and mean catches in the dry and wet seasons respectively).

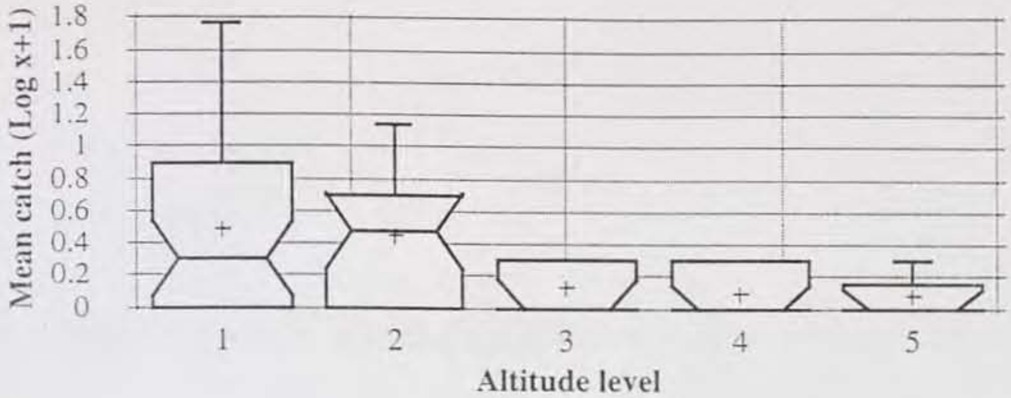

Figure 22: Box-and -Whiskers of the catches of *G. pallidipes* by altitude level in the dry season with 95 % CI (w =11.4, P-value = 0.022)

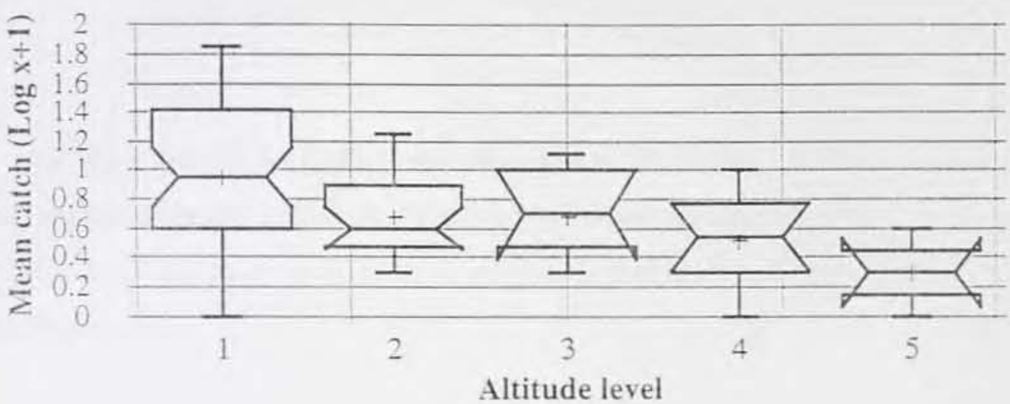

Figure 23: Box -and-Whisker of *G. pallidipes* by altitude level in the wet season with 95 % CI (w =13.03, P = 0.01).
1= <=1250, 2= 1251-1300, 3 = 1301-1350, 4= 1351-1400 and 5 = > 1400m

Female *G. pallidipes* catches were higher (70%) in the dry and 60 % in the wet season) than males in the entire altitude levels. In the dry season, this difference was significant (χ^2 = 59.7, DF = 4, P = 0.0000). However, in the wet season they were not significantly different (χ^2 =7.51, DF = 4, P = 0.111). Average catches (pooled data) of *G. pallidipes* were significantly different (w =17.54, P = 0.0015) from one altitude level to another.

A simple linear regression analysis for the pooled data was performed to see if there was a correlation between *G. pallidipes* distribution and altitude. According to this, the distribution of G. *pallidpes* was negatively correlated with altitude. Thus, when altitude increased there was a decrease in tsetse catch. The correlation coefficient (r) was -0.37 which indicates that there was a relatively weak relationship between altitude and *G. pallidipes* distribution (Figure 24).

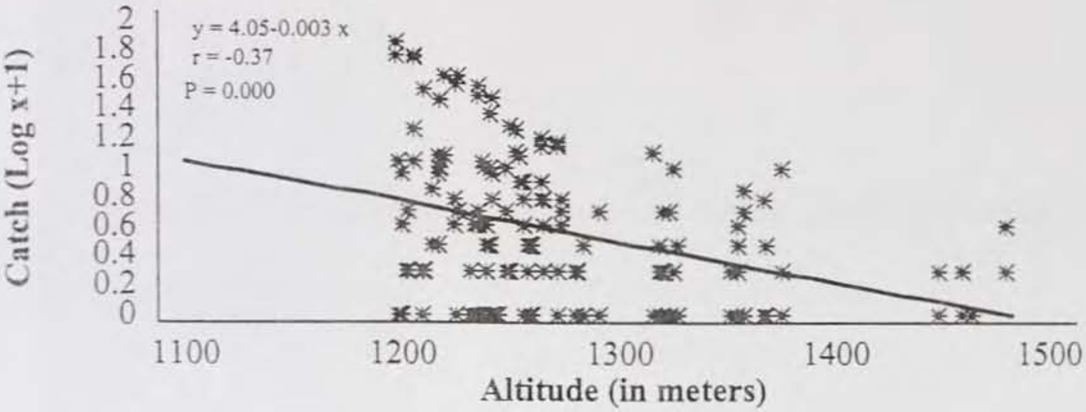

Figure 24: The relationship between the density and distribution of *G. pallidipes* and altitude level.

A Digital Elevation Model (DEM) was created in a GIS database from the contour digitisation of the base map (scale 1:50,000). *Glossina pallidipes* distribution was overlaid with respect to the DEM of the study area. High *G. pallidipes* distribution was observed at lower altitude level (Figure 25).

