TSETSE CONTROL IN KENYA'S SPATIALLY AND TEMPORALLY DYNAMIC CONTROL RESERVOIRS: A COST ANALYSIS

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ABSTRACT

TSETSE CONTROL IN KENYA'S SPATIALLY AND TEMPORALLY DYNAMIC CONTROL RESERVOIRS: A COST ANALYSIS

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Funding for control of the tsetse fly, the primary vector of African trypanosomiasis, has been decreasing since the 1970s. This decrease in funding from governments and donor groups has limited the success of control campaigns and has necessitated the development of more cost-efficient methods of control. This study uses Kenya as its area of focus and introduces control of spatially and temporally constrained fly distributions, termed control reservoirs, as an economical means of reducing tsetse presence. These reservoirs are formed when seasonal fluctuations in environmental conditions reduce the habitat available to the fly. To identify the reservoirs, spatially and temporally dynamic species distribution maps are used, which provide tsetse distributions every sixteen days. After identifying the reservoirs, a tsetse management campaign within the control reservoirs is simulated. Finally, a costing analysis is conducted. This costing analysis calculates the results that are realized when spatial and temporal fluctuations in fly distributions are considered. The results of the costing analysis reveal that large savings are achieved if control operations take place within the reservoirs.

DEDICATION

To Grammie,
Your passion for education and learning has inspired
an entire generation of grandsons.

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LIST OF ABBREVIATIONS

AAT	African Animal Trypanosomiasis
ADB	African Development Bank
ADF	African Development Fund
ASALs	Arid and Semi-Arid Lands
AU	African Union
AU-IBAR	African Union – Inter-African Bureau for Animal Resources
BICOT	Biological Control of Tsetse Fly
CF	Sleeping Sickness Active Case Finding
CR	Control Reservoir
DDT	Dichloro-Diphenyl-Trichloroethane
DFID	Department for International Development
EA	Environmental Impact Assessment
EE	Environmental and Entomological Monitoring
ELISA	Enzyme-Linked Immunosorbent Assay
ERGO	Environmental Research Group Oxford
ET	Entomological Survey and Tsetse Fly Population Genetics Survey
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
HAT	Human African Trypanosomiasis
IAEA	International Atomic Energy Agency

ILRI	International Livestock Research Institute
ITCZ	Intertropical Convergence Zone
KETRI	Kenya Trypanosomiasis Research Institute
NDVI	Normalized Difference Vegetation Index
OAU/ISCTRC	Organization of African Union / International Scientific Council for Trypanosomiasis Research and Control
PAAT	Programme Against African Trypanosomiasis
PATTEC	Pan African Tsetse and Trypanosomiasis Eradication Campaign
PCV	Packed Cell Volume
PS	Parasitological and Serological Data Collection
SARD	Sustainable Agriculture and Rural Development
SE	Socioeconomic Survey
SIT	Sterile Insect Technique
SS	Sleeping Sickness Survey
TED Model	Tsetse Ecological Distribution Model
TLU	Tropical Livestock Unit
TZ	Tsetse Zone
USAID	United States Agency for International Development
WHO	World Health Organization
WHO-CHOICE	World Health Organization – Choosing Interventions that are Cost Effective
WWII	World War II

CHAPTER 1

TRYPANOSOMIASIS, THE TSETSE FLY, AND TSETSE CONTROL IN KENYA

1.1 Introduction

African trypanosomiasis, a neglected tropical disease, is a zoonotic, parasitic infection of wildlife, domesticated animals, and humans endemic solely in sub-Saharan Africa. Transmitted by the bite of the tsetse fly (genus *Glossina*), the causative agents are parasites of the *Trypanosoma* genus (WHO 2010). In humans the disease is referred to as human African trypanosomiasis (HAT) or sleeping sickness, while in animals the disease is known as African animal trypnaosomiasis (AAT) or nagana in cattle. Three severe HAT epidemics occurred during the twentieth century with the first taking place from 1896 to 1906 in Uganda and the Congo Free State (Steverding 2008; WHO 2010). This epidemic resulted in the deaths of 300,000 to 500,000 people (Steverding 2008; WHO 2010). The second epidemic took place in numerous African countries from 1920 to the late 1940s (Steverding 2008; WHO 2010). Finally, in the 1970s, after most trypanosomiasis-endemic countries became independent, the third epidemic occurred (de Raadt 2005; WHO 2010). This epidemic was largely brought under control in the 1990s due in part to the development of eflornithine, a treatment for HAT in its advanced stages (Steverding 2008). In 2009, the number of reported cases of sleeping sickness dropped below 10,000 (WHO 2010); however, as Cattand, Jannin, and Lucas (2001) discussed, the actual number of infected individuals is underreported and misdiagnosis common in low endemic areas

(Katsidzira and Fana 2010). If left untreated, the disease is fatal (Simarro, Jannin, and Cattand 2008).

Regarding AAT, it is estimated that at least 46 million cattle are at risk of nagana with countless sheep, goats, donkeys, and horses additionally threatened with infection (Budd 1999; Kristjanson et al. 1999). Areas at risk of tsetse-transmitted AAT are accordingly subjected to large economic losses due to livestock mortalities, reduced milk and meat outputs, and lower calving rates (Swallow 2000; Shaw 2004). AAT also prevents farmers the use of animals for traction, and impacts livestock management practices by limiting the number of livestock kept by farmers, influencing breed compositions, and altering grazing practices (Putt et al. 1980; Swallow 2000). The rural poor bear a disproportionately larger share of the economic burden due to their reliance on livestock as a form of savings and income, and close proximity to infested areas (Feldmann et al. 2005). All told, it is estimated that when considering both the direct and indirect costs of AAT, over $4.5 billion is lost each year to the disease (Budd 1999; Hursey 2001; Shaw 2004; Oluwafemi 2009).

Tsetse flies are biting flies endemic to thirty-seven sub-Saharan African countries covering an area of 8.5 million km^2 (Allsopp 2001; WHO 2010). The appearance of tsetse has been described as "rather dull" looking and resembling that of the common housefly (Jordan 1986). Twenty-two species of the fly exist with divisions made into three groups according to anatomical and habitat preferences: the *fusca* group found in the forests of west, central, and east Africa; the *palpalis* group found in the forests and riparian vegetation of west and central Africa; and the *morsitans* group occupying the woodland savannas of west, east, and southern Africa (Pollock 1982a; Jordan 1986; Rogers, Hay, and Packer 1996; Bourn et al. 2001). All species of tsetse are classified as k-strategist insects meaning that they have low fecundity rates and have populations at or near carrying capacity. As k-strategists, tsetse are also unique in that they are relatively long-lived compared to other insects and that their offspring have a higher degree of survival (Leak 1999). These biological traits have given hope to some that the tsetse fly can be adequately controlled through only low sustained mortalities (Weidhaas and Haile 1978; Hargrove and Vale 1979; PATTEC 2001). Tsetse range from 6 to 14 mm in length and prefer to feed upon wild ungulates and ruminants, with the warthog, bushpig, kudu, and bushbuck, among others playing important roles as reservoirs of trypanosomes (Pollock 1982a, 1982b).

Due to the health and economic burdens imposed by the tsetse fly, active vector control[1] efforts have taken place for over a century (Schofield and Maudlin 2001; Hargrove 2003; Vreysen 2006). These efforts will be described in more detail in the following chapter. Despite a century's worth of fly control campaigns and existing techniques capable of reducing fly populations (Molyneux, Ndung'u, and Maudlin 2010), past vector control efforts have won only limited successes. Campaigns have failed due to a host of issues, including limited funding, poor coordination between neighboring countries, inability to prevent fly reinvasion, and imposed environmental regulations (Hargrove 2000; Kamuanga 2003; Torr, Hargrove, and Vale 2005; Kgori, Modo, and Torr 2006). This study addresses the limited funding component and focuses on improving the efficiency of

[1] In this study, 'control' of tsetse is defined as it is described in Thrusfield (1995): "The reduction of the morbidity and mortality from disease… a general term embracing all measures intended to interfere with the unrestrained occurrence of disease, whatever its cause." Unless otherwise noted, hereinafter, 'control' of tsetse should accordingly take this meaning.

tsetse control campaigns by maximizing the use of scarce financial resources, as well as capital and labor resources, in Kenya.

1.2 Disease and Tsetse in Kenya

Kenya lies on the equator in East Africa. It occupies an area of 582,646 km^2 and is bordered by the Indian Ocean and Somalia to the east, Tanzania to the south, Uganda in the west, and Sudan and Ethiopia to the north (Figure 1.1). Physiographically, the country features the Great Rift Valley, which runs from Lake Turkana in the north to the soda lakes of Natron and Magadi in the south (Bourn et al. 2001). The highest point within Kenya is Mount Kenya at 5,199 m. Additionally, several climatic regions are featured in the country including the cool moist highlands at elevations above 1,500 m, desert conditions in the northern reaches of the country, and warm humid conditions along the Indian Ocean (DeVisser et al. 2010). Kenya's climate fluctuations are largely driven by the Intertropical Convergence Zone (ITCZ) as it passes over the equator (Camberlin and Wairoto 1997; Gatebe et al. 1999; Awange et al. 2008). The hot dry season occurs in January and February when the ITCZ is south of Kenya. As the ITCZ passes north over the equator, the long rains season begins which lasts from early March to late May. Following the long rains, with the ITCZ to the north of Kenya, is the cool dry season, which lasts from early June to late October. Finally, as the ITCZ passes south through Kenya, the short rains occur. This season begins in late October and lasts until late December.

The economy of Kenya is more diversified than the economies of other countries in East Africa with agriculture accounting for 27.1 percent of gross domestic product (GDP), followed by trade, hotels, and restaurants at 14.5 percent, and manufacturing at 11.5

percent (ADB and ADF 2008).

Figure 1.1 *Geographic location of Kenya displayed with topography. Note: For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.*

Reported HAT cases in Kenya have been limited to the western provinces of Nyanza and Western near Lake Victoria, with 3,539 cases reported in this area from 1950 to 2007 (Rutto and Karuga 2009; Grady, Messina, and McCord 2011). The locations of the Kenyan provinces are shown in Figure 1.2. The most recent case to be reported was diagnosed in 2009 (J. Ouma, correspondence, 19 and 20 October 2010).

Compared to HAT, AAT is much more widely dispersed across Kenya with infection rates being the highest in Coast Province at 15.6 percent of cattle, followed by a 12.9 percent infection rate in Rift Valley Province, and a rate of 8.3 percent in Western Province (Bourn et al. 2001). Since livestock production accounts for 12 percent of the country's total GDP and makes up 47 percent of agricultural GDP, rural inhabitants in tsetse-endemic areas face significant economic hardship as well as nutritional deficiencies from poor food production (FAO and AGAL 2005; Grady, Messina, and McCord 2011).

Eight species of the tsetse fly are present in Kenya: *Glossina austeni*, *G. brevipalpis*, *G. fuscipes*, *G. fuscipleuris*, *G. longipennis*, *G. morsitans submorsitans*, *G. pallidipes*, and *G. swynnertoni*, with those species belonging to the *morsitans* group (i.e., *G. austeni*, *G. morsitans submorsitans*, *G. pallidipes*, and *G. swynnertoni*) being the most widely distributed. In 1973 it was estimated that 22 percent of the country was infested by tsetse (Ford and Katondo 1977); this figure grew to an estimated 34 percent in 1996, approximately 202,774 km^2 (KETRI 2008) (Figure 1.3). According to Bourn et al. (2001), these fly distributions exist in "relatively isolated areas" due to expanding agriculture and deforestation.

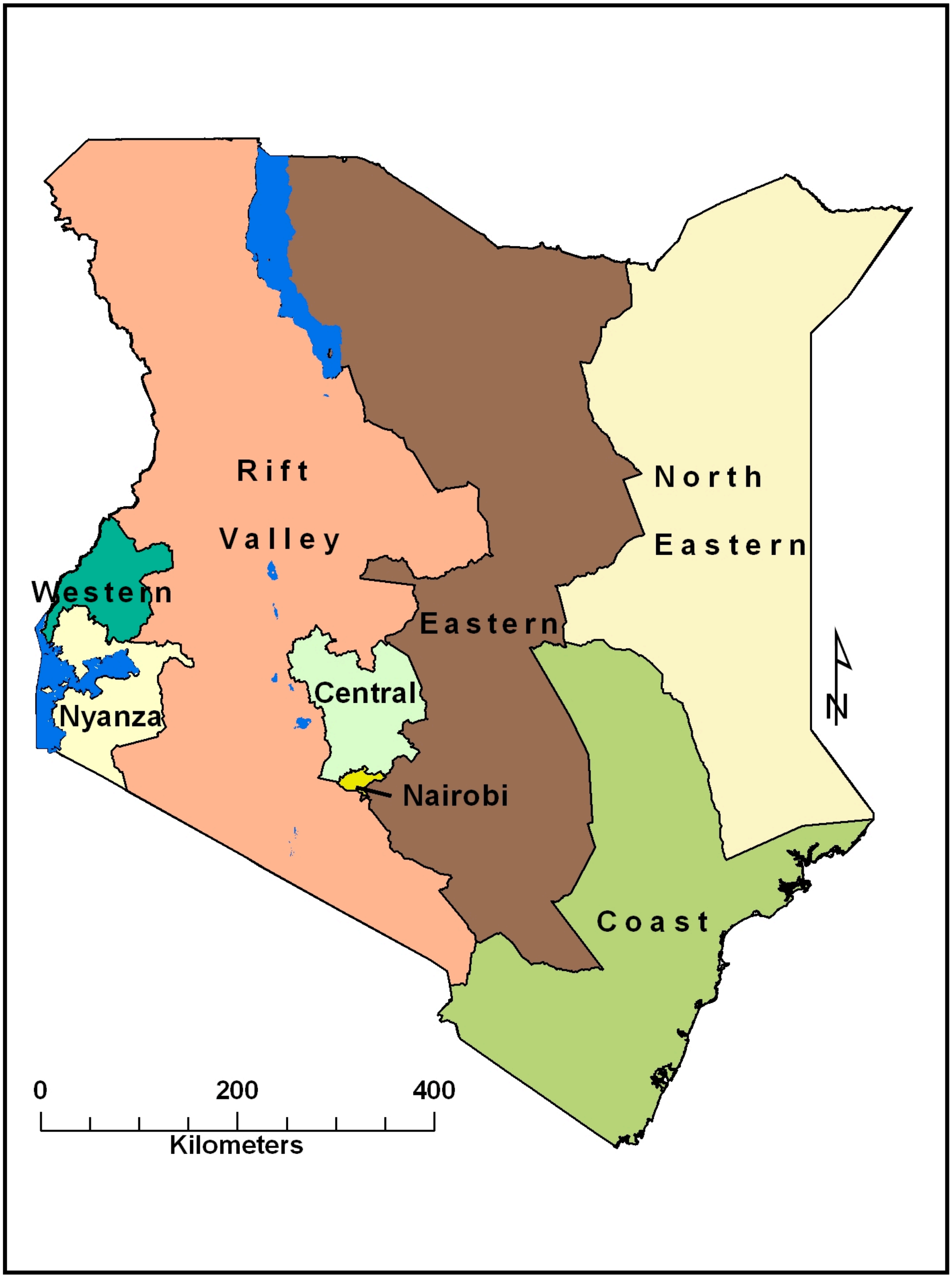

Figure 1.2 *Kenyan provinces displayed with major bodies of water.*

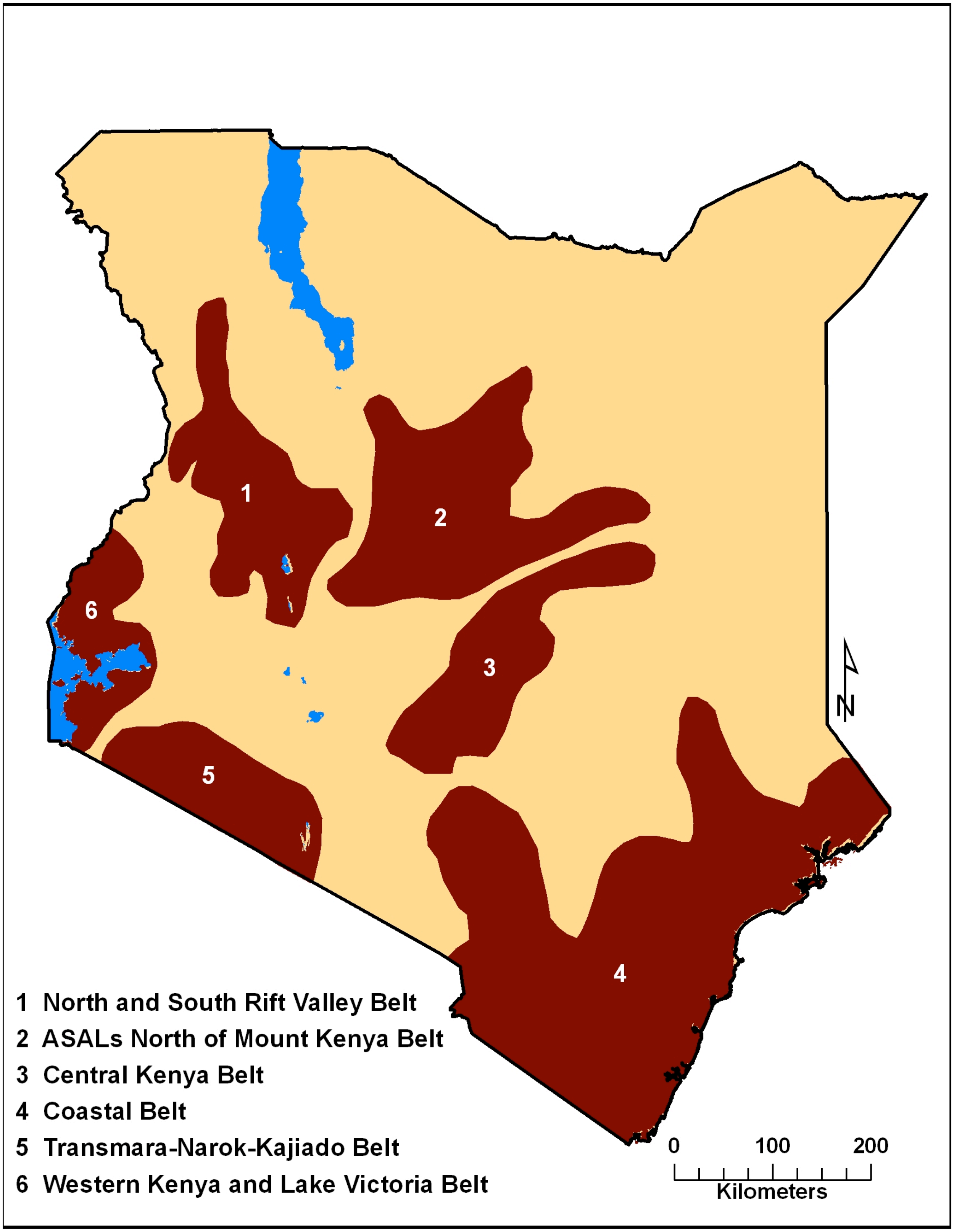

Figure 1.3 *The location of the 1996 fly belts as described by KETRI (2008).*

1.3 Statement of Problem

Limited funding and the high costs of identifying areas where the fly is located have jeopardized previous tsetse control campaigns (Rogers and Randolph 2002; Kamuanga 2003; Shaw et al. 2007). Additionally, beginning in the 1970s, a shift in spending began that has witnessed reduced funding for large control operations by governments and donor groups (Hargrove 2000; Hargrove 2003). This shift was partly due to reduced donor support stemming from concerns regarding the destructive nature and wisdom of large-scale tsetse control campaigns, as well as structural adjustment programs in many developing countries transferring the burden of tsetse control from national governments to livestock owners (Hargrove 2000; Peter et al. 2006). Making matters worse is that of the thirty-seven countries infested with tsetse, thirty-two are also classified as heavily indebted countries (Feldmann et al. 2005). Thus, funding for tsetse control is often difficult to obtain.

In Kenya, von Wissmann et al. (2011) stated that, since the 1980s, cuts have been made in the budget of the Veterinary Department, which led to fewer large-scale control campaigns. Instead, vector control has frequently become the duty of individual livestock owners or small communities. It is against this backdrop of limited financial resources and preference for localized control that this study is conducted.

1.4 Purpose of this Study

As poor funding has jeopardized the success of past vector control projects and financial support for large and small-scale management campaigns has diminished since the 1970s, this study offers a method by which limited financial resources are maximized.

This is accomplished by presenting a tsetse fly management[2] simulation that accounts for the spatial-temporal dynamics of fly distributions across Kenya, the study's country of focus.

Past simulations attempting to cost and control tsetse populations have given insufficient attention to the spatial and temporal dynamics of tsetse populations; rather, these studies have represented fly distributions as static and existing in isolated "control blocks" (e.g., Vale and Torr 2005; Shaw et al. 2007). By accounting for spatial and temporal fluctuations in tsetse distributions, it is possible to identify the location and timing of constrained fly distributions (DeVisser et al. 2010). In this study, I introduce control reservoirs (CRs), which represent tsetse distributions that are spatially and temporally constrained due to the limited availability of suitable habitat. By accounting for these dynamics, fewer capital and labor inputs are needed in order to achieve elimination[3] of the fly population. To identify the CRs, I use dynamic tsetse species distribution maps produced by the Tsetse Ecological Distribution (TED) Model (DeVisser et al. 2010) to observe the fluctuations in Kenya's fly distributions during the study period, 1 January 2002 to 19 December 2010. These species distribution maps are produced at a spatial resolution of 250 m every sixteen days; therefore, a total of 207 species distribution maps are used in this study. Following the identification of Kenya's CRs, a costing exercise of fly management activities is carried out to demonstrate the savings from conducting management activities in the dynamic CRs.

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[2] Management encompasses all aspects of a tsetse fly control campaign. These activities include: field control operations, surveying, monitoring, and administration tasks.
[3] In this study, elimination is defined as a remaining fly density of 0.5 per km^2 since it is difficult for remaining flies to find a mate at this density level (Shaw et al. 2007).

CHAPTER 2

LITERATURE REVIEW

2.1 The Tsetse Fly Throughout History

Sleeping sickness is far from a recent phenomenon. As far back as 1374, the Arab writer al-Qualquashandi described the death of the King of Mali as the result of sleeping sickness. In fact, the discovery of *Glossina* fossil impressions in Colorado by Theodore Dru Alison Cockerell in the early 1900s allowed researchers to conclude that tsetse flies existed in North America during the Miocene (Brues 1923). Additionally, Brues (1923) argued that these flies possibly carried trypanosomes during this period, suggesting that tsetse may have contributed to the extinction of select large mammals that once inhabited North America.

More recently, John Atkins, an English naval surgeon, recognized the presence of sleeping sickness when he used the term 'negro lethargy' in 1742 to describe slaves in western Africa, and in 1803 Dr. Thomas Winterbottom commented that slave-dealers would not buy Africans with enlarged glands, perhaps the most physically identifiable trait of trypanosomiasis (Lambrecht 1964). Undoubtedly, sleeping sickness played a large role in the slave trade, and in the process, promoted negative stereotypes. In Browne (1953, 150), the late Milton J. Rosenau, once a professor of public health at Harvard University, noted:

> The ravages of sleeping sickness were well known to the old slave traders and the presence of 'lazy niggers' lying prostrate on wharves and decks with saliva drooling from their mouths, insensible to pain or emotion, was a familiar sight.

2.2 Early Practices of Living and Coping with the Vector

African societies have long coexisted with trypanosomiasis. In John Ford's seminal work *The Role of the Trypanosomiases in African Ecology*, Ford contended that pre-colonial societies achieved resistance to the disease through limited, continuous exposure to the trypanosome (Ford 1971). Accordingly, protection was acquired by modifying the environment to regulate interactions between humans, domesticated animals, wild fauna, tsetse flies, and the trypanosome. Giblin (1990) reviewed Ford's work, and presented alternative pre-colonial methods of responding to the tsetse fly. One such method was found in Kjekshus' *Ecology Control and Economic Development in East African History: the Case of Tanganyika, 1850-1950* (1977) in which avoidance of the tsetse fly was encouraged. Kjekshus' method therefore was one of evading the fly, while Ford found low levels of contact necessary in man's coexistence with tsetse. Torday (1910) seemed to agree with Kjekshus' isolationist approach when he described the people of the Kasai Basin in the Belgian Congo where sleeping sickness was controlled by keeping populations away from the fly and through the practice of removing sick villagers to isolated forests.

2.2.1 Colonization and Coping with the Vector

Whether pre-colonial Africans coexisted with trypanosomiasis and its persistent vector through a process of limited but continuous exposure as suggested by Ford or if an isolationist approach was key to survival, the arrival of Europeans certainly disrupted the established cohabitation practices. In discussing the colonial administration of Zambia, Vail (1977) listed gun control laws, game control policies, village amalgamation policies, hut taxes, and labor recruitment campaigns as a collection of policies that disrupted the pre-colonial coexistence of man and the fly. Indeed, as early as 1908, David Bruce (1908), the Scottish microbiologist who played the largest role in identifying the cause of sleeping sickness, noted the impact of colonists in spreading sleeping sickness:

> It cannot be forgotten that the introduction of sleeping sickness into Uganda was due to England's interference with existing conditions. The movement of large masses of men or animals from the conditions to which they have become adapted is always attended with danger. Civilized man presents the untutored savage… with what he calls the dignity of labour with one hand, while with the other he scatters abroad the seeds of tuberculosis, sleeping-sickness, and other pestilences which I need not enumerate.

In their influential work examining land degradation from the political ecology perspective, Blaikie and Brookfield (1987) discussed the colonial role in the spread of the tsetse fly and trypanosomiasis. Such an expansion in distribution occurred as the result of colonial policies annexing land and forcing indigenous groups to move to areas previously avoided. These forced relocations following the Europeans' arrival contributed in no small part to the first sleeping sickness epidemic (Vail 1977). Uganda and the Congo Basin experienced the worst of this epidemic where, from 1896 to 1906, 200,000 people died from the disease (WHO 2010).

2.3 Early Colonial Tsetse and Trypanosomiasis Control Practices

The early colonial control practices were implemented from the end of the nineteenth century to the beginning of World War II (WWII). These included population evacuation, wild host removal, tsetse habitat destruction, and the point-source techniques of traps and targets.

2.3.1 Population Evacuation

Knight (1971) suggested that the earliest form of active trypanosomiasis control was population evacuation. This technique often involved moving entire villages to "safe areas." In 1908, North-East Rhodesia, ruled by the British South Africa Company, pursued one such mass-evacuation from the eastern bank of the Luapula River (Figure 2.1). All villages along the bank from Kabila to the Nsakaluba stream were moved to higher ground to avoid the tsetse population at the river's edge (Musambachime 1981). During this move, the abandoned villages were burned in an effort to discourage the natives from returning. Those who were sick were sent into quarantines from which they rarely returned.

Often during these evacuation events, the villagers were only allowed to carry basic necessities, and rarely were their destinations adequately prepared for their arrival (Musambachime 1981). Once relocated, it was common for villages to be densely resettled in order to promote expedient collection of taxes by colonial officials and to allow for ease in medically examining the resettled people (Vail 1977). The crowded conditions spawned enormous overuse of land, which contributed to soil erosion, and the abandonment of previously used land allowed tsetse habitat to regenerate, creating an environment ripe for the continued spread of sleeping sickness (Vail 1977). Thus, the practice of population relocation was often nothing short of disastrous. In fact, Musambachime (1981) presented an observation that, due to the disorderly nature of such relocations from the Luapula River, more people died from hunger than died of sleeping sickness.

In addition to fostering conditions disastrous to the resettled population's health, these programs also disrupted lives both spiritually and economically. Relocation meant the abandonment of ancestral resting places. According to Torday (1929), such displacement was like "a tree cut off from its roots," as relocated people were moved to environments deprived of physical, cultural, and religious familiarity. Furthermore, relocation as well as the restrictions placed on the resettled individuals' movement disrupted rituals such as rain prayers and made pilgrimages to sacred locations impossible (Musambachime 1981). Cattle, the economic core for many African villages, often fared poorly in the newly settled areas due to concentrated conditions that facilitated the spread of the disease (Soff 1969). As villagers lost their cattle and other animals to AAT, it was not uncommon for livestock theft to increase, as occurred between tribal groupings in British East Africa at the turn of the twentieth century (Soff 1969). Additionally, population relocation further jeopardized economic prospects by eliminating the use of more fertile land and disrupting local and regional trading of items such as salt, palm oil, and fish (Musambachime 1981).

2.3.2 Wild Host Removal

Bruce (1905) presented an early discussion of the role wild animals play as a reservoir of the disease. Bruce remarked that wild animals such as the buffalo and the wildebeest carried trypanosomes in their blood, but that the parasite did not seem to hurt these animals. On the other hand, when the parasite was introduced in domestic animals, AAT would result, often leading to death. The practice of game destruction as a means of eliminating both the parasite reservoir and a food source for tsetse quickly followed Bruce's discovery. In fact, Bruce (1905) personally suggested the value of this control technique:

> We have found that the reservoir of the disease exists in the wild animals, and that we can blot out this disease from any particular tract of country by the simple expedient of destroying or driving away the wild animals.

Elimination of wild species was widely debated following the discovery of their role in harboring the parasite. At a meeting of The Royal African Society in 1913, Dr. Warrington Yorke claimed that the only effective means of combating sleeping sickness was through the elimination of the virus' (today known to be a protist) reservoir. Dr. Yorke was specifically addressing the situation in Rhodesia and Nyasaland where the population was troubled by the tsetse species *G. morsitans*. As the local population could not be moved away from the infested areas, Dr. Yorke advised "attempting to destroy the reservoir of the virus (Yorke 1913):"

> It is obvious that the mere isolation of infected human beings is futile in view of the fact that the main reservoir of the virus is the blood of the big game.

In addition to ridding the population of the parasite's host, big game destruction was also promoted as a means of eliminating the fly's food supply, and thus causing the fly to disappear (Yorke 1913).

Three years before Dr. Yorke's call for the destruction of wild game, Alfred Sharpe, a British colonial administrator, warned the Royal African Society of the difficulties and potential unintended consequences of game destruction. He emphasized that certain conditions make areas suitable for the existence of tsetse flies, and the presence of big game makes little difference in their choice of habitat (Sharpe 1910). Additionally, it was cautioned that if the primary food source for the fly was removed, humans could be targeted as a secondary source, thus making sleeping sickness more prevalent (Sharpe 1910). Arguments were also made for more judicious slaughtering of game, acknowledging the successes of host destruction but calling for better knowledge of the relationship between the fly and wild animals to avoid ruthless mass killings (Swynnerton and Buxton 1938).

Ultimately, active host destruction declined as a control technique by the 1940s due to its increasing social anathema and the rise of insecticides as a vector control option (Hargrove 2003; Cox 2004). However, during its period of popularity and even after insecticides became more broadly used, host destruction did offer effective, though modest, tsetse control. Jordan (1986) described one such success that took place in Uganda from 1946 to 1966 (Figure 2.1). During this period, active hunting of wild animals substantially reduced the populations of two tsetse species from an area more than 20,000 km^2 primarily due to its intensive culling of even the most elusive animals (Jordan 1986).

2.3.2.1 Interference of Colonial Policies in Removing Wild Hosts

Often, host destruction is jeopardized when the level of hunting is not sufficient to achieve the necessary degree of wild animal elimination. Reinvasion of the fly is common, and sustainable elimination of hosts is therefore required for successful tsetse control. Vail (1977) demonstrated how colonial policies limited the ability to sustain this necessary level of wildlife suppression in eastern Zambia. During the first half of the twentieth century, the administration of eastern Zambia, between the Luangwa River and the Zambia-Malawi border, was not unlike many colonial regions of its time. Policies concerned with the capturing of resources and the promotion of European interests frequently increased the vulnerability of Africans and left them to cope with foreseen and unforeseen consequences of these policies. Such policies included gun control laws stemming from the Brussels Act of 1890, the conservation of wild animals from the London Convention of 1900, hut taxes, and labor recruitment programs (Vail 1977).

Throughout Central Africa, the British, fearing confrontation with the vastly more numerous local populations, implemented gun control laws (Vail 1977). While largely successful in sterilizing the chances of conflict, gun control, coupled with the protection of wildlife at sites such as the Mweru Marsh Game Reserve, increased tsetse food supplies, and simultaneously increased the number of reservoirs for the parasite. With infected wildlife existing in greater numbers and the means for checking their growth becoming increasingly limited, trypanosomiasis was able to sweep across eastern Zambia with ease in the early 1900s. Furthermore, as early as 1898, the North-East Rhodesia administration had been imposing a five shilling hut tax within its villages (Vail 1977). Unable to pay the tax due to limited employment opportunities, the men of North-East Rhodesia often journeyed, and were recruited, to Southern Rhodesia where employment opportunities were more widespread, further reducing the available labor pool most capable of managing wildlife populations.

2.3.3 Tsetse Habitat Destruction

The discovery that many sleeping sickness cases existed along the shores of rivers and lakes led to discussions of tsetse habitat clearing. In Bruce (1908), the distribution of sleeping sickness cases was presented to the Royal African Society: along the west coast of Africa, along the shores of Lake Tanganyika and Lake Victoria, in parts of western Uganda, and at Wadelai on the Nile. Additionally, these sites were shown to coincide with the existence of *G. palpalis*. With such reports clearly locating the presence of sleeping sickness to such confined areas inhabited by *G. palpalis*, bush clearing practices became more frequent, and often were employed alongside game destruction to curb sleeping sickness cases caused by the more dispersed *G. morsitans* (Harcourt 1912).

Shrub and bush clearing occurred around Central and East African lakes in the early 1900s, and these practices were met with some success; however, the projects were often costly and required the movement of populations (Harcourt 1912). In Bruce (1908) the daunting task of habitat destruction was made clear:

> If we picture the hundreds of miles of lake and island shore, with huge trees and dense undergrowth up to the water's edge, we must come to the conclusion that the wholesale destruction of the fly is impossible.

