PN-ABA-186
56903

ECONOMICS OF AFRICAN ANIMAL TRYPANOSOMIASIS (A.A.T.) CONTROL*

by

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1982

*This report was financed under the Alternative Rural Development Strategies Cooperative Agreement (AID/ta-CA-3) between the U.S. Agency for International Development and the Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

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Over the last decade sub-Saharan Africa has been running a deficit in average index of food production per capita. Thus, using 1969-71 as the base year, per capita food production index in 1977-79 was only 91. Annual agricultural production per capita growth over the ten year period, 1970-79, was -0.9. This is mainly due to average annual population growth rate outstripping the agricultural growth rate (2.7 percent to 1.8 percent).

Such a gap between population growth and food production rates is creating an increasing pressure to bring additional lands to production. Unfortunately, much of the land is unsuitable for agricultural exploitation currently due to tsetse fly infestation creating problems of trypanosomiasis in livestock and sleeping sickness in humans. At present the total area showing seasonal or year round tsetse infestation in Africa is about 9 to 10 million square kilometers (km^2) of which 6 to 7 million could be used for agricultural practices; 3 to 4 million has savanna type ecology well suited for livestock grazing. The extent of the areas in each of the 37 sub-Saharan African countries affected by A.A.T. are shown in Table 1.

The problem is compounded in that the greatest per capita food deficit in Africa is in animal proteins. Africa produces only 542 kg. per 1,000 ha. of livestock farming compared to 4,113 kgs. for Latin America and 38,085 kgs. for Europe [ILRAD, 1980]. The control or eradication of A.A.T. by itself will not guarantee a fair distribution of the food from livestock sources. However,

Table 1 ECONOMIC WELFARE INDICATORS IN AFRICA

Sub-Saharan Africa	1960-70	1970-79
1. Annual population growth rates (%)	2.5	2.7
2. Annual GNP/capita growth (%)	1.3	0.8
3. Annual agricultural production per capita (%)	-	-0.9
4. Average index of food production per capita (1969-71 = 100)		91
5. Average annual growth rate in agriculture		1.8
6. Average annual GDP growth rate	3.9	2.9

Source: Accelerated Development in Sub-Saharan Africa [World Bank, 1982].

Table 2 TSETSE INFECTED AFRICAN COUNTRIES[a]

Countries	Total Area (km^2)	Areas Currently Infested by Tsetse (km^2)	Areas Currently Infested by Tsetse (Percent)	Population (million) 1969	Population (million) 1978	Increase Percent[b]	Density 1978[c]
Angola	1,246,700	500,000	40	5.43	6.73	2.5	5
Benin*	112,600	112,000	99	2.65	3.38	2.8	30
Botswana*	600,400	30,000	5	0.57	0.73	1.7	1
Burundi*	27,800	7,000	25	3.55	4.26	2.7	153
Cameroun*	475,400	398,000	84	6.65	8.06	2.3	17
Central African Rep.*	623,000	600,000	96	-	-	-	-
Chad*	1,284,000	298,000	23	3.57	4.31	2.3	3
Congo*	342,000	342,000	100	1.17	1.46	2.6	4
Equatorial Guinea	28,000	28,000	100	0.29	0.35	2.3	12
Ethiopia*	1,221,900	200,000	16	24.02	29.71	2.6	24
Gabon*	267,700	267,000	100	0.50	0.54	1.1	2
Gambia*	11,300	10,000	88	0.45	0.57	2.8	30
Ghana*	238,500	238,000	100	8.41	10.97	3.6	46
Guinea*	246,000	246,000	100	3.83	4.76	2.8	19
Guinea Bissau	36,100	36,000	100	0.48	0.55	1.7	15
Ivory Coast	322,500	322,000	100	5.06	7.61	4.3	24
Kenya*	582,700	102,000	18	10.88	14.86	3.5	26
Liberia*	111,400	111,000	100	1.29	1.74	3.4	16
Malawi*	118,500	20,000	17	4.33	5.67	-	48
Mali*	1,240,000	200,000	16	4.93	6.29	2.7	5
Mozambique*	801,600	550,000	69	7.36	9.94	2.6	12
Namibia	824,300	10,000	1	-	-	-	-
Niger*	1,267,000	1,000	0.1	3.90	5.00	2.8	4
Nigeria*	923,800	600,000	65	54.69	72.22	3.2	78
Rwanda*	26,300	6,500	25	3.57	4.51	2.4	171
Senegal*	196,200	59,600	30	4.13	5.38	2.6	27
Sierra Leone*	71,700	71,000	99	2.63	3.29	2.6	46
Somalia*	637,700	20,000	3	2.73	3.44	2.8	5
Sudan*	2,505,800	248,000	10	13.75	17.38	3.4	7
Swaziland	17,400	250	1	0.41	0.54	2.4	32
Tanzania*	945,100	540,000	57	12.93	16.55	2.6	18
Togo*	56,000	56,000	100	1.96	2.41	2.6	43
Uganda*	236,000	50,000	21	9.55	12.78	3.4	54
Upper Volta*	274,200	180,000	66	5.28	6.55	2.6	24
Zaire*	2,345,400	2,300,000	98	20.88	27.75	3.7	12
Zambia*	752,600	250,000	33	4.12	5.47	3.2	7
Zimbabwe	390,600	40,000	10	5.13	6.93	3.3	18
TOTAL (37)	21,408,200	9,050,350	42.3	241.08	312.69	+30.0%	15