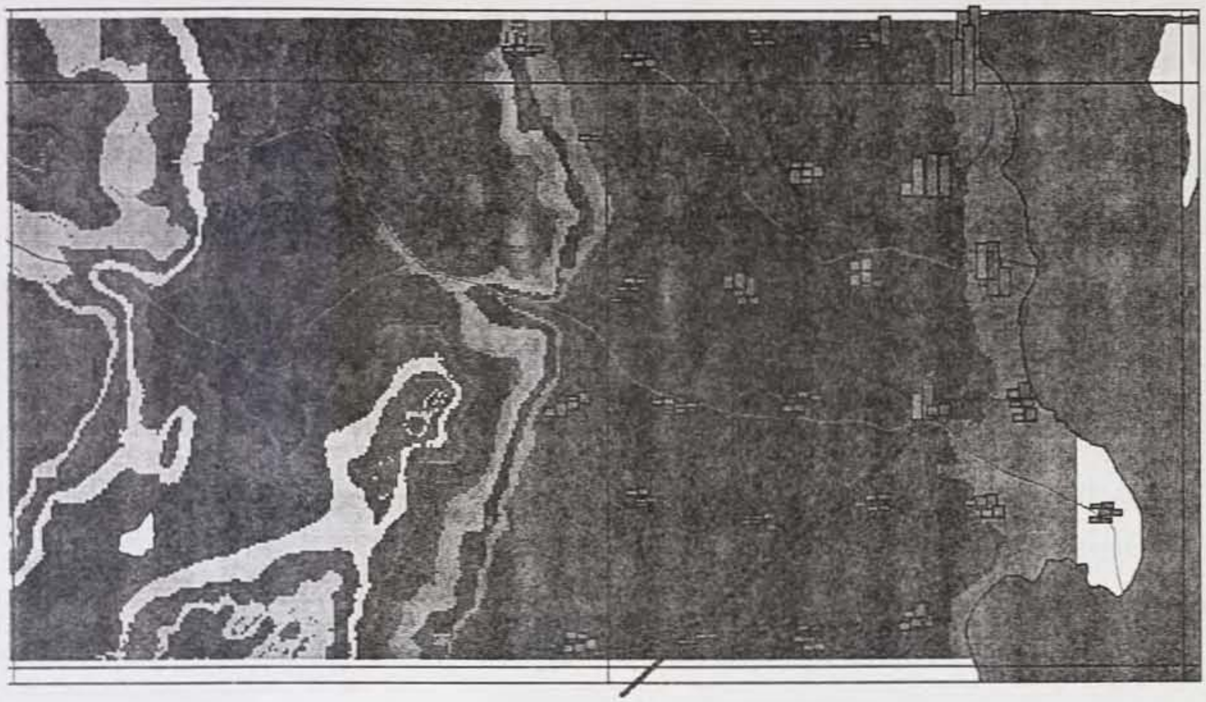

Figure 25: The Digital Elevation Model (in 50 meters interval) of the study area and *G. pallidipes* distribution overlaid with DEM. Bar charts show male and female *G. pallidipes* distributed along the altitude gradient (SRVETEP site, around Mirab Abaya).

Legend

Altitude - meters above sea level

Lake Abaya

Up to 1250 m	1550-1600 m	1800-1850 m
1250-1300 m	1550-1600 m	1850-1900 m
1300-1350 m	1600-1650 m	1900-1950 m
350-1400 m	1650-1700 m	1950-2000 m
1450-1500	1750-1800m	2000-2050 m
1500-1550 m	1700-1750 m	2050-2100m

4.6 The GIS database

The satellite image (a raster data) of the area as taken from the Landsat TM was processed and analysed in IDRISI. Band selection for the land cover types, image colour composition, enhancement and classification (supervised classification procedure with a maximum likelihood decision rule) and NDVI calculation to produce NDVI image of the area were done.

A geographic information system (GIS) database was established for the area using data from satellite image (Landsat TM), digitised features from the base map (roads, rivers, lakes and settlement mainly the town), and tsetse catches in two seasons from the sampling grids. Layers of these different features, each layer containing information about a specific aspect in the same area were integrated in ArcView GIS database. Most of the layers in the GIS database were discussed in the previous sections with respect to the area they are related.

5. DISCUSSION

In this study, an attempt was made to integrate data from satellite image (Landsat TM) and geo-referenced ground survey data on the tsetse fly distribution and habitat (vegetation types), and other agro-ecological characteristics in a GIS database. The remotely sensed Landsat TM data of the area were used to produce the vegetation map (land cover/use map) of the area. Tsetse catches were examined towards possible factors that could affect their abundance and distribution, like season (temporal distribution), the vegetation coverage of the area and altitude gradient.

5.1 Tsetse fly species.

Only one species of tsetse fly (*G. pallidipes*) was caught. This finding was in agreement with the pervious works in the area. Langridge (1976), in a tsetse and trypanosomiasis survey of Ethiopia, had reported the presence of *G. pallidipes*, probably the only species in the area. Since then, various pilot studies at local level had been carried out and all failed to catch other tsetse fly species than *G. pallidipes*. Recent studies by Vreysen *et al.* (1999), Muturi *et al.* (1999) and the work of Msangi (1999) have also substantiated the findings of Langridge (1976) and are all in agreement with the current finding.

Glossina pallidipes Austen is among the most important vectors of animal trypanosomosis in tsetse infested area of the African continent. It is a vector of importance for the transmission of pathogenic trypanosomes to livestock. Langridge (1976) had reported the same species as being the most efficient in the transmission of *T. congolense* (the most dominant trypanosome parasite in cattle in the SRVETEP area, Karanja, 1999) than T.*vivax* in East Africa. Works of Muturi *et al.* (1999) in the SRVETEP area have also substantiated this, where they found a high percentage of cattle infected with *T. congolense* in areas where high catches of *G. pallidipes* was recorded.

5.2 Temporal distribution of tsetse flies (*G.pallidipes*)

There was a significant variation ($P < 0.05$) in the distribution of *G. pallidipes* in the study area. High *G. pallidipes* catches (72.2%) was observed during the wet season compared to the dry season catch (29.8%). The apparent fly density was also high (3.1 fly/trap/day) during the wet season compared to the dry season (1.3 fly/trap/day). High percent catches of *G. pallidipes* in the wet season may indicate the presence of favourable conditions for maintaining the population of tsetse flies in this season. This could be attributed to the change in the vegetation that could provide an optimal condition for the growth and survival of the flies.Vegetation type and condition is determined by climate of the area, mainly rainfall. There was a marked increase in the amount of rainfall from January to May in the area. Highest rainfall (182mm) was recorded at Mirab Abaya meteorological station during the month of May. The sequential increase in rainfall from hot dry season to wet season and relatively high rainfall in May had contributed to the change in vegetation of the area. Thus, catches increased in June and July (wet season) following the heavy rain in May. Vale (1998) has found similar results for *G. pallidipes* in Zimbabwe. He reported that catches of *G. pallidipes* were lowest in the hot dry weather of October and November, rising rapidly with the rains of December. Working in Lambwe Valley, Kenya, Kitron *et al.* (1996), have found a positive correlation of tsetse fly catches with rainfall ($r = 0.55$, $P < 0.05$) for the same species of tsetse fly. Vreysen *et al.* (1999) and Muturi *et al.* (1999) have also reported similar results in the SRVETEP area. In both studies, it has been indicated that the catch of *G. pallidipes* increased during the wet season compared to the dry season catch.

The seasonal distribution of tsetse flies in relation to other climatic factors such as mean maximum and minimum temperature and relative humidity in the study area was not discussed here. Because the nature of data collected did not allow to examine the correlation in monthly, as the data was collected only in two months, one in March and the other in June and first week of July.

Female *G. pallidipes* had a higher proportion in the sample when compared to males in each season. The female catches accounted for about 60% in each survey. Although this difference was not significant, it is still in accordance with findings of other workers. Msangi (1999) has reported 71% of female *G. pallidipes* catch in the project area. Works of Vreysen et al. (1999) in the block one of the SRVETEP area has also revealed that the catches of female G. *pallidipes* accounting for more than 62 %. Leak (1999) described this as in unbiased sample female would comprise between 70-80% of an average population. The higher proportion catch of female *G. pallidipes* in the sample may be attributed the fact that they live longer (mean life span being 8 weeks) than males (about 4 weeks) so that more females could be caught.