Soff (1969) highlighted the inefficiencies often found in bush clearing when recounting Ugandan Protectorate's Governor Hesketh Bell's belief that "all bush harbored tsetse." Such views frequently led to total destruction of lakeshore vegetation when, in reality, only certain species of bush, based on physiological structure, provide habitat for the fly. Additionally, unless the land was populated after clearing or the bush kept from regenerating, the tsetse fly would return. As a result, habitat destruction typically included the encouragement of villagers to live closer together, as their routines of building, collecting firewood, and practicing agriculture would discourage the return of tsetse habitat (*Fight Tsetse Fly* 1927). The increase in agriculture that followed the process of concentrating villagers was promoted as an opportunity to increase the standard of living for those in the fly belts. This in turn was believed to have a positive cyclical effect: as the economic status of an area increased, so too would the public health (Gilks 1935).

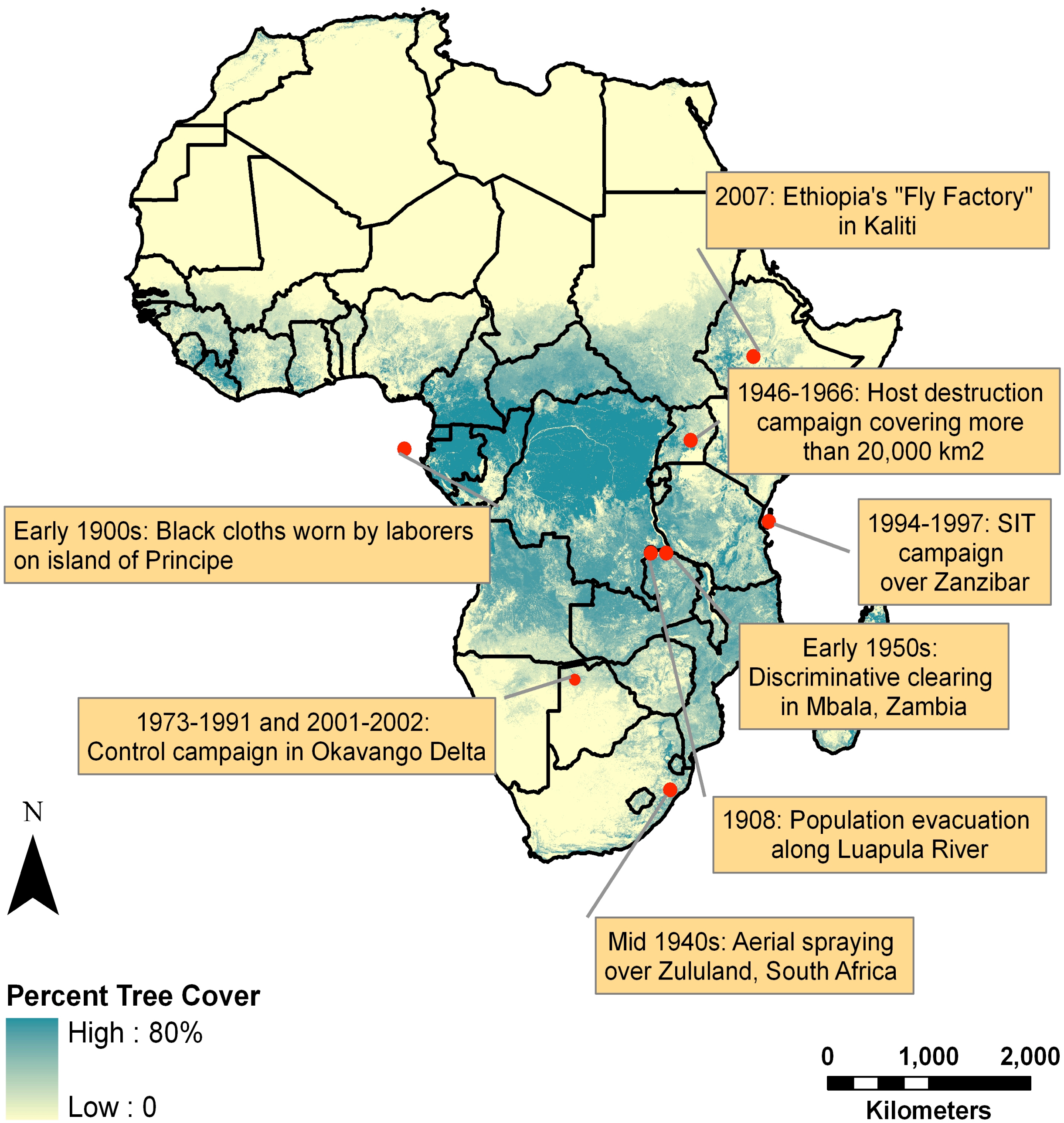


Figure 2.1 *Location of tsetse fly control campaigns that have taken place during the past century. The map displays the percentage of tree-cover across the continent (Source: DeFries et al. 2000), as the tsetse fly has a similar distribution (Cecchi et al. 2008). Note: Current political boundaries displayed.*

Despite its inefficiencies, the practice of habitat destruction, when coupled with additional control techniques, has proven to be very effective at combating the tsetse fly (Hargrove 2003). Moreover, the practice of removing all habitat believed to be harboring tsetse, employed in the infancy of tsetse habitat removal, was discovered to be only one of several effective forms of habitat clearing, with the others (i.e., partial, selective, and discriminative clearing) being far less damaging. As an example, using a discriminative clearing scheme where only the woody vegetation from a plant community was removed, Mbala, Zambia (then Abercorn, Northern Rhodesia) was able to effectively control the tsetse fly in the early 1950s after more than a decade's worth of discriminative clearing (Figure 2.1). Remarkably, this achievement resulted from clearing only 3 percent of the vegetation in a 725 km^2 area (Hargrove 2003). Other successes achieved by discriminative clearing have occurred in Nigeria and Ghana (Hargrove 2003).

2.3.3.1 Interference of Colonial Policies in Destroying Tsetse Habitat

As stated above, the success of habitat removal requires the settlement or use of an area to discourage the vegetation from re-growing. During the colonial period, continuous and intensive use of the land was often hampered by official policies (Vail 1977; Musambachime 1981). The unfortunate result was the expansion of tsetse habitat during the early twentieth century and the continued pervasiveness of sleeping sickness cases.

It has already been demonstrated that man and tsetse coexisted for centuries in Africa prior to the arrival of Europeans. Kjekshus (1977), among others, suggests that tsetse were cleared from areas leading to tsetse-free zones. Such zones were created by the intensive use of land, which eliminated the fly's preferred habitat. Unfortunately, several of the European policies already mentioned as allowing reservoir host populations to increase also led to tsetse habitat expansion; the hut tax is one such policy. With the imposition of the North-East Rhodesia hut tax in 1898, men moved to areas offering better employment opportunities (Southern Rhodesia), and, consequently, land management of the fields left behind declined (Vail 1977). Accordingly, agricultural output decreased and the fields were allowed to revert to habitat conducive to the fly.

The conclusion of World War I provided another opportunity for the fly to reclaim lost habitat. In the early 1920s, the administration of North-East Rhodesia was eager to move Africans off from the most fertile lands in order to attract European settlers intent on growing tobacco. This resulted in approximately 3,500 mi^2 of inferior land set aside for African reserves, and 6,500 mi^2 of the most fertile land allocated to Europeans and those settlers expected to follow (Vail 1977). The collapse of the tobacco market in the 1920s discouraged settlers from moving to the 'European' land, and after a fallow period the area was reclaimed by the tsetse fly. Sleeping sickness then became a greater risk for the Africans living in the nearby reserves and in one village a death rate of sixty-six per thousand was reported each year throughout the 1930s (Vail 1977).

2.4 Post World War II Tsetse and Trypanosomiasis Control Practices

Contemporary control practices have been implemented since WWII, which include ground and aerial spraying of tsetse habitat with insecticides, the sterile insect technique (SIT), and the point-source techniques of traps, targets, and insecticide-treated cattle.

2.4.1 Insecticides to Control Vectors

In 1874, DDT was first synthesized. It was not until 1936, however, that its insecticidal properties were realized, and not until the conclusion of WWII were insecticides widely used to control vector populations (Garnham 1967). With the use of insecticides, vector eradication (i.e., the complete removal of all wild populations of a species) finally seemed possible, and critically the process by which it could be achieved was often easier than previous control measures (Garnham 1967). In *DDT Can Wipe Out Plagues* (1945), optimism was expressed that DDT could send disease-carrying insects to "join the dodo and the dinosaur," and thereby end "these particular plagues for all time."

2.4.1.1 Ground Spraying

Application of insecticides initially occurred most commonly in the form of ground spraying (Allsopp 2001). These operations typically included large teams of trained staff dispatched over the control area. The staff, consisting of control officers and laborers equipped with pressurized and non-pressurized sprayers carried on their backs, applied insecticides to vegetation frequented by tsetse. Spraying operations could only be successful if the control area was made uninhabitable for both the adult flies and the tsetse puparia buried in the soil (Jordan 1986). This was, and still is, achieved in one of two ways: through the use of residual insecticides that remain lethal long enough to control tsetse after they have emerged from the puparia (i.e., about 22 to 25 days) (Hargrove 2003), or through reapplication of a non-residual insecticide.

Currently, ground spraying is used infrequently due to its high costs, dependence on large numbers of well-trained technicians, susceptibility to reinvasion, and regular dependence on residual insecticides (Hargrove 2003). In fact, the presence of residual insecticides in West Africa in the late 1970s and early 1980s led to a decline in aquatic arthropod populations (FAO

1992). Other creatures that saw population numbers drop after sprayings included the plant-hoppers and silverfish in Zimbabwe at the beginning of the 1990s and the little bee-eaters during the 1980s (FAO 1992). Due in no small part to the devastating effects it had on non-target species, such indiscriminate, high-dose sprayings have largely been replaced by more selective, low-dose sprayings.

2.4.1.2 Aerial Spraying

In the mid and late 1940s, South African Air Force pilots flying over Zululand, South Africa participated in the first widespread aerial spraying of tsetse habitat (*DDT War on African Flies* 1947) (Figure 2.1). During the operation, pilots applied DDT to an area of 100 mi^2, and ground teams set off DDT grenades to target habitat missed by the aerial spraying. The campaign effectively controlled *G. pallidipes* in the sprayed area (Hargrove 2003), and optimism that the fly could be removed from the continent began to grow. Unfortunately, limited funding, environmental concerns, poor coordination between countries, and the ability and efficiency of the fly reinvading cleared areas have limited the successes of control efforts (PATTEC 2001). The large scale 1973 to 1991 control campaign over Botswana's Okavango Delta is one such example (Figure 2.1). During this operation, extensive and repeated aerial sprayings occurred over the vast delta, but in order to entirely remove any opportunity for reinvasion, pilots also needed to spray the portion of the fly belt that extended into neighboring Namibia (Hargrove 2003). Unfortunately, permission was not granted for such cross-boundary flights, and a corridor of reinvasion was made available to the fly. The inability to spray along the Namibian border, however, was by no means the sole culprit for the operation's ultimate failure. When conducting aerial sprayings it is critical that the spray zones are of sufficient size and that barriers are erected to inhibit the fly's movement between the successively sprayed zones. In the Okavango Delta campaign, spray zones were far too small and movement between sprayings was not impeded to any great degree allowing the fly to avoid treatments (Hargrove 2003). In fact, spray blocks were so small that, over the course of a year, approximately 30 percent of a spray zone's tsetse population was capable of avoiding treatments by passing into successively sprayed areas (Hargrove 2003). Thus, despite nearly two decades of active suppression, fly invasions into the sprayed areas and the persistence of flies already in the control region continued the Okavango Delta's tsetse-infestation. In 2001, determined to eliminate the fly from the Delta, aerial spraying operations were renewed (Figure 2.1).

The second spraying operation, a campaign spanning 16,000 km^2, took place during two periods (Torr, Hargrove, and Vale 2005). The first treatment occurred in the northern half of the Delta from June to September 2001, and the second treatment in the southern half from May to August 2002 (Kgori, Modo, and Torr 2006). The sheer size of the separate spray regions was an improvement upon the 1973 to 1991 operation, as it was much more difficult for flies to seek refuge in untreated areas. Hargrove (2003) discussed an experiment that found female tsetse flies capable of traveling 1,000 meters per day, but even a fly traveling at this rate would have had difficulty reaching the Delta's untreated area. What is more, the 2001 to 2002 campaign importantly included a barrier of 12,000 deltamethrin-treated targets to separate the northern spray zone from the southern zone (Kgori, Modo, and Torr 2006). Since the completion of this operation, no tsetse flies have been caught in the Delta, allowing for the claim that the Okavango Delta is now tsetse-free. Such claims must be made with great caution, though, since detecting and trapping fly populations at low densities is difficult and inefficient. Nevertheless, the 2001 to 2002 campaign in the Okavango Delta demonstrates how improvements can be made to previous control efforts, and how the fly's ability to reinvade or persist in sprayed regions can be challenged.

2.4.2 The Sterile Insect Technique

The sterile insect technique (SIT) is another large-scale and internationally popular method for control. This technique, which relies on the use of radiation to sterilize male flies, has been advanced as a less destructive means of achieving control since only the target species is harmed (SIT, however, is used in conjunction with other techniques that may cause damage to non-target species). In the 1950s, the release of artificially sterilized male screw-worm flies over the island of Curacao successfully eliminated the screw-worm from the island and led to the use of sterilized male flies to eliminate the pest from the southern United States (Simpson 1958). Elsewhere, SIT eradicated the melon fly from Okinawa and the Mediterranean fruit fly from Mexico, Chile, and southern Peru (Townson 2009). Such successes naturally spurred interest in the use of the sterilized male technique to confront the tsetse fly. Simpson (1958) suggested that the sterilized male technique would be most effective when eliminating a low-density population especially after the area had been treated with insecticide. The tsetse fly particularly lends itself to SIT due to its unusual reproductive behavior. Female flies rarely mate more than once during the course of their lives; in fact, they vigorously resist males after they have once mated (Jordan 1986). Therefore, by exploiting this mating practice, fly populations can be sent crashing as female flies increasingly mate with sterile males.

In Tanga, Tanzania in the 1970s, researchers supported by the U.S. Agency for International Development (USAID) set up a "fly factory" that produced thousands of sterile male tsetse flies per week. In this operation, unhatched male pupae were sterilized with small doses of Cesium

137, and then released, sometimes 10,000 each week, into the wild where it was determined that the sterilized males led to a decrease in the tsetse population (Broad 1978). More recently, the island of Zanzibar was declared tsetse-free in 1997 following the release of nearly 8 million sterile male flies over the island from 1994 to 1997 (Figure 2.1) (*Tsetse fly eliminated on Zanzibar* 1998). Other countries have also explored SIT, such as Ethiopia which recently spent roughly $12 million on a "fly factory" (Enserink 2007) expected to assist in tsetse eradication from 25,000 km^2 of Ethiopia's Southern Rift Valley by 2017 (Figure 2.1).

The costs of SIT are a barrier to implementation. In the successful use of sterile males over Zanzibar, nearly $6 million was spent from 1994 to 1997. This figure, while large, does not include the costs of establishing a facility to rear the sterile flies, nor does it include the costs of previous suppression work on the island (Molyneux 2001). Furthermore, Zanzibar, as an island, is an anomaly due to its natural barriers to reinvasion and presence of only one tsetse species. On the African mainland, SIT success is questionable with few natural barriers to reinvasion and the frequent presence of several tsetse species in the same area. The rearing of more than one sterile species, which would be required across much of Africa, for any SIT campaign would lead to a substantial increase in costs (Hargrove 2003). Furthermore, SIT is only successful if the sterile males outnumber wild males ten to one (Enserink 2007), and in order to achieve this, traditional insecticidal techniques are still required. On the island of Zanzibar, the wild tsetse population had to be suppressed by 90 percent using traps and other techniques before SIT could achieve its goal. This has caused some skeptics to suggest that continued use of the control technique that has achieved 90 percent control should be able to clear the remaining flies (Rogers and Randolph 2002). In this way, the economic burden of rearing sterile males would be avoided.

2.5 Point-Source Techniques

As mentioned above, the apparent success of the control effort in the Okavango Delta was largely due to the use of barriers to restrict reinvasion of sprayed areas. In that operation, tsetse attempts to reinvade the northern zone after treatment were prevented by a barrier of targets (screens sprayed with insecticides) set up between the two spray zones. This method of using targets and traps (the target's 3-dimensional counterpart; Figure 2.2) to impede the fly's reinvasion efforts has frequently been used alongside large-scale control efforts (IAEA 1997; Kuzoe and Schofield 2004). More recently, traps and targets have been used alone due to the rise of community participation in control campaigns. These two devices as well as insecticide-treated cattle constitute the point-source techniques. The success of point-source techniques hinges on their ability to provide an attractive visual and/or aromatic stimulant to lure in the fly.

2.5.1 Visual and Aromatic Attractants for Traps and Targets

The use of visual stimuli to attract tsetse to control devices has taken a variety of creative forms since the early 1900s. Several of these traps include the animal trap by Morris and Morris (Jordan 1986) and the "moving staircase" trap (Swynnerton 1933). However, the first successful use of visual stimuli to capture tsetse quite possibly took place on the island of Principe, off the west coast of Africa (Figure 2.1). Bulhões Maldonado, the estate manager of a cocoa and coffee plantation on the island, noticed that *G. p. palpalis* were attracted to the backs of the plantation's laborers (Maldonado 1910). In an innovative strategy to limit the fly's presence in and around the plantation, Mr. Maldonado ordered the laborers to wear black cloths covered with a "glutinous substance" on their backs. The strategy was successful: between April 1906 and the end of 1907, 133,778 tsetse were captured (Maldonado 1910), and in the process, the use of visual stimuli to attract tsetse to control devices was born.

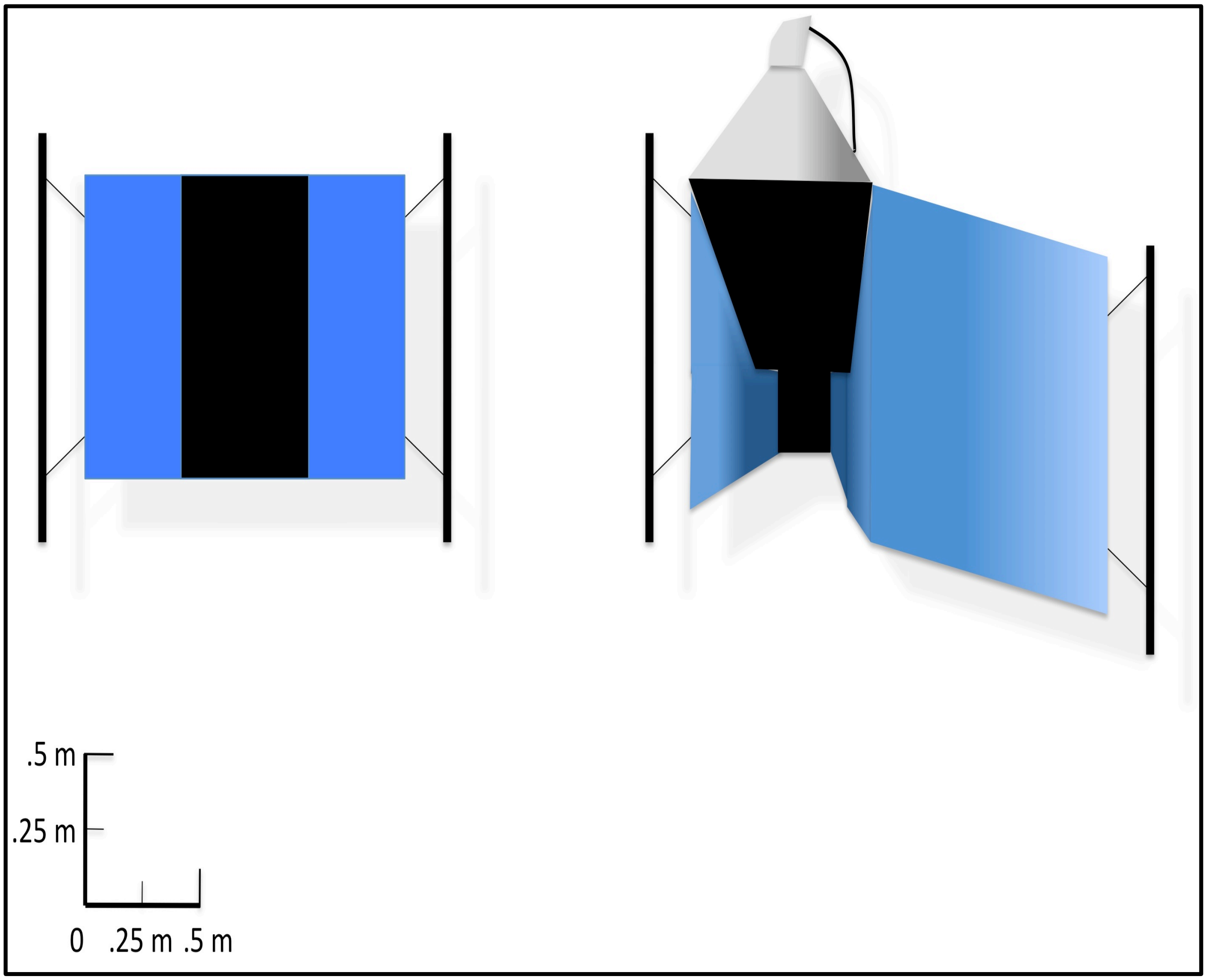


Figure 2.2 *Two point-source control techniques: The tsetse target and the tsetse trap. The target (left) is two-dimensional and relies on the use of insecticides. The NG2G trap (right) is three-dimensional with insecticides being optional.*

The visual responses of tsetse had not been extensively studied at the time of Mr. Maldonado's control campaign; however, according to Steverding and Troscianko (2004), the tsetse fly searches for shaded areas when seeking daytime resting sites. Thus, by using dark cloths to attract the flies, the laborers were effectively mimicking the darkness of daytime shadows. Today, nearly all trapping and targeting devices rely on black and blue surfaces to provide a visual attractant for the fly.

In terms of the aromatic attractants used when deploying traps and targets, a progression of ideas similar to the development of visual stimuli occurred. In the 1930s, observations that tsetse were particularly attracted to traps baited with a live animal kept out of view of the fly indicated that efficiency could be improved by using host scents (Kuzoe and Schofield 2004). In Charles Swynnerton's 1933 work, *Some Traps for Tsetse-Flies*, a list of potential host scents to act as baits was recorded, including urine, dung, blood, and hides. Since discovering the potential benefits of animal scents, much effort has gone into improving the effectiveness of attractive odors. Today, odor attractants largely consist of acetone, octenol, and synthetic phenols, or blends of these attractants, placed in sachets and attached to the trap or target (Leak, Ejigu, and Vreysen 2008).

2.5.2 Differences between Traps and Targets

The dissimilarities between traps and targets, though subtle, may result in one device preferred to the other depending on the goals and/or limitations of the control operation. As stated earlier, targets are two-dimensional insecticide-impregnated screens utilizing visual and aromatic stimuli to attract tsetse. Traps, on the other hand, are three-dimensional devices of various shapes. And while both traps and targets utilize visual and aromatic attractants, traps do not necessitate the use of insecticides since a cage is used to retain the attracted flies. Thus, there are potential benefits to choosing one form of attractive device over the other. Ecologically, the trap may be preferred due to the optional use of insecticides. From a cost perspective, however, Lindh et al. (2009) found a large savings when using targets to control fly populations. Additionally, the simpler design of targets makes the task of maintenance much easier (Leak, Ejigu, and Vreysen 2008). Despite the differences between traps and targets, they are both less expensive and less environmentally damaging than many of their counterparts (Day and Sjogren 1994; Hargrove 2003), and combined with their favorable use in community-centered control efforts, support for these devices is strong and growing.

2.5.3 Insecticide-Treated Cattle

The third form of point-source control, the deployment of insecticide-treated cattle, has also witnessed a recent surge in popularity. In this method, also referred to as cattle dipping, cattle are commonly sprayed with pyrethroids (Hargrove 2003) along the parts of the body where the tsetse feed, typically the legs and belly (Torr, Hargrove, and Vale 2005). As a point-source control, using the host is an inexpensive and simple alternative to trapping and targeting devices. This method also finds allies in those advocating for smaller-scale, community-driven control efforts. With cattle dipping, often the livestock owner, rather than the government or a donor agency, is responsible for applying the insecticide and determining the frequency of applications (Torr, Maudlin, and Vale 2007). Thus, the individuals investing in the spraying of the livestock are also those receiving the direct benefit of control.

Like other tsetse control efforts the deployment of insecticide-treated cattle presents efficiency challenges. The tendency of cattle to roam differentiates them from other point-source methods of control. While traps, targets, and cattle can all be used at prescribed densities to achieve control, the mobility of cattle does not ensure that the entire control area will be equally served. In the Tanga Region of North-East Tanzania, such cattle mobility contributed to a failed control effort as the treated cattle did not penetrate areas of tsetse habitat, thereby allowing fly populations to persist (Hargrove et al. 2000). In fact, the Tanga control effort demonstrated that if tsetse are present in high densities, the use of insecticide-treated cattle is entirely ineffective (Hargrove et al. 2000) as the cattle avoid these large residual populations of tsetse. From a financial perspective, ability and willingness to pay may also become an issue when expecting stockowners to purchase the insecticides. This financial burden was calculated to be roughly $.20/animal/year (Torr, Maudlin, and Vale 2007), which could be a considerable obstacle in sub-Saharan Africa where it is not uncommon for 70 percent of a country's population, or more, to live on less than $1.25 per day (World Bank 2010).

2.5.4 Community Participation

Community participation is a farmer/community-based approach, which treats tsetse control as a rural development project (Dransfield and Brightwell 2004). It allows for the mobilization of labor, with economic and social benefits accrued by those individuals participating in the control effort. Often, the approach is seen as the alternative to the top-down, area-wide control campaigns that have relied heavily on more sophisticated technologies and highly trained staff. And because the large-scale control campaigns are typically very expensive, community participation offers a sustainable solution (Barrett and Okali 1998). Additionally, local involvement limits expenditures by government when programs are centrally coordinated. Unfortunately, community participation has had only mixed successes when put into practice. Gouteux and Sinda (1990) demonstrated that as tsetse become scarce, active participation in tsetse control by the local community decreases, since control is no longer seen as a priority. Brightwell et al. (2001) also identified decreasing participation following the success of control as an issue that must be addressed if community participation is to succeed. Other problem areas identified in their study included poor maintenance and failure to replace baits and insecticide, and poor placement of traps. Allsopp (1999) also demonstrated the importance of maintaining and spraying control devices when appropriate. Above all, the success of community involvement hinges on proper education of the local community (Sindato, Kimbita, and Kibona 2008). This study provides a cost for the training of local communities. Additionally, I assume that community participation will be limited to shorter periods with a trained central staff carrying out activities over the long term; by doing this, I avoid the problems of attrition and decreased interest that have burdened local control programs.

2.6 Trypanotolerant Cattle

A second livestock-centered method of "controlling" AAT within tsetse regions is the keeping of trypanotolerant breeds. While such a technique does not rid an area of the tsetse fly, and, thus, should not be considered a tsetse population control technique, it does present an insecticide-free method by which land inhabited by tsetse can be put to productive use. Unfortunately, not all cattle are trypanotolerant; resistance is found in the N'dama cattle of West Africa as well as a number of breeds of dwarf West African shorthorn, including Lagune, Baoule, Simba, and Muturu (Ormerod 1976). However, despite their ability to exist alongside tsetse, trypanotolerant cattle are not often the first choice of many pastoralists due to their smaller relative size when compared to zebu cattle (Rogers and Randolph 1988). In 2005, the Food and Agriculture Organization (FAO), reporting on trypanotolerant livestock, summarized a 1979 study by the International Livestock Centre for Africa, which disputed the widely-held belief by pastoralists that trypanotolerant livestock are substantially less productive than those that are trypanosusceptible due to their smaller size. In fact, by constructing a productivity index, created by combining several production and viability traits, the zebu were found to be only 7 percent more productive than the smaller trypanotolerant breeds under nominal disease burden conditions (FAO 2005).

The ability of certain breeds of domestic livestock to remain productive in tsetse-infested areas has long been recognized. Murray et al. (1984) listed a summary from 1906 that offered an early account of the ability of West African cattle to survive in tsetse belts; however, Roberts and Gray (1973) pointed out that the nature of the resistance, despite numerous studies, was not clear. Today, more remains to be learned about the responses in trypanotolerant breeds, but evidence exists that resistance is the result of at least two mechanisms. Specifically, non-hemopoietic tissues are responsible for efficient control of parasitemia, the content of parasites in the blood, and hemopoietic tissues allow for resistance to anemia in trypanotolerant cattle (Naessens, Teale, and Sileghem 2002). This natural resistance has generated interest in the ability to cross the trypanosomiasis-resistant phenotype into improved cattle. However, much work remains to be done in this area as the mechanisms that allow trypanotolerant livestock to maintain their health under challenging conditions are complex and may differ between trypanotolerant breeds (Black, Seed, and Murphy 2001).

2.7 Control versus Eradication

The aforementioned methods of ground spraying, aerial spraying, and SIT comprise the group of large-scale techniques. These were, and are, the methods that have given hope to the idea of Africa-wide tsetse eradication, which is defined as it was earlier: The complete removal of all wild populations of a species. However, since the 1970s there has been an ongoing decline in spending by African governments on tsetse and trypanosomiasis control (Hargrove 2000). This decline in funding has partly been the result of a reduction in donor support due to increasing donor concerns regarding the environmental consequences of large-scale control efforts and impatience that has resulted from witnessing only minimal improvements from large investments (Hargrove 2000). As donor and government support for control projects has waned, community participation has become a common phrase in aid projects (Catley and Leyland 2001). Under this approach, direct involvement from those benefitting from the aid program is encouraged. Predictably, this shift from government-centered or donor-centered control to local control has also brought about a shift from large-scale to small-scale control techniques (Hargrove 2000; Hargrove et al. 2000; Torr, Hargrove, and Vale 2005). The consequences of this shift have yet to be fully realized, but Torr, Hargrove, and Vale (2005) offered that if eradication of tsetse is to occur, a return to large-scale campaigns must occur.

The feasibility of eradication has been questioned by some (e.g., Molyneux 2001; Hargrove 2003; Torr, Hargrove, and Vale 2005), and outright refuted by others (Rogers and Randolph 2002), with issues of financial resources, coordination between countries, and fly reinvasion raised as potential problem areas (Rogers and Randolph 2002). Still, there are others who claim that eradication is the best solution, due to the heavy economic burden that tsetse exact in endemic areas (e.g., Kabayo 2002; Kamuanga 2003). If eradication is to be achieved on the African continent, the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC) will need to play a large role.

2.7.1 PATTEC

PATTEC is responsible for coordinating continent-wide tsetse eradication across political boundaries, providing technical guidance to member countries, and obtaining financial and material support when possible (PATTEC 2001). PATTEC includes such members as the FAO, International Atomic Energy Agency (IAEA), and World Health Organization (WHO), as well as the African Union Inter-African Bureau for Animal Resources (AU-IBAR) (Taverne 2001). It promotes a variety of control methods, including aerial spraying and SIT, to attack tsetse in distinct fly belts across the continent (Kabayo 2002). In a direct appeal to the donor community, PATTEC (2001) offered that the environmental impact of all eradication campaigns will be considered before implementation, and that, despite the substantial initial cost of the large-scale efforts, eradication is a "once-and-for-all cost," while control costs recur indefinitely. Even with such announcements, the large initial cost of eradication may simply be too great for donors and governments given the long legacy of eradication and control failures. Consequently, the transition to cheaper, smaller, and more environmentally benign forms of control seems irreversible (Brightwell et al. 2001).

2.8 Tsetse Ecology

Tsetse rely on the presence of suitable conditions for their survival. These conditions consist of proper land cover types, climate conditions, and food sources (Pollock 1982a, 1982b). Preferred conditions vary by tsetse species. However, regarding land cover types, irrespective of the tsetse species considered, it is the geometry of the vegetation that makes land cover suitable, including the vegetation's ability to mitigate higher temperatures that may be damaging to the fly (e.g., temperatures above 32°C for the *morsitans* group) (Cecchi et al. 2008; Leak, Ejigu, and Vreysen 2008).

Climatically, depending on the species, temperatures between 19 and 28°C are preferred with conditions ranging from very dry to highly humid (Challier 1982; Pollock 1982b). When temperatures rise above the preferred levels, tsetse seek shelter that helps to mitigate the higher temperatures (Leak 1999). As temperatures drop below the preferred levels, a "chill coma" sets in, which prevents tsetse from flying and eventually leads to starvation (Knight 1971; Hargrove 1980; Terblanche et al. 2008).

Regarding food sources, tsetse take a blood meal from a host every two to three days (Schofield and Torr 2002). Tsetse primarily feed on wild ungulates and ruminants, including the warthog, bushpig, kudu, and bushbuck (Pollock 1982a; Jordan 1986). Tsetse also feed upon livestock, including cattle, sheep, and goats.

2.8.1 Seasonal Fluctuations in Tsetse Distributions

Seasonal fluctuations of fly distributions have been extensively recognized and recorded (e.g., Nash 1933; Bursell 1957; Leak 1999; Bett et al. 2008). As moisture levels, temperatures, and the availability of food sources fluctuate, so too do tsetse distributions. In Kenya, these fluctuations in fly distributions often show a bimodal or unimodal pattern corresponding with the changing seasons (DeVisser et al. 2010). Generally, distributions contract during the hot dry season, expand during the long rains, contract once again during the prolonged cool dry season, and expand during the short rains. Refer to section 1.2 for a review of the timing of each of these seasons.

Davies (1964) and Glover (1967) both recognized the importance of understanding the ecological traits of tsetse and their responses to seasonal events. Both stressed the potential for reduce fly control costs if these traits were understood. In this study, the seasonal fluctuations in tsetse fly distributions will be examined to reduce tsetse management costs by controlling fly populations when they are spatially and temporally constrained. This will be explained further in the next chapter.