The estimated area of the tsetse infested zones is between 9-10 million km^2 of which about 3 million are areas covered by thick forest. The areas presently infested by tsetse, and which offer a potential for livestock and crop production can be estimated at about 6-7 million km^2.

[a]Summary Table of Statistics of African Countries Infested by Tsetse Fly, FAO, Rome, 1981. Rounded to the nearest 100 km^2 including inland water.

[b]Increase 1975-1978 (%).

[c]Population ÷ surface area.

*Member of Commission on African Animal Trypanosomiasis.

Source: FAO, Rome, 1981 (Summary Table of Statistics of African Countries Infested by Tsetse Fly).

the availability of the infected areas for grazing is expected to double the current livestock population of Africa from 114 million to 230 million heads [Kamarck, 1976]; and meat production could double to 1.5 million tons [GTZ, 1980]. Thus, it may improve the general per capita livestock protein intake in many African countries.

How important is trypanosomiasis in Africa relative to other diseases? Eicher and Baker [1982] rank it fifth after rinderpest, contagious pleuro-pneumonia, clostridial diseases and internal parasites. It is very difficult to quantify the full economic implications of these diseases. Thus, while trypanosomiasis may rank fifth in livestock mortality and morbidity, other serious factors such as livestock production inhibiting affects on large areas of Africa, the threat of an upsurge of the disease due to lack of protection by vaccination and its relation to sleeping sickness in humans could easily make it the most important disease today.

While the danger from either trypanosomiasis or sleeping sickness (both of which are basically a tsetse fly problem) has not been so menacing in the recent past as it used to, there are sporadic signs that the problem is far from being contained. Thus, sleeping sickness is increasing in some places of Uganda [Jahnke, 1974]; of some Ugandan lands cleared before 1972 and whose protection was not maintained, Jahnke [1974] says "Re-infestation of the fly is then only a matter of time" [p. 202]. Tsetse flies are gradually adopting their habitat to the extent of becoming a concern even in some urban areas of Nigeria [Putt _et al._, 1980]; trypanosomiasis infection are becoming more common now in the higher plateau's of Ethiopia, places which had no such history of infection [ILCA Newsletter, 1982]; and finally, the persistent success of some trypanosome strains to develop resistance to curative and preventive drugs is potentially a dangerous situation. All these are

indications that there should be no relaxation in the vigilance for possible spread of the disease. Beyond these indications however, the current relevance of the problem for many African countries seems well established. As already indicated, out of the 9 to 10 million km^2 of land infested with tsetse, some 6-7 million km^2 has potential for agricultural exploitation, particularly for livestock production, the rest being under heavy forest cover. About 37 countries are affected by tsetse fly and for a fourth of these countries, their entire land area is infested; more than 40 percent of the countries have over three-fourths of their land infested and one-half of them have one-half of their land under tsetse control (Table 2). The economic .. impact of such a constraint will be discussed next.