5.3 Spatial distribution of tsetse flies (*G. pallidipes*)

5.3.1 Vegetation

Describing the importance of vegetation for tsetse flies, Leak (1999) has noted that vegetation is vital for providing shade and maintaining a suitable microclimate for tsetse as well as a habitat for their hosts. In this study, four major vegetation types were classified in the study area. The distribution of *G. pallidipes* significantly varied from vegetation type to vegetation in both seasons. The highest total proportion catches were in bushland (BUL) vegetation type (46% in the dry season and 68% in the wet season) followed by wooded land (WL) (26.7% in the dry and 15% in the wet season). However, in this context, the highest catch in BUL does not necessarily mean that *G. pallidipes* prefers BUL to WL or WGL. It shows that these flies are widely dispersed over the BUL vegetation type despite of the relative low density compared to the other vegetation types.The highest catch in BUL vegetation type could be due the fact that this was the predominant vegetation type in the study area. As a result, the proportion of traps deployed in BUL was considerably higher to the other vegetation types (60% of the total trap deployment was in BUL vegetation type). Therefore, the overall highest total catch could be expected in BUL in relation to the large number of traps deployed and the wide spread of the flies in this vegetation type.

Mean catches of *G. pallidipes* in relation to vegetation type have yielded different results regarding their abundance. Thus, in the dry season highest mean catch was in WGL (mean = 11.7) followed by WL (mean = 9.2). In the wet season, mean catch was still highest in WGL (mean = 13.7) and also followed by WL (mean = 12.5). *Glossina pallidipes* were abundantly distributed in WGL and WL. Flies are regarded as abundant where most are caught(Vale, 1998.). From this result, it can be concluded that these vegetation types are suitable habitats for *G. pallidipes* in the area. Thus, with the few number of traps (only six traps) deployed in WGL the mean catch was higher compared to catches in other vegetation types indicating the highest density in this vegetation type. This result was in agreement with the findings of Vreysen *et al.* (1999) and Msangi (1999) who found the highest mean catch of *G. pallidipes* in the project area in WGL/BUL. *Glossina pallidipes* was also caught from banana plantation (main perennial cultivation type in the low land area), maize fields and cotton plantations, although the apparent density was low (0.27 flies/trap/day in the dry season and 0.7 flies/trap/day in the wet season) compared to densities in other vegetation types. The catch in CUL may indicate how these flies can move away from their natural habitats into settlement and agricultural areas.

5.3.2 Altitude

In the five altitude levels chosen in the study area, *G. pallidipes* distribution was significantly different ($P< 0.005$) from one to another in both the dry and wet seasons. 75% of the total catch was in the lower altitude level (up to 1250m) and the catch was decreasing with increasing altitude. The highest catch in this lower altitude level could be attributed to the presence of favourable environmental conditions for the existance the flies. These findings are in agreement with the previous works of Vreysen *et al.* (1999) who found a significantly high male and female catches (over 93%) in altitude between 1100 and 1400 m in the project area.

Basically the objective of analysing tsetse fly distribution in relation to altitude in this study was not to determine the upper limit of altitude for tsetse fly existence, which has been discussed by several workers in tsetse infested areas including this one. It was mainly to observe the spatial relationship between tsetse fly and altitude in lowland areas (the valley). The analysis revealed that there was a significant correlation ($r = - 0.37$, $P = 0.000$) between altitude and tsetse fly distribution. This implies that there is a decrease in tsetse fly distribution and abundance as altitude increased. The weak correlation may be due to the small range of altitude (100 meters interval), as it was only in the low land areas below 1500 meters. The unproportional distribution of traps with a high number of traps (46%) deployed in altitude up to 1250 meters, which resulted in higher catches in this altitudev level could have also contributed to this weak correlation.

5.4 Landsat TM image classification and vegetation types

The analysis of Landsat TM data using the supervised classification procedure yielded a detailed land cover/use map of the study area. The four major vegetation types: BUL, WGL, WL and CUL observed during the ground survey were accordingly classified. However, BUL and CUL were subdivided into more detailed classes. BUL was classified as BUL of shrubby type (dense) and BUL of tree type (less dense). CUL was also differentiated into mixed, annual and perennial cultivation. However, during field survey these were considered as cultivated land (CUL) only. The detailed classification of these vegetation types in the image may be attributed to the variation in the reflectance of the wavebands in each vegetation type.

The other land cover/use classification included water bodies (Lake Abaya and Ella) and open grassland. The open grassland classified in the image was found mainly in the higher altitude areas (highland areas above the escarpment and over 2000 meters). Observation on the distribution and abundance of *G. pallidipes* in this particular land cover type was not possible as tsetse sampling was made only in areas below the escarpment in the valley (lower altitude areas). Open grassland was also only found in the valley, in both the classified image and ground survey, in very few areas along the shore of Lake Abaya. In general, the vegetation map derived from this satelite image showed the various vegetation types in the study area which can be associated with tsetse fly distribution. Boone *et al.* (2000) noted that remotely sensed data are commonly used to generate maps of vegetation types, which can be useful indicators of environmental characteristics, including moisture, soil type and elevation. Although these vegetation maps provide a basic information on environmental facors, the accuracy of such maps should be verified by field observation.

The results of digital image classification revealed that about 77% of the BUL and about 63% of CUL were classified to the respective vegetation type in the image when compared to the ground (reference) data. The classification of WGL and WL vegetation types was less accurate, only 33.3% were classified as respective vegetation type. There was also some misclassification of the two (WGL and WL) vegetation types. The relative high accuracy (77%) for BUL could be attributed to the fact that BUL was the most abundant vegetation type in the study area and much of the samples during ground survey were taken from it. As a result, identifying BUL in the field was done with a better accuracy. Moreover, this helped the careful selection and location of representative training areas during the digital image classification. The selection of the training areas is crucial matter, as the classification performance is highly dependent upon the proper selection of the training sites (Karteris, 1991). Following the BUL, CUL was also predominant in the area and comparatively accurately classified in the image (63%).

The lower accuracy of classification for WGL and WL could be related to the fact that as the study area was small, there were few representative vegetation types as WGL or WL as land cover type. Instead of WGL or WL we can have BUL with some trees and CUL with crops. Few samples were taken in the field and this might have affected the selection of proper representative training site. The other possibility may be that the WGL area could easily be classified as WL or vice versa (misclassification) as long as WGL is a mixture of the two classes in different proportion.

In general, transforming remotely sensed images into vegetation maps could be subjective and it could sometimes be imprecise. Classification accuracy is a general estimate of the prediction accuracy of each method if it were applied to new sites in similar landscape (Boone *et al.*, 2000). Using the SPOT data for the classification of Mediterranean forest, Kateris

(1991) found an overall classification accuracy over 70%. He further emphasised to consider the substantial contribution the satellite technology could make in combination with GIS in the forest management and planning.

Although the classification accuracy in this particular study can not be considered as excellent, it is still acceptable (overall classification accuracy was over 64%), albeit the small size of the study area. The BUL and CUL vegetation type classification is promising. This may demonstrate the potential for using remotely sensed image to determine vegetation types and predict suitable tsetse habitat and associated environmental correlates. Therefore, the vegetation map output constructed from such classification could be used for the study of land cover/use of the area in general, and identifying and predicting tsetse habitat with a relatively good accuracy in particular.