2.9 Costing Tsetse Control

Concern regarding the cost of tsetse control using the above described control techniques has existed since the very earliest campaigns. Bulhoes Maldonado chose to control the fly population on the island of Principe by equipping his laborers with glutinous black cloths, since this was determined to be a cost-effective means of control (Maldonado 1910). Not too long after Mr. Maldonado's effort on the island of Principe, Pearce (1925) mentioned the efficiency (or lack thereof) and costs of habitat destruction before stating that treatment of the actual disease with trypanocides would be more efficient. In removing *Glossina palpalis* from streams, Glasgow and Duffy (1947) concluded that, at the time, hand catching was the most economical means of eradicating the fly population. Wilson (1953) found DDT ground spraying to be more cost-effective than hand catching at eradicating *G. palpalis* in what was a more comprehensive costing exercise than previous studies. Further costing the ground spraying technique, Davies (1964) examined the savings and effectiveness of spraying only *G. tachinoides* and *G. morsitans submorsitans* habitat in the dry season. Similarly, Glover (1967) emphasized the importance of understanding ecological preferences and responses to seasonal changes when conducting and costing tsetse control More recent cost studies have provided greater detail regarding field and administrative costs and have tended to compare the cost-effectiveness of several control options in the same study (Brandl 1988; Barrett 1991, 1997; Shaw et al. 2007). This is likely due to the increasing importance of efficiently using control resources as a result of the reduced commitment of African governments and donor groups to tsetse control in recent years.

The concern of this study, however, is not one of comparing the costs of different control techniques; rather, it is to examine the cost effectiveness of controlling geographically constrained fly distributions using a single technique. A wealth of research has amassed evaluating the particular qualities of each technique (e.g., Hargrove 2003; Vale and Torr 2004; Feldmann 2004; Leak, Ejigu, and Vreysen 2008; Tsetse.org 2010). Recent estimates of the costs of control using these methods have been summarized by Shaw et al. (2007) (Table 2.1). However, as Shaw (2004) warned, comparing the costs of techniques from separate studies can be misleading due to differences in the goals of control campaigns (i.e., reducing fly densities to differing levels), inconsistencies regarding the costs that are included in the compared studies, and the simple fact that costs vary by study location. Shaw (2003) provided economic guidelines to be followed when carrying out costing simulations in order to avoid the above errors. These included discounting costs to their net present value to create a temporally-dynamic costing simulation, inclusion of costs from all facets of the management campaign (i.e., overhead, surveying, monitoring, and field costs), and use of control input prices that are consistent with the region where the control campaign is taking place. Each of these conditions has been met in this study, and they will be explained further in the next chapter.

Table 2.1 *Recent costs of tsetse control techniques*

Tsetse control technique	Costs in US$ per km^2 (Year)	Control or eradication	Included in study	Source, *country*
Insecticide treated cattle: 44 cattle per km^2	60 (1996)	Annual control cost	Pour-on, tsetse monitoring, farmers' time, transport	Woudyalew et al. (1999) *Ghibe, Ethiopia*
Insecticide treated cattle: 15 cattle per km^2	250[a] (1990)	Eradication	Pour-on, delivery cost, dipping service	Barrett (1997) *Zimbabwe*
Aerial spraying	270 (2000-2001)	Elimination	Operational costs for insecticide and aerial spraying	Allsopp and Hursey (2004) *Okavango, Botswana*
Aerial spraying	700-900[a] (1990)	Eradication	Operational costs for spraying, monitoring	Barrett (1997) *Zimbabwe*
Targets	219 (1996)	Control	Field costs for tsetse control division	Mullins et al. (1999) *Botswana*
Targets	96 (1999)	Control	Cost of contract for initial deployment	Allsopp and Hursey (2004)
Trapping (mono – pyramidal traps)	26 (1992)	Annual control cost	All field level costs, capital items, local administration and salaries, donor costs	Shaw, Zessin, and Munstermann (1994) *Northern Côte d'Ivoire*
Trapping (Isolated population – 4 traps per km^2)	283 (End of 2005)	Eradication	Administration, surveying, monitoring, field costs	Shaw et al. (2007) *Uganda*
Sterile insect technique (SIT)	800 (2004)	Post suppression: elimination of fly population	Cost of breeding and releasing sterile flies for 18 months post suppression	Feldmann (2004)

Source: Adapted from Shaw (2004)

Notes: [a]*Costs are as they appear in Budd (1999) who updated Barrett (1997) costs.*

CHAPTER 3

METHODS

3.1 Creating the Control Reservoirs

3.1.1 Introducing Control Reservoirs and Tsetse Zones

Identifying the location and timing of constrained fly distributions was of primary importance for this study. These constrained fly distributions were named "control reservoirs" (CRs) and were specifically defined as spatially constrained tsetse fly distributions limited by seasonal fluctuations to suitable habitat. And while CRs accounted for fluctuations in habitat, I have also introduced "tsetse zones" (TZs) to act as a comparative feature for the CRs. TZs are simply the maximum spatial extent of a fly distribution.

The locations of tsetse during the study period of 1 January 2002 to 19 December 2010 were identified using spatially and temporally dynamic species distribution maps. These maps were produced at a 250 m spatial resolution every sixteen days; as a result, a total of 207 distribution maps were produced and used in this study. The species distribution maps were produced using the Tsetse Ecological Distribution (TED) Model (DeVisser et al. 2010), which uses habitat suitability and fly movement rates to predict the location of fly distributions. The TED Model was parameterized to identify suitable habitat for *Glossina* subgenus *Morsitans*, which, as stated earlier, is the most widely distributed subgenus in Kenya. As a result, hereinafter "tsetse" will refer to the *morsitans* group, and the concern of this study will accordingly be control of this subgenus.

3.1.2 Fly Belts and Tsetse Zones

To locate the CRs, as well as the TZs, it was first necessary to group fly distributions into fly belts. Currently and historically, fly belts have been produced by estimating the distributional limits of fly species based on vegetation type, meteorological records, and altitude (Ford and Katondo 1975; Rogers and Robinson 2004); therefore tsetse are not necessarily confirmed in all areas where fly belts represent them to be. The creation of fly belts was done in the current study to form administrative units for the fly management simulation and to allow for greater ease in distinguishing between separate control areas. To establish the fly belts, the TED Model was run using daily mean maximum and minimum temperatures and daily mean Normalized Difference Vegetation Index (NDVI) as a surrogate for moisture for each day across all years of the study period (i.e., from 1 January 2002 to 19 December 2010), as well as mode land cover. Using mean and mode TED Model inputs was done to reduce inter-annual variability in climatic events. A percent probability map of tsetse presence using ArcGIS version 9.3 was then created. Areas where the fly was predicted to be present less than 50 percent of the time were then eliminated, the same break point used by ERGO (1999). This break point was selected so that the belts represented locations where a high probability of encountering tsetse existed, not simply areas where the fly may be present only several days over a period of years. Next, tsetse distributions that occupied less than 150 km^2 were eliminated as these small distributions would not be targeted as priority control areas by policy makers. Remaining tsetse distributions were then expanded by 1 km to join distributions that were expected to be continuous during the wet seasons following fly distribution expansion (see Hargrove 2000). These final tsetse distributions were then classified as “major distributions” if their area was greater than 8,000 km^2, an area similar in size to the smallest of Kenya's 1996 fly belts (Muriuki et al. 2005; KETRI 2008). Smaller distributions were identified as "pockets" and were grouped in with the nearest major distribution (Figure 3.1). Grouping of pockets to the nearest major distributions was based on the Euclidean distance to each major distribution. Although pockets were any continuous distribution less than 8,000 km^2, most pockets had areas less than 1,000 km^2. The resulting belts from this analysis are shown in Figure 3.2.

Following identification of the fly belts, the TZs within each belt were identified. Using the maximum extent of fly distributions (i.e., Σ 207 distribution maps), distributions were expanded by 3 km. This distance is consistent with a fly front moving at a distance of 1 km each month (Hargrove 2000) for three months, the longest of Kenya's wet seasons. If, after expanding, fly distributions remained separated from the major distributions and had an area of 150 km^2 or greater, they were considered isolated TZs. If isolated TZs were less than 150 km^2, they were grouped with the nearest TZ meeting this size requirement (Figure 3.3). The geographic extent of each of these TZs was then used to form a maximum area boundary for each of the CRs. In other words, each CR would be nested within a TZ.

3.1.3 Control Reservoirs

CRs were identified by first plotting the predicted tsetse surface area for each TZ over the nine years of the study (Figure 3.4). Tsetse control simulations using the population

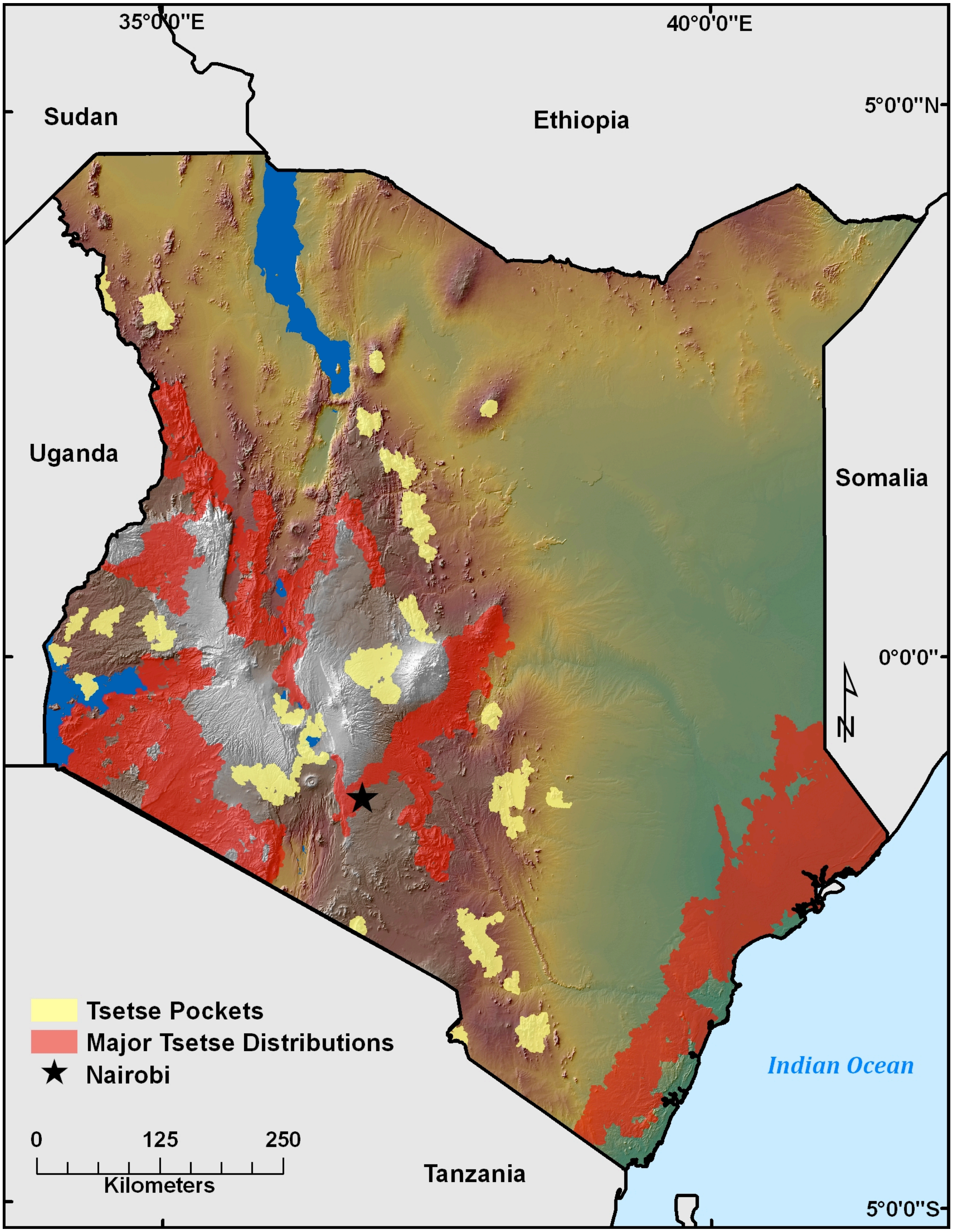


Figure 3.1 *Major tsetse distributions and tsetse pockets identified during the creation of tsetse fly belts. Topography and major bodies of water additionally displayed.*

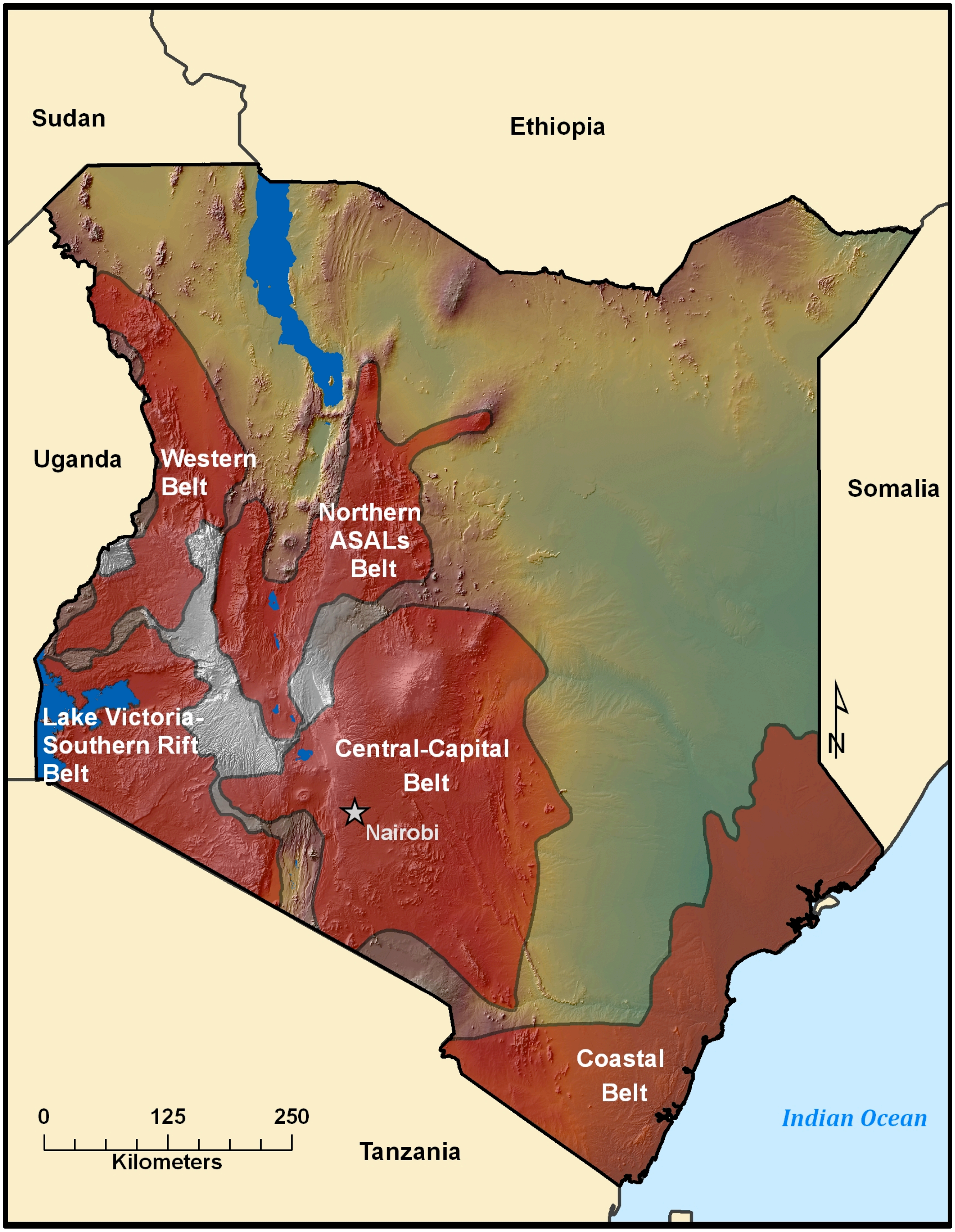


Figure 3.2 *Location of the tsetse fly belts. Topography and major bodies of water additionally displayed.*

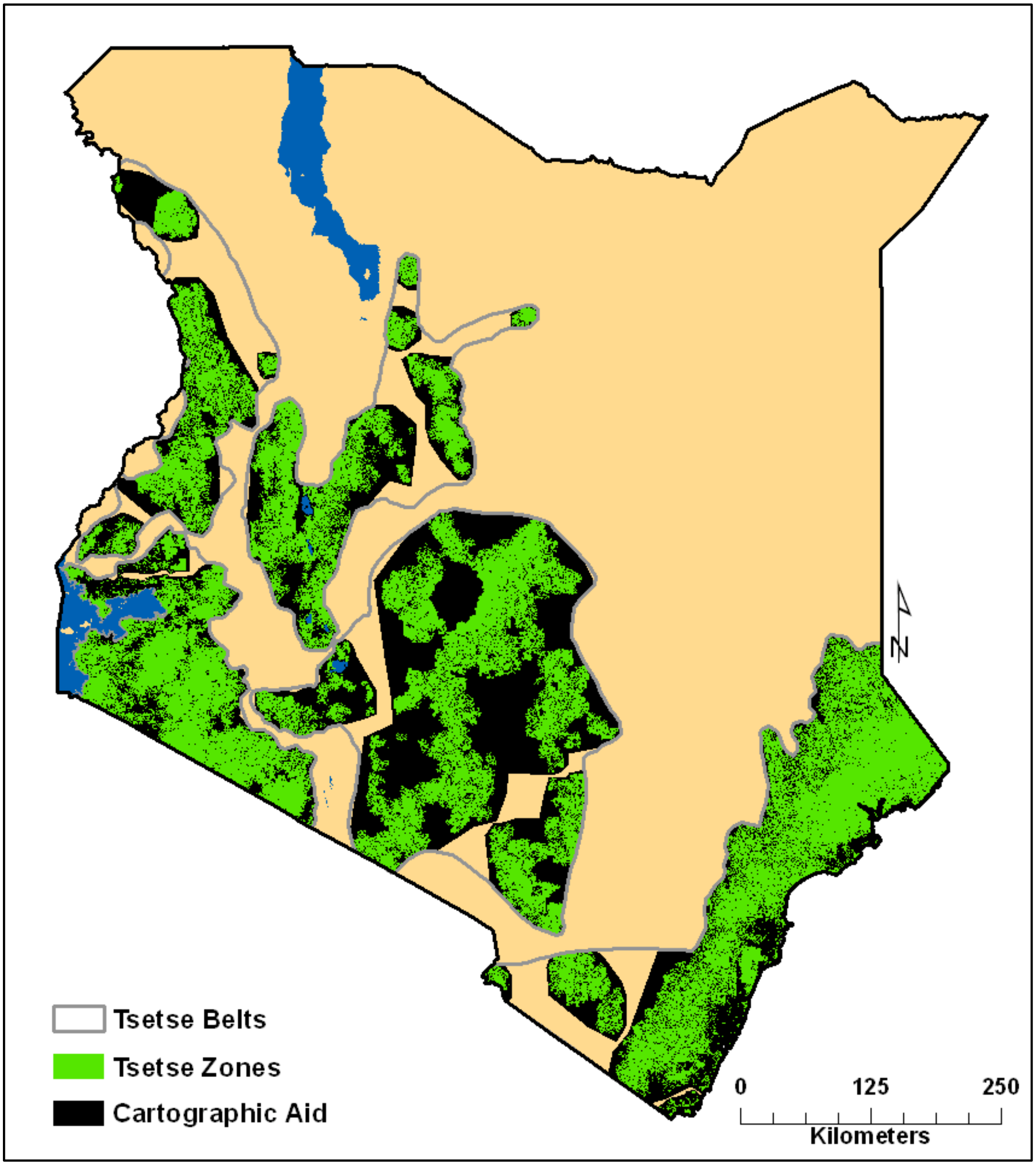


Figure 3.3 *Location of the tsetse zones. The green areas represent the tsetse zones, which are maximum extent fly distributions. These maximum extent fly distributions represent locations where the fly was present at least once from 1 January 2002 to 19 December 2010. The cartographic aid is simply used to help the reader visually distinguish between the separate tsetse zones within each belt.*

dynamic model Tsetse Muse (Vale and Torr 2005), available at http://www.tsetse.org, revealed that sustained control using targets for 216 consecutive days led to elimination of a tsetse population (i.e., 0.5 flies per km^2) (Figure 3.5). Therefore, the CR for each TZ was produced in two steps. First, the predicted surface area for each TZ was plotted, and the 216-day interval where the tsetse distribution occupied the least area, measured in km^2, was identified (see Figure 3.4). This continuous 216-day period will be referred to as the minimum area interval. A preference was given to minimum area intervals that occurred during the cool dry season, as it is easier to locate and reach targets for repair and replacement during the dry season, and targets tend to be more effective during the dry season since the rains have not limited the effectiveness of the insecticides (Williams, Dransfield, and Brightwell 1992; Brightwell et al. 2001; D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, conversation, 24 August 2010). The distribution map representing the largest surface area, measured in km^2, was then identified for each minimum area interval (see Figure 3.4). By choosing the largest surface area map, it was ensured that the CR would encompass the fly distribution during the entire 216-day period needed to eliminate the distribution. Second, a probability map was created using tsetse distributions from the largest surface area maps identified in step one for each of the nine years of the study. The locations within these probability maps where the fly was predicted to be 50 percent of the time or more constituted a CR. The break point of 50 percent was chosen since it is important that CRs represent locations where tsetse are reliably present, not sites where the fly is present only during abnormal climatic events.

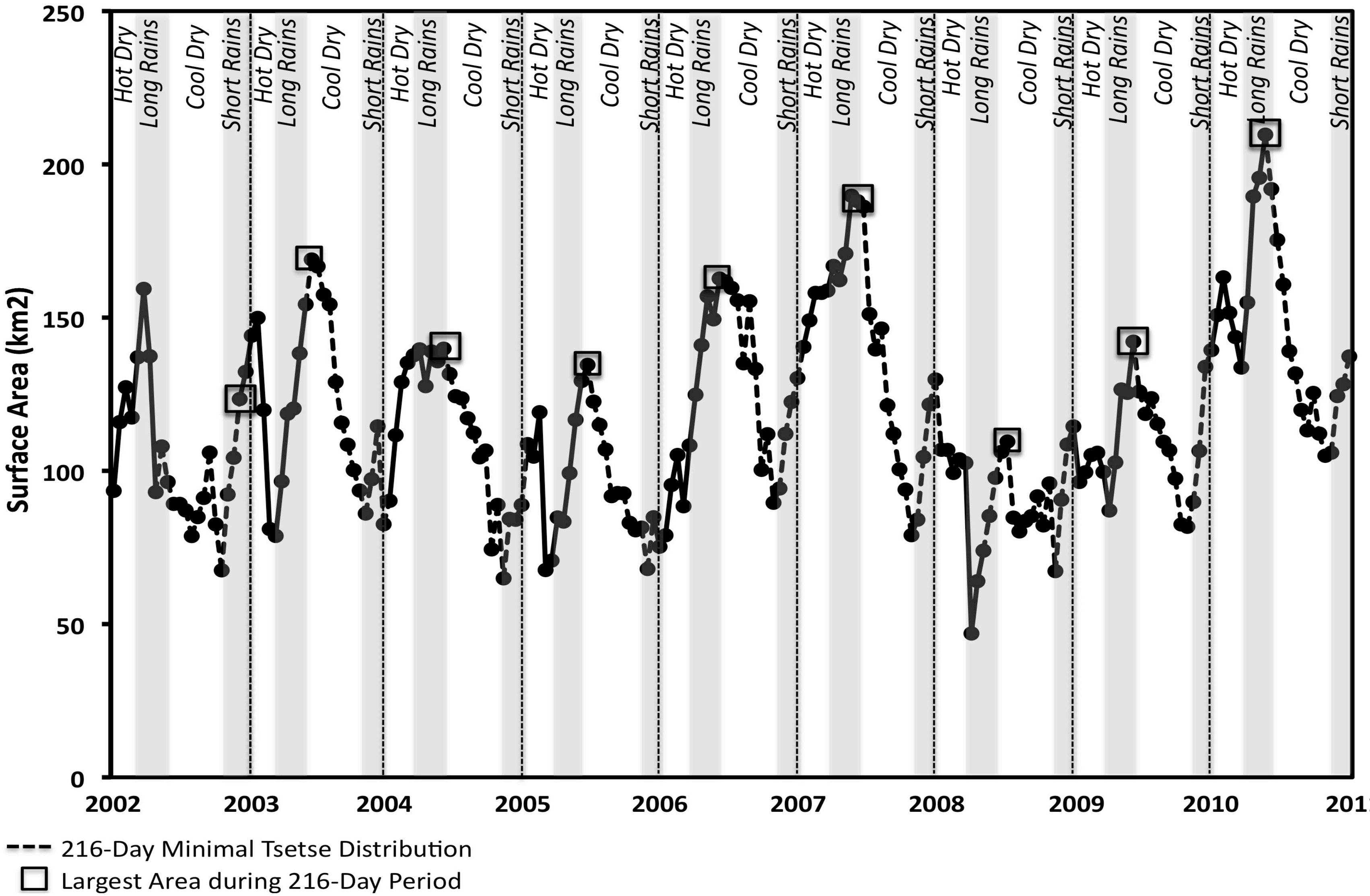


Figure 3.4 *Predicted tsetse distribution surface area for tsetse zone two of the Coastal Belt. The dotted line marks the 216-day period of tsetse elimination.*

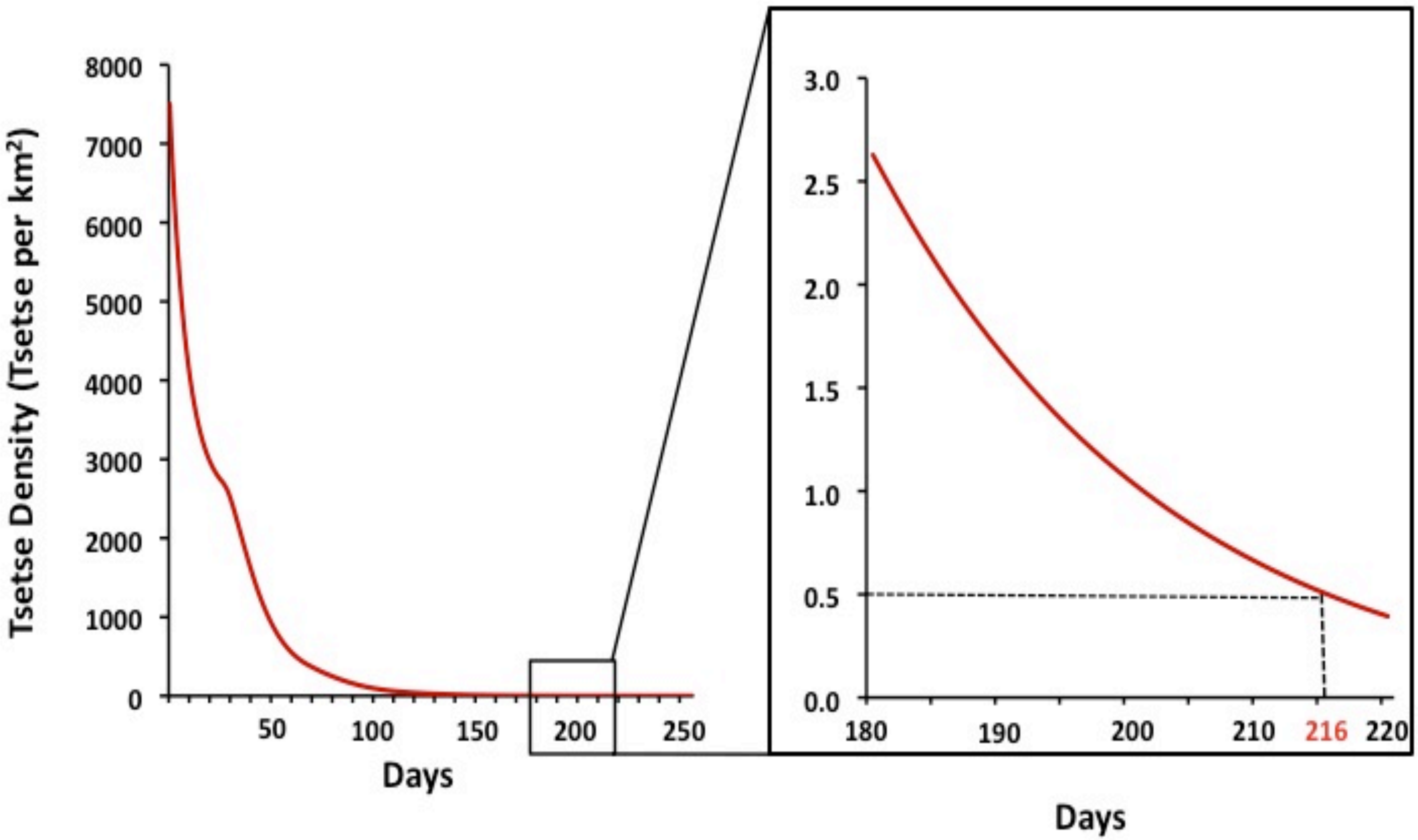


Figure 3.5 *Tsetse Muse output showing fly elimination after 216 days of continuous targeting. Tsetse fly elimination is defined as a density of 0.5 flies per km^2 since the ability to find a mate is restricted at this density (Shaw et al. 2007).*

By definition, CRs occupied a smaller area than the TZs (Figure 3.6). Therefore, fly management within the CRs relates to a reduction in the capital and labor inputs needed to achieve fly elimination.

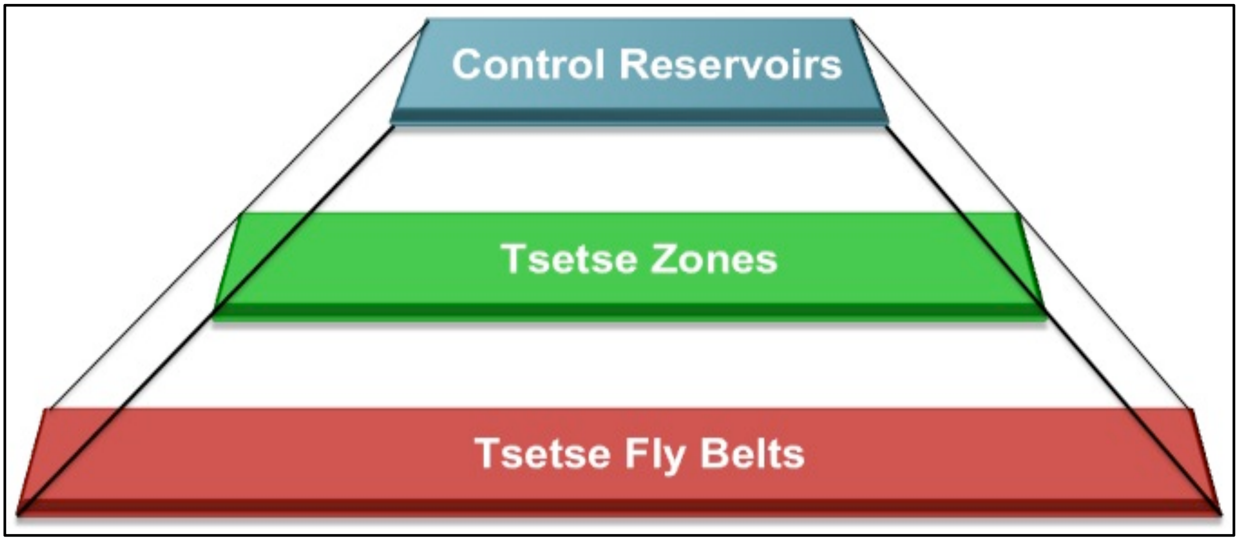


Figure 3.6 *Nesting of control reservoirs within tsetse zones within tsetse fly belts. Fly belts are administrative units for the management campaign; the fly may not be present at all locations within the fly belts. On the other hand, the control reservoirs and tsetse zones both represent genuine tsetse distributions.*

3.2 Control Simulation and Costing Exercise

3.2.1 Introducing the Control Simulation and the Costing Exercise

Two studies (i.e., AU, IAEA, and ADB (2004), and Shaw et al. (2007)) as well as personal correspondence were used to ensure accuracy and inclusion of all relevant costs. Shaw et al. (2007) provided a framework for structuring the schedule of target deployment and the various surveying and monitoring tasks. AU, IAEA, and ADB (2004) provided an extensive list of the various inputs needed to control the fly in the field, and the inputs necessary to maintain a central control office, conduct surveys, and monitor the progress in the field.

Taken together, these tasks constitute fly management. A list of the inputs to accomplish fly management used in this study along with their costs is given in Table A-1 of the Appendices. These costs were calculated at end 2010 prices, and are consistent with management projects in Kenya.

3.2.2 Tsetse Fly Management

Tsetse fly management consisted of field control of the fly, as well as surveying tasks, monitoring tasks, and central control office administration. These tasks, the capital and labor inputs needed to fulfill each task, and the duration of each task have been described in AU, IAEA, and ADB (2004) and Shaw et al. (2007). A description of each task is given below, and information regarding the timing of each task is given in Table 3.1. This table shows that non-field control operations (i.e., monitoring, surveying, and administration) can share the necessary inputs needed to complete each operation with other operations occurring during the same year. This is done by avoiding overlap of operations if they occur during the same year (e.g., the sleeping sickness survey, parasitological and serological data collection, and environmental impact assessment activities would all occur at different times during Year 2). However, field control capital and labor inputs are not shared with non-field control operations due to the length of time needed for field control. As shown in Table 3.1, field control has a duration of 336 days, making it impossible to avoid overlap with any of the non-field control operations and therefore removing the ability to share inputs between field and non-field control tasks. These field control inputs, on the other hand, *can* be shared with other field control operations, since field control occurs in separate years for each belt. The capital and labor inputs needed for each task are listed in Table A-1 and Figures A-1 and A-2. Inputs have been adjusted according to the size of the area in which the operation took place. Table 3.2 gives an explanation of how a selection of non-field control inputs fluctuated depending on the size of the control area.

3.2.2.1 Entomological Survey and Tsetse Fly Population Genetics Survey

This task includes the trapping and sampling of flies, as well as the studying of fly genetics to assist in carrying out control operations. These surveys are the first operations of tsetse management; they occur in Year 1 with a duration of 180 days.

3.2.2.2 Socioeconomic Survey

This survey is conducted to understand the socioeconomic status of households within tsetse areas before control operations begin. The information gathered from these surveys is to be used to assess the effects of fly removal in improving human livelihoods (e.g., keeping of more productive livestock). The socioeconomic survey is conducted during Year 1 and has a duration of sixty days. Like all of the surveying and monitoring tasks, it does not overlap with another surveying and monitoring task conducted in the same year (i.e., the entomological and tsetse fly population genetics surveys). This is done to allow for sharing of capital inputs between tasks, such as 4x4 vehicles, radio sets, and global positioning system (GPS) units.