A. Impact of A.A.T. on Economic Development

The impact of the tsetse problem on economic development is seen through its impact on the following three categories:

a. Human population;

b. Land use and ecology and

c. Livestock production systems.

In the past sleeping sickness wiped out whole villages or badly disrupted economic and social life in many West and East African communities. During the second half of the last century, there were scattered but devastating epidemics in many places of West Africa. For example, at about 1889, a town population of 4,000 was wiped out except for 50 in Northern Nigeria [Putt *et al.*, 1980]. Shortly after its introduction into that part of Africa, sleeping sickness in 1903 was claiming 11,000 lives daily in Uganda, eventually wiping out close to 200,000 people. As late as 1934, the population of one district in Nigeria declined from 32,000 to 10,000 in 10 years due to the

disease [Ibid, 1980]. A disruption of this magnitude causes severe social and economic dislocation. Settlements may be abandoned or the area may be so depopulated causing decline in agricultural activities and thus expanding the fly habitat further. New economic areas may be off limits for agricultural production due to the fly threat. Kamarck [1976] also points out that the threat of the disease was very instrumental in limiting contacts, communications and trade between many AFrican communities and regions.

The direct effect of sleeping sickness on economic development is expressed in several ways: First, the human suffering and death among the infected people is an immeasurable social loss in itself; people infected even with milder forms of the disease "become chronically sub-normal, both mentally and physically and the death rate [is] higher than expected since patients often succumbed to various intercurrent diseases" [Putt et al., 1980]; second, costs in disease diagnosis and drug treatment is a drain on the scarce resources of a country; and third, the capacity and energy of the infected people to produce is greatly reduced thus costing the national economy a considerable loss in production. These human and economic costs vary from one place to another and are dependent on many interrelated factors. for treated animals [see for example Putt et al., 1980, p. 51]. With improved management, the mortality rate among the infected animals is unlikely to go beyond 5 percent. About 50 percent of the value of such a dying animal can also be economically recovered in the form of meat and hides.

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The need to reduce trypanosomiasis related wastage in livestock production, the increased demand for more space and the possible threat of fly invasion to tsetse free areas have made it necessary for many countries to engage in some sort of tsetse or trypanosomiasis controls. The existence of an infested area that could be exploited for agricultural or other economic

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ventures or even the threat of fly invasion does not however constitute in itself an adequate economic justification to engage in such control measures The necessity for any control or eradication measure must be based on a genuine need for more tsetse free land, economic viability of the control measure and a concurrent implementation of an integrated land use and conservation plan. An integrated land use plan is necessary for efficient exploitation and preventing land degradation such as through over grazing. Additionally, resources spent to control or eradicate trypanosomiasis could possibly be used more profitably in other areas of investment. For all these reasons, it is vital that the control be based on economic need and integrated land use plan as well as on benefit-cost analysis of the expected expenditure. Not unexpectedly, the particular control technique employed, the extent of the control measure achieved and efficiency in subsequent production project implementation and timing will greatly impact on the costs and benefits. In the following section, the major tsetse and trypanosomiasis control techniques presently employed will be briefly reviewed to enrich the review on cost-benefit analysis.

At present, the epidemic manifestation of the disease is almost nonexistent. This is a result of a natural decline of the fly over the years and a systematic attempt of isolating people from tsetse infested areas, the administration of curative and preventive drugs and certain measures taken to control or reduce the fly population and distribution. The natural decline is usually accompanied by expanding human population changing the ecosystem, thus drastically altering the preferred fly habits. Thus while some people still suffer from the economic and