5.4 Data integration into a GIS database

The integration of the satellite data, ground surveyed tsetse catch data and vegetation types along with the other environmental characteristics into a GIS database revealed the combination of different layers which can be overlaid one on the other. The different layers established in the GIS produced a specific information of each feature and the relationship among the features integrated. This shows the capabilities of a GIS as a tool to combine information from different sources (geo-referenced data) so that the association and link of one environmental feature with the others can be observed. The present study has demonstrated these functional capabilities of GIS that can greatly facilitate the integration of data from satellite image with ground surveyed data (tsetse catch data and vegetation types) to produce a map output with meaningful interpretation. Kitron (1998) noted that a GIS can be used to associate remotely sensed data with ground-based information (i.e. ground verification), and assessing the links of satellite data and ground-verified habitat with vector distribution and disease transmission.

The overlay of tsetse distribution data from the field with the satellite derived thematic map of the study area showed that *G. pallidpes* were distributed in almost all BUL vegetation types (where trap was set) especially in the wet season. In the dry season, their distribution in BUL vegetation type was more or less confined to areas around the Lake where wet and green vegetation is available. This explains the spatial distribution of tsetse flies in relation to the vegetation type and condition.Thus, even with the same type of vegetation , their distribution varied depending on the condition of the vegetation. This observation has been verified by ground survey and that the findings coincided with the results of ground survey, in which *G. pallidipes* was caught almost in all the traps deployed in BUL vegetation types. This implies the importance of remote sensing data to forecast tsetse fly distribution and identify suitable habitat in areas with similar environmental characteristics (vegetation type in this case) where it is difficult to undertake ground survey. Robinson (1998) noted that ground survey data could be complemented by aerial survey and high-resolution satellite data to make increasingly accurate predictions in areas where ground data are sparse or absent. It can be concluded, in the current study, the integration of data from remote sensing (satellite data) with ground survey (tsetse catch data) helped understand the association of tsetse fly distribution with land cover/use of the area.

Several research works done by different researchrs have indicated the potential use of remote sensing and GIS capabilities to integrate data from remote sensing and ground surveyed data using GPS.The work of Robinson (1998) who used of GIS to prioritise areas for tsetse and trypanosomosis control in Zambia is among others to mention here. He noted that integration of digital maps of land tenure, stocking rates and relative arable potential in a GIS helped identify areas where tsetse transmitted trypanosomosis is a constraint to agricultural development.

Other climate data such as minimum and maximum temperature and relative humidity in both dry and wet seasons were not incorporated in a GIS database, because of lack of data from some sites, which are required for the extrapolation of the climate data in the study area. Extrapolation of the existing data resulted in the theme covering only the upper half of the study area.

5.5 Normalised Difference Vegetation Index (NDVI)

The NDVI image of the study area showed that there were at least three types of vegetation cover. The green areas that are corresponded to the WL vegetation type along the base and flunk of the escarpment and trees of dense canopy, and also CUL. The bright yellow areas corresponded to the entire BUL vegetation type (tress of less canopy type) all over the study area. The golden yellow areas are corresponded to the grasslands and less vegetated areas: areas like around the town of Mirab Abaya. The grasslands are only in the highland areas and only few of them are along the lakeshore of Lake Abaya.

The NDVI is usually assumed to be broadly indicative of, and associated with, plant photosynthetic activity. The spatial and temporal patterns of NDVI can be linked with temperature and precipitation, soil physical properties, plant evapotranspirations and root zone soil moisture. NDVI association with precipitation is affected by soil water status and land cover characteristics (Wenli *et al.*, 1994).

In the current work, the nature of data analysis (basically to produce map output) and the time image was taken (one time image and a long ago) did not allow to understand the correlation of different NDVI values with spatial and temporal tsetse distribution. However, NDVI from remotely sensed satellite data has been used for the study of vectors and disease distribution and their association with the environmental characteristics. Rogers and Williams (1993) have demonstrated the maximum mean NDVI as the single most important variable to correctly predict the pre-rinderpest distribution of tsetse in Kenya and Tanzania. Based on the linear discriminant analysis, they found a correct predictions over 69% of the countries. Moreover, they suggested that this be improved to 82% when other climate and vegetation variables were considered.

This suggests the importance of using remote sensing data for NDVI estimation and its correlation with ecological parameters, which could indicate the possibility of predicting vector and disease distribution in a given geographic locality.

6. CONCLUSIONS AND RECOMMENDATIONS

Geographic information technologies; Remote sensing (RS), Global positioning system (GPS) and Geographic information system (GIS) were used to help understand the relationship between the distribution and abundance of *G. pallidipes* and the environmental parameters that may explain the spatial and temporal pattern of the flies.

The results of the present study demonstrated that the distribution of *G. pallidipes* was significantly associated with seasonal variation (temporal distribution) which may indicate the effect of climatic factor and its influence on the habitat (vegetation type). Although this study established the seasonal variation in fly distribution and abundance, it was carried out only in two months, each representing the two main seasons (the dry and wet seasons). However, the understanding of the temporal fluctuation of *G. pallidipes* in relation to climate factors (rainfall, temperature, humidity and soil moisture) to a great extent requires the availability of quality data and establishing the correlation between them at least in monthly basis.

The analysis and integration of RS satellite data has also demonstrated the potential for using remote sensed data for the study of tsetse fly distribution in relation to environmental characteristics. The spatial distribution of tsetse flies is related to the major vegetation types in the area with high densities in wooded grassland and wooded land. The classification of digital image in to different vegetation types has also yielded a promising result. Both the vegetation map (land cover/use) and NDVI derived from the satellite image can be used to correlate the fly distribution with changes in vegetation. This change is mainly due to changes in climate in different seasons. However, the satellite image used for this study was taken some years ago (in 1994) and it is a one-time image. Hence, it is recommended to use a multitemporal comparison with a real-time satellite data to establish the correlation between tsetse fly distribution and environmental factors in the project area.

The incorporation of various layers of geo-referenced data in a GIS database has demonstrated the capabilities of GIS as a tool for effective data capture and linking of different features and their relationship. It has also been understood that using GIS functional capabilities, the land cover/use map produced can be used, in the future, for modelling the spatial distribution of tsetse flies in relation to remote sensing and environmental variables. This could help furthering the understanding of the impact of these factors on the tsetse fly distribution so that effective prediction could be made in other areas with similar environmental characteristics.

A ground survey had enabled to gather more information on tsetse fly density and associated environmental characteristics. The prediction capacity of GIS could also be enhanced when combined with the ground survey. More data should be incorporated in a GIS database to explain the relation between tsetse fly and the disease (trypanosomosis) distribution. This also requires the availability of more relevant data on the disease situation (trypanosomosis), tsetse host animal preference (livestock and wild life), livestock management system, and other environmental parameters so that they can be combined in a GIS for effective decision process.

This study is not exhasutive because it was implemented in a small area and in short time period. As a result, obtaining all the necessary information and performing detailed spatial analysis was not done. Therefore, further study shoul be conducted with extensive ground surveys in expansive geographic area for a longer time period in order to obtain sufficient information. This could help performing adavnced spatial analysis (e.g. autocorrelation and applied geostatistics) for modelling the spatial and temporal patterns of tsetse flies even the control program is underway in the project area It is hoped that this will contribute substantially to facilitate the decision process on tsetse fly control on sound economic basis and evaluate the effectiveness of the control program implemented.