3.2.2.3 Sleeping Sickness Survey

The sleeping sickness survey is to identify areas at risk for sleeping sickness. This is the first task to be conducted in Year 2, and it has a duration of sixty days.

Table 3.1 *Fly management schedule including monitoring, surveying, and field control operations*

Year **(Discount Factor)**	Activity	Duration (days)
1 **(1.210)**	ET	180
	SE	60
2 **(1.100)**	SS	60
	PS	180
	EA	90
3 **(1.000)**	Coastal Belt Control	336
	CF	90
	EE	90
4 **(0.909)**	Cent.-Capital Belt Control	336
	CF	90
	EE	90
5 **(0.826)**	No. ASALs Belt Control	336
	CF	90
	EE	90
6 **(0.751)**	Western Belt Control	336
	CF	90
	EE	90
7 **(0.683)**	L. Vict.-So. Rift Belt Cont	336
	CF	90
	EE	90
8 **(0.621)**	PS	180

Notes: Fly management campaign activities –
Belt Control includes the 120 days to set up, bait, and spray targets as well as the 216 days that targets are left in the field to eliminate the fly population. During these 216 days, targets are re-baited, re-sprayed, and replaced if damaged or stolen.
ET *– Entomological Survey and Tsetse Fly Population Genetics Survey.* ***SE*** *– Socioeconomic Survey.* ***SS*** *– Sleeping Sickness Survey.* ***PS*** *- Parasitological and Serological Data Collection.* ***EA*** *– Environmental Impact Assessment.* ***CF*** *– Sleeping Sickness Active Case Finding.* ***EE*** *– Environmental and Entomological Monitoring.*
Activities that take place in the same year (e.g., ET and SE in Year 1) are performed during different periods of that year to allow for sharing of capital. Belt Control efforts are allowed to take place at the same time as other activities (e.g., Coastal Belt Control taking place at the same time as CF in Year 3), since the capital items used for the belt control efforts are only shared amongst other belt control operations, which occur in separate years.

Table 3.2 *Determination of the number of non-field control capital and labor inputs*

Input	Explanation
Entomological Survey	
Teams	One team consisting of a team leader, three entomological assistants (EAs), and one driver assigned for each 2,000 km^2 surveyed.
GPS Units	Two GPS units per team.
Tsetse Fly Population Genetics Survey	
Teams	One team consisting of a team leader, three EAs, one biochemist, two lab techs., and one driver assigned for each 10,000 km^2 surveyed.
4x4 Vehicles	One 4x4 vehicle per team.
Socioeconomic Survey	
Teams	One team consisting of a team leader assigned for each 2,500 km^2 surveyed, and one socio-economist and two data entry clerks assigned for each 10,000 km^2 surveyed.
Enumerators	One enumerator to conduct household survey for each 125 km^2.
Bicycles	One bicycle per enumerator.
Sleeping Sickness Survey	
Teams	One team consisting of four medical officers and a driver for each 10,000 km^2 surveyed.
Laptops	One laptop per team.
GPS Units	Four GPS units per team.
Parasitological and Serological Data Collection	
Teams	One team consisting of one team leader, two lab techs., one lab assistant, one veterinary officer, and one driver for each 2,500 km^2.
PCV Readers	One PCV reader per team.
Centrifuges	One centrifuge per team.
Environmental Impact Assessment	
Teams	One team consisting of one ecologist, two assistants, and two drivers for each 5,000 km^2 studied.
Compasses	Two compasses per team.
Sleeping Sickness Active Case Finding	
Teams	Three teams consisting of four medical officers and one driver per team assigned to areas where sleeping sickness has been reported.
Microscopes	Four microscopes assigned per team.
Entomological Monitoring	
Teams	One team consisting of one team leader, two EAs, and one driver for each 2,000 km^2 monitored.
Tsetse Traps	One tsetse trap for monitoring fly levels per 10 km^2.
Environmental Monitoring	
Teams	One team consisting of one consultant, two assistants, and one driver for each 5,000 km^2 monitored.
Binoculars	One set of binoculars per team.

3.2.2.4 Parasitological and Serological Data Collection

This task includes taking record of AAT cases to identify areas where livestock are most at risk of the disease and where intervention efforts to prevent nagana should be targeted. According to AU, IAEA, and ADB (2004), parasitological and serological data collection takes place both during the initial collection of information for the management campaign and once control efforts in the field have ceased. Therefore, the data collection activity will occur for 180 days in Year 2 of fly management and for 180 days in Year 8 of fly management (i.e., the final year).

3.2.2.5 Environmental Impact Assessment

The environmental impact assessment is undertaken to identify key biotic and abiotic indicators, such as insects and soils, to assist in monitoring the environmental impacts of fly control operations. It is conducted over ninety days in Year 2.

3.2.2.6 Sleeping Sickness Active Case Finding

This task includes the surveillance of areas where sleeping sickness is known to be endemic, as well as the treatment of diagnosed cases. This operation lasts for ninety days and is carried out for each of the years that field control efforts are taking place (i.e., five years).

3.2.2.7 Environmental and Entomological Monitoring

Environmental and entomological monitoring consists of surveillance of key environmental and entomological parameters in order to assess the effects of field control operations. Monitoring is conducted for ninety days and is carried out for each of the years that field control efforts are taking place (i.e., five years).

3.2.2.8 Administration and Office Support

Administration and office support includes the necessary capital and labor inputs to run a central coordinating office. Tasks performed at the central coordinating office, such as attendance at meetings, are conducted for each of the eight years of fly management.

3.2.2.9 Field Control

Field control consists of setting up targets, baiting targets with odors, spraying with insecticides, and retreating and replacing targets as needed. This is the operation where fly distributions are eliminated. Field control takes place for 336 days in each of the five belts, with one belt controlled per year from Year 3 to Year 7.

3.2.3 Field Control Period

The 336 days that control operations were taking place in each belt were split into two phases (Table 3.3). The first phase, which had a duration of 120 days and was entitled the deployment phase, consisted of the setting up of all targets in the CRs of the particular belt receiving control, as well as the baiting of targets with attractants and spraying with insecticides. Targets were set up at 4 per km^2 since a high probability of tsetse encountering targets at this density has been reported, which leads to their eventual elimination (Vale et al. 1988; Hargrove 2003). Table 3.3 shows that one fourth of the targets needed to achieve elimination were set up in Month 1, followed by the next fourth in Month 2, until all targets were deployed at the end of Month 4. I assumed that one laborer was able to deploy four baited and sprayed targets each day (D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, conversation, 24 August 2010). Additionally, the staggered approach was followed for the re-baiting of targets, which began in Month 4 for the targets that were deployed in Month 1. Targets were re-baited with acetone and octenol every three months (D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, conversation, 24 August 2010).

The second phase of the control period, the targeting phase, began on the first day of Month 5 (i.e., the first day that the fly was confined to the spatial limits of the CR) and continued until the end of Month 11. This duration represented the 216 days needed to achieve elimination. During the targeting phase, baits were replaced every three months, and targets were re-sprayed with insecticides beginning in Month 7. Additionally, previous studies have shown the importance of replacing targets once they are damaged or stolen (Swallow and Woodyalew 1994; Brightwell et al. 2001). Therefore, beginning in Month 7, 17 percent of targets were replaced when teams were in the field retreating the targets with insecticides (D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, conversation, 24 August 2010).

Table 3.4, similar to Table 3.2, provides an explanation of how the number of field control capital and labor inputs were determined and how these inputs fluctuated with changes in the size of the control area.

Table 3.3 *Control period operations*

Deployment Phase

Month 1	Month 2	Month 3	Month 4
Set up Targets	**Set up Targets**	**Set up Targets**	**Set up Targets**
Bait with Attractants	**Bait with Attractants**	**Bait with Attractants**	**Bait with Attractants**
Spray with Insecticide	**Spray with Insecticide**	**Spray with Insecticide**	**Spray with Insecticide**
			Replace Attractants

Targeting Phase

Tsetse distribution is within the spatial extent of the CR from the beginning of Month 5 to the end of Month 11

Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11
Replace Attractants	**Replace Attractants**	**Replace Attractants**	**Replace Attractants**	**Replace Attractants**	**Replace Attractants**	**Replace Attractants**
		Re-spray Insecticide	**Re-spray Insecticide**	**Re-spray Insecticide**	**Re-spray Insecticide**	
		Replace Targets	**Replace Targets**	**Replace Targets**	**Replace Targets**	
		Replace Attractants			**Replace Attractants**	

Notes: All operations during the "Deployment Phase" and "Targeting Phase" are staggered. In other words, one fourth of all targets will be set up in the first month, then another fourth in the second month until all targets are set up by the fourth month. At the time of the fourth month, the targets that were set up in the first month need to have their attractants replaced. This rotation continues throughout the duration of the control period. The shading of the cells indicates what set of targets are receiving the treatment (e.g., in Month 7 the fourth set of targets that were set up are having their attractants replaced, while the first set of targets are being re-sprayed, re-baited, and replaced if they are damaged or missing).

Table 3.4 *Determination of the number of field control capital and labor inputs*

Input	Explanation
Targets	Initially, four targets deployed per km^2. Then, during the sixth month of the control period, an additional 17 percent of those initially deployed is placed in the field to replace damaged targets.
Teams	One team consisting of one team leader, eight laborers, two entomological assistants (EAs), and one driver for every 3,840 targets initially deployed. 3,840 is the number of targets that can be deployed in four months if one laborer deploys four targets per day.
GPS Units	Two GPS units per team.
4x4 Vehicles	One 4x4 vehicle per team.
Lorries	One lorry to carry equipment per team.
Camping Equipment	Eight sets of camping equipment (i.e., one set per laborer) per team.
Stationary	One set of stationary per team.
Batteries	Two sets of batteries (for GPS units) per team.
Deltamethrin	One liter of deltamethrin insecticide per 112 targets. This is found by assuming that 1 L of deltamethrin, when diluted to a 0.3 percent active ingredient final solution, provides 67 L of mix. Each target receives two applications of the mix at 300 mL per treatment.
Acetone	100 mL applied to each target on three occasions during control.
Octenol	One sachet of octenol applied to each target on three occasions during control.

3.2.4 Costing the Tsetse Management Campaign

3.2.4.1 Meeting the Requirements of Shaw (2003)

Shaw (2003) provided economic guidelines that needed to be followed to obtain an accurate cost of tsetse fly management. These were as follows: first, all costs must be discounted to a present value; second, costs from all facets of the tsetse management campaign must be included (i.e., overhead, surveying, monitoring, and field control costs); and third, labor and capital input prices must be consistent with the region where the management campaign takes place.

To account for the timing of different events, monies received or dispersed in the future and the past must be discounted to their present value. This is necessary because a dollar in the present is worth more than it is in the future given the dollar's ability to earn interest. Discounting relied on the establishment of a baseline year with compound interest removed from monies received or disbursed after the base year and added to monies received or dispersed before the base year (Shaw 2004). Following Shaw et al. (2007), the year in which field control operations began was chosen as the study's baseline year (i.e., Year 3). To deal with compound interest, a discount rate needed to be selected. A discount rate of 10 percent is typically used for the valuing of livestock projects (Itty et al. 1995; Shaw 2003), and since AAT is much more prevalent in Kenya compared to HAT (Bourn et al. 2001; Grady, Messina, and McCord 2011), this study used a 10 percent discount rate. The discount rate was then used to calculate a discount factor; the discount factor for each year is listed in Table 3.1 from Section 3.2.2. Discount factors were multiplied by the cost incurred in each year to give the present value of each activity. The discount factor for each year was calculated using the following equation:

$$\text{Discount Factor} = (1 + r\%)^{t} \qquad \text{Equation 3.1}$$

where *r%* is the discount rate of 10 percent, and *t* is the year for which the discount factor is being calculated. Therefore, *t* for Year 1 would equal 2, *t* for Year 3 would equal 0, and *t* for Year 8 would equal -5.

To meet the second requirement from Shaw (2003), all facets from the management campaign described in AU, IAEA, and ADB (2004), which specified the capital and labor inputs for monitoring, surveying, administrating, and field control, were included in this study. These facets of the management campaign have been described above.

Finally, the third requirement was met through email and personal correspondence with project specialists in Kenya (e.g., D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, email correspondence, 12 February 2011; J. Maitima, Consultant at Ecodym Africa, Nairobi, Kenya, email correspondence, 22 February 2011). Costs specific to management campaigns in Kenya were provided in these emails, as well as guidance regarding the timing of the different management activities.

3.2.4.2 Depreciation and Sharing of Capital Items

In order to spread the costs of the capital items over the course of their useful lives, the life expectancy of each item was recorded. For this, life expectancies were taken from online resources (e.g., WHO 2011). The life expectancies of inputs are given in Table A-1 of the Appendices. A straight-line depreciation method was then used to spread the costs evenly over the course of the capital item's useful life (Karris 2003).

To ensure that tsetse management costs were kept at a minimum, capital items were shared between activities when possible. As stated earlier, administration, monitoring, and surveying capital items were shared with other similar activities, and field control capital items were shared with other field control activities. However, field control items were not shared with monitoring, surveying, and administration activities, and vice versa, due to the sheer length of the field control activities. This sharing of capital items is demonstrated in Figures A-1 and A-2 of the Appendices.

CHAPTER 4

TSETSE FLY MANAGEMENT IN THE CONTROL RESERVOIRS: RESULTS

4.1 Introducing the Results

All CRs as well as the maximum extent of each TZ for each belt are shown in Figure A-3. These are also analyzed individually by belt later in this chapter. In TZ two of the Central-Capital Belt and TZs two and three of the Lake Victoria-Southern Rift Belt, the predicted tsetse surface area fell to zero after 18 February 2004, 1 November 2006, and 7 April 2009, respectively. This occurred due to seasonal fluctuations in climate and suitable tsetse habitat in these areas. Thus, the TZs and their corresponding CRs found at these locations have been excluded from the analysis. The total area for all remaining CRs and TZs sum to 41,562 km^2 and 112,230 km^2, respectively. The latter area is representative of a management campaign that takes place at all locations where evidence suggests tsetse presence. It would be the size of a campaign conducted at the maximum spatial extent of tsetse distributions. Conversely, the former area represents the size of a campaign that accounts for spatial and temporal dynamics of tsetse populations, while targeting areas of more frequent infestation (i.e., fly presence 50 percent of the time or more). All told, the entire fly management campaign amounts to $14,212,647 if the campaign is conducted within the CRs; however, this amount jumps to $33,721,516 if the campaign is conducted at the spatial extent of the TZs. Consequently, a total savings of $19,508,869 is achieved if tsetse management occurs in the CRs, a sizeable savings and one demonstrating the value of managing spatially constrained populations. These costs will now be divided into non-field control costs and field control costs and discussed within these categories. Afterwards, a belt-by-belt analysis of the field control costs will be conducted.

4.2 Tsetse Management Tasks: Administration, Surveying, and Monitoring

Using the total area figures for the CRs and TZs listed above, the costs of conducting the non-field control tasks of administration, surveying, and monitoring in the CRs and TZs are given in Tables 4.1 and 4.2, respectively. The most expensive task for both the CRs and the TZs is, not surprisingly, "Environmental and Entomological Monitoring," since this task is performed for each of the five years of field control operations. Shaw et al. (2007) provided for fewer accompanying studies when comparing the costs of control for different techniques. Therefore, while the accompanying surveys and monitoring programs are important, one area where costs could be lowered would be through fewer studies or less time spent monitoring. All told, the total cost for non-field control tasks conducted for the CRs amounts to $6,305,705. For the TZs, the cost of non-field control tasks amounts to $15,718,791. A savings of $9,413,086 is therefore achieved if the non-field control activities account for seasonal and temporal tsetse distribution fluctuations.

4.3 Tsetse Management Tasks: Field Control Costs

For field control, the costs of achieving fly elimination in the CRs amounts to $7,906,942 (Table 4.3), but this figure grows to $18,002,725 if field control operations are conducted at the spatial extent of the TZs (Table 4.4). The savings resulting from field control operations conducted in the CRs rather than the TZs therefore amounts to $10,095,783. Results for the field control costs for each tsetse fly belt are given below.

Table 4.1 *Control reservoirs: Administration, surveying, and monitoring costs*

Year	Admin. And Office Support	Ent. Survey /Tsetse Pop. Survey	Socio-economic Survey	Sleeping Sickness Survey	Parasit-ological and Serolog-ical Data	Environ. Impact Assess-ment	Sleeping Sickness Case Finding	Environ. and Ent. Mon-itoring	Total Costs
1	$97,975	$1,101,893	$177,795	$0	$0	$0	$0	$0	$1,377,663
2	$89,068	$114,213	$13,546	$64,064	$800,560	$204,462	$0	$0	$1,285,913
3	$80,971	$37,740	$10,788	$8,070	$65,483	$27,993	$84,400	$469,438	$784,883
4	$73,603	$29,588	$9,807	$5,454	$59,524	$25,406	$76,738	$433,082	$713,202
5	$66,882	$26,886	$8,911	$4,956	$54,089	$22,977	$69,731	$393,571	$648,003
6	$67,929	$6,797	$3,145	$0	$9,525	$998	$72,336	$331,553	$492,283
7	$62,803	$6,181	$2,861	$0	$8,662	$836	$66,825	$302,570	$450,738
8	$57,102	$5,620	$2,601	$0	$415,178	$760	$34,388	$37,371	$553,020
Total	$596,332	$1,328,918	$229,454	$82,544	$1,413,022	$283,432	$404,418	$1,967,583	**$6,305,705**
Cost Per km²	$14	$32	$6	$2	$34	$7	$10	$47	**$152**

Source: Adapted from AU, IAEA, and ADB (2004) and Shaw et al. (2007)
Notes: All costs have been discounted to their present value in Year 3.

The total area for all control reservoirs summed to 41,562 km^2. Inputs needed to carry out each of the tasks were adjusted from the inputs specified in the AU, IAEA, and ADB (2004) document. The size of the control area in AU, IAEA, and ADB (2004) varied from 10,000 km^2 to 40,000 km^2; as a result, the number of inputs for each task have been adjusted to agree with the total control reservoir area. Inputs from one task were shared with another when possible in order to reduce costs.

Table 4.2 *Tsetse zones: Administration, surveying, and monitoring costs*

Year	Admin. And Office Support	Ent. Survey /Tsetse Pop. Survey	Socio-economic Survey	Sleeping Sickness Survey	Parasit-ological and Serolog-ical Data	Environ. Impact Assess-ment	Sleeping Sickness Case Finding	Environ. and Ent. Mon-itoring	Total Costs
1	$97,975	$3,171,966	$488,737	$0	$0	$0	$0	$0	$3,758,678
2	$89,068	$309,273	$37,070	$176,176	$2,201,541	$562,125	$0	$0	$3,375,253
3	$80,971	$114,319	$30,369	$22,220	$180,367	$77,006	$84,400	$1,289,285	$1,878,937
4	$73,603	$86,099	$27,605	$14,999	$163,954	$69,888	$76,738	$1,194,276	$1,707,162
5	$66,882	$78,238	$25,085	$13,629	$148,983	$63,207	$69,731	$1,085,318	$1,551,073
6	$67,929	$15,898	$9,176	$0	$26,410	$2,764	$72,336	$918,960	$1,113,473
7	$62,803	$14,458	$8,346	$0	$24,019	$2,299	$66,825	$812,878	$991,628
8	$57,102	$13,146	$7,588	$0	$1,141,903	$2,090	$34,388	$86,370	$1,342,587
Total	$596,332	$3,803,397	$633,976	$227,024	$3,887,177	$779,378	$404,418	$5,387,088	**$15,718,791**
Cost Per km²	$5	$34	$6	$2	$35	$7	$4	$48	**$140**

Source: Adapted from AU, IAEA, and ADB (2004) and Shaw et al. (2007)
Notes: All costs have been discounted to their present value in Year 3.
The total area for all tsetse zones summed to 112,230 km². Inputs needed to carry out each of the tasks were adjusted from the inputs specified in the AU, IAEA, and ADB (2004) document. The size of the control area in AU, IAEA, and ADB (2004) varied from 10,000 km² to 40,000 km²; as a result, the number of inputs for each task have been adjusted to agree with the total tsetse zone area. Inputs from one task were shared with another when possible in order to reduce costs.

Table 4.3 *Control reservoirs: Field control costs*

Year	Coastal Belt	Cent.-Capital Belt	Northern ASALs Belt	Western Belt	L. Victoria-So. Rift Belt	Total Costs
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$4,170,381	$0	$0	$0	$0	$4,170,381
4	$247,421	$1,282,604	$0	$0	$0	$1,530,025
5	$188,229	$47,057	$742,194	$0	$0	$977,480
6	$147,136	$42,717	$33,224	$488,579	$0	$711,656
7	$120,864	$38,849	$30,216	$21,631	$305,778	$517,338
8	$0	$0	$0	$43	$19	$62
Total	$4,874,031	$1,411,227	$805,634	$510,253	$305,797	**$7,906,942**
Cost Per km^2	$205.62	$165.23	$207.48	$175.83	$120.77	**$190.24**

Source: Adapted from Shaw et al. (2007).
Notes: All costs have been discounted to their present value in Year 3.
Cost per km^2 is found using the following control reservoir areas for each belt: Coastal Belt, 23,704 km^2; Central-Capital Belt, 8,541 km^2; Northern ASALs Belt, 3,883 km^2; Western Belt, 2,902 km^2; Lake Victoria-Southern Rift Belt, 2,532 km^2. Cost per km^2 for the "Total Costs" field used the total area of all control reservoirs, 41,562 km^2. Inputs were shared across tasks when possible in order to reduce costs.

Table 4.4 *Tsetse zones: Field control costs*

Year	Coastal Belt	Cent.-Capital Belt	Northern ASALs Belt	Western Belt	L. Victoria-So. Rift Belt	Total Costs
1	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0
3	$6,420,681	$0	$0	$0	$0	$6,420,681
4	$276,191	$4,582,138	$0	$0	$0	$4,858,329
5	$183,000	$141,172	$2,205,555	$0	$0	$2,529,727
6	$122,443	$128,151	$85,434	$1,470,042	$0	$1,806,070
7	$53,629	$81,796	$67,453	$56,204	$2,128,544	$2,387,626
8	$0	$0	$0	$81	$211	$292
Total	$7,055,944	$4,933,257	$2,358,442	$1,526,327	$2,128,755	**$18,002,725**
Cost Per km^2	$193.14	$160.23	$157.48	$136.07	$113.74	**$160.41**

Source: Adapted from Shaw et al. (2007).

Notes: All costs have been discounted to their present value in Year 3.

Cost per km^2 is found using the following tsetse zone areas for each belt: Coastal Belt, 36,533 km^2; Central-Capital Belt, 30,788 km^2; Northern ASALs Belt, 14,976 km^2; Western Belt, 11,217 km^2; Lake Victoria-Southern Rift Belt, 18,716 km^2. Cost per km^2 for the "Total Costs" field used the total area of all tsetse zones, 112,230 km^2. Inputs were shared across tasks when possible in order to reduce costs.

In order to control spatially constrained fly distributions, it is necessary to identify the date that the CR forms, which is also the date that the targeting phase begins. This date is given for each CR in Tables 4.5 through 4.9. Formation of the CR takes place on the first day of the minimum area interval (i.e., the continuous 216-day period where the tsetse distribution occupied the least area, measured in km^2). This is shown in Figure 4.1. To ensure that each year has a CR formation date, the minimum area interval is not allowed to extend into the following year. In other words, targeting, at the very latest, needs to begin by 25 May of each year, day 145 of each year, to ensure that 216 days of control operations can take place. In cases where multiple formation dates exist over the nine-year study period, the most frequent date is chosen as the date of formation for that CR. Tables 4.5 through 4.9 demonstrate that 25 May is most frequently the date to start the targeting phase. This is not surprising as 25 May corresponds with the end of the long rains season and is often followed by a prolonged decrease in tsetse surface area as the cool dry season sets in.

4.3.1 Coastal Belt

Table 4.5 provides a summary of selected capital and labor inputs needed to achieve tsetse elimination in each of the CRs and TZs from the Coastal Belt. The area for each CR and TZ is provided in Figure 4.2. Table 4.5 shows that the 216-day targeting phase begins on 25 May for each of the CRs in the Coastal Belt, which marks the beginning of the cool dry season. Due to its sheer size, the Coastal Belt is the most costly to achieve elimination: $4,874,031 for elimination in the CRs, and $7,055,944 for elimination in the TZs. A total savings of $2,181,913 is therefore realized if control operations are conducted in the CRs.

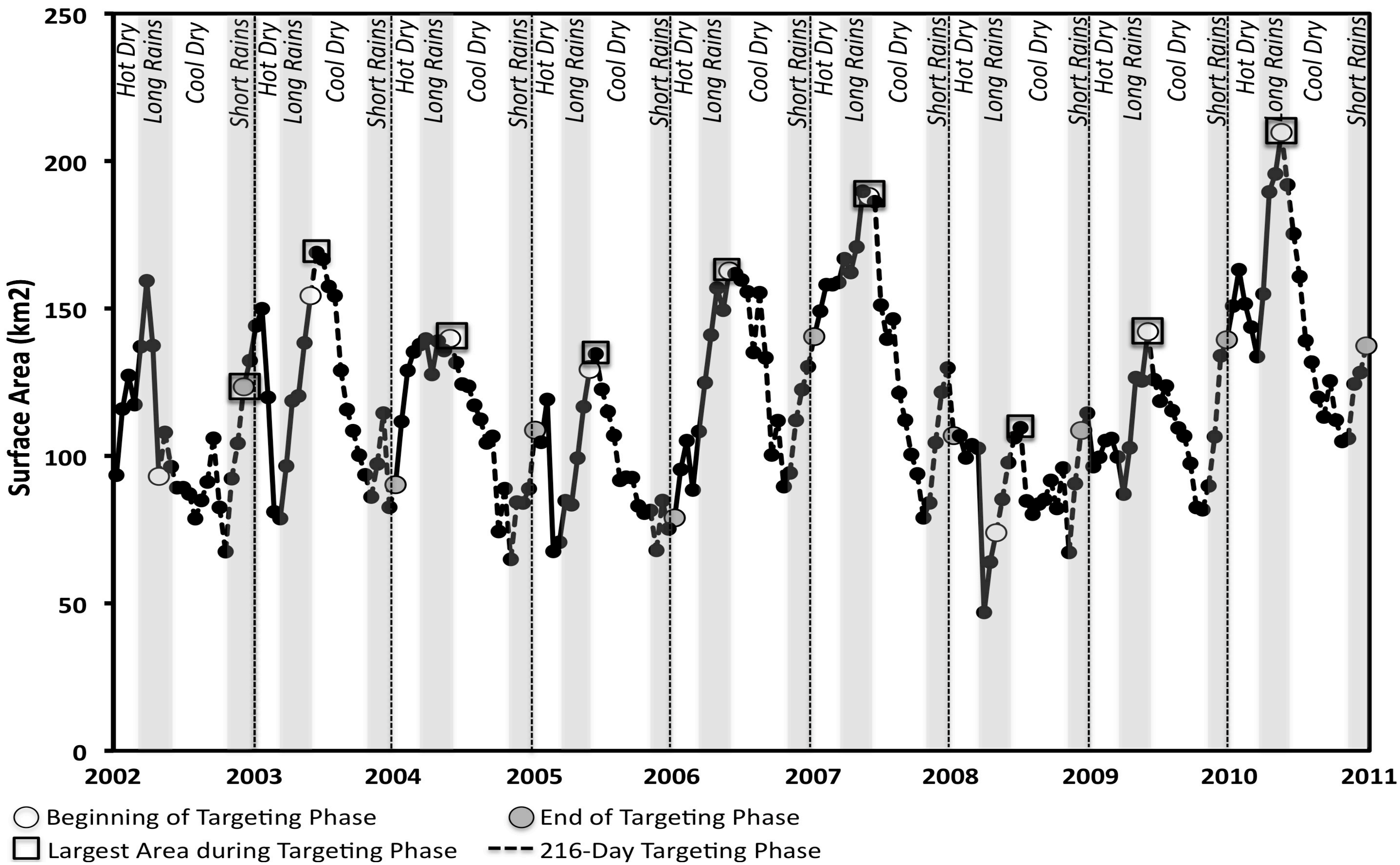


Figure 4.1 *Predicted tsetse distribution surface area for tsetse zone two of the Coastal Belt with the starting and ending date for the targeting phase.*

Table 4.5 *Coastal Belt: Summary of control period capital and labor inputs*

Input	CR Inputs TZ Inputs			
	CR 1 *(25 May)* **TZ 1**	**CR 2 *(25 May)*** **TZ 2**	**CR 3 *(25 May)*** **TZ 3**	**CR 4 *(25 May)*** **TZ 4**
Targets	104,355 156,813	768 1,409	5,139 11,700	674 1,053
4x4 Vehicles	23 35	1 1	1 3	1 1
Camping Equip.	184 280	8 8	8 24	8 8
Team Leaders	23 35	1 1	1 3	1 1
Laborers	184 280	8 8	8 24	8 8
Deltameth. (L)	798 1,199	6 11	39 89	5 8
Octenol (Sachets)	267,576 402,084	1,968 3,612	13,176 30,000	1,728 2,700
Acetone (L)	26,758 40,208	197 361	1,318 3,000	173 270

Notes: Targeting date is listed in parentheses for each CR. "Deltameth." is deltamethrin abbreviated.

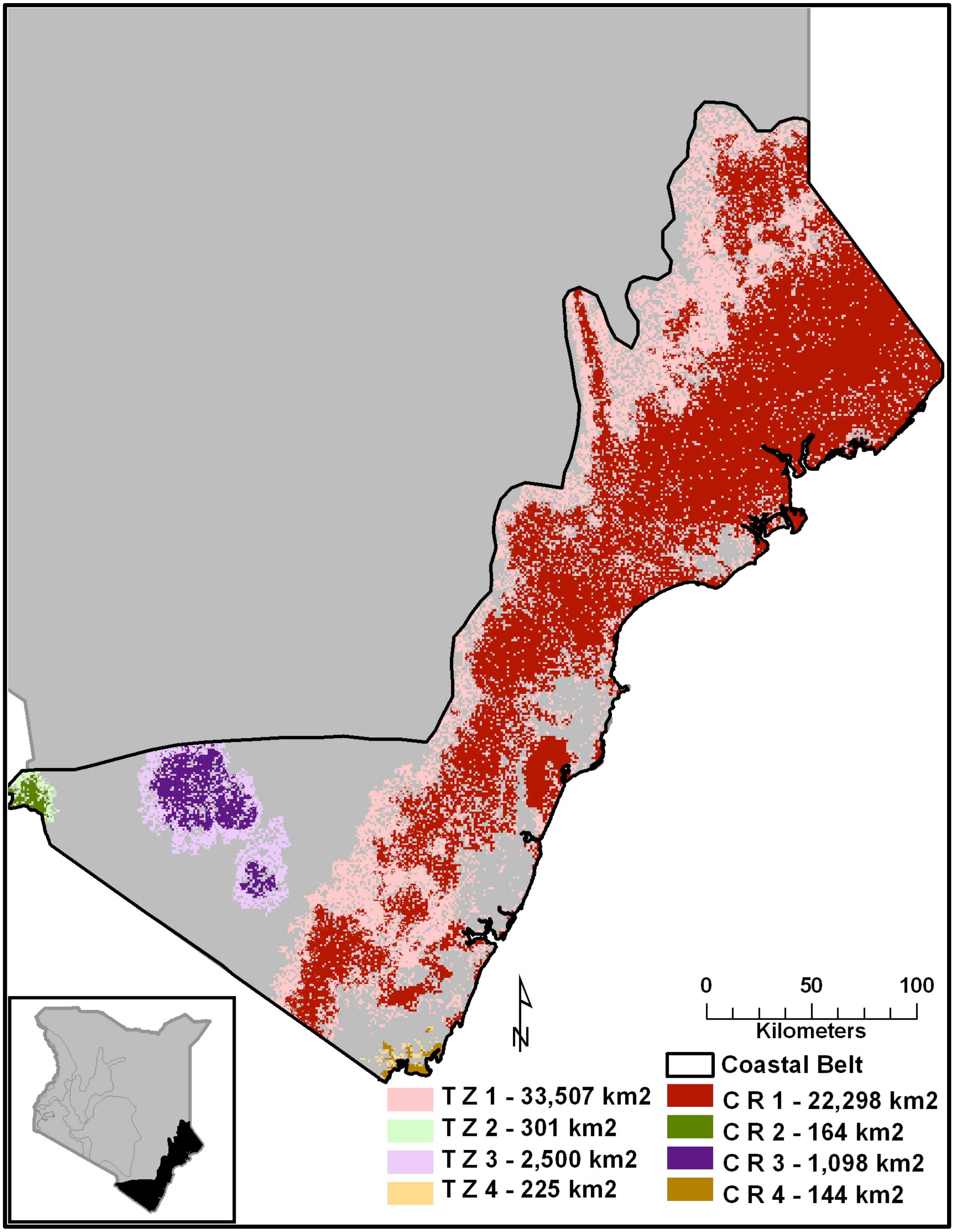


Figure 4.2 *Coastal Belt: Control reservoirs and tsetse zones with surface areas (km^2).*

4.3.2 Central-Capital Belt

Table 4.6 gives a summary of selected capital and labor inputs for the CRs and TZs of the Central-Capital Belt. The area for each CR and TZ is provided in Figure 4.3. It is worth noting that CR 2 and TZ 2 have both been removed from this analysis since the predicted tsetse surface area fell to zero in these locations. Table 4.6 shows the 216-day targeting phase beginning on 25 May for both CRs in the Central-Capital Belt. The total cost of achieving elimination in the CRs of the Central-Capital Belt sums to $1,411,227, while achieving elimination in the TZs amounts to $4,933,257. Total savings therefore amount to $3,522,030 if control operations are conducted in the CRs of the Central-Capital Belt.