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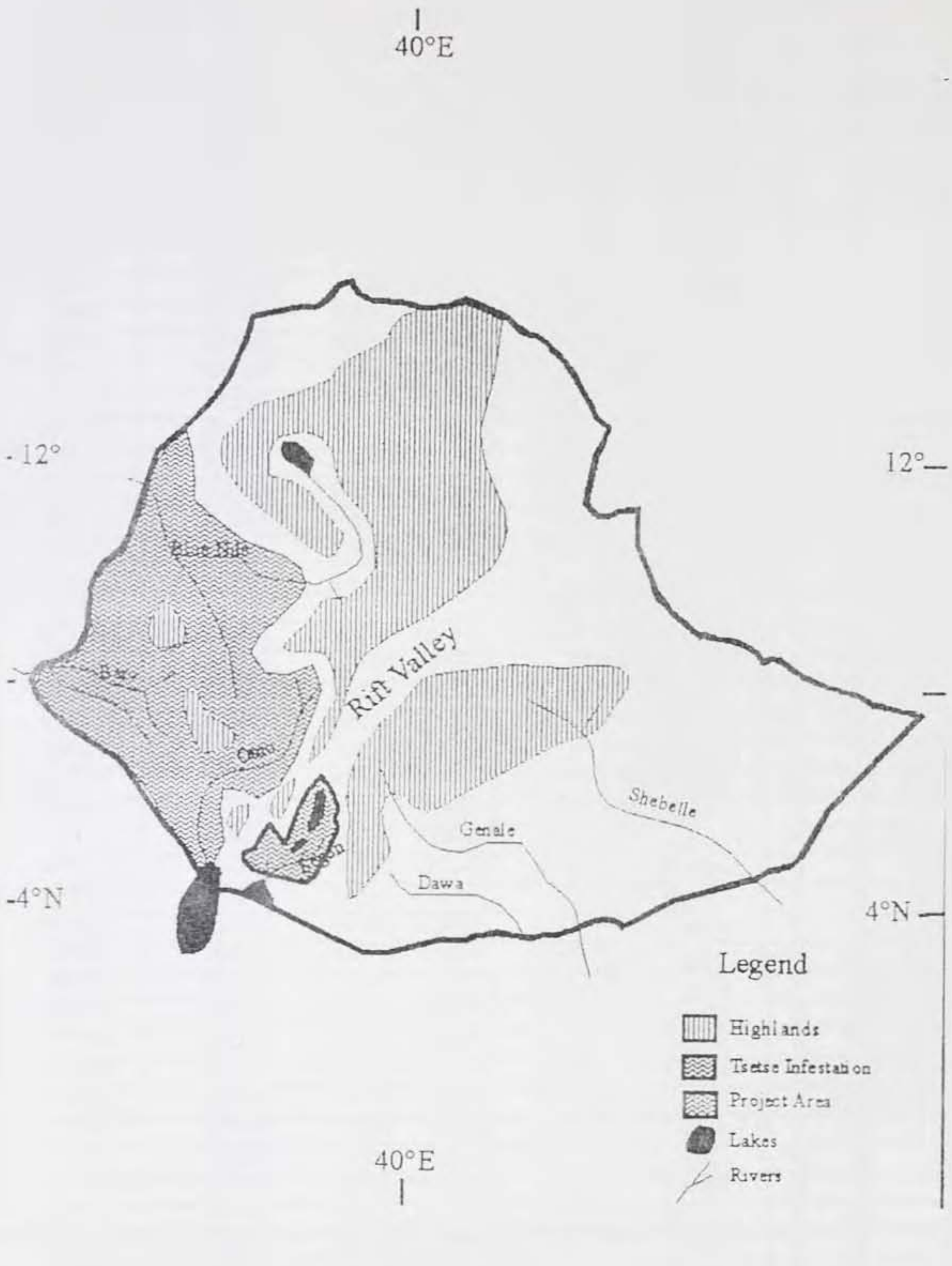
8. ANNEXES

Annex: Map of Ethiopia showing tsetse fly distribution and the project (SRVETEP) area



Annex 2: Field survey data of tsetse fly catch, vegetation type and altitude at every trapping location in a transect (the dry season)

Trans	Trap No.	X coordinate (UTM)	Y coordinate (UTM)	Alt.	Veg.	Date[1]	Date[2]	Tsetse Species	Number caught			Tabanids	Other
									M	F	Total		
1	T1S11	690559	365290	1235	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
1	T1S12	690647	365474	1237	BUL	6.3.01	9.3.01	G.pallid	0	0	0	70	35
1	T1S13	690829	365351	1241	BUL	6.3.01	9.3.01	G.pallid	0	0	0	70	35
1	T1S21	690213	363638	1224	CUL	6.3.01	9.3.01	G.pallid	0	0	0	74	15
1	T1S22	690356	363452	1233	CUL	6.3.01	9.3.01	G.pallid	2	1	3	80	50
1	T1S23	690538	363547	1231	CUL	6.3.01	9.3.01	G.pallid	0	0	0	82	12
1	T1S31	690416	361783	1239	BUL	6.3.01	9.3.01	G.pallid	0	0	0	85	25
1	T1S32	690224	361676	1240	CUL	6.3.01	9.3.01	G.pallid	1	2	3	108	10
1	T1S33	690300	361461	1242	CUL	6.3.01	9.3.01	G.pallid	0	0	0	50	5
1	T1S41	690260	359690	1256	BUL	6.3.01	9.3.01	G.pallid	0	0	0	45	10
1	T1S42	690401	359532	1274	BUL	6.3.01	9.3.01	G.pallid	0	0	0	25	6
1	T1S43	690194	359483	1264	BUL	6.3.01	9.3.01	G.pallid	0	4	4	20	5
2	T2S11	692384	368580	1209	WGL	6.3.01	9.3.01	G.pallid	0	0	12	0	0
2	T2S12	692520	368773	1200	WGL	6.3.01	9.3.01	G.pallid	0	0	0	12	8
2	T2S13	692630	368601	1202	CUL	6.3.01	9.3.01	G.pallid	0	0	0	8	2
2	T2S21	692702	366592	1216	BUL	6.3.01	9.3.01	G.pallid	0	1	1	8	5
2	T2S22	692722	366419	1214	BUL	6.3.01	9.3.01	G.pallid	1	1	2	72	50
2	T2S23	692524	366721	1216	BUL	6.3.01	9.3.01	G.pallid	0	2	2	65	70
2	T2S31	692794	364720	1235	CUL	6.3.01	9.3.01	G.pallid	4	5	9	65	60
2	T2S32	692598	364739	1239	CUL	6.3.01	9.3.01	G.pallid	0	0	0	78	20
2	T2S33	692658	364533	1244	CUL	6.3.01	9.3.01	G.pallid	0	1	1	68	15
2	T2S41	692474	362768	1259	WGL	6.3.01	9.3.01	G.pallid	0	0	0	45	10
2	T2S42	692368	362585	1260	CUL	6.3.01	9.3.01	G.pallid	0	0	0	27	15
2	T2S43	692263	362814	1260	WGL	6.3.01	9.3.01	G.pallid	0	0	0	2	3
2	T2S51	692889	360607	1274	CUL	6.3.01	9.3.01	G.pallid	0	2	2	35	10
2	T2S52	692670	360577	1272	CUL	6.3.01	9.3.01	G.pallid	0	3	3	21	5
2	T2S53	692759	360758	1265	CUL	6.3.01	9.3.01	G.pallid	0	0	0	27	10
3	T3S11	694191	367284	1200	BUL	6.3.01	9.3.01	G.pallid	0	0		0	0
3	T3S12	694414	367240	1203	BUL	6.3.01	9.3.01	G.pallid	0	0	0	30	20
3	T3S13	694617	367184	1198	BUL	6.3.01	9.3.01	G.pallid	1	0	1	20	15
3	T3S21	694659	365521	1240	WL	6.3.01	9.3.01	G.pallid	0	0	0	7	12
3	T3S22	694413	365502	1235	WL	6.3.01	9.3.01	G.pallid	5	4	9	35	16
3	T3S23	694286	365778	1238	WL	6.3.01	9.3.01	G.pallid	18	12	30	34	25
3	T3S31	694501	363586	1259	CUL	6.3.01	9.3.01	G.pallid	4	5	9	36	22
3	T3S32	694568	363370	1258	CUL	6.3.01	9.3.01	G.pallid	1	1	2	20	14
3	T3S33	694340	363283	1256	CUL	6.3.01	9.3.01	G.pallid	0	1	1	16	5
3	T3S41	694378	361434	1281	WL	6.3.01	9.3.01	G.pallid	1	2	3	12	3
3	T3S42	694279	361255	1284	WL	6.3.01	9.3.01	G.pallid	0	1	1	5	4
3	T3S43	694444	361038	1291	WL	6.3.01	9.3.01	G.pallid	0	0	0	6	5
3	T3S51	694501	359581	1358	BUL	6.3.01	9.3.01	G.pallid	0	0	0	20	14
3	T3S52	694389	359403	1358	BUL	6.3.01	9.3.01	G.pallid	0	0	0	8	2
3	T3S53	694300	359208	1375	BUL	6.3.01	9.3.01	G.pallid	0	0	0	5	3
4	T4S11	696666	366689	1217	BUL	6.3.01	9.3.01	G.pallid	7	2	9	40	45
4	T4S12	696539	366836	1210	BUL	6.3.01	9.3.01	G.pallid	7	2	9	40	25
4	T4S13	696868	366632	1219	BUL	6.3.01	9.3.01	G.pallid	1	0	1	16	3
4	T4S21	696600	364455	1250	BUL	6.3.01	9.3.01	G.pallid	7	4	11	45	35
4	T4S22	696802	364437	1248	BUL	6.3.01	9.3.01	G.pallid	1	0	1	26	10
4	T4S23	696463	364655	1248	BUL	6.3.01	9.3.01	G.pallid	0	1	1	20	15

Annex 2 (continued)

Trans	Trap No.	X coordinate (UTM)	Y coordinate (UTM)	Alt	Veg	Date[1]	Date[2]	Tsetse Species	Number caught M	F	Total	Tabanids	Other
4	T4S31	696214	362532	1254	WL	6.3.01	9.3.01	G.pallid	0	1	1	22	12
4	T4S32	696421	362448	1264	WL	6.3.01	9.3.01	G.pallid	1	6	7	26	18
4	T4S33	696524	362278	1272	WL	6.3.01	9.3.01	G.pallid	3	10	13	28	32
4	T4S41	696192	360339	1351	BUL	6.3.01	9.3.01	G.pallid	6	7	13	29	30
4	T4S42	696389	360445	1355	BUL	6.3.01	9.3.01	G.pallid	0	0	0	8	10
4	T4S43	696535	360585	1355	BUL	6.3.01	9.3.01	G.pallid	0	1	1	6	2
5	T5S11	698321	365793	1226	BUL	6.3.01	9.3.01	G.pallid	1	3	4	34	15
5	T5S12	698340	365573	1225	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S13	698305	365344	1241	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S21	698313	363441	1316	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S22	698394	363645	1325	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S23	698515	363471	1321	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S31	698800	361980	1320	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S32	698710	361922	1354	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
5	T5S41	698994	359814	1459	BUL	6.3.01	9.3.01	G.pallid	0	0	0	0	0
6	T6S11	700784	366315	1205	WGL	6.3.01	9.3.01	G.pallid	20	35	55	60	0
6	T6S12	700605	366222	1205	WGL	6.3.01	9.3.01	G.pallid	3	7	10	35	
6	T6S13	700321	366225	1197	BUL	6.3.01	9.3.01	G.pallid	0	0	0	35	6
6	T6S21	700818	364768	1252	BUL	6.3.01	9.3.01	G.pallid	28	29	57	54	12
6	T6S22	700712	364594	1265	BUL	6.3.01	9.3.01	G.pallid	0	12	12	34	8
6	T6S23	700569	364437	1280	BUL	6.3.01	9.3.01	G.pallid	1	2	3	68	15
6	T6S31	700807	362718	1327	BUL	6.3.01	9.3.01	G.pallid	0	0	35	14	12
6	T6S32	700611	362768	1324	BUL	6.3.01	9.3.01	G.pallid	0	0	0	10	3
6	T6S33	700611	362795	1319	BUL	6.3.01	9.3.01	G.pallid	0	0	0	35	14
6	T6S41	700319	360359	1375	BUL	6.3.01	9.3.01	G.pallid	0	1	1	24	18
6	T6S42	700397	360559	1368	BUL	6.3.01	9.3.01	G.pallid	0	0	0	16	12
6	T6S43	700264	360733	1367	BUL	6.3.01	9.3.01	G.pallid	0	0	0	15	5
6	T6S51	700498	358808	1448	BUL	6.3.01	9.3.01	G.pallid	0	0	0	25	10
6	T6S52	700419	358662	1464	BUL	6.3.01	9.3.01	G.pallid	0	0	0	1	3
6	T6S53	700513	358499	1480	BUL	6.3.01	9.3.01	G.pallid	0	0	0	3	5

Veg-Vegetation type at evry trapping site

BUL-bushland

WGL-wooded grassland

WL-wooded land

CUL-cultivated land

Alt-altitude (in meters) at every trapping site

Date[1]- date of trap deployment

Date[2]- date of collection

X and Y coordinate-position of each trapping site

M- male *G. pallidipes*

F- female *G. pallidipes*

T1S11….ID of each trap, eg. Transect 1, sample grid 1 and trap site 1
Other- non-biting flies

Annex 3: Field survey data of tsetse fly catch, vegetation type and altitude at every trapping location in a transect (during the wet season