Table 4.6 *Central-Capital Belt: Summary of control period capital and labor inputs*

Input	**CR Inputs** **TZ Inputs**	
	CR 1 ***(25 May)*** **TZ 1**	**CR 3** ***(25 May)*** **TZ 3**
Targets	32,297 119,930	7,675 24,158
4x4 Vehicles	7 27	2 5
Camping Equip.	56 216	16 40
Team Leaders	7 27	2 5
Laborers	56 216	16 40
Deltameth. (L)	247 917	59 185
Octenol (Sachets)	82,812 307,512	19,680 61,944
Acetone (L)	8,281 30,751	1,968 6,194

Notes: Targeting date is listed in parentheses for each CR. "Deltameth." is deltamethrin abbreviated. CR 2 and TZ 2 have been eliminated from this analysis, because the tsetse density in these areas dropped to zero before the end of the study period.

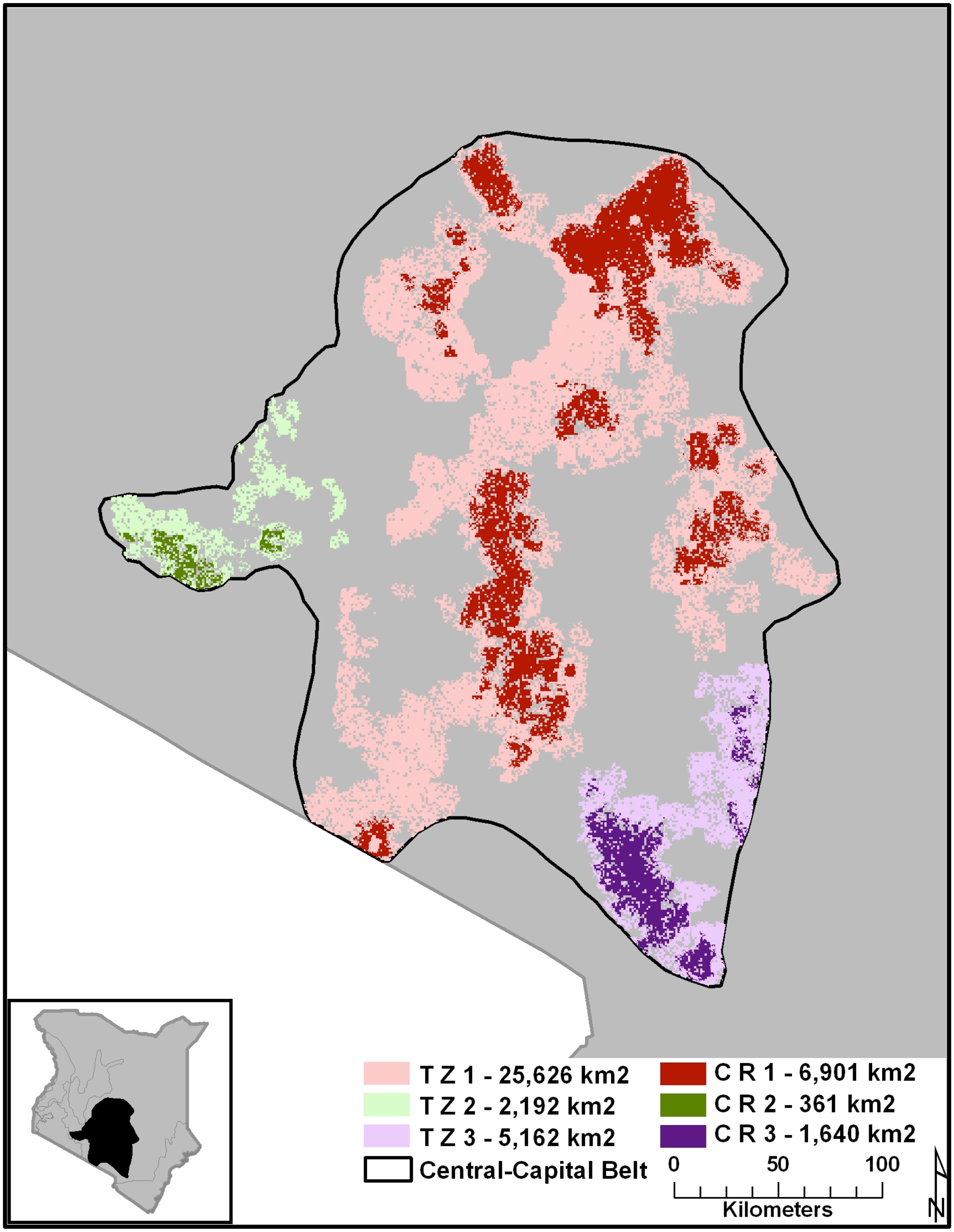


Figure 4.3 *Central-Capital Belt: Control reservoirs and tsetse zones with surface areas (km^2).*

4.3.3 Northern Arid and Semi-Arid Lands Belt (Northern ASALs Belt)

Table 4.7 gives a summary of the capital and labor inputs for the CRs and TZs of the Northern ASALs Belt. The area for each CR and TZ is provided in Figure 4.4. The Northern ASALs belt has more individual CR and TZ locations than any other belt, since there are more isolated tsetse pockets in this belt. Table 4.7 suggests that the targeting phase should begin on 25 May in each of the CRs, except CR 1 where targeting should begin on 1 January. The total cost of achieving elimination in the CRs of the Northern ASALs Belt sums to \$805,634, while elimination costs \$2,358,442 in the TZs. Therefore, a total savings of \$1,552,808 is realized if control operations are conducted in the CRs.

Table 4.7 *Northern Arid and Semi-Arid Lands Belt: Summary of control period capital and labor inputs*

Input	**CR Inputs** **TZ Inputs**				
	CR1*(1Jan)* **TZ1**	**CR2*(25May)*** **TZ2**	**CR3*(25May)*** **TZ3**	**CR4*(25May)*** **TZ4**	**CR5*(25May)*** **TZ5**
Targets	11,536 52,065	3,220 11,321	1,540 3,206	870 1,956	1,006 1,540
4x4 Vehicles	3 12	1 3	1 1	1 1	1 1
Camping Eq.	24 96	8 24	8 8	8 8	8 8
Team Leaders	3 12	1 3	1 1	1 1	1 1
Laborers	24 96	8 24	8 8	8 8	8 8
Deltameth. (L)	88 398	25 87	12 25	7 15	8 12
Oct. (Sachet)	29,580 133,500	8,256 29,028	3,948 8,220	2,232 5,016	2,580 3,948
Acetone (L)	2,958 13,350	826 2,903	395 822	223 502	258 395

Notes: Targeting date is listed in parentheses for each CR. "Camping Eq." is camping equipment abbreviated, "Oct." is octenol abbreviated, "Deltameth." is deltamethrin abbreviated.

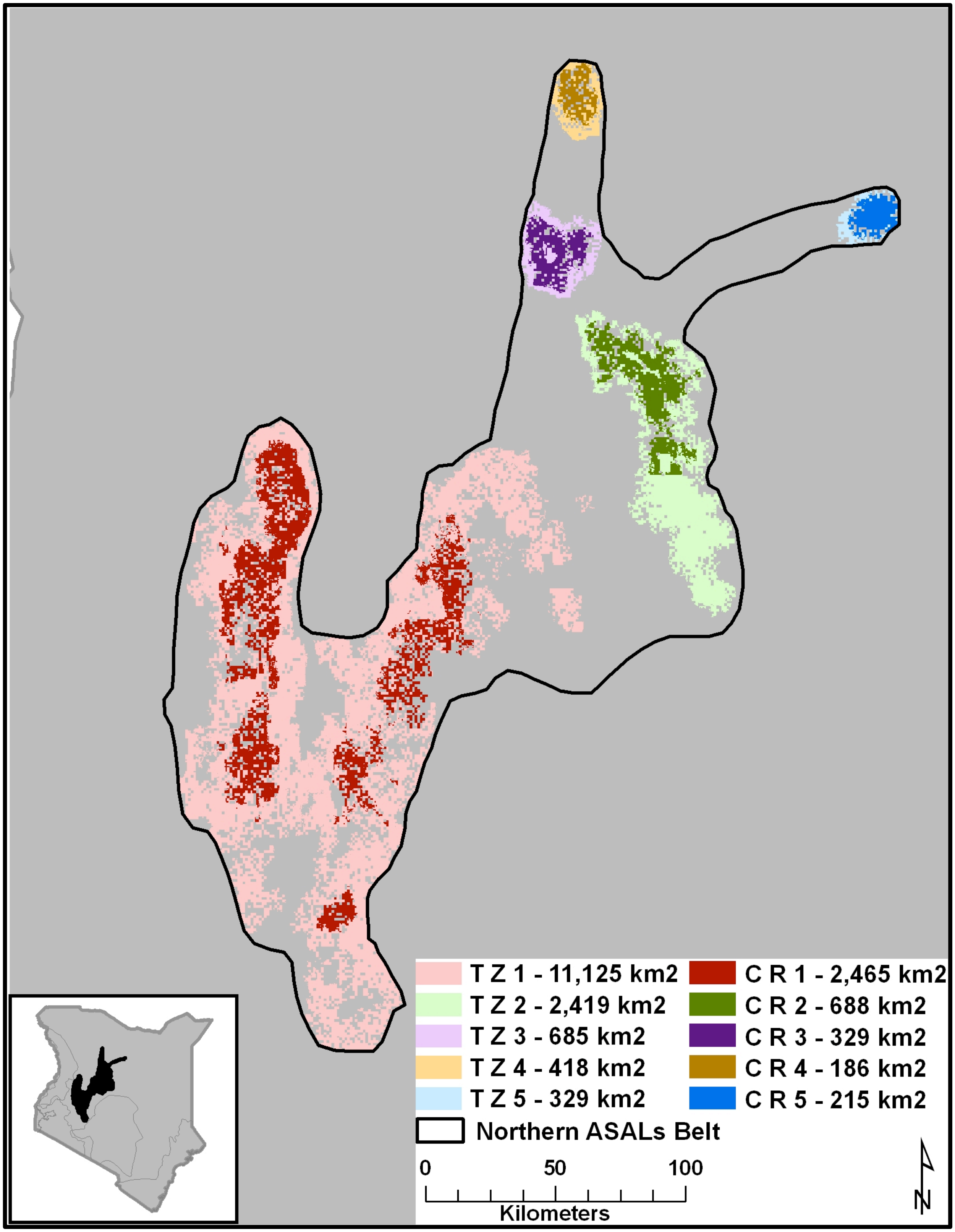


Figure 4.4 *Northern Arid and Semi-Arid Lands Belt: Control reservoirs and tsetse zones with surface areas (km^2).*

4.3.4 Western Belt

Table 4.8 gives a summary of the capital and labor inputs for the CRs and TZs of the Western Belt. Figure 4.5 provides the areas for each CR and TZ in this belt. Table 4.8 shows that the targeting phase should begin on 1 January for all CRs in the Western Belt except CR 1, which has a date of 25 May for the beginning of the targeting phase. The cost of elimination in the CRs of the Western Belt totals $510,253, while elimination in the TZs sums to $1,526,327. All told, a savings of $1,016,074 is achieved if control operations are conducted in the CRs.

Table 4.8 *Western Belt: Summary of control period capital and labor inputs*

Input	**CR Inputs** **TZ Inputs**			
	CR 1 ***(25 May)*** **TZ 1**	**CR 2** ***(1 Jan)*** **TZ 2**	**CR 3** ***(1 Jan)*** **TZ 3**	**CR 4** ***(1 Jan)*** **TZ 4**
Targets	8,546 40,374	2,012 3,964	285 1,259	2,738 6,898
4x4 Vehicles	2 9	1 1	1 1	1 2
Camping Equip.	16 72	8 8	8 8	8 16
Team Leaders	2 9	1 1	1 1	1 2
Laborers	16 72	8 8	8 8	8 16
Deltameth. (L)	65 309	15 30	2 10	21 53
Octenol (Sachets)	21,912 103,524	5,160 10,164	732 3,228	7,020 17,688
Acetone (L)	2,191 10,352	516 1,016	73 323	702 1,769

Notes: Targeting date is listed in parentheses for each CR. "Deltameth." is deltamethrin abbreviated.

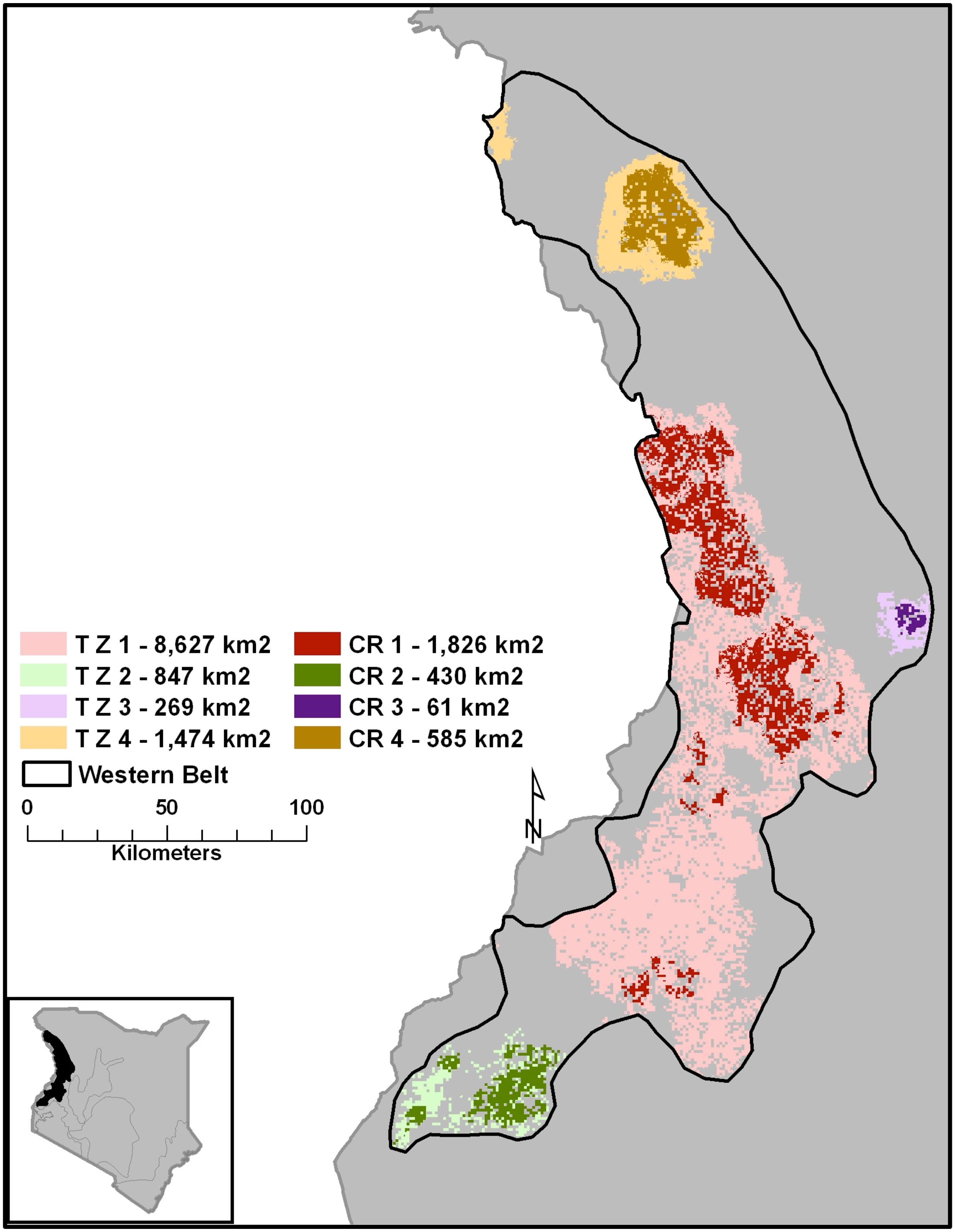


Figure 4.5 *Western Belt: Control reservoirs and tsetse zones with surface areas (km^2).*

4.3.5 Lake Victoria-Southern Rift Belt

Table 4.9 provides a summary of selected capital and labor inputs for the CR and TZ of the Lake Victoria-Southern Rift Belt. The area for the CRs and TZs of this belt is given in Figure 4.6. It is worth noting that CR 2 and CR 3, as well as TZ 2 and TZ 3 have been excluded from this analysis since the predicted tsetse distribution surface area dropped to zero in these locations. Table 4.9 shows that the targeting phase should begin on 25 May in the CR of the Lake Victoria-Southern Rift Belt. The cost of elimination in the CR of this belt totals $305,797, while elimination in the TZ costs $2,128,755. All told, a savings of $1,822,958 is achieved if control operations are conducted in the CR.

Table 4.9 *Lake Victoria-Southern Rift Belt: Summary of control period capital and labor inputs*

Input	CR Inputs TZ Inputs
	CR 1 *(25 May)* TZ 1
Targets	11,850 87,591
4x4 Vehicles	3 20
Camping Equip.	24 160
Team Leaders	3 20
Laborers	24 160
Deltameth. (L)	91 670
Octenol (Sachets)	30,384 224,592
Acetone (L)	3,038 22,459

Notes: The targeting date is listed in parentheses for CR 1. "Deltameth" is deltamethrin abbreviated. CR 2, CR 3, TZ 2, and TZ 3 have been eliminated from this analysis, because the tsetse density in these areas dropped to zero before the end of the study period.

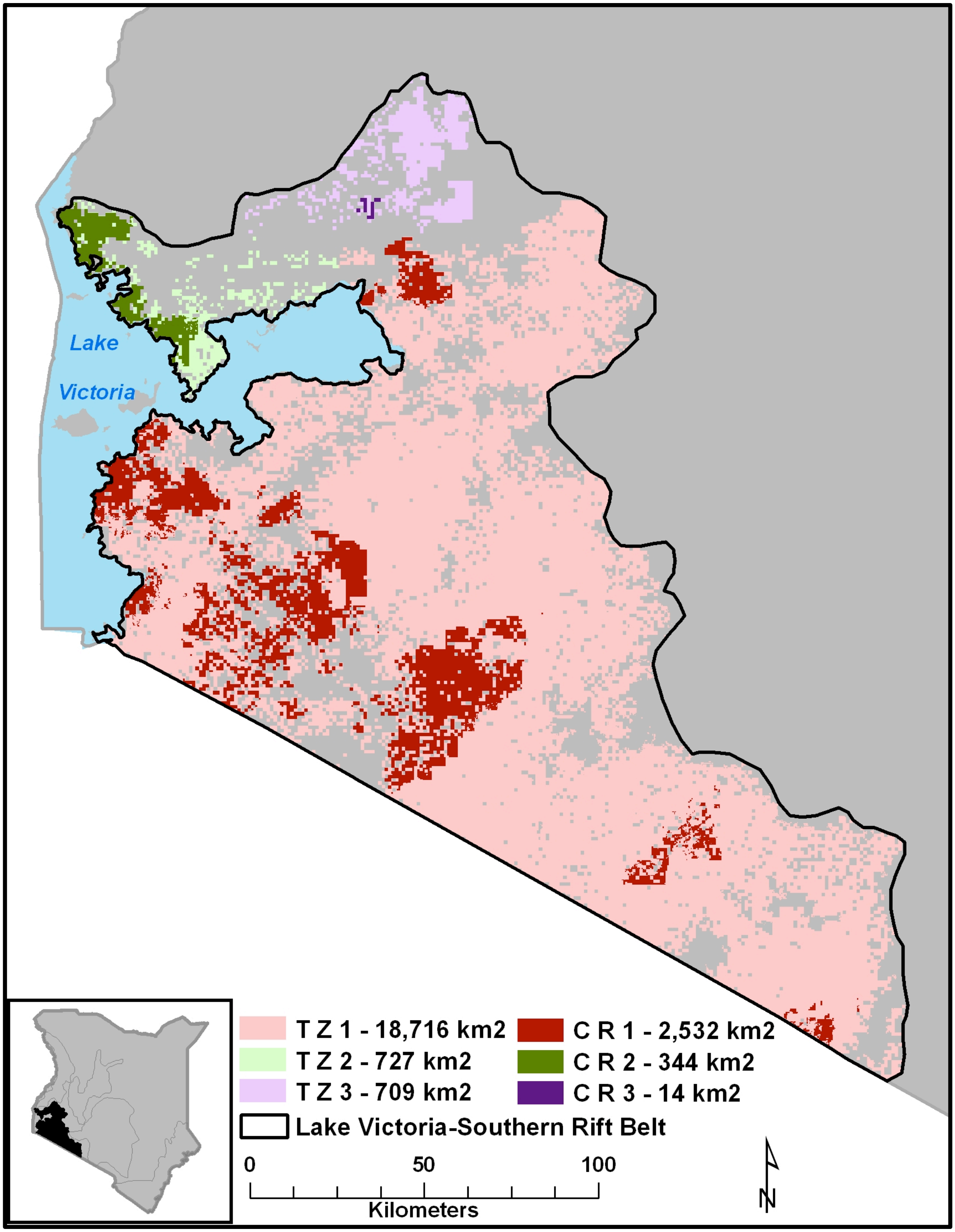


Figure 4.6 *Lake Victoria-Southern Rift Belt: Control reservoirs and tsetse zones with surface areas (km^2).*

CHAPTER 5

CONCLUSIONS AND DISCUSSION

5.1 Introducing the Conclusions

von Wissmann et al. (2011) stated that, since the 1980s, cuts have been made to tsetse and trypanosomiasis control efforts in Kenya, which placed the burden of disease control on local farmers rather than public officials. These cuts, as well as the shift toward localized control, are consistent with the continent-wide reduction in funding for tsetse and trypanosomiasis control projects since the 1970s. I believe, therefore, that this analysis is both timely and vital given the trend in funding. And while this analysis was conducted at the nation-wide scale rather than the local level, the target method precisely lends itself to control conducted by local communities. This transferability to the local level is due to targets being relatively inexpensive and requiring little training and resources for deployment (Brightwell et al. 2001; Vale and Torr 2004; Tsetse.org 2010).

Arguably, the most significant obstacles to overcome when using the target method are the prevention of fly reinvasion once the tsetse population has been suppressed to a sufficient level (e.g., 0.5 flies per km^2) and the necessary coordination to deploy all targets and re-treat them when necessary (Dransfield and Brightwell 2004; Van den Bossche and De Deken 2004). For the above management campaign, I chose *elimination* of the fly distributions within each CR as the ultimate goal rather than *eradication* in order to create a more realistic management campaign capable of addressing these problem areas. Eradication is defined as the removal of all wild populations of a species, not just those species found in a defined geographic area (Molyneux, Hopkins, and Zagaria 2004); thus, eradication would require a greater degree of coordination than that accounted for in this analysis, since operations would need to take place across political boundaries. Here, the level of coordination needed to achieve *elimination* is assigned a dollar amount through the maintaining of a central control office (i.e., the administration costs listed in Tables 4.1 and 4.2). Moreover, to the discredit of eradication, achieving complete removal of all populations of a tsetse species has been questioned by some (Molyneux 2001; UN Wire 2002; Hargrove 2003; Torr, Hargrove, and Vale 2005), and outright refuted by others (Rogers and Randolph 2002), with issues of financial resources, coordination between countries, and fly reinvasion raised as potential problem areas (Rogers and Randolph 2002). Admittedly, fly reinvasion may also jeopardize the success of the management campaign in each of the belts from this analysis. However, a major benefit of targets is that they can remain in the field and continue to control the same area provided that they are adequately maintained. Therefore, if the fly population in a particular CR is not eliminated during the initial 216-day targeting phase, because tsetse are slow to reproduce k-strategists, the fly population may be eliminated when they are again confined to the CR in the following year.

5.2 Summary of Results

This analysis has demonstrated the benefit of conducting tsetse management operations when fly distributions are constrained by fluctuations to suitable habitat. The fluctuations in suitable habitat within Kenya roughly follow a seasonal pattern: contraction of habitat in January and February (hot dry), expansion of habitat from March to the end of

May (long rains), contraction from June to the end of October (cool dry), and expansion in November and December (short rains). This oscillation between dry and wet seasons allowed for the establishment of CRs where fly distributions were constrained by seasonal fluctuations in suitable habitat. By conducting tsetse management operations in the CRs, the capital and labor inputs needed for control were greatly reduced, leading to a large savings in the costs of successfully eliminating the fly from each tsetse fly belt. More specifically, by accounting for seasonal fluctuations in habitat rather than conducting management operations at the maximum extent of fly distributions, a savings of $19,508,869 was achieved. The formation of the CR (i.e., the beginning of the targeting phase) occurred on two dates. For the majority of the CRs, formation occurred on 25 May. This was not surprising as 25 May corresponds with the end of the long rains season and the beginning of the longest of the dry seasons, the cool dry. The remaining CRs were formed on 1 January, which also was not surprising as this date coincides with the beginning of the hot dry season. Therefore, as expected, the formation of CRs appeared to be consistent with seasonal events.

By creating the CRs described in this study, not only were savings achieved by reducing the management area from the TZs to the CRs, but also if the CRs had been compared to the more traditional practice of conducting tsetse management at the belt level (e.g., Lovemore 1992; PATTEC 2001), enormous savings would have been realized by identifying CRs. While such a comparison did not take place in this study, it should be recognized that had the comparative unit been the belts rather than the TZs, savings would have been even more dramatic than those presented.

5.3 Discussion: Shortcomings of Study

5.3.1 Excluded Costs

While great efforts were made to include all costs of fly management in this study, it was natural that some costs would be missed. One such cost is the environmental effect of in-migration of people following elimination. Swallow (2000) and Bourn et al. (2001) both pointed to the importance of understanding the effect that tsetse removal might have if in-migration led to degradation of soils, overuse of water resources, and conflicts over available land. Despite the importance of these costs, they fell outside of the realm of this study. I was primarily concerned with all costs directly related to the tsetse management operations. The costs associated with in-migration occur following the management operation and were therefore viewed as indirectly, rather than directly, related to tsetse management.

Another often-overlooked cost in assessing tsetse control campaigns are those of transaction costs (McDermott and Coleman 2001; T. F. Randolph, Agricultural Economist with the International Livestock Research Institute (ILRI), Nairobi, Kenya, conversation, 25 August 2010). Transaction costs are those costs associated with participating in a market. For example, they could include the time and economic cost of searching for capital inputs that are not readily available. These costs are not often included when valuing tsetse control projects because they are frequently too difficult to price (T. F. Randolph, Agricultural Economist with ILRI, Nairobi, Kenya, conversation, 25 August 2010). Transaction costs were excluded from this analysis, since monetary figures for these costs simply could not be found.

Finally, the costs of access development (e.g., roads, airstrips) were not included in this analysis. Shaw (2003) lists these costs as frequently excluded. Since many locations where field control and other aspects of the tsetse management campaign would likely take place in remote locations with poor infrastructure, this would be a valuable cost to include. However, obtaining a figure for increased access across all of Kenya was not successful. Fortunately, the omission of access development does not greatly alter the total savings from this analysis, since a similar cost would likely be added to both management conducted at the CR extent and management conducted at the TZ extent.

5.3.2 Reinvasion

The issue of reinvasion was not extensively dealt with in this analysis. Above, it was stated that because tsetse are slow to reproduce k-strategists, if the fly is not eliminated in a particular CR during the targeting phase, it could be eliminated if the fly returned to the same CR the following year. However, if an external source provides the reinvading flies, elimination may be difficult to achieve. Reinvasion is frequently listed as one of the greatest, if not the greatest, obstacles for successful tsetse control (Leak 1999; Warnes et al. 1999; Hargrove 2000; Hargrove 2003; Shaw et al. 2007). In Kenya, reinvasion may be particularly troubling in the Lake Victoria-Southern Rift belt with reinvasion coming from Tanzania, and in the Western belt with the source of reinvasion being Uganda.

Barriers of targets and/or traps are listed as the solution to keep tsetse from reinvading cleared land, but the cost of deploying and maintaining barriers is very expensive (Brandl 1988; Warnes et al. 1999; Shaw et al. 2007), with one study showing a 30-60 percent increase in the cost per km^2 if a trap barrier is deployed (Shaw et al. 2007).

For the purposes of this analysis, I was solely concerned with analyzing the savings achieved from tsetse management performed when spatio-temporal dynamics were considered compared to fly management that neglected these dynamics. Reinvasion was not a major question for this analysis, but it should be analyzed on a belt-by-belt basis in future work.

5.3.3 Target Maintenance

This study assumed that teams of laborers would be able to re-bait odors every three months and re-spray targets with insecticides every six months, as well as replace damaged targets after they had been in the field for six months. However, due to the inaccessibility of remote areas, attrition from the labor force, or reduced funding, it may be difficult or impossible for targets to be maintained at the prescribed intervals. The outcome of a "worst case scenario" is shown in Figure 5.1, which assumes that after two months of the targeting phase, *all* targets become ineffective. While this may be unusual, the figure illustrates the importance of continuous control and frequent checking of targets, which the literature advocates for (e.g., Torr et al. 1997; Mangwiro et al. 1999; Kuzoe and Schofield 2004). As can be seen, on day sixty when the targets are no longer effective, the tsetse density is at 541 per km^2. However, the density increases immediately, and at day 216, the final day of the targeting phase, the density is at 1,307 flies per km^2. As a reminder, at day 216 when targets are maintained at 4 per km^2, the fly population reaches the elimination density of 0.5 flies per km^2. This disparity reinforces the importance of effectively deploying and maintaining targets during the duration of the targeting phase.

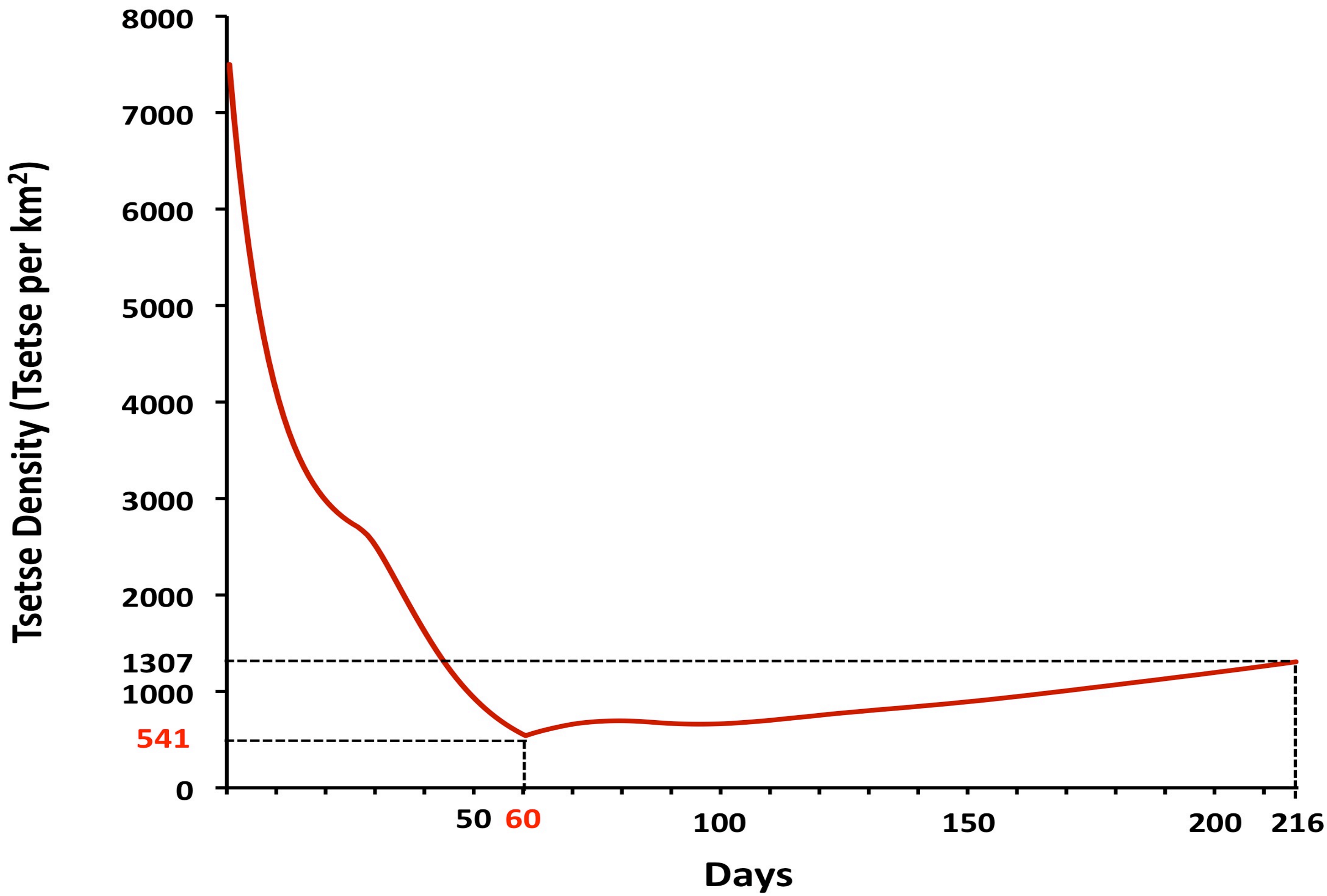


Figure 5.1 *Tsetse Muse output demonstrating the increase in tsetse density once control operations cease due to poor target maintenance. Poor maintenance could include failure to replace odor attractants, insufficient re-application of insecticides, or failure to replace damaged or stolen targets.*

5.3.4 Consideration of Parks and Conservation Areas

During the early twentieth century tsetse habitat destruction and host removal were common methods of controlling the tsetse fly. Due to the success of such programs, control efforts frequently took place in parks and natural reserves (Suich, Child, and Spenceley 2009). Today, owing to environmental and ecological concerns, control activities in parks are limited, and if control is to take place in these areas, fees are often paid to rangers to allow for the deployment of tsetse control (D. O. Gamba, Project Entomologist of PATTEC, Nairobi, Kenya, conversation, 24 August 2010). To some, these measures are necessary to ensure that environmentally damaging activities do not threaten the survival of rare plant and animal species (Reid et al. 1997). However, from the perspective of tsetse control, the presence of parks and conservation areas create a source of perpetual infestation and makes elimination of the fly population very difficult (Vale et al. 1988; Hargrove 2003).

In Kenya, areas protected by human settlement such as Galana Ranch, Maasai Mara, Olambwe Valley, Shimba Hills, and Tsavo create refuge for the fly (Bourn et al. 2001). The protected areas provided by World Resources Institute et al. (2007) are displayed for the Northern ASALs Belt in Figure 5.2. Alongside the parks, Figure 5.2 also presents the CRs within this belt. The figure demonstrates that some CRs are nearly or, in the case of the Marsabit CR in the northeast, completely enclosed within the parks. In fact, of the 3,883 km^2 that all CRs in this belt account for, 1,082 km^2, or 28 percent, are enclosed within protected areas. While control activities within protected areas may be discouraged, a major benefit of the target method is its minimal environmental impact. This may make fly control using targets in some protected areas tolerable, especially when compared to alternative fly control techniques (e.g., aerial spraying).

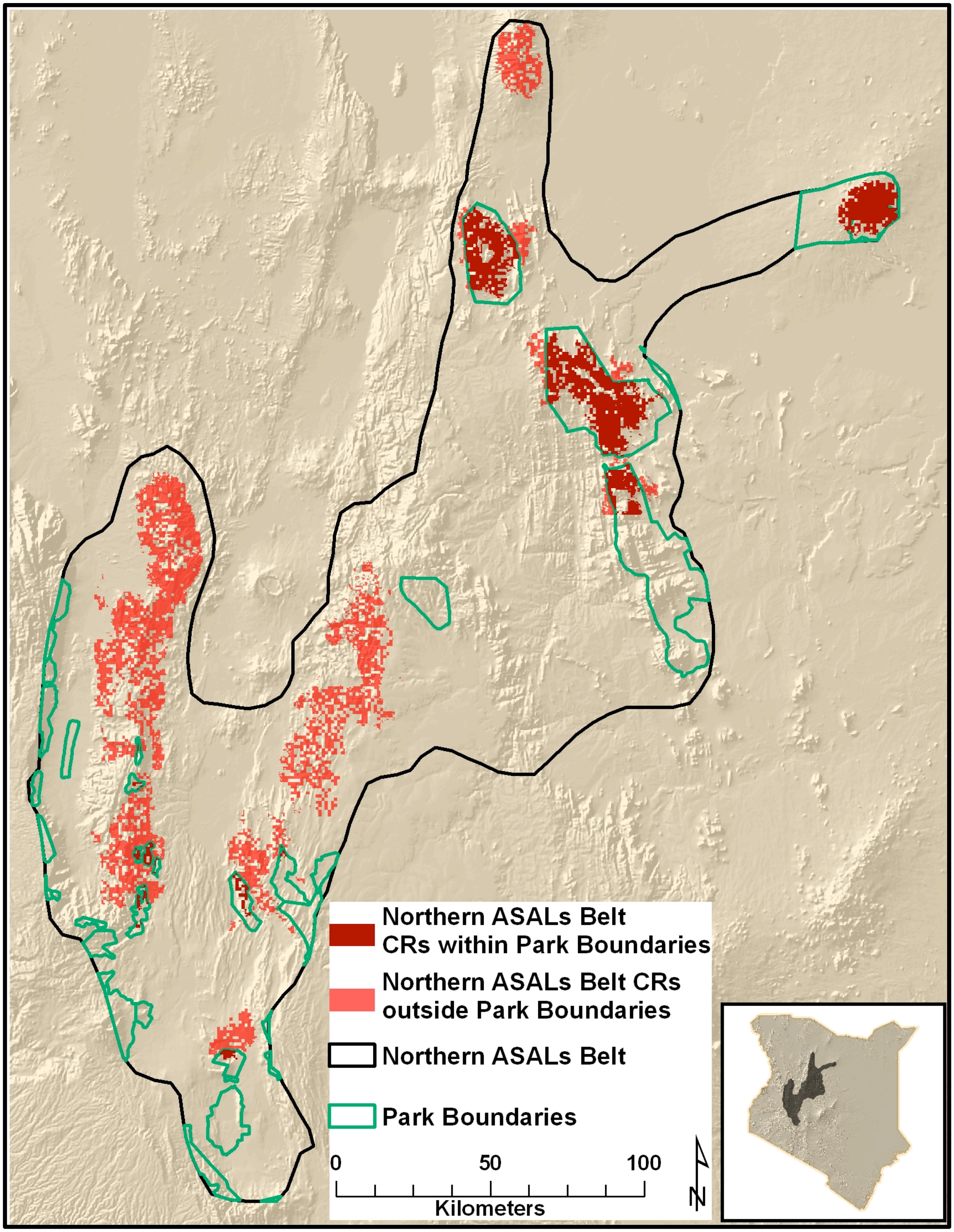


Figure 5.2 *Park boundaries within the Northern ASALs Belt and tsetse distributions found within the park boundaries. Topography is additionally displayed.*

5.4 Prioritizing Control: Sustainable Agriculture and Rural Development

This study has repeated the idea that funding for tsetse management is limited. In fact, the study was motivated by a need to reduce the costs of tsetse management to make the best use of the limited financial resources available in tsetse-endemic areas. Also stemming from this limited financing is the need to prioritize which areas within a country would yield the greatest benefits from control. The analysis that follows is merely exploratory; it is being done to demonstrate that tsetse control will yield larger benefits in some areas compared to others. Because this is only an exploratory analysis, rather than using the CRs, I am simply using the *belt* administrative units to distinguish between control areas. Figure 5.3 displays the five tsetse fly belts along with information for crop agriculture and livestock density, both of which are important with regards to the concept of sustainable agriculture and rural development (SARD) (Mattioli et al. 2004). SARD emphasizes the need to evaluate control locations based on their potential for sustainable and improved agricultural production. By improving agricultural production, the rural development component is met as human well being increases. While SARD considers several aspects of sustainability and rural development, such as limited-exploitation of natural resources and involvement by local communities and national governments, only livestock and agricultural potential are considered here. This is based on the common principle that tsetse and trypanosomiasis constrain agricultural production (see Barrett 1997; Swallow 2000; Shaw 2004). Consideration of SARD when prioritizing control areas is consistent with Shaw (2003) and Shaw et al. (2007), which both discussed the importance of examining non-economic factors when identifying intervention areas.

Figure 5.3 shows that productive cropping and livestock practices are taking place in all five belts. However, it is clear that the potential for productive cropping is mostly limited to central and western Kenya, as these are areas that receive more regular rainfall. These areas are associated with more profitable agricultural practices, such as cash cropping and the keeping of dairy cattle (World Resources Institute et al. 2005). In the arid and semi-arid lands that make up the remainder of Kenya, pastoralism dominates livelihood approaches (World Resources Institute et al. 2005). Tsetse control in all areas is important, but Figure 5.3 shows that benefits in one area may be different from those in another. This in turn implies that the benefits of tsetse control may be directed at, for example, pastoralists if control operations take place in remote arid areas, but sedentary farmers may receive the benefits of fly control if operations take place in the more productive central and western portions of the country.

SARD and prioritizing tsetse control areas clearly brings up a host of issues that must be considered when conducting a tsetse management campaign. Amongst these is how to value the benefits of fly control and what areas may be more in need of fly management. As stated above, the SARD and prioritization of control areas in this study were merely exploratory topics. Further analysis would need to be done to arrange the tsetse fly belts according to their benefit yield.

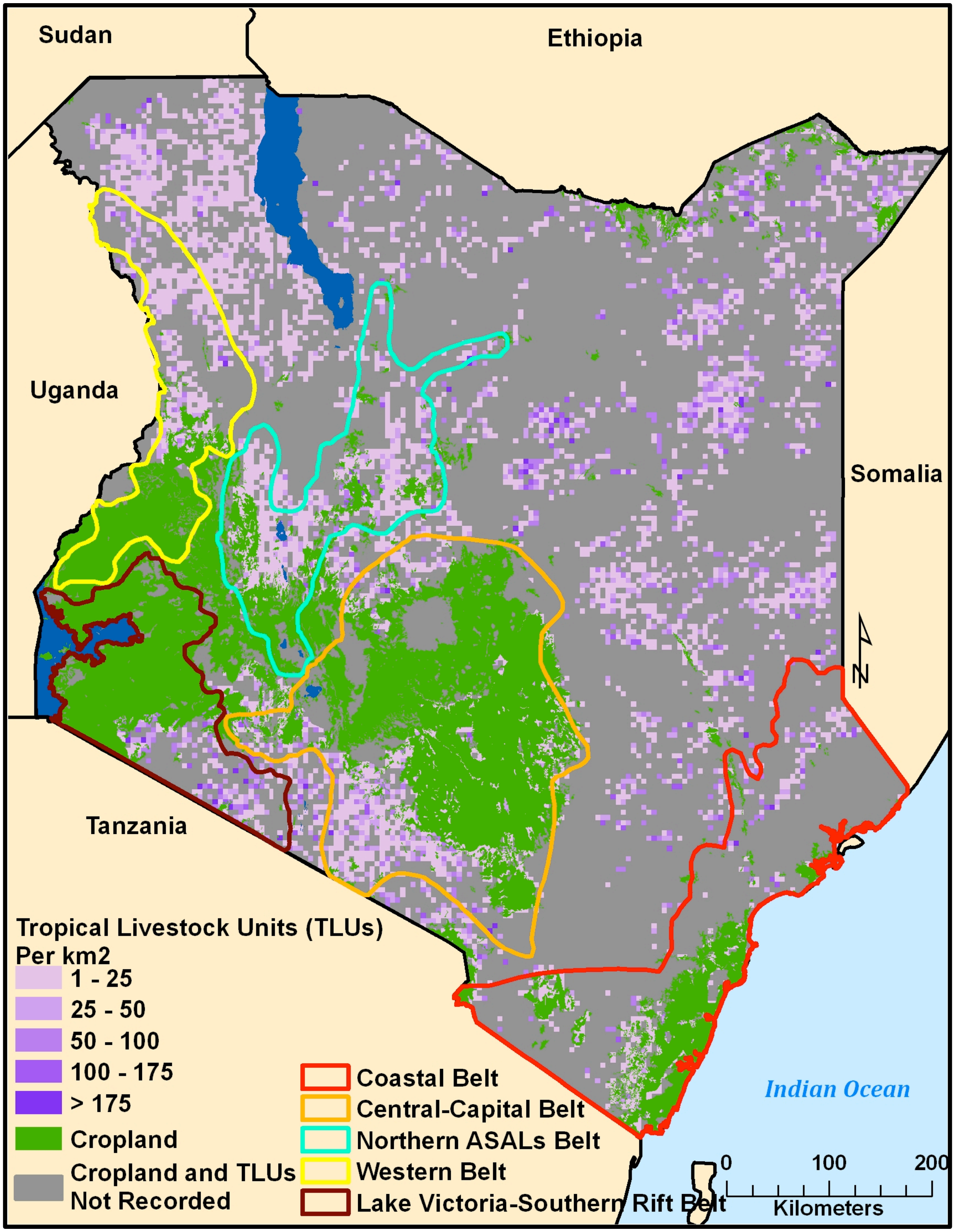


Figure 5.3 *Sustainable agriculture and rural development: Livestock keeping and crop production within the tsetse fly belts. Note: One TLU is equivalent to an animal weight of 250 kilograms. Livestock includes cattle, sheep, goats, camels, and donkeys.*

APPENDICES

Table A-1 *Inputs and costs used in all activities of management campaign*

Inputs	Input Life in Years	Total Cost (Annual Cost)	Activity	Inputs	Input Life in Years	Total Cost (Annual Cost)	Activity
General Equipment				*Specialized Eq. (Cont.)*			
4x4 Vehicle	5	$30,000 ($6,000)	ET, SS, SE, PS, EA, CF, EE, A, F	Dissecting Kit	8	$100 ($12.50)	ET, EE
Lorry	5	$30,000 ($6,000)	F	Sample Vial	1	$0.10 ($0.10)	ET, EE
Bicycle	8	$80 ($10)	SE, CF	Pipette	8	$200 ($25)	CF
Motorbike	8	$2,500 ($312.50)	ET, SE, PS, EE	Hematocrit Centrifuge	8	$200 ($25)	PS, CF
Laptop Computer	3	$3,000 ($1,000)	ET, SS, CF, EE, A	Bench Centrifuge	8	($1,000) ($125)	CF
Desktop Computer	5	$1,500 ($300)	A	PCV Reader	8	$20 ($2.50)	PS
Photo Copier	5	$3,000 ($600)	A	Cool Box	8	$60 ($7.50)	PS
Fax Machine	5	$300 ($60)	A	Consum. Parasit.	8	$5,000 ($625)	PS
Printer	5	$500 ($100)	ET, EE	Consum. Serology	8	$5,000 ($625)	PS
Office Furniture	8	$2,500 ($312.50)	A	ELISA Reader	8	$4,000 ($500)	PS
Portable Generator	5	$1,000 ($200)	ET, CF, EE	Glass Ware	8	$45,000 ($5,625)	CF
Radio Set	5	$500 ($100)	ET, EA, EE	Sampling Equipment	8	$1,100 ($137.50)	EA, EE
Camping Equipment	5	$400 ($80)	ET, EE, F				
Binoculars	8	$500 ($62.50)	EA, EE	*Recurring Specialized Equipment*			
Stationary	1	$124 ($124)	A, F	Tryp. Drugs	1	$6,500 ($6,500)	PS
Batteries	1	$20 ($20)	F	HAT Drugs	3	$25,000 ($8,333)	CF
Compass	5	$40 ($8)	EA, EE,	Training – Field Staff	1	$125 ($125)	F
Measuring Tape	3	$30 ($10)	EA, EE	Delta-methrin	1	$350 ($350)	F

Table A-1 (cont'd) *Inputs and costs used in all activities of management campaign*

				Octenol	1	$1.50 ($1.50)	F
Specialized Equipment				Acetone	1	$3.50 ($3.50)	F
Target	1	$8 ($8)	F	Fuel/Maint. Vehicles	1	$32/day	ET, SS, SE, PS, EA, CF, EE, F
Trap	1	$8 ($8)	ET, EE				
Satellite Imagery	8	$700 (87.50)	ET, EA, EE	*Staff Salaries*			
Land Use / Veg. Map	8	$20,000 ($2,500)	ET	Team Leader	1	Varies[a]	ET, SS, SE, PS, EA, CF, EE, F
GPS Unit	3	$30 ($10)	ET, SS, EA, CF, EE, F	Entomolog-ical Ass't.	1	$25/day	ET, EE, F
Dissection Microscope	8	$1,000 ($125)	ET, CF, EE	Laborer	1	$5/day	F
Compound Microscope	8	$2,000 ($250)	ET, EE	Driver	1	$17/day	ET, SS, PS, CF, EE, F, A
GIS Processing	1	$1,000 ($1,000)	EA, EE	Local Support	1	$1/day	ET

Notes: Control campaign activities –
ET – Entomological Survey and Tsetse Fly Population Genetics Survey. Includes trapping and sampling of flies and studying their genetics to assist in carrying out control operations. This survey also includes updating and identifying fly distributions.
SE – Socioeconomic Survey. A survey to understand the socioeconomic status of households within tsetse areas before control operations. This information is to be used to assess the effect of fly removal in improving human livelihoods.
SS – Sleeping Sickness Survey. A survey to identify areas at risk of sleeping sickness.
PS – Parasitological and Serological Data Collection. Includes taking record of African animal trypanosomiasis cases to identify areas where livestock are most at risk and where intervention efforts should be targeted.
EA – Environmental Impact Assessment. Study undertaken to identify key biotic and abiotic parameters to assist in monitoring the environmental impacts of fly control operations.
CF – Sleeping Sickness Active Case Finding. Surveillance of areas where sleeping sickness is known to be endemic, and treatment of diagnosed cases. This operation is carried out during the entire duration of the field control efforts.

Table A-1 (cont'd) *Inputs and costs used in all activities of management campaign*

EE – Environmental and Entomological Monitoring. Surveillance of key environmental and entomological parameters in order to assess the effects of fly control operations. Monitoring is conducted during the entire duration of the field control efforts.
A – Administration and Office Support. Includes equipment, personnel, and attendance at meetings necessary to maintain a central tsetse management office.
F – Field Control. Includes setting up targets, baiting with odors, spraying with insecticides as well as the retreating and replacement of targets during fly control.

[a] *"Team Leader" varies in cost depending on the control activity since responsibilities vary across activities. Team leaders include general team leaders ($30/day), biochemists ($30/day), medical officers ($30/day), veterinary officers ($30/day), consultants/ecologists ($130/day), and socio-economists ($130/day).*

Figure A-1 *Worksheets for tsetse management campaign conducted in the control reservoirs*

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Administration and Office Support

Shared	Cost ($)	
Desktop Computers		
Full		300
Full	500 (over 3 yrs)	
Photo Copiers		
Full		600
Full	1000 (over 3 yrs)	
Office Furniture		
Full		312.5
Fax Machines		
Full		60
Full	100 (over 3 yrs)	
Laptops		
Full		1000
Full	1500 (over 2 yrs)	
Stationary		
Full		240
4x4 Vehicles		
Full		6000
Full	10000 (over 3 yrs)	
Coordinating Office Meetings		
		960
Technical Committee Meetings		
		828

Shared	Cost($)
One EO Meeting for Coord. Office	
	240
Animal Resources Meeting	
	540
OAU/ISCTRC Meetings	
	270
45 Air Travel Tickets	
	2250
Service and Mgmt of Office Equip.	
	200
Utilities, Elec., Water, Phones, Email	
	2500
Chairman	
	900
Director Animal Resources	
	900
Director	
	900
Deputy Director	
	900
Commissioner Livestock Health/Ent	
	900

__Figure A-1 (cont'd)__ Worksheets for tsetse management campaign conducted in the control reservoirs

Shared	Cost($)			
One EO Meeting for Tech. Comm.				
	138			
Accountant				
	9000			
National Project Coordinator				
	900			
Accountant				
	9000			
Internal Auditor				
	9000			
GIS/Data Manager				
	9000			
Stenographer Secretary				
	6120			
Driver				
	6120			
Accountants Assistant				
	6120			
Per Diem for Sr. Level Officials				
	3000			
Per Diem for Jr. Level Officials				
	1200			

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Administration and Office Support	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Desktop Computers	3 F	3 F	3 F	3 F	3 F	3 F (over3yrs)	3 F (over3yrs)	3 F (over3yrs)
Photo Copiers	2 F	2 F	2 F	2 F	2 F	2 F (over3yrs)	2 F (over3yrs)	2 F (over3yrs)
Office Furniture	2 F	2 F	2 F	2 F	2 F	2 F	2 F	2 F
Fax Machines	2 F	2 F	2 F	2 F	2 F	2 F (over3yrs)	2 F (over3yrs)	2 F (over3yrs)
Laptops	3 F	3 F	3 F	3 F	3 F	3 F	3 F (over2yrs)	3 F (over 2yrs
Stationary	1 F	1 F	1 F	1 F	1 F	1 F	1 F	1 F
4x4 Vehicles	2 F	2 F	2 F	2 F	2 F	2 F (over3yrs)	2 F (over3yrs)	2 F (over3yrs)
Coordinating Office Meetings	1 F	1F	1F	1F	1F	1F	1F	1F
Technical Committee Meetings	1F	1F	1F	1F	1F	1F	1F	1F
One extra-ordinary meeting for Technical C	1F	1F	1F	1F	1F	1F	1F	1F
One extra-ordinary meeting for Coordinatin	1F	1F	1F	1F	1F	1F	1F	1F
Animal Resources	1F	1F	1F	1F	1F	1F	1F	1F
OAU/ISCTRC Meetings	1F	1F	1F	1F	1F	1F	1F	1F
45 Air Travel Tickets	1F	1F	1F	1F	1F	1F	1F	1F
Service and Management of Office Equipme	1F	1F	1F	1F	1F	1F	1F	1F
Utilites, Electricity, Water, Phones, Email	1F	1F	1F	1F	1F	1F	1F	1F
Chairman	1F	1F	1F	1F	1F	1F	1F	1F
Director Animal Resources	1F	1F	1F	1F	1F	1F	1F	1F
Director	1F	1F	1F	1F	1F	1F	1F	1F
Deputy Director	1F	1F	1F	1F	1F	1F	1F	1F
Commissioner Livestock Health and Entomo	1F	1F	1F	1F	1F	1F	1F	1F
National Project Coordinator	1F	1F	1F	1F	1F	1F	1F	1F
Accountant	1F	1F	1F	1F	1F	1F	1F	1F
Internal Auditor	1F	1F	1F	1F	1F	1F	1F	1F
GIS/Data Manager	1F	1F	1F	1F	1F	1F	1F	1F
Stenographer Secretary	1F	1F	1F	1F	1F	1F	1F	1F
Accounts Assistant	1F	1F	1F	1F	1F	1F	1F	1F
Driver	1F	1F	1F	1F	1F	1F	1F	1F
Per Diem for Sr. Level Officials	1F	1F	1F	1F	1F	1F	1F	1F
Per Diem for Jr. Level Officials	1F	1F	1F	1F	1F	1F	1F	1F

Figure A-1 (cont'd) Worksheets for tsetse management campaign conducted in the control reservoirs

Desktop Computers	900	900	900	900	900	1500	1500	1500
Photo Copiers	1200	1200	1200	1200	1200	2000	2000	2000
Office Furniture	625	625	625	625	625	625	625	625
Fax Machines	120	120	120	120	120	200	200	200
Laptops	3000	3000	3000	3000	3000	3000	4500	4500
Stationary	240	240	240	240	240	240	240	240
4x4 Vehicles	12000	12000	12000	12000	12000	20000	20000	20000
Coordinating Office Meetings	960	960	960	960	960	960	960	960
Technical Committee Meetings	828	828	828	828	828	828	828	828
One extra-ordinary meeting for Technical C	138	138	138	138	138	138	138	138
One extra-ordinary meeting for Coordinatin	240	240	240	240	240	240	240	240
Animal Resources	540	540	540	540	540	540	540	540
OAU/ISCTRC Meetings	270	270	270	270	270	270	270	270
45 Air Travel Tickets	2250	2250	2250	2250	2250	2250	2250	2250
Service and Management of Office Equipme	200	200	200	200	200	200	200	200
Utilites, Electricity, Water, Phones, Email	2500	2500	2500	2500	2500	2500	2500	2500
Chairman	900	900	900	900	900	900	900	900
Director Animal Resources	900	900	900	900	900	900	900	900
Director	900	900	900	900	900	900	900	900
Deputy Director	900	900	900	900	900	900	900	900
Commissioner Livestock Health and Entomo	900	900	900	900	900	900	900	900
National Project Coordinator	900	900	900	900	900	900	900	900
Accountant	9000	9000	9000	9000	9000	9000	9000	9000
Internal Auditor	9000	9000	9000	9000	9000	9000	9000	9000
GIS/Data Manager	9000	9000	9000	9000	9000	9000	9000	9000
Stenographer Secretary	6120	6120	6120	6120	6120	6120	6120	6120
Accounts Assistant	6120	6120	6120	6120	6120	6120	6120	6120
Driver	6120	6120	6120	6120	6120	6120	6120	6120
Per Diem for Sr. Level Officials	3000	3000	3000	3000	3000	3000	3000	3000
Per Diem for Jr. Level Officials	1200	1200	1200	1200	1200	1200	1200	1200
Total	80971	80971	80971	80971	80971	90451	91951	91951
10%Discount	**97975**	**89068**	**80971**	**73603**	**66882**	**67928.701**	**62802.533**	**57101.571**
								596331.5

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Entomological Survey / Tsetse Fly Population Genetics Survey			
Shared	Cost ($)	Shared	Cost($)
Satellite Imagery		**Portable Generators**	
Full	87.5	Full	200
Half	43.75	Half	100
Quarter	21.875	Quarter	50
Land Use Map		**Camping Equipment**	
Full	2500	Full	80
GPS Units		Half	40
Full	10	Quarter	20
Half	5	**Sample Vials**	
Quarter	2.5	Full	0.1
Dissection Microscope		**Printers**	
Full	125	Full	100
Half	62.5	Half	50
Quarter	31.25	Quarter	25
Compound Microscope		**Laptop Computers**	
Full	250	Full	1000
Half	125	Half	500
Quarter	62.5	Quarter	250
Dissecting Kits		**Radio Sets**	
Full	13.75	Full	100
Half	6.875	Half	50
Quarter	3.44	Quarter	25

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Shared	Cost($)
4x4 Vehicles	
Full	6000
Half	3000
Quarter	1500
Eigth	750
Motorbikes	
Full	312.5
Half	156.25
Quarter	78.13
Eigth	39
Traps	
Full	8
Team Leader (ES)	
	4800
Entomological Assistant (ES)	
	4000
Driver (ES)	
	2720
Comm. Support (ES)	
	51
Fuel and Maint. - 4x4 (ES)	
	5120
Fuel and Maint. - M'bikes (ES)	
	2240

Shared	Cost($)
Team Leader (TPGS)	
	4800
Entomological Assistant (TPGS)	
	4000
Driver (TPGS)	
	2720
Comm. Support (TPGS)	
	51
Biochemist (TPGS)	
	4800
Lab Technician (TPGS)	
	4000
Fuel and Maint. - 4x4 (TPGS)	
	5120

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Entom. Survey/Tsetse Pop. Genetics Survey								
Traps	4156F							
Satellite Imagery	4 - Full	4 Half	4 Q	4 Q	4 Q	4Q	4Q	4Q
Land Use / veg Map	1 - Full	1 Full	1 Full	1 Full	1 Full	1 Full	1 Full	1 Full
GPS Units	40 - Full	16 F, 24 H	36 H, 4 Q					
Dissection microscopes	20 - Full	20 Full	8 H, 12 Q	8 H, 12 Q	8 H, 12 Q	8 H, 12 Q	8H, 12Q	8H, 12Q
Compound microscopes	20 - Full	20 Full	20H	20 H	20H	20H	20H	20H
Dissecting kits	40 - Full	40 Full	40 H	40H	40H	40H	40H	40H
Portable generators	20 - Full	20 Full	8 H, 12 Q	8 H, 12 Q	8 H, 12Q			
Camping equipment	20 - Full	20 Full	20 Half	20 Half	20 H			
Sample vials	4156 - Full							
Printers	20 - Full	20 Full	20 H	20 H	20H			
Laptop computers	20 - Full	16 Full, 4	20 Q					
Radio sets	20 - Full	12 Full, 8	12 H, 8 Q	12 H, 8 Q	12 H, 8 Q			
4x4 Vehicles	20 - Full, 4 -	16 H, 8Q	2Q, 22E	2Q, 22E	2 Q, 22E			
Motorbikes	24 - Full 16 -	32 H, 8 Q	32 Q, 8 E	32 Q, 8 E	32 Q, 8 E	32Q, 8 E	32 Q, 8 E	32Q, 8E
Team Leader (ES)	20F							
Entomological Assistant (ES)	60F							
Driver (ES)	20F							
Fuel and Maintenance for 4x4 Ve	20F							
Fuel and Maintenance for Motorb	20F							
Community Support (ES)	120F							
Team Leader (TPGS)	4F							
Entomological Assistant (TPGS)	12F							
Driver (TPGS)	4F							
Community Support (TPGS)	12F							
Biochemist (TPGS)	4F							
Lab Technician (TPGS)	8F							
Fuel and Maintenance for 4x4 Ve	4F							

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Entom. Survey/Tsetse Pop. Genetics Survey (cont)								
Traps	33248							
Satellite Imagery	350	175	87.5	87.5	87.5	87.5	87.5	87.5
Land Use / veg Map	2500	2500	2500	2500	2500	2500	2500	2500
GPS Units	400	280	190					
Dissection microscopes	2500	2500	875	875	875	875	875	875
Compound microscopes	5000	5000	2500	2500	2500	2500	2500	2500
Dissecting kits	550	550	275	275	275	275	275	275
Portable generators	4000	4000	1400	1400	1400			
Camping equipment	1600	1600	800	800	800			
Sample vials	415.6							
Printers	2000	2000	1000	1000	1000			
Laptop computers	20000	18000	5000					
Radio sets	2000	1600	800	800	800			
4x4 Vehicles	132000	60000	19500	19500	19500			
Motorbikes	10000	5625	2812.5	2812.5	2812.5	2812.5	2812.5	2812.5
Team Leader (ES)	96000							
Entomological Assistant (ES)	240000							
Driver (ES)	54400							
Fuel and Maintenance for 4x4 Ve	102400							
Fuel and Maintenance for Motorb	44800							
Community Support (ES)	6120							
Team Leader (TPGS)	19200							
Entomological Assistant (TPGS)	48000							
Driver (TPGS)	10880							
Community Support (TPGS)	612							
Biochemist (TPGS)	19200							
Lab Technician (TPGS)	32000							
Fuel and Maintenance for 4x4 Ve	20480							
Total	910655.6	103830	37740	32550	32550	9050	9050	9050
10%Discount	**1101893.3**	**114213**	**37740**	**29588**	**26886**	**6796.6**	**6181.2**	**5620.05**
10% Discount Total								**1328918.28**

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Socioeconomic Survey	
Shared	Cost($)
Bicycles	
Full	10
Half	5
Motorbikes	
Full	312.5
Half	156.25
Quarter	78.125
Eigth	39.06
4x4 Vehicles	
Full	6000
Half	3000
Quarter	1500
Eigth	750
Supervisors	
	1800
Socioeconomist	
	11700
Data-entry Clerks	
	1500
Fuel and Maint. -4x4	
	2560
Fuel and Maint. -M'bikes	
	1120

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Socioeconomic Survey								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Bicycles for Enumerators	332 - Full	332 Full	242 F, 90	242 F, 90	242 F, 90	242 F, 90	242 F, 90	242 F, 90 H
Motorbikes	16 - Half	8 H, 8 Q	8 Q, 8 E	8 Q, 8 E	8 Q, 8 E	8 Q, 8 E	8 Q, 8 E	8 Q, 8 E
4x4 Vehicles	4 - Half	4 Q	4Q	4 Q	4 Q			
Supervisors	16F							
Co-Coordinator (Socioecon	4F							
Data Entry Clerk	8F							
Fuel and Maintenance for 4	4F							
Fuel and Maintenance for M	16F							
Contingency (10% of above costs)								
Bicycles for Enumerators	3320	3320	2870	2870	2870	2870	2870	2870
Motorbikes	2500	1875	937.5	937.5	937.5	937.5	937.5	937.5
4x4 Vehicles	12000	6000	6000	6000	6000			
Supervisors	28800							
Co-Coordinator (Socioecon	46800							
Data Entry Clerk	12000							
Fuel and Maintenance for 4	10240							
Fuel and Maintenance for M	17920							
Contingency (10% of above	13358	1119.5	980.75	980.75	980.75	380.75	380.75	380.75
Total	146938	12314.5	10788.3	10788.3	10788.3	4188.25	4188.25	4188.25
10%Discount	**177795**	**13546**	**10788**	**9806.5**	**8911.1**	**3145.4**	**2860.6**	**2600.9**
10% Discount Total								**229454**

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Sleeping Sickness Survey				
Shared	Cost ($)			
4x4 Vehicles				
Quarter	1500			
GPS Sets				
Full	10			
Half	5			
Quarter	2.5			
Laptops				
Full	1000			
Half	500			
Quarter	250			
Medical Officers				
	1800			
Driver				
	1020			
Fuel and Maint. -4x4				
	1920			
Per Diem for Med Officer				
	600			

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Sleeping Sickness Survey	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
4x4 Vehicles		4 Q	4Q	4 Q	4 Q			
GPS Sets		16 - Half	12 H, 4 Q					
Laptops		4 - Half	4 H					
Medical Officers		16F						
Driver		4F						
Fuel and Maintenance for 4x4 Vehicle		4F						
Per Diem for Med Officer		16F						
4x4 Vehicles		6000	6000	6000	6000			
GPS Sets		80	70					
Laptops		2000	2000					
Medical Officers		28800						
Driver		4080						
Fuel and Maintenance for 4x4 Vehicle		7680						
Per Diem for Med Officer		9600						
Total	0	58240	8070	6000	6000	0	0	0
10%Discount	**0**	**64064**	**8070**	**5454**	**4956**	**0**	**0**	**0**
10% Discount Total								**82544**

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Parasitological and Serological Data Collection				
Shared	Cost ($)		Shared	Cost ($)
Haematocrit Centrifuge			**Team Leader**	
Full	25			4800
Half	12.5		**Lab. Technician**	
PCV Reader				4000
Full	2.5		**Driver**	
Cool Boxes				2720
Full	7.5		**Lab. Assistant**	
Consumables Parasitology				2720
Full	625		**Veterinary Officer**	
Consumables Serology				4800
Full	625		**Fuel and Maintenance - 4x4**	
ELISA Reader				5120
Full	500		**Fuel and Maintenance - M'bike**	
Computer ELISA Work				2240
Full	375		**Per Diem - Tm Leader/Vet Officer**	
Trypanocidal Drugs				1600
Full	6500			
4x4 Vehicles				
Half	3000			
Motorbikes				
Half	156.25			
Quarter	78.125			

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Parasitological and Serological Data Collection								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
PS Data Collection								
Haematocrit Centrifuge		16 Full	4 F, 12 H	4 F, 12 H	4 F, 12 H	4 F, 12 H	4 F, 12 H	4 F, 12 H
PCV Reader		16 Full	16 Full	16 Full	16 Full	16 Full	16 Full	16 Full
Cool Boxes		32 Full	32 Full	32 Full	32 Full	32 Full	32 Full	32 Full
Consumables Parasitology		4 Full	4 Full	4 Full	4 Full	4 Full	4 Full	4 Full
Consumables Serology		4 Full	4 Full	4 Full	4 Full	4 Full	4 Full	4 Full
ELISA Reader		4 Full	4 Full	4 Full	4 Full	4 Full	4 Full	4 Full
Computer ELISA Work		4 Full	4 Full	4 Full	4 Full	4 Full	4 Full	4 Full
Trypanocidal Drugs		4 Full						4 Full
4x4 Vehicles		16 H	16H	16H	16H			
Motorbikes		32 H	32 Q	32 Q	32 Q	32 Q	32 Q	32 Q
Team Leader		16F						16F
Laboratory Technicians		32F						32F
Driver		16F						16F
Laboratory Assistants		16F						16F
Veterinary Officer		16F						16F
Fuel and Maintenance for 4x4 Vehicle		16F						16F
Fuel and Maintenance for Motorbike		32F						32F
Per Diem for Team Leader and Vet Offic		32F						32F
Contingency (10% of above)								