Trans	Trap No.	X coordinate (UTM)	Y coordinate (UTM)	Alt	Veg	Date[1]	Date[2]	Tsetse Species	Number caught M	F	Total	Tabanids	Other
1	T1S11	690559	365290	1235	BUL	21.6.01	24.6.01	G.pallid	3	1	4	2	5
1	T1S12	690647	365474	1237	BUL	21.6.01	24.6.01	G.pallid	4	6	10	0	30
1	T1S13	690829	365351	1241	BUL	21.6.01	24.6.01	G.pallid	2	6	8	2	40
1	T1S21	690213	363638	1224	CUL	21.6.01	24.6.01	G.pallid	2	3	5	3	15
1	T1S22	690356	363452	1233	CUL	21.6.01	24.6.01	G.pallid	2	1	3	6	4
1	T1S23	690538	363547	1231	CUL	21.6.01	24.6.01	G.pallid	1	0	1	0	18
1	T1S31	690416	361783	1239	BUL	21.6.01	24.6.01	G.pallid	0	1	1	3	18
1	T1S32	690224	361676	1240	CUL	21.6.01	24.6.01	G.pallid	1	1	2	0	30
1	T1S33	690300	361461	1242	CUL	21.6.01	24.6.01	G.pallid	0	0	0	0	40
1	T1S41	690260	359690	1256	BUL	21.6.01	24.6.01	G.pallid	2	5	7	2	17
1	T1S42	690401	359532	1274	BUL	21.6.01	24.6.01	G.pallid	3	2	5	0	30
1	T1S43	690194	359483	1264	BUL	21.6.01	24.6.01	G.pallid	3	4	7	8	25
2	T2S11	692384	368580	1209	WGL	21.6.01	25.6.01	G.pallid	1	0	1	15	35
2	T2S12	692520	368773	1200	WGL	22.6.01	25.6.01	G.pallid	2	1	3	4	15
2	T2S13	692630	368601	1202	CUL	22.601	25.6.01	G.pallid	0	1	1	10	5
2	T2S21	692702	366592	1216	BUL	22.6.01	25.6.01	G.pallid	4	7	11	2	12
2	T2S22	692722	366419	1214	BUL	22.6.01	25.6.01	G.pallid	2	4	6	3	16
2	T2S23	692524	366721	1216	BUL	22.6.01	25.6.01	G.pallid	3	5	8	10	5
2	T2S31	692794	364720	1235	CUL	22.6.01	25.6.01	G.pallid	1	2	3	4	18
2	T2S32	692598	364739	1239	CUL	22.6.01	25.6.01	G.pallid	1	1	2	21	0
2	T2S33	692658	364533	1244	CUL	22.6.01	25.6.01	G.pallid	0	0	0	10	1
2	T2S41	692474	362768	1259	WGL	22.6.01	25.6.01	G.pallid	0	2	2	1	25
2	T2S42	692368	362585	1260	CUL	22.6.01	25.6.01	G.pallid	1	1	2	15	2
2	T2S43	692263	362814	1260	WGL	22.6.01	25.6.01	G.pallid	0	2	2	4	25
2	T2S51	692889	360607	1274	CUL	22.6.01	25.6.01	G.pallid	1	2	3	4	14
2	T2S52	692670	360577	1272	CUL	22.6.01	25.6.01	G.pallid	0	1	1	2	23
2	T2S53	692759	360758	1265	CUL	6/22/01	25.6.01	G.pallid	0	1	1	4	25
3	T3S11	694191	367284	1200	BUL	23.6.01	26.6.01	G.pallid	2	6	8	5	20
3	T3S12	694414	367240	1203	BUL	23.6.01	26.6.01	G.pallid	1	3	4	2	15
3	T3S13	694617	367184	1198	BUL	23.6.01	26.6.01	G.pallid	3	7	10	3	12
3	T3S21	694659	365521	1240	WL	23.6.01	26.6.01	G.pallid	7	15	22	2	13
3	T3S22	694413	365502	1235	WL	23.6.01	26.6.01	G.pallid	15	20	35	4	21
3	T3S23	694286	365778	1238	WL	23.6.01	26.6.01	G.pallid	4	5	9	36	22
3	T3S31	694501	363586	1259	CUL	23.6.01	26.6.01	G.pallid	1	1	2	0	5
3	T3S32	694568	363370	1258	CUL	23.6.01	26.6.01	G.pallid	0	2	2	1	3
3	T3S33	694340	363283	1256	CUL	23.6.01	26.6.01	G.pallid	2	3	5	4	3
3	T3S41	694378	361434	1281	WL	23.6.01	26.6.01	G.pallid	0	1	1	2	3
3	T3S42	694279	361255	1284	WL	23.6.01	26.6.01	G.pallid	0	2	2	3	5
3	T3S43	694444	361038	1291	WL	23.6.01	26.6.01	G.pallid	1	3	4	2	15
3	T3S51	694501	359581	1358	BUL	23.6.01	26.6.01	G.pallid	2	4	6	1	5
3	T3S52	694389	359403	1358	BUL	23.6.01	26.6.01	G.pallid	1	3	4	2	8
3	T3S53	694300	359208	1375	BUL	23.6.01	26.6.01	G.pallid	3	6	9	4	10
4	T4S11	696666	366689	1217	BUL	27.6.01	30.6.01	G.pallid	15	13	28	10	22
4	T4S12	696539	366836	1210	BUL	27.6.01	30.6.01	G.pallid	18	15	33	1	16
4	T4S13	696868	366632	1219	BUL	27.6.01	30.6.01	G.pallid	20	21	41	6	12
4	T4S21	696600	364455	1250	BUL	27.6.01	30.6.01	G.pallid	6	11	18	5	23
4	T4S22	696802	364437	1248	BUL	27.6.01	30.6.01	G.pallid	4	5	9	3	17

Trans	Trap No.	X coordinate (UTM)	Y coordinate (UTM)	Alt	Veg	Date[1]	Date[2]	Tsetse Species	Number caught M	F	Total	Tabanids	Other
4	T4S23	696463	364655	1248	BUL	27.6.01	30.6.01	G.pallid	1	3	4	6	13
4	T4S31	696214	362532	1254	WL	27.6.01	30.6.01	G.pallid	6	5	11	4	15
4	T4S32	696421	362448	1264	WL	27.6.01	30.6.01	G.pallid	5	10	15	7	24
4	T4S33	696524	362278	1272	WL	27.6.01	30.6.01	G.pallid	6	8	14	0	2
4	T4S41	696192	360339	1351	BUL	27.6.01	30.6.01	G.pallid	1	0	1	1	2
4	T4S42	696389	360445	1355	BUL	27.6.01	30.6.01	G.pallid	1	1	2	1	1
4	T4S43	696535	360585	1355	BUL	27.6.01	30.6.01	G.pallid	2	1	3	1	4
5	T5S11	698321	365793	1226	BUL	2.7.01	5.7.01	G.pallid	17	24	41	2	5
5	T5S12	698340	365573	1225	BUL	2.7.01	5.7.01	G.pallid	11	25	36	1	4
5	T5S13	698305	365344	1241	BUL	2.7.01	5.7.01	G.pallid	7	22	29	0	3
5	T5S21	698313	363441	1316	BUL	2.7.01	5.7.01	G.pallid	7	5	12	3	0
5	T5S22	698394	363645	1325	BUL	2.7.01	5.7.01	G.pallid	4	5	9	3	0
5	T5S23	698515	363471	1321	BUL	2.7.01	5.7.01	G.pallid	2	2	4	3	0
5	T5S31	698800	361980	1320	BUL	2.7.01	5.7.01	G.pallid	0	1	1	2	5
5	T5S32	698710	361922	1354	BUL	2.7.01	5.7.01	G.pallid	0	0	0	1	2
5	T5S41	698994	359814	1459	BUL	2.7.01	5.7.01	G.pallid	1	0	1	0	7
6	T6S11	700784	366315	1205	WGL	3.7.01	6.7.01	G.pallid	27	30	57	0	5
6	T6S12	700605	366222	1205	WGL	3.7.01	6.7.01	G.pallid	5	12	17	6	2
6	T6S13	700321	366225	1197	BUL	3.7.01	6.7.01	G.pallid	31	40	71	15	32
6	T6S21	700818	364768	1252	BUL	3.7.01	6.7.01	G.pallid	2	15	17	3	4
6	T6S22	700712	364594	1265	BUL	3.7.01	6.7.01	G.pallid	1	4	5	10	5
6	T6S23	700569	364437	1280	BUL	3.7.01	6.7.01	G.pallid	0	1	1	5	1
6	T6S31	700807	362718	1327	BUL	3.7.01	6.7.01	G.pallid	1	1	2	6	2
6	T6S32	700611	362768	1324	BUL	3.7.01	6.7.01	G.pallid	2	2	4	1	2
6	T6S33	700611	362795	1319	BUL	3.7.01	6.7.01	G.pallid	1	1	2	5	0
6	T6S41	700319	360359	1375	BUL	4.7.01	7.7.01	G.pallid	0	0	0	0	1
6	T6S42	700397	360559	1368	BUL	4.7.01	7.7.01	G.pallid	1	1	2	0	0
6	T6S43	700264	360733	1367	BUL	4.7.01	7. 7.01	G.pallid	2	3	5	1	3
6	T6S51	700498	358808	1448	BUL	4.7.01	7.7.01	G.pallid	0	1	1	3	5
6	T6S52	700419	358662	1464	BUL	4.7.01	7.7.01	G.pallid	0	0	0	2	20
6	T6S53	700513	358499	1480	BUL	4.7.01	7.7.01	G.pallid	1	2	3	4	30

Annex 4: The Normalised Difference Vegetatiopn Index (NDVI) image of the area

9. CURRICULUM VITAE

1. Personal identification

Name:	Bergenie Bancha Helisso
Birth Place:	Wollayita, Southern Ethiopia
Birth Date / Month / Year:	June 18, 1969
Sex:	Male
Marital status:	Married
Nationality:	Ethiopian
Profession:	Veterinarian
Occupation:	Project Leader

Contact Address

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2. Educational Background:

1976/77 - 1979/80	Elementary School Degaga Lenda Elementary School, Wollayita, Southern Ethiopia.
1980/81 - 1981/82	Junior Secondary School Sakie Adventist Mission School, Sakie, Wollayita, Southern Ethiopia.
1982/83 - 1985/86	High School Awassa Comprehensive High School, Awassa, Ethiopia Achievement: ESLCE Certificate
1986/87 - 1991/92	University Studied: Addis Ababa University, Faculty of Veterinary Medicine, Debre-Zeit, Ethiopia. Achievement: Doctorate Degree in Veterinary Medicine, D.V.M

3. Working experience:

1991-1992	Research as undergraduate associate with FARM Africa (co-financing) on Reproductive problems of peasant's cattle in Wollayita, North Omom Zone
1992 - 1994	Min.of Agric., Kindo Koysha district, North Omo Zone, Southern Ethiopia • District Veterinary Officer • Head, Animals & Fisheries Resources Development Department • Head, District Min.of Agric.
1994-1996	Min.of Agric., North Omo Zone, Southern Ethiopia Head, Animals & Fisheries Resources Development Department
1996 - 1997	Min. of Agric., North Omo Zone Head, Veterinary Service Department
1998 - 1999	Project Co-ordinater at Soddo Field Operation Site Southern Rift Valley of Ethiopia Tsetse Eradication Project

4. Language skill

Wollayiita qaalla	Writing, reading and speaking
Amharic	Writing, reading and speaking
English	Writing, reading and speaking

5. Awards Received: Conferences & Training Attended

- Training course on Dairy Goat Production by FARM-Africa Dairy Goat Development Project. Awassa University of Agriculture, Southern Ethiopia. 5 - 16, July 1993. Certificate
- Advanced level training in Goat health by FARM-Africa Dairy Goat Development Project, Dire Dawa Zonal Veterinary Laboratory, Ethiopia. 29 Nov.- 14 December 1995. Certificate
- National Group Training on Tsetse Management, Monitoring and Control by I.C.I.P.E Nairobi, Kenya in collaboration with the Southern Region Bureau of Agriculture, Awassa, Ethiopia. 14 - 24 December 1995. Certificate
- Partner Conference on Program Planning, by Norwegian Church Aid in collaboration with the International Institute for Rural Reconstruction (IIRR) Nairobi, Kenya. Awassa University of Agric., Ethiopia. 19-23 June 1995. Certificate

- Training course on Tsetse Trapping Technology by I.C.I.P.E, Nairobi, Kenya. Nguruman, Kenya.16 May - 24 June 1996. Certificate
- Training Course on Tsetse Trapping Technology .by I.C.I.P.E, Nairobi, Kenya and Ethiopia (Arbaminch, Debre Zeit and Wolkitie), Ethiopia. 5 August - September 13, 1996. As a resource person. Certificate
- Partner Conference on Credit and Saving Schemes by Norwegian Church Aid in collaboration with Limat Consultancy, Addis Ababa. Megga, Ethiopia. 18-23 May 1997. Certificate
- Training Program on Management, Development in the Areas of Management, Finance, Integrated Rural Development, Policy, Project and Development Planning. Organised by the Office of Prime Minister of the Federal Democratic Republic of Ethiopia in collaboration with the Southern Regional Government, Awassa, Ethiopia. September 10 - December 20, 1996. Certificate
- IAEA / FAO Regional Training Course on Principles of Integrated Area-wide Tsetse / Trypanosomiasis Control / Eradication with Emphasis on the Sterile Insect Techniques (SIT). Tanga and Zanzibar, United Republic of Tanzania. 17 November - 12 December 1997. Certificate

6. Technical papers / Publications

Bergenie, B (1991): Assessment of economic losses due to treatment of Helmenthiasis in small ruminants in and around Debre Zeit. Seminar on Livestock Development Program, Debre Zeit, Ethiopia.

Bergenie, B. (1992): Reproductive problems of peasants' cattle in Wolayita. DVM thesis. Addis Ababa University Faculty of Veterinary Medicine, Debre Zeit, Ethiopia.

Bergenie, B. and Kindness, H. (1994): In: Alemayehu, K. (ed). Cattle problems in Wolayita; Reproductive problems of Peasants' cattle in Wollayita. FARM-Africa, Farmers Participatory Research Project. Technical Pamphlet No. 5. Addis Ababa, Ethiopia.

Vreysen, M. J. B., Assefa, M., Minutet, M., **Bergenie, B.**, Gizaw, W., Kiflom, M., Kassahun, B. and Gezahegn, A. (1999): The distribution and relative abundance of tsetse flies in the Southern Rift Valley of Ethiopia: Preliminary survey results. Proceedings of the 25th meeting of the International Scientific Council for Trypanosomiasis Research and

Control (ISCTRC) held 27 September-1 October 1999. Mombassa, Kenya. Publication No.120.

Muturi, K. S., Msangi, S., Münstermann, S, Clausen, P. H., Getachew, A., Getachew, T., **Bergenie, B**. and Assefa, M. (1999): Trypanosomosis risk assessment in selected sites of the Southern Rift Valley of Ethiopia: i) Distribution, density and infection rates of tsetse flies, ii) Epidemiology of bovine trypanosomosis. Proceedings of the 25th meeting of the International Scientific Council for Trypanosomosis Research and Control (ISCTRC) held 27 September- 1 October 1999. Publication No. 120. Mombassa, Kenya

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Declaration sheet

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

Name BERGENIE BANCHA

Signature [signature]

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