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Parasitological and Serological Data Collection (cont.)								
Haematocrit Centrifuge		400	250	250	250	250	250	250
PCV Reader		40	40	40	40	40	40	40
Cool Boxes		240	240	240	240	240	240	240
Consumables Parasitology		2500	2500	2500	2500	2500	2500	2500
Consumables Serology		2500	2500	2500	2500	2500	2500	2500
ELISA Reader		2000	2000	2000	2000	2000	2000	2000
Computer ELISA Work		1500	1500	1500	1500	1500	1500	1500
Trypanocidal Drugs		26000						26000
4x4 Vehicles		48000	48000	48000	48000			
Motorbikes		5000	2500	2500	2500	2500	2500	2500
Team Leader		76800						76800
Laboratory Technicians		128000						128000
Driver		43520						43520
Laboratory Assistants		43520						43520
Veterinary Officer		76800						76800
Fuel and Maintenance for 4x4 Vehicle		81920						81920
Fuel and Maintenance for Motorbike		71680						71680
Per Diem for Team Leader and Vet Offic		51200						51200
Contingency (10% of above)		66162	5953	5953	5953	1153	1153	57594
Totall		727782	65483	65483	65483	12683	12683	668564
10%Discount		**800560**	**65483**	**59524**	**54089**	**9524.9**	**8662.5**	**415178.244**
Total 10% Discount								**1413021.871**

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental Impact Assessment				
Shared	Cost ($)		Shared	Cost ($)
Satellite Imagery			**Radio Sets**	
Half	43.75		Half	20
Quarter	21.875		Quarter	10
GIS Processing			**Consultants**	
Full	1000			10400
4x4 Vehicles			**Assistant**	
Half	3000			2000
GPS Units			**Driver**	
Half	5			1020
Compass			**Fuel and Maint. -4x4**	
Full	8			1920
Half	4			
Measuring Tape				
Full	10			
Half	5			
Sampling Equipment				
Full	137.5			
Half	68.75			
Binoculars				
Full	62.5			
Half	31.25			

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental Impact Assessment								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Env. Impact Assessment								
Satellite Imagery		4 Half	4 Q	4Q	4Q	4Q	4Q	4Q
GIS Processing		4 Full						
4x4 Vehicles		8 H	8H	8H	8H			
GPS Units		8 H	8 H					
Compass		16 Full	8 F, 8 H	8 F, 8 H	8 F, 8 H	8 F, 8 H		
Measuring Tape		16 Full	8 F, 8 H	8 F, 8 H				
Sampling Equipment		4 Full	4 H	4 H	4 H	4 H	4 H	4 H
Binoculars		16 Full	8 F, 8 H	8 F, 8 H	8 F, 8 H	8 F, 8 H	8 F, 8 H	8 F, 8 H
Radio Sets		8 H	8 Q	8 Q	8 Q			
Consultants		8F						
Assistant		16F						
Driver		8F						
Fuel and Maintenance for 4x4 Vehicl		8F						
Contingency (10% of above)								

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental Impact Assessment (cont.)							
Satellite Imagery	218.75	87.5	87.5	87.5	87.5	87.5	87.5
GIS Processing	4000						
4x4 Vehicles	24000	24000	24000	24000			
GPS Units	40	40					
Compass	128	96	96	96	96		
Measuring Tape	160	120	120				
Sampling Equipment	550	275	275	275	275	275	275
Binoculars	1000	750	750	750	750	750	750
Radio Sets	160	80	80	80			
Consultants	83200						
Assistant	32000						
Driver	8160						
Fuel and Maintenance for 4x4 Vehicl	15360						
Contingency (10% of above)	16897.7	2544.85	2540.85	2528.85	120.85	111.25	111.25
Total	185874	27993.4	27949.4	27817.4	1329.35	1223.75	1223.75
10%Discount	**204462**	**27993**	**25406**	**22977**	**998.34**	**835.82**	**759.95**
10% Discount Total							**283432**

Figure A-1 (cont'd) Worksheets for tsetse management campaign conducted in the control reservoirs

Sleeping Sickness Active Case Finding					
Shared	Cost ($)			Shared	Cost($)
Bicycle				**Lab Reagents**	
Half	5			Full	5625
4x4 Vehicles				**Drugs**	
Half	5000 (over 3 years)			Full	8333.33
Quarter	1500			**Safari Allowance**	
Dissection Microscopes					185
Quarter	62.5			**Medical Officers**	
Haematocrit Centrifuges					2250
Half	12.5			**Driver**	
Portable Generators					1275
Half	166.67 (over 3 years)			**Fuel and Maintenance -4x4**	
Quarter	50				2400
Bench Centrifuges					
Full	125				
GPS Sets					
Full	10				
Half	5				
Half	7.5 (over 2 years)				
Laptops					
Half	500				
Half	750 (over 2 years)				
Pipettes					
Full	25				

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Sleeping Sickness Active Case Finding								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Sleeping Sickness ACF								
Bicycle			90 Half	90 Half	90 Half	90 Half	90 Half	90 Half
4x4 Vehicles			3 Q	3Q	3Q	**3H(over3y**	**3H(over3yr**	**3H(over3yr)**
Dissection Microscopes			12Q	12Q	12Q	12Q	12Q	12Q
Haematocrit Centrifuges			12 H	12H	12H	12H	12H	12H
Portable Generators			12 Q	12 Q	12 Q	12H (over3	12H(over3yr	12H(over3yr)
Bench Centrifuge			12 Full	12 F	12 F	12 F	12 F	12 F
GPS Sets			12 H	4 F, 8 H	4 F, 8 H	4F, 8H	4F, 8H(over	4F, 8H(over2)
Laptops			6 H	6H	6H	6H	6H (over2yrs	6H (over2yrs)
Pipettes			12 Full	12 F	12 F	12 F	12 F	12 F
Laboratory reagents (Glass Ware)			1 Full	1 F	1 F	1 F	1 F	1 F
Drugs (Mel-B, Suramin, Pentamidine)			3 Full	3 F	3F	3F	3F	3F
Safari Day Allowances			24F	24F	24F	24F	24F	
Medical Officers			12F	12F	12F	12F	12F	
Driver			3F	3F	3F	3F	3F	
Fuel and Maintenance for 4x4 Vehicle			3F	3F	3F	3F	3F	

Figure A-1 (cont'd) Worksheets for tsetse management campaign conducted in the control reservoirs

Sleeping Sickness Active Case Finding (cont)							
Bicycle		450	450	450	450	450	450
4x4 Vehicles		4500	4500	4500	15000	15000	15000
Dissection Microscopes		750	750	750	750	750	750
Haematocrit Centrifuges		150	150	150	150	150	150
Portable Generators		600	600	600	2000	2000	2000
Bench Centrifuge		1500	1500	1500	1500	1500	1500
GPS Sets		60	80	80	80	100	100
Laptops		3000	3000	3000	3000	4500	4500
Pipettes		300	300	300	300	300	300
Laboratory reagents (Glass Ware)		5625	5625	5625	5625	5625	5625
Drugs (Mel-B, Suramin, Pentamidine)		25000	25000	25000	25000	25000	25000
Safari Day Allowances		4440	4440	4440	4440	4440	
Medical Officers		27000	27000	27000	27000	27000	
Driver		3825	3825	3825	3825	3825	
Fuel and Maintenance for 4x4 Vehicle		7200	7200	7200	7200	7200	
Total		84400	84420	84420	96320	97840	55375
10%Discount		**84400**	**76738**	**69731**	**72336.3**	**66824.72**	**34387.88**
10% Discount Total							**404417.6**

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental and Entomological Monitoring

Shared	Cost ($)		Shared	Cost ($)
Pyramidal Traps			**Printers**	
Full	8		Full	167 (over 3 years)
Dissection Microscopes			Half	50
Half	62.5		**Radio Sets**	
Compound Microscopes			Full	100
Half	125		Half	50
Dissecting Kits			**4x4 Vehicles**	
Half	6.25		Full	6000
Portable Generator			Half	5000 (over 2 years)
Full	200		Quarter	1500
Half	100		**Motorbikes**	
Half	167 (over 3 years)		Half	156.25
Camping Equipment			**Satellite Imagery**	
Full	133 (over 3 years)		Half	43.75
Half	80		**GIS Processing**	
Sample Vials			Full	1000
Full	0.1		**GPS Units**	
Laptop Computers			Half	5
Full	1000		Half	7.5 (over 2 years)
Half	500		**Compass**	
Half	750 (over 2 years)		Half	8

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Shared	Cost ($)		
Measuring Tape			
Full	10		
Half	5		
Sampling Materials / Equip.			
Half	68.75		
Binoculars			
Half	31.25		
Team Leader (Entomological Mon.)			
	2700		
Entomological Assistant (Entom. Mon.)			
	2250		
Driver (Entomological Mon.)			
	1530		
Fuel/Maintenance -4x4 (Entom. Mon.)			
	2880		
Fuel/Maintenance -M'bikes (Entom. Mon.)			
	1260		
Consultants/Ecologist (Environ. Mon.)			
	5200		
Assistant (Environ. Mon.)			
	1000		
Driver (Environ. Mon.)			
	510		

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental and Entomological Monitoring								
Env and Entomological Monitorin	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Pyramidal Traps			4156F	4156F	4156F	4156F	4156F	
Dissection Microscopes			20H	20 H	20H	20H	20H	20H
Compund Microscopes			20H	20H	20H	20H	20H	20H
Dissecting Kits			40 H	40H	40H	40H	40H	40H
Portable Generator			20 H	20H	20H	8F, 12H (over :	8F, 12H (over :	8F,12H(over3)
Camping Equipment			20 Half	20 H	20H	20F (over3yr)	20F(over3yr)	20F(over3yrs)
Sample Vials			4156 Full	4156F	4156F	4156F	4156F	
Laptop Computers			20 H	14F, 6H	14F, 6H	14F, 6H	14F, 6H (over2	14F, 6H(over2)
Printers			20 H	20H	20H	20F(over3yrs)	20F(over3yrs)	20F(over3yrs)
Radio Sets			8 F, 20 H	8 F, 20 H	8 F, 20 H	**8F**	**8F**	
4x4 Vehicles			4 F, 24 Q	4F, 24Q	4F, 24Q	**1F, 3H (over3**	**1F, 3H (over3**	**1F, 3H(over3**
Motorbikes			40H	40H	40H	40H	40H	40H
Satellite Imagery			4 H	4H	4H	4H	4H	4H
GIS Processing			4F	4F	4F	4F	4F	
GPS Units			8 H	8 H	8H	8H	8H (over 2yrs)	8 H (over2yrs)
Compass			8 H	8H	8H	8H	**8H**	**8H**
Measuring Tape			8 H	8H	8F	8F	8F	
Sampling Equipment and Materials			4 H	4H	4H	4H	4H	4H
Binoculars			8 H	8H	8H	8H	8H	8H
Team Leader (Ent Monitoring)			20F	20F	20F	20F	20F	
Entomological Assistant (Ent Mon)			40F	40F	40F	40F	40F	
Driver (Ent Mon)			20F	20F	20F	20F	20F	
Fuel and Maint. - 4x4 Vehicles (Ent Mon)			20F	20F	20F	20F	20F	
Fuel and Maint. - Motorbikes (Ent Mon)			40F	40F	40F	40F	40F	
Consultants/Ecologists (Env Mon)			8F	8F	8F	8F	8F	
Assistant (Env Mon)			16F	16F	16F	16F	16F	
Driver (Env Mon)			8F	8F	8F	8F	8F	

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Environmental and Entomological Monitoring (cont)						
Pyramidal Traps	33248	33248	33248	33248	33248	
Dissection Microscopes	1250	1250	1250	1250	1250	1250
Compund Microscopes	2500	2500	2500	2500	2500	2500
Dissecting Kits	250	250	250	250	250	250
Portable Generator	2000	2000	2000	3604	3604	3604
Camping Equipment	1600	1600	1600	2660	2660	2660
Sample Vials	415.6	415.6	415.6	415.6	415.6	
Laptop Computers	10000	17000	17000	17000	18500	18500
Printers	1000	1000	1000	3340	3340	3340
Radio Sets	1800	1800	1800	800	800	
4x4 Vehicles	60000	60000	60000	21000	21000	21000
Motorbikes	6250	6250	6250	6250	6250	6250
Satellite Imagery	175	175	175	175	175	175
GIS Processing	4000	4000	4000	4000	4000	
GPS Units	40	40	40	40	60	60
Compass	64	64	64	64	64	64
Measuring Tape	40	40	80	80	80	
Sampling Equipment and Materials	275	275	275	275	275	275
Binoculars	250	250	250	250	250	250
Team Leader (Ent Monitoring)	54000	54000	54000	54000	54000	
Entomological Assistant (Ent Mon)	90000	90000	90000	90000	90000	
Driver (Ent Mon)	30600	30600	30600	30600	30600	
Fuel and Maint. - 4x4 Vehicles (Ent Mon)	57600	57600	57600	57600	57600	
Fuel and Maint. - Motorbikes (Ent Mon)	50400	50400	50400	50400	50400	
Consultants/Ecologists (Env Mon)	41600	41600	41600	41600	41600	
Assistant (Env Mon)	16000	16000	16000	16000	16000	
Driver (Env Mon)	4080	4080	4080	4080	4080	
Total	469438	476438	476478	441481.6	443001.6	60178
10%Discount	**469438**	**433082**	**393570**	**331552.682**	**302570.093**	**37370.538**
10% Discount Total						**1967583.2**

Figure A-1 (cont'd) Worksheets for tsetse management campaign conducted in the control reservoirs

Field Control			
Shared	Cost ($)	Shared	Cost ($)
Targets		**Deltamethrin**	
Full	8	Full	350
GPS Sets		**Octenol**	
Full	10	Full	1.5
Full	15 (over 2 years)	**Acetone**	
Half	5	Full	3.5
4x4 Vehicles		**Fuel and Maintenance -4x4**	
Full	6000		10752
Half	3000	**Fuel and Maintenance -Lorry**	
Quarter	1500		10752
Lorries		**Team Leader**	
Full	6000		10080
Half	3000	**Entomological Assistant**	
Quarter	1500		8400
Camping Equipment		**Laborers**	
Full	80		1680
Half	40	**Drivers**	
Stationary			5712
Full	124	**Allowances for Team Leader**	
Batteries			5000
Full	20	**Allowances for Ent. Assistants/Driver**	
Training Course for Field Staff			3000
Full	125		

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Field Control								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Coastal Belt Field Inputs								
Targets			110936F					
GPS Sets			52F	34 F, 18 H	20 F, 32 H			
4x4 Vehicles			26F	17 F, 9 H	10 F, 16 H	5 F, 21 H	2 F, 24 H	
Lorries			26F	17 F, 9 H	10 F, 16 H	5 F, 21 H	2 F, 24 H	
Camping Equipment			208F	136 F, 72	80 F, 128H	40 F, 168	16 F, 192 H	
Stationary			26F					
Batteries			52F					
Training Course For Field Staff			52F					
Deltamethrin			848F					
Octenol			284448F					
Acetone			28446F					
Fuel and Maintenance for 4x4 Vehicles			26F					
Fuel and Maintenance for Lorry			26F					
Team Leader			26F					
Entomological Assistants			52F					
Laborers			208F					
Drivers			26F					
Allowances for Team Leader			26F					
Allowances for E As and Driver			78F					

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Coastal Belt Field Inputs (cont)								
Targets			887488					
GPS Sets			520	430	360			
4x4 Vehicles			156000	129000	108000	93000	84000	
Lorries			156000	129000	108000	93000	84000	
Camping Equipment			16640	13760	11520	9920	8960	
Stationary			3224					
Batteries			1040					
Training Course For Field Staff			6500					
Deltamethrin			296800					
Octenol			426672					
Acetone			99561					
Fuel and Maintenance for 4x4 Vehicles			279552					
Fuel and Maintenance for Lorry			279552					
Team Leader			262080					
Entomological Assistants			436800					
Laborers			349440					
Drivers			148512					
Allowances for Team Leader			130000					
Allowances for E As and Driver			234000					
Total	0	0	4170381	272190	227880	195920	176960	0
10%Discount	0	0	4170381	247421	188229	147136	120864	0
								4874030.19

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Central-Capital Belt Field Inputs								
Targets				39972F				
GPS Sets				18 H	18 H			
4x4 Vehicles				9 H	9 H	9 H	9 H	
Lorries				9 H	9 H	9 H	9 H	
Camping Equipment				72 H	72 H	72 H	72 H	
Stationary				9 F				
Batteries				18 F				
Training Course For Field Staff				18F				
Deltamethrin				306F				
Octenol				102492F				
Acetone				10249F				
Fuel and Maintenance for 4x4 Vehicles				9F				
Fuel and Maintenance for Lorry				9F				
Team Leader				9F				
Entomological Assistants				18F				
Laborers				72F				
Drivers				9F				
Allowances for Team Leader				9F				
Allowances for E As and Driver				27F				

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Central-Capital Belt Field Inputs (cont)								
Targets				319776				
GPS Sets				90	90			
4x4 Vehicles				27000	27000	27000	27000	
Lorries				27000	27000	27000	27000	
Camping Equipment				2880	2880	2880	2880	
Stationary				1116				
Batteries				360				
Training Course For Field Staff				2250				
Deltamethrin				107100				
Octenol				153738				
Acetone				35872				
Fuel and Maintenance for 4x4 Vehicles				96768				
Fuel and Maintenance for Lorry				96768				
Team Leader				90720				
Entomological Assistants				151200				
Laborers				120960				
Drivers				51408				
Allowances for Team Leader				45000				
Allowances for E As and Driver				81000				
Total	0	0	0	1411006	56970	56880	56880	0
10%Discount	0	0	0	1282604	47057.2	42716.9	38849	0
								1411227.59

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Northern ASALs Belt Field Inputs								
Targets					18172F			
GPS Sets					14 H			
4x4 Vehicles					7H	7 H	7H	
Lorries					7 H	7 H	7 H	
Camping Equipment					56 H	56 H	56 H	
Stationary					7F			
Batteries					14 F			
Training Course For Field Staff					14F			
Deltamethrin					140F			
Octenol					46596F			
Acetone					4660F			
Fuel and Maintenance for 4x4 Vehicles					7F			
Fuel and Maintenance for Lorry					7F			
Team Leader					7F			
Entomological Assistants					14F			
Laborers					56F			
Drivers					7F			
Allowances for Team Leader					7F			
Allowances for E As and Driver					21F			

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Northern ASALs Belt Field Inputs (cont)								
Targets					145376			
GPS Sets					70			
4x4 Vehicles					21000	21000	21000	
Lorries					21000	21000	21000	
Camping Equipment					2240	2240	2240	
Stationary					868			
Batteries					280			
Training Course For Field Staff					1750			
Deltamethrin					49000			
Octenol					69894			
Acetone					16310			
Fuel and Maintenance for 4x4 Vehicles					75264			
Fuel and Maintenance for Lorry					75264			
Team Leader					70560			
Entomological Assistants					117600			
Laborers					94080			
Drivers					39984			
Allowances for Team Leader					35000			
Allowances for E As and Driver					63000			
Total	0	0	0	0	898540	44240	44240	0
10%Discount	0	0	0	0	742194	33224.2	30215.9	0
								805634.2

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Western Belt Field Inputs								
Targets						13581F		
GPS Sets						10 F	4 F, 6 H	4 F, 6 H
4x4 Vehicles						5 H	5 H	
Lorries						5 H	5 H	
Camping Equipment						40 H	40 H	
Stationary						5 F		
Batteries						10 F		
Training Course For Field Staff						10F		
Deltamethrin						103F		
Octenol						34824F		
Acetone						3482F		
Fuel and Maintenance for 4x4 Vehicles						5F		
Fuel and Maintenance for Lorry						5F		
Team Leader						5F		
Entomological Assistants						10F		
Laborers						40F		
Drivers						5F		
Allowances for Team Leader						5F		
Allowances for E As and Driver						15F		

Figure A-1 (cont'd) *Worksheets for tsetse management campaign conducted in the control reservoirs*

Western Belt Field Inputs (cont)								
Targets						108648		
GPS Sets						100	70	70
4x4 Vehicles						15000	15000	
Lorries						15000	15000	
Camping Equipment						1600	1600	
Stationary						620		
Batteries						200		
Training Course For Field Staff						1250		
Deltamethrin						36050		
Octenol						52236		
Acetone						12187		
Fuel and Maintenance for 4x4 Vehicles						53760		
Fuel and Maintenance for Lorry						53760		
Team Leader						50400		
Entomological Assistants						84000		
Laborers						67200		
Drivers						28560		
Allowances for Team Leader						25000		
Allowances for E As and Driver						45000		
Total	0	0	0	0	0	650571	31670	70
10%Discount	0	0	0	0	0	488579	21630.6	43.47
								510252.901

Figure A-1 (cont'd) Worksheets for tsetse management campaign conducted in the control reservoirs

Lake Victoria-So. Rift Belt Field Inputs								
Targets							11850F	
GPS Sets							6 H	6 H
4x4 Vehicles							3 H	
Lorries							3 H	
Camping Equipment							24 H	
Stationary							3 F	
Batteries							6 F	
Training Course For Field Staff							6F	
Deltamethrin							91F	
Octenol							30384F	
Acetone							3038F	
Fuel and Maintenance for 4x4 Vehicles							3F	
Fuel and Maintenance for Lorry							3F	
Team Leader							3F	
Entomological Assistants							6F	
Laborers							24F	
Drivers							3F	
Allowances for Team Leader							3F	
Allowances for E As and Driver							9F	

__Figure A-1 (cont'd)__ Worksheets for tsetse management campaign conducted in the control reservoirs

Lake Victoria-So. Rift Belt Field Inputs (cont)								
Targets							94800	
GPS Sets							30	30
4x4 Vehicles							9000	
Lorries							9000	
Camping Equipment							960	
Stationary							372	
Batteries							120	
Training Course For Field Staff							750	
Deltamethrin							31850	
Octenol							45576	
Acetone							10633	
Fuel and Maintenance for 4x4 Vehicles							32256	
Fuel and Maintenance for Lorry							32256	
Team Leader							30240	
Entomological Assistants							50400	
Laborers							40320	
Drivers							17136	
Allowances for Team Leader							15000	
Allowances for E As and Driver							27000	
Total	0	0	0	0	0	0	447699	30
10%Discount	0	0	0	0	0	0	305778	18.63
								305797.047

Figure A-2 *Worksheets for tsetse management campaign conducted in the tsetse zones*

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Administration and Office Support				
Shared	Cost ($)		Shared	Cost($)
Desktop Computers			**One EO Meeting for Coord. Office**	
Full		300		240
Full	500 (over 3 yrs)		**Animal Resources Meeting**	
Photo Copiers				540
Full		600	**OAU/ISCTRC Meetings**	
Full	1000 (over 3 yrs)			270
Office Furniture			**45 Air Travel Tickets**	
Full		312.5		2250
Fax Machines			**Service and Mgmt of Office Equip.**	
Full		60		200
Full	100 (over 3 yrs)		**Utilities, Elec., Water, Phones, Email**	
Laptops				2500
Full		1000	**Chairman**	
Full	1500 (over 2 yrs)			900
Stationary			**Director Animal Resources**	
Full		240		900
4x4 Vehicles			**Director**	
Full		6000		900
Full	10000 (over 3 yrs)		**Deputy Director**	
Coordinating Office Meetings				900
		960	**Commissioner Livestock Health/Ent**	
Technical Committee Meetings				900
		828		

__Figure A-2 (cont'd)__ Worksheets for tsetse management campaign conducted in the tsetse zones

Shared	Cost($)			
One EO Meeting for Tech. Comm.				
	138			
Accountant				
	9000			
National Project Coordinator				
	900			
Accountant				
	9000			
Internal Auditor				
	9000			
GIS/Data Manager				
	9000			
Stenographer Secretary				
	6120			
Driver				
	6120			
Accountants Assistant				
	6120			
Per Diem for Sr. Level Officials				
	3000			
Per Diem for Jr. Level Officials				
	1200			

__Figure A-2 (cont'd)__ Worksheets for tsetse management campaign conducted in the tsetse zones

Administration and Office Support								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Desktop Computers	3 F	3 F	3 F	3 F	3 F	3 F (over3	3 F (over3	3 F(over3y
Photo Copiers	2 F	2 F	2 F	2 F	2 F	2 F (over3	2 F (over3	2 F(over3y
Office Furniture	2 F	2 F	2 F	2 F	2 F	2 F	2 F	2 F
Fax Machines	2 F	2 F	2 F	2 F	2 F	2 F (over3	2 F (over3	2 F(over3y
Laptops	3 F	3 F	3 F	3 F	3 F	3 F	3 F (over2	3 F(over 2
Stationary	1 F	1 F	1 F	1 F	1 F	1 F	1 F	1 F
4x4 Vehicles	2 F	2 F	2 F	2 F	2 F	2 F (over3	2 F (over3	2 F(over3y
Coordinating Office Meetings	1 F	1F	1F	1F	1F	1F	1F	1F
Technical Committee Meetings	1F	1F	1F	1F	1F	1F	1F	1F
One ex.-ordinary meeting for Tech. Committ	1F	1F	1F	1F	1F	1F	1F	1F
One ex.-ordinary meeting for Coord. Office -	1F	1F	1F	1F	1F	1F	1F	1F
Animal Resources	1F	1F	1F	1F	1F	1F	1F	1F
OAU/ISCTRC Meetings	1F	1F	1F	1F	1F	1F	1F	1F
45 Air Travel Tickets	1F	1F	1F	1F	1F	1F	1F	1F
Service and Management of Office Equipme	1F	1F	1F	1F	1F	1F	1F	1F
Utilites, Electricity, Water, Phones, Email	1F	1F	1F	1F	1F	1F	1F	1F
Chairman	1F	1F	1F	1F	1F	1F	1F	1F
Director Animal Resources	1F	1F	1F	1F	1F	1F	1F	1F
Director	1F	1F	1F	1F	1F	1F	1F	1F
Deputy Director	1F	1F	1F	1F	1F	1F	1F	1F
Commissioner Livestock Health and Entomo	1F	1F	1F	1F	1F	1F	1F	1F
National Project Coordinator	1F	1F	1F	1F	1F	1F	1F	1F
Accountant	1F	1F	1F	1F	1F	1F	1F	1F
Internal Auditor	1F	1F	1F	1F	1F	1F	1F	1F
GIS/Data Manager	1F	1F	1F	1F	1F	1F	1F	1F
Stenographer Secretary	1F	1F	1F	1F	1F	1F	1F	1F
Accounts Assistant	1F	1F	1F	1F	1F	1F	1F	1F
Driver	1F	1F	1F	1F	1F	1F	1F	1F
Per Diem for Sr. Level Officials	1F	1F	1F	1F	1F	1F	1F	1F
Per Diem for Jr. Level Officials	1F	1F	1F	1F	1F	1F	1F	1F

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Administration and Office Support (cont)								
Desktop Computers	900	900	900	900	900	1500	1500	1500
Photo Copiers	1200	1200	1200	1200	1200	2000	2000	2000
Office Furniture	625	625	625	625	625	625	625	625
Fax Machines	120	120	120	120	120	200	200	200
Laptops	3000	3000	3000	3000	3000	3000	4500	4500
Stationary	240	240	240	240	240	240	240	240
4x4 Vehicles	12000	12000	12000	12000	12000	20000	20000	20000
Coordinating Office Meetings	960	960	960	960	960	960	960	960
Technical Committee Meetings	828	828	828	828	828	828	828	828
One extra-ordinary meeting for Technical C	138	138	138	138	138	138	138	138
One extra-ordinary meeting for Coordinatin	240	240	240	240	240	240	240	240
Animal Resources	540	540	540	540	540	540	540	540
OAU/ISCTRC Meetings	270	270	270	270	270	270	270	270
45 Air Travel Tickets	2250	2250	2250	2250	2250	2250	2250	2250
Service and Management of Office Equipme	200	200	200	200	200	200	200	200
Utilites, Electricity, Water, Phones, Email	2500	2500	2500	2500	2500	2500	2500	2500
Chairman	900	900	900	900	900	900	900	900
Director Animal Resources	900	900	900	900	900	900	900	900
Director	900	900	900	900	900	900	900	900
Deputy Director	900	900	900	900	900	900	900	900
Commissioner Livestock Health and Entomo	900	900	900	900	900	900	900	900
National Project Coordinator	900	900	900	900	900	900	900	900
Accountant	9000	9000	9000	9000	9000	9000	9000	9000
Internal Auditor	9000	9000	9000	9000	9000	9000	9000	9000
GIS/Data Manager	9000	9000	9000	9000	9000	9000	9000	9000
Stenographer Secretary	6120	6120	6120	6120	6120	6120	6120	6120
Accounts Assistant	6120	6120	6120	6120	6120	6120	6120	6120
Driver	6120	6120	6120	6120	6120	6120	6120	6120
Per Diem for Sr. Level Officials	3000	3000	3000	3000	3000	3000	3000	3000
Per Diem for Jr. Level Officials	1200	1200	1200	1200	1200	1200	1200	1200
Total	80971	80971	80971	80971	80971	90451	91951	91951
10%Discount	**97975**	**89068**	**80971**	**73603**	**66882**	**67929**	**62803**	**57102**
								596332

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Entomological Survey / Tsetse Fly Population Genetics Survey			
Shared	Cost ($)	Shared	Cost($)
Satellite Imagery		**Portable Generators**	
Full	87.5	Full	200
Half	43.75	Half	100
Quarter	21.875	Quarter	50
Land Use Map		**Camping Equipment**	
Full	2500	Full	80
GPS Units		Half	40
Full	10	Quarter	20
Half	5	**Sample Vials**	
Quarter	2.5	Full	0.1
Dissection Microscope		**Printers**	
Full	125	Full	100
Half	62.5	Half	50
Quarter	31.25	Quarter	25
Compound Microscope		**Laptop Computers**	
Full	250	Full	1000
Half	125	Half	500
Quarter	62.5	Quarter	250
Dissecting Kits		**Radio Sets**	
Full	13.75	Full	100
Half	6.875	Half	50
Quarter	3.44	Quarter	25

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Shared	Cost($)
4x4 Vehicles	
Full	6000
Half	3000
Quarter	1500
Eigth	750
Motorbikes	
Full	312.5
Half	156.25
Quarter	78.13
Eigth	39
Traps	
Full	8
Team Leader (ES)	
	4800
Entomological Assistant (ES)	
	4000
Driver (ES)	
	2720
Comm. Support (ES)	
	51
Fuel and Maint. - 4x4 (ES)	
	5120
Fuel and Maint. - M'bikes (ES)	
	2240

Shared	Cost($)
Team Leader (TPGS)	
	4800
Entomological Assistant (TPGS)	
	4000
Driver (TPGS)	
	2720
Comm. Support (TPGS)	
	51
Biochemist (TPGS)	
	4800
Lab Technician (TPGS)	
	4000
Fuel and Maint. - 4x4 (TPGS)	
	5120

__Figure A-2 (cont'd)__ Worksheets for tsetse management campaign conducted in the tsetse zones

Entom. Survey/Tsetse Pop. Genetics Survey								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
ES and TPGS								
Traps	11223F							
Satellite Imagery	11 - Full	11H	11Q	11Q	11Q	11Q	11Q	11Q
Land Use / veg Map	1 - Full	1 F	1 F	1F	1F	1F	1F	1F
GPS Units	110 - Full	44 F, 66 H	10F, 100H					
Dissection microscopes	55 - Full	55 F	43H, 12Q	43H, 12Q	43H, 12Q	43H, 12Q	43H, 12Q	43H, 12Q
Compound microscopes	55 - Full	55 F	55 H	55H	55H	55H	55H	55H
Dissecting kits	110 - Full	110 F	110H	110H	110H	110H	110H	110H
Portable generators	55 - Full	55 F	43H, 12Q	43H, 12Q	43H, 12Q			
Camping equipment	55 - Full	55 F	55H	55H	55H			
Sample vials	11223 - Full							
Printers	55 - Full	55 F	55 H	55H	55H			
Laptop computers	55 - Full	44 F, 11 H	21 H, 34 Q					
Radio sets	55 - Full	33 F, 22 H	33H, 22Q	33H, 22Q	33H, 22Q			
4x4 Vehicles	55 - Full, 11 -	44 H, 22 (	16 Q, 50 E	16Q, 50E	16Q, 50E			
Motorbikes	66 - Full 44 -	88 H, 22 (	88Q, 22E	88Q, 22E	88Q, 22E	88Q, 22E	88Q, 22E	88Q, 22E
Team Leader (ES)	55F							
Entomological Assistant (ES)	165F							
Driver (ES)	55F							
Fuel and Maintenance for 4x4 Ve	55F							
Fuel and Maintenance for Motorb	110F							
Community Support (ES)	330F							
Team Leader (TPGS)	11F							
Entomological Assistant (TPGS)	33F							
Driver (TPGS)	11F							
Community Support (TPGS)	33F							
Biochemist (TPGS)	11F							
Lab Technician (TPGS)	22F							
Fuel and Maintenance for 4x4 Ve	11F							

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Entom. Survey/Tsetse Pop. Genetics Survey (cont)								
Traps	89784							
Satellite Imagery	962.5	481.25	240.625	240.625	240.625	240.625	240.625	240.625
Land Use / veg Map	2500	2500	2500	2500	2500	2500	2500	2500
GPS Units	1100	770	600					
Dissection microscopes	6875	6875	3062.5	3062.5	3062.5	3062.5	3062.5	3062.5
Compound microscopes	13750	13750	6875	6875	6875	6875	6875	6875
Dissecting kits	1512.5	1512.5	756.25	756.25	756.25	756.25	756.25	756.25
Portable generators	11000	11000	4900	4900	4900			
Camping equipment	4400	4400	2200	2200	2200			
Sample vials	1122.3							
Printers	5500	5500	2750	2750	2750			
Laptop computers	55000	49500	19000					
Radio sets	5500	4400	2200	2200	2200			
4x4 Vehicles	363000	165000	61500	61500	61500			
Motorbikes	27500	15468.8	7734.38	7734.38	7734.38	7734.38	7734.38	7734.38
Team Leader (ES)	264000							
Entomological Assistant (ES)	660000							
Driver (ES)	149600							
Fuel and Maintenance for 4x4 Ve	281600							
Fuel and Maintenance for Motorb	246400							
Community Support (ES)	16830							
Team Leader (TPGS)	52800							
Entomological Assistant (TPGS)	132000							
Driver (TPGS)	29920							
Community Support (TPGS)	1683							
Biochemist (TPGS)	52800							
Lab Technician (TPGS)	88000							
Fuel and Maintenance for 4x4 Ve	56320							
Total	2621459.3	281158	114319	94718.8	94718.8	21168.8	21168.8	21168.755
10%Discount	**3171965.8**	**309273**	**114319**	**86099**	**78238**	**15898**	**14458**	**13145.7969**
10% Discount Total								**3803396.59**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Socioeconomic Survey	
Shared	Cost($)
Bicycles	
Full	10
Half	5
Motorbikes	
Full	312.5
Half	156.25
Quarter	78.125
Eigth	39.06
4x4 Vehicles	
Full	6000
Half	3000
Quarter	1500
Eigth	750
Supervisors	
	1800
Socioeconomist	
	11700
Data-entry Clerks	
	1500
Fuel and Maint. -4x4	
	2560
Fuel and Maint. -M'bikes	
	1120

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Socioeconomic Survey								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Bicycles for Enumerators	898 - Full	898 F	808 F, 90	808F, 90H	808 F, 90	808F, 90H	808 F, 90	808F, 90H
Motorbikes	44 - Half	22 H, 22 (	22Q, 22E	22Q, 22E	22Q, 22E	22Q, 22E	22Q, 22E	22Q, 22E
4x4 Vehicles	11 - Half	11Q	11Q	11Q	11Q			
Supervisors	44F							
Co-Coordinator (Socioeco	11F							
Data Entry Clerk	22F							
Fuel and Maint. - 4x4 Veh	11F							
Fuel and Maint. - Motorbi	44F							
Contingency (10% of above costs)								
Bicycles for Enumerators	8980	8980	8530	8530	8530	8530	8530	8530
Motorbikes	6875	5156.25	2578.13	2578.13	2578.13	2578.13	2578.13	2578.13
4x4 Vehicles	33000	16500	16500	16500	16500			
Supervisors	79200							
Co-Coordinator (Socioeco	128700							
Data Entry Clerk	33000							
Fuel and Maint. - 4x4 Veh	28160							
Fuel and Maint. - Motorbi	49280							
Contingency (10% of abo	36719.5	3063.63	2760.81	2760.81	2760.81	1110.81	1110.81	1110.81
Total	403915	33699.9	30368.9	30368.9	30368.9	12218.9	12218.9	12218.9
10%Discount	**488737**	**37070**	**30369**	**27605**	**25085**	**9176.4**	**8345.5**	**7588**
10% Discount Total								**633975**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Sleeping Sickness Survey				
Shared	Cost ($)			
4x4 Vehicles				
Quarter	1500			
GPS Sets				
Full	10			
Half	5			
Quarter	2.5			
Laptops				
Full	1000			
Half	500			
Quarter	250			
Medical Officers				
	1800			
Driver				
	1020			
Fuel and Maint. -4x4				
	1920			
Per Diem for Med Officer				
	600			

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Sleeping Sickness Survey								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Sleeping Sickness Survey								
4x4 Vehicles		11Q	11Q	11Q	11Q			
GPS Sets		44 H	44H					
Laptops		11H	11H					
Medical Officers		44F						
Driver		11F						
Fuel and Maintenance - 4x4		11F						
Per Diem for Med Officer		44F						
4x4 Vehicles		16500	16500	16500	16500			
GPS Sets		220	220					
Laptops		5500	5500					
Medical Officers		79200						
Driver		11220						
Fuel and Maintenance - 4x4		21120						
Per Diem for Med Officer		26400						
Total	0	160160	22220	16500	16500	0	0	0
10%Discount	**0**	**176176**	**22220**	**14999**	**13629**	**0**	**0**	**0**
10% Discount Total								**227024**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Parasitological and Serological Data Collection				
Shared	Cost ($)		Shared	Cost ($)
Haematocrit Centrifuge			**Team Leader**	
Full	25			4800
Half	12.5		**Lab. Technician**	
PCV Reader				4000
Full	2.5		**Driver**	
Cool Boxes				2720
Full	7.5		**Lab. Assistant**	
Consumables Parasitology				2720
Full	625		**Veterinary Officer**	
Consumables Serology				4800
Full	625		**Fuel and Maintenance - 4x4**	
ELISA Reader				5120
Full	500		**Fuel and Maintenance - M'bike**	
Computer ELISA Work				2240
Full	375		**Per Diem - Tm Leader/Vet Officer**	
Trypanocidal Drugs				1600
Full	6500			
4x4 Vehicles				
Half	3000			
Motorbikes				
Half	156.25			
Quarter	78.125			

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Parasitological and Serological Data Collection								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
PS Data Collection								
Haematocrit Centrifuge		44F	32F, 12 H	32F, 12 H	32F, 12H	32F, 12H	32F, 12H	32F, 12H
PCV Reader		44F	44F	44F	44F	44F	44F	44F
Cool Boxes		88F	88F	88F	88F	88F	88F	88F
Consumables Parasitology		11F	11F	11F	11F	11F	11F	11F
Consumables Serology		11F	11F	11F	11F	11F	11F	11F
ELISA Reader		11F	11F	11F	11F	11F	11F	11F
Computer ELISA Work		11F	11F	11F	11F	11F	11F	11F
Trypanocidal Drugs		11F						11F
4x4 Vehicles		44H	44H	44H	44H			
Motorbikes		88H	88Q	88Q	88Q	88Q	88Q	88Q
Team Leader		44F						44F
Laboratory Technicians		88F						88F
Driver		44F						44F
Laboratory Assistants		44F						44F
Veterinary Officer		44F						44F
Fuel and Maintenance for 4x4 Vehicle		44F						44F
Fuel and Maintenance for Motorbike		88F						88F
Per Diem for Team Leader and Vet Officer		88F						88F
Contingency (10% of above)								

Figure A-2 (cont'd) Worksheets for tsetse management campaign conducted in the tsetse zones

Parasitological and Serological Data Collection (cont)								
Haematocrit Centrifuge		1100	950	950	950	950	950	950
PCV Reader		110	110	110	110	110	110	110
Cool Boxes		660	660	660	660	660	660	660
Consumables Parasitology		6875	6875	6875	6875	6875	6875	6875
Consumables Serology		6875	6875	6875	6875	6875	6875	6875
ELISA Reader		5500	5500	5500	5500	5500	5500	5500
Computer ELISA Work		4125	4125	4125	4125	4125	4125	4125
Trypanocidal Drugs		71500						71500
4x4 Vehicles		132000	132000	132000	132000			
Motorbikes		13750	6875	6875	6875	6875	6875	6875
Team Leader		211200						211200
Laboratory Technicians		352000						352000
Driver		119680						119680
Laboratory Assistants		119680						119680
Veterinary Officer		211200						211200
Fuel and Maintenance for 4x4 Vehicle		225280						225280
Fuel and Maintenance for Motorbike		197120						197120
Per Diem for Team Leader and Vet Officer		140800						140800
Contingency (10% of above)		181945.5	16397	16397	16397	3197	3197	158383.5
Totall		2001401	180367	180367	180367	35167	35167	1838813.5
10%Discount		**2201541**	**180367**	**163954**	**148983**	**26410**	**24019**	**1141903**
Total 10% Discount								**3887177**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Environmental Impact Assessment				
Shared	Cost ($)		Shared	Cost ($)
Satellite Imagery			**Radio Sets**	
Half	43.75		Half	20
Quarter	21.875		Quarter	10
GIS Processing			**Consultants**	
Full	1000			10400
4x4 Vehicles			**Assistant**	
Half	3000			2000
GPS Units			**Driver**	
Half	5			1020
Compass			**Fuel and Maint. -4x4**	
Full	8			1920
Half	4			
Measuring Tape				
Full	10			
Half	5			
Sampling Equipment				
Full	137.5			
Half	68.75			
Binoculars				
Full	62.5			
Half	31.25			

Figure A-2 (cont'd) Worksheets for tsetse management campaign conducted in the tsetse zones

Environmental Impact Assessment								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Env. Impact Assessment								
Satellite Imagery		11H	11Q	11Q	11Q	11Q	11Q	11Q
GIS Processing		11F						
4x4 Vehicles		22H	22H	22H	22H			
GPS Units		22 H	22H					
Compass		44F	22F, 22H	22F, 22H	22F, 22H	22F, 22H		
Measuring Tape		44F	22F, 22H	22F, 22H				
Sampling Equipment		11F	11H	11 H	11H	11H	11H	11H
Binoculars		44F	22F, 22H	22F, 22H	22F, 22H	22F, 22H	22F, 22H	22F, 22H
Radio Sets		22H	22Q	22Q	22Q			
Consultants		22F						
Assistant		44F						
Driver		22F						
Fuel and Maint. - 4x4 Vehicle		22F						
Contingency (10% of above)								

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Environmental Impact Assessment (cont)								
Satellite Imagery		481.25	240.63	240.63	240.63	240.63	240.63	240.63
GIS Processing		11000						
4x4 Vehicles		66000	66000	66000	66000			
GPS Units		110	110					
Compass		352	286	286	286	286		
Measuring Tape		440	330	330				
Sampling Equipment		1512.5	756.25	756.25	756.25	756.25	756.25	756.25
Binoculars		2750	2062.5	2062.5	2062.5	2062.5	2062.5	2062.5
Radio Sets		440	220	220	220			
Consultants		228800						
Assistant		88000						
Driver		22440						
Fuel and Maint. - 4x4		42240						
Contingency (10% of above)		46456.6	7000.54	6989.54	6956.54	334.538	305.938	305.938
Total		511022	77005.9	76884.9	76521.9	3679.92	3365.32	3365.32
10%Discount		**562125**	**77006**	**69888**	**63207**	**2763.6**	**2298.5**	**2089.9**
10% Discount Total								**779378**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Sleeping Sickness Active Case Finding				
Shared	Cost ($)		Shared	Cost($)
Bicycle			**Lab Reagents**	
Half	5		Full	5625
4x4 Vehicles			**Drugs**	
Half	5000 (over 3 years)		Full	8333.33
Quarter	1500		**Safari Allowance**	
Dissection Microscopes				185
Quarter	62.5		**Medical Officers**	
Haematocrit Centrifuges				2250
Half	12.5		**Driver**	
Portable Generators				1275
Half	166.67 (over 3 years)		**Fuel and Maintenance -4x4**	
Quarter	50			2400
Bench Centrifuges				
Full	125			
GPS Sets				
Full	10			
Half	5			
Half	7.5 (over 2 years)			
Laptops				
Half	500			
Half	750 (over 2 years)			
Pipettes				
Full	25			

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Sleeping Sickness Active Case Finding								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Sleeping Sickness ACF								
Bicycle			90 Half	90 Half	90 Half	90 Half	90 Half	90 Half
4x4 Vehicles			3 Q	3Q	3Q	**3H(over3y**	**3H(over3yr**	**3H(over3yrs**
Dissection Microscopes			12Q	12Q	12Q	12Q	12Q	12Q
Haematocrit Centrifuges			12 H	12H	12H	12H	12H	12H
Portable Generators			12 Q	12 Q	12 Q	12H (over3	12H(over3yr	12H(over3yr)
Bench Centrifuge			12 Full	12 F	12 F	12 F	12 F	12 F
GPS Sets			12 H	4 F, 8 H	4 F, 8 H	4F, 8H	4F, 8H(over	4F, 8H (over2
Laptops			6 H	6H	6H	6H	6H (over2yrs	6H (over2yrs
Pipettes			12 Full	12 F	12 F	12 F	12 F	12 F
Laboratory reagents (Glass Ware)			1 Full	1 F	1 F	1 F	1 F	1 F
Drugs (Mel-B, Suramin, Pentamidine)			3 Full	3 F	3F	3F	3F	3F
Safari Day Allowances			24F	24F	24F	24F	24F	
Medical Officers			12F	12F	12F	12F	12F	
Driver			3F	3F	3F	3F	3F	
Fuel and Maintenance for 4x4 Vehicle			3F	3F	3F	3F	3F	

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Sleeping Sickness Active Case Finding (cont)						
Bicycle	450	450	450	450	450	450
4x4 Vehicles	4500	4500	4500	15000	15000	15000
Dissection Microscopes	750	750	750	750	750	750
Haematocrit Centrifuges	150	150	150	150	150	150
Portable Generators	600	600	600	2000	2000	2000
Bench Centrifuge	1500	1500	1500	1500	1500	1500
GPS Sets	60	80	80	80	100	100
Laptops	3000	3000	3000	3000	4500	4500
Pipettes	300	300	300	300	300	300
Laboratory reagents (Glass Ware)	5625	5625	5625	5625	5625	5625
Drugs (Mel-B, Suramin, Pentamidine)	25000	25000	25000	25000	25000	25000
Safari Day Allowances	4440	4440	4440	4440	4440	
Medical Officers	27000	27000	27000	27000	27000	
Driver	3825	3825	3825	3825	3825	
Fuel and Maintenance for 4x4 Vehicle	7200	7200	7200	7200	7200	
Total	84400	84420	84420	96320	97840	55375
10%Discount	**84400**	**76738**	**69731**	**72336.3**	**66824.72**	**34387.88**
10% Discount Total						**404417.6**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Environmental and Entomological Monitoring

Shared	Cost ($)	Shared	Cost ($)
Pyramidal Traps		**Printers**	
Full	8	Full	167 (over 3 years)
Dissection Microscopes		Half	50
Half	62.5	**Radio Sets**	
Compound Microscopes		Full	100
Half	125	Half	50
Dissecting Kits		**4x4 Vehicles**	
Half	6.25	Full	6000
Portable Generator		Half	5000 (over 2 years)
Full	200	Quarter	1500
Half	100	**Motorbikes**	
Half	167 (over 3 years)	Half	156.25
Camping Equipment		**Satellite Imagery**	
Full	133 (over 3 years)	Half	43.75
Half	80	**GIS Processing**	
Sample Vials		Full	1000
Full	0.1	**GPS Units**	
Laptop Computers		Half	5
Full	1000	Half	7.5 (over 2 years)
Half	500	**Compass**	
Half	750 (over 2 years)	Half	8

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Shared	Cost ($)		
Measuring Tape			
Full	10		
Half	5		
Sampling Materials / Equip.			
Half	68.75		
Binoculars			
Half	31.25		
Team Leader (Entomological Mon.)			
	2700		
Entomological Assistant (Entom. Mon.)			
	2250		
Driver (Entomological Mon.)			
	1530		
Fuel/Maintenance -4x4 (Entom. Mon.)			
	2880		
Fuel/Maintenance -M'bikes (Entom. Mon.)			
	1260		
Consultants/Ecologist (Environ. Mon.)			
	5200		
Assistant (Environ. Mon.)			
	1000		
Driver (Environ. Mon.)			
	510		

Figure A-2 (cont'd) Worksheets for tsetse management campaign conducted in the tsetse zones

Environmental and Entomological Monitoring								
	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8
Pyramidal Traps			11223F	11223F	11223F	11223F	11223F	
Dissection Microscopes			55H	55H	55H	55H	55H	55H
Compund Microscopes			55H	55H	55H	55H	55H	55H
Dissecting Kits			110H	110H	110H	110H	110H	110H
Portable Generator			55H	55H	55H	43F, 12H (over	43F, 12H (over	43F,12H(over3
Camping Equipment			55H	55H	55H	55F (over3yr)	55F(over3yr)	55F(over3yrs)
Sample Vials			11223F	11223F	11223F	11223F	11223F	
Laptop Computers			55H	49F, 6H	49F, 6H	49F, 6H	14F, 6H (over2	14F, 6H(over2
Printers			55H	55H	55H	55F(over3yrs)	55F(over3yrs)	55F(over3yrs)
Radio Sets			22F, 55H	22F, 55H	22F, 55H	**22F**	**22F**	
4x4 Vehicles			11 F, 66 Q	11F, 66Q	11F, 66Q	**8F, 3H (over3**	**8F, 3H (over3**	**8F, 3H(over3**
Motorbikes			110H	110H	110H	110H	110H	110H
Satellite Imagery			11H	11H	11H	11H	11H	11H
GIS Processing			11F	11F	11F	11F	11F	
GPS Units			22H	10F, 12H	10F, 12H	10F, 12H	10F, 12H (over	10F, 12H(ovr2
Compass			22H	22H	22H	22H	**22H**	**22H**
Measuring Tape			22H	22H	22F	22F	22F	
Sampling Equipment and Materials			11H	11H	11H	11H	11H	11H
Binoculars			22H	22H	22H	22H	22H	22H
Team Leader (Ent Monitoring)			55F	55F	55F	55F	55F	
Entomological Assistant (Ent Mon)			110F	110F	110F	110F	110F	
Driver (Ent Mon)			55F	55F	55F	55F	55F	
Fuel and Maintenance for 4x4 Vehicles (Ent Mon)			55F	55F	55F	55F	55F	
Fuel and Maintenance for Motorbikes (Ent Mon)			110F	110F	110F	110F	110F	
Consultants/Ecologists (Env Mon)			22F	22F	22F	22F	22F	
Assistant (Env Mon)			44F	44F	44F	44F	44F	
Driver (Env Mon)			22F	22F	22F	22F	22F	

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Environmental and Entomological Monitoring (cont)						
Pyramidal Traps	89784	89784	89784	89784	89784	
Dissection Microscopes	3437.5	3437.5	3437.5	3437.5	3437.5	3437.5
Compund Microscopes	6875	6875	6875	6875	6875	6875
Dissecting Kits	687.5	687.5	687.5	687.5	687.5	687.5
Portable Generator	5500	5500	5500	10604	10604	10604
Camping Equipment	4400	4400	4400	7315	7315	7315
Sample Vials	1122.3	1122.3	1122.3	1122.3	1122.3	
Laptop Computers	27500	52000	52000	52000	18500	18500
Printers	2750	2750	2750	9185	9185	9185
Radio Sets	4950	4950	4950	2200	2200	
4x4 Vehicles	165000	165000	165000	63000	63000	63000
Motorbikes	17187.5	17187.5	17187.5	17187.5	17187.5	17187.5
Satellite Imagery	481.25	481.25	481.25	481.25	481.25	481.25
GIS Processing	11000	11000	11000	11000	11000	
GPS Units	110	160	160	160	190	190
Compass	176	176	176	176	176	176
Measuring Tape	110	110	220	220	200	
Sampling Equipment and Materials	756.25	756.25	756.25	756.25	756.25	756.25
Binoculars	687.5	687.5	687.5	687.5	687.5	687.5
Team Leader (Ent Monitoring)	148500	148500	148500	148500	148500	
Entomological Assistant (Ent Mon)	247500	247500	247500	247500	247500	
Driver (Ent Mon)	84150	84150	84150	84150	84150	
Fuel and Maintenance for 4x4 Vehicles (Ent Mon)	158400	158400	158400	158400	158400	
Fuel and Maintenance for Motorbikes (Ent Mon)	138600	138600	138600	138600	138600	
Consultants/Ecologists (Env Mon)	114400	114400	114400	114400	114400	
Assistant (Env Mon)	44000	44000	44000	44000	44000	
Driver (Env Mon)	11220	11220	11220	11220	11220	
Total	1289285	1313835	1313945	1223648.8	1190158.8	139082.5
10%Discount	**1289285**	**1194276**	**1085318**	**918960.249**	**812878.46**	**86370.233**
10% Discount Total						**5387088**

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Field Control			
Shared	Cost ($)	Shared	Cost ($)
Targets		**Deltamethrin**	
Full	8	Full	350
GPS Sets		**Octenol**	
Full	10	Full	1.5
Full	15 (over 2 years)	**Acetone**	
Half	5	Full	3.5
4x4 Vehicles		**Fuel and Maintenance -4x4**	
Full	6000		10752
Half	3000	**Fuel and Maintenance -Lorry**	
Quarter	1500		10752
Lorries		**Team Leader**	
Full	6000		10080
Half	3000	**Entomological Assistant**	
Quarter	1500		8400
Camping Equipment		**Laborers**	
Full	80		1680
Half	40	**Drivers**	
Stationary			5712
Full	124	**Allowances for Team Leader**	
Batteries			5000
Full	20	**Allowances for Ent. Assistants/Driver**	
Training Course for Field Staff			3000
Full	125		

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Field Control								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Coastal Belt Field Inputs								
Targets			170975F					
GPS Sets			80 F	16 F, 64 H	60 H, 20 Q			
4x4 Vehicles			40F	8 F, 32 H	30 H, 10 (	4H, 36 Q	10 Q, 30 E	
Lorries			40F	8F, 32H	30H, 10 Q	4H, 36Q	10 Q, 30 E	
Camping Equipment			320F	64F, 256 H	240 H, 80	32 H, 288	32 Q, 288	E
Stationary			40F					
Batteries			80F					
Training Course For Field Staff			80F					
Deltamethrin			1307F					
Octenol			438396F					
Acetone			43839F					
Fuel and Maintenance for 4x4 Vehicles			40F					
Fuel and Maintenance for Lorry			40F					
Team Leader			40F					
Entomological Assistants			80F					
Laborers			320F					
Drivers			40F					
Allowances for Team Leader			40F					
Allowances for E As and Driver			120F					

Figure A-2 (cont'd) Worksheets for tsetse management campaign conducted in the tsetse zones

Coastal Belt Field Inputs (cont)								
Targets			1367800					
GPS Sets			800	480	350			
4x4 Vehicles			240000	144000	105000	78000	37500	
Lorries			240000	144000	105000	78000	37500	
Camping Equipment			25600	15360	11200	7040	3520	
Stationary			4960					
Batteries			1600					
Training Course For Field Staff			10000					
Deltamethrin			457450					
Octenol			657594					
Acetone			153437					
Fuel and Maintenance for 4x4 Vehicles			430080					
Fuel and Maintenance for Lorry			430080					
Team Leader			403200					
Entomological Assistants			672000					
Laborers			537600					
Drivers			228480					
Allowances for Team Leader			200000					
Allowances for E As and Driver			360000					
Total	0	0	6420681	303840	221550	163040	78520	0
10%Discount	0	0	6420681	276191	183000	122443	53629.2	0
								7055943.56

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Central-Capital Belt Field Inputs								
Targets				144088F				
GPS Sets				64H	44 H, 20 Q			
4x4 Vehicles				32H	22 H, 10 Q	22H, 10 Q	6 H, 26 Q	
Lorries				32H	22 H, 10 Q	22H, 10Q	6 H, 26 Q	
Camping Equipment				256 H	176 H, 80	176 H, 80	32 H, 224	Q
Stationary				32 F				
Batteries				64 F				
Training Course For Field Staff				64F				
Deltamethrin				1102F				
Octenol				369456F				
Acetone				36945F				
Fuel and Maintenance for 4x4 Vehicles				32F				
Fuel and Maintenance for Lorry				32F				
Team Leader				32F				
Entomological Assistants				64F				
Laborers				256F				
Drivers				32F				
Allowances for Team Leader				32F				
Allowances for E As and Driver				94F				

__Figure A-2 (cont'd)__ Worksheets for tsetse management campaign conducted in the tsetse zones

Central-Capital Belt Field Inputs (cont)								
Targets				1152704				
GPS Sets				320	270			
4x4 Vehicles				96000	81000	81000	57000	
Lorries				96000	81000	81000	57000	
Camping Equipment				10240	8640	8640	5760	
Stationary				3968				
Batteries				1280				
Training Course For Field Staff				8000				
Deltamethrin				385700				
Octenol				554184				
Acetone				129308				
Fuel and Maintenance for 4x4 Vehicles				344064				
Fuel and Maintenance for Lorry				344064				
Team Leader				322560				
Entomological Assistants				537600				
Laborers				430080				
Drivers				182784				
Allowances for Team Leader				160000				
Allowances for E As and Driver				282000				
Total	0	0	0	5040856	170910	170640	119760	0
10%Discount	0	0	0	4582138	141172	128151	81796.1	0
								4933256.03

Figure A-2 (cont'd) Worksheets for tsetse management campaign conducted in the tsetse zones

Northern ASALs Belt Field Inputs								
Targets					70088F			
GPS Sets					36H			
4x4 Vehicles					18 H	18H	13 H, 5 Q	
Lorries					18 H	18H	13 H, 5 Q	
Camping Equipment					144 H	144 H	144 H	
Stationary					18F			
Batteries					36 F			
Training Course For Field Staff					36F			
Deltamethrin					537F			
Octenol					179712F			
Acetone					17972F			
Fuel and Maintenance for 4x4 Vehicles					18F			
Fuel and Maintenance for Lorry					18F			
Team Leader					18F			
Entomological Assistants					36F			
Laborers					144F			
Drivers					18F			
Allowances for Team Leader					18F			
Allowances for E As and Driver					54F			

__Figure A-2 (cont'd)__ Worksheets for tsetse management campaign conducted in the tsetse zones

Northern ASALs Belt Field Inputs (cont)								
Targets					560704			
GPS Sets					180			
4x4 Vehicles					54000	54000	46500	
Lorries					54000	54000	46500	
Camping Equipment					5760	5760	5760	
Stationary					2232			
Batteries					720			
Training Course For Field Staff					4500			
Deltamethrin					187950			
Octenol					269568			
Acetone					62902			
Fuel and Maintenance for 4x4 Vehicles					193536			
Fuel and Maintenance for Lorry					193536			
Team Leader					181440			
Entomological Assistants					302400			
Laborers					241920			
Drivers					102816			
Allowances for Team Leader					90000			
Allowances for E As and Driver					162000			
Total	0	0	0	0	2670164	113760	98760	0
10%Discount	0	0	0	0	2205555	85433.8	67453.1	0
								2358442.30

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Western Belt Field Inputs								
Targets						52495F		
GPS Sets						26 F	26 H	26H
4x4 Vehicles						13H	13 H	
Lorries						13H	13 H	
Camping Equipment						104 H	104H	
Stationary						13F		
Batteries						26F		
Training Course For Field Staff						26F		
Deltamethrin						402F		
Octenol						134604F		
Acetone						13460F		
Fuel and Maintenance for 4x4 Vehicles						13F		
Fuel and Maintenance for Lorry						13F		
Team Leader						13F		
Entomological Assistants						26F		
Laborers						104F		
Drivers						13F		
Allowances for Team Leader						13F		
Allowances for E As and Driver						39F		

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Western Belt Field Inputs (cont)								
Targets						419960		
GPS Sets						260	130	130
4x4 Vehicles						39000	39000	
Lorries						39000	39000	
Camping Equipment						4160	4160	
Stationary						1612		
Batteries						520		
Training Course For Field Staff						3250		
Deltamethrin						140700		
Octenol						201906		
Acetone						47110		
Fuel and Maintenance for 4x4 Vehicles						139776		
Fuel and Maintenance for Lorry						139776		
Team Leader						131040		
Entomological Assistants						218400		
Laborers						174720		
Drivers						74256		
Allowances for Team Leader						65000		
Allowances for E As and Driver						117000		
Total	0	0	0	0	0	1957446	82290	130
10%Discount	0	0	0	0	0	1470042	56204.1	80.73
								1526326.75

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Lake Victoria-So. Rift Belt Field Inputs								
Targets							87591F	
GPS Sets							14F(2yrs),	14F(2yrs),26 H
4x4 Vehicles							20 H	
Lorries							20 H	
Camping Equipment							160H	
Stationary							20F	
Batteries							40F	
Training Course For Field Staff							40F	
Deltamethrin							670F	
Octenol							224592F	
Acetone							22459F	
Fuel and Maintenance for 4x4 Vehicles							20F	
Fuel and Maintenance for Lorry							20F	
Team Leader							20F	
Entomological Assistants							40F	
Laborers							160F	
Drivers							20F	
Allowances for Team Leader							20F	
Allowances for E As and Driver							60F	

Figure A-2 (cont'd) *Worksheets for tsetse management campaign conducted in the tsetse zones*

Lake Victoria-So. Rift Belt Field Inputs (cont)								
Targets							700728	
GPS Sets							340	340
4x4 Vehicles							60000	
Lorries							60000	
Camping Equipment							6400	
Stationary							2480	
Batteries							800	
Training Course For Field Staff							5000	
Deltamethrin							234500	
Octenol							336888	
Acetone							78606.5	
Fuel and Maintenance for 4x4 Vehicles							215040	
Fuel and Maintenance for Lorry							215040	
Team Leader							201600	
Entomological Assistants							336000	
Laborers							268800	
Drivers							114240	
Allowances for Team Leader							100000	
Allowances for E As and Driver							180000	
Total	0	0	0	0	0	0	3116463	340
10%Discount	0	0	0	0	0	0	2128544	211.14
								2128755.03

Figure A-3 *All tsetse zones and control reservoirs in each tsetse fly belt*

a) The Coastal Belt

b) The Central-Capital Belt

c) The Northern Arid and Semi-Arid Lands Belt

d) The Western Belt

e) The Lake Victoria-Southern Rift Belt

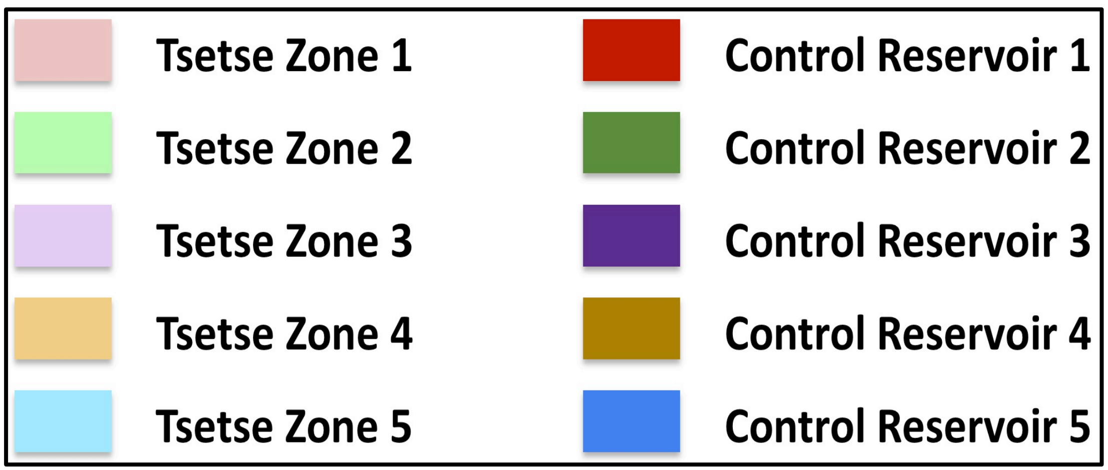
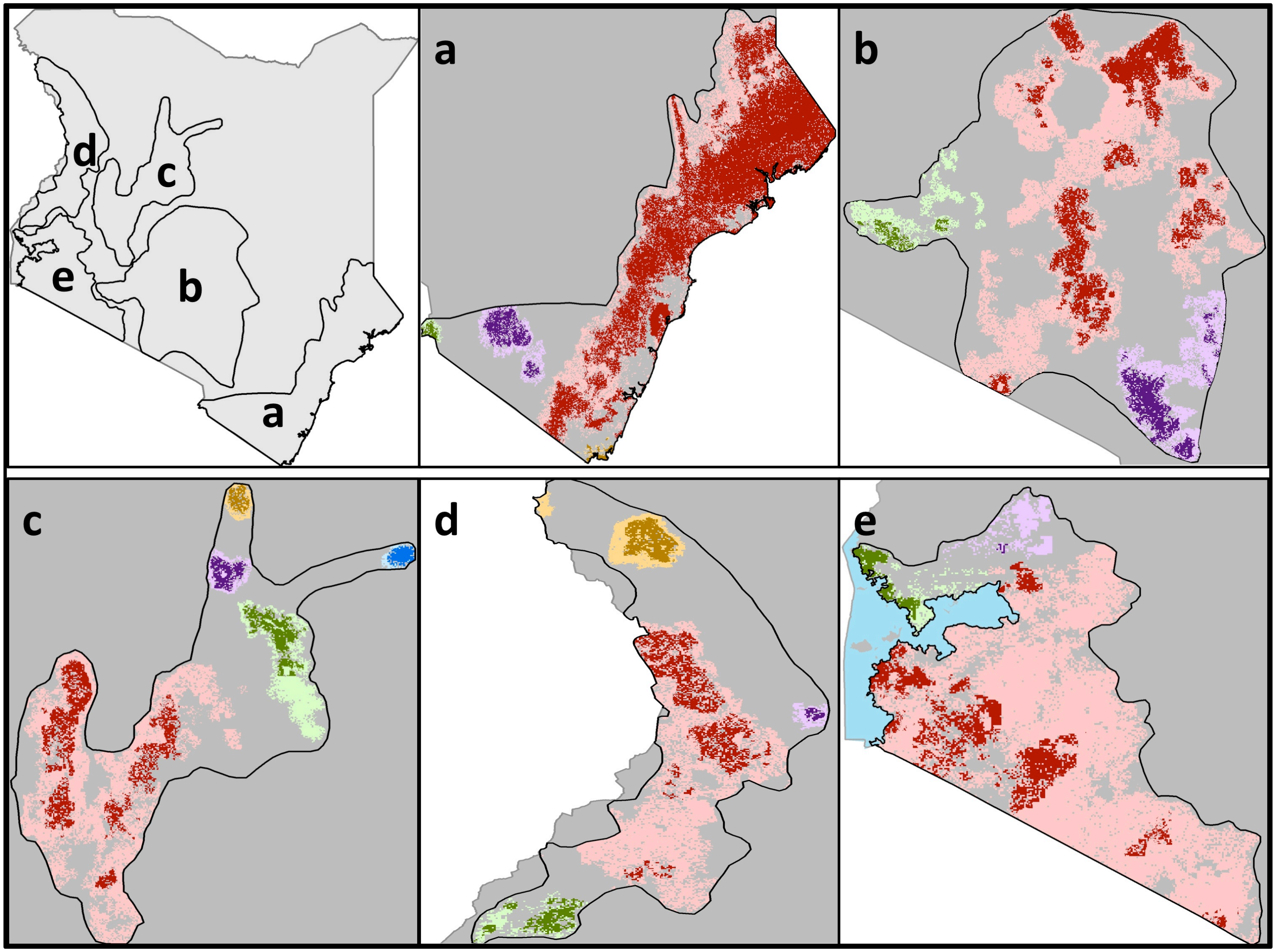


Figure A-3 (cont'd) *All tsetse zones and control reservoirs in each tsetse fly belt*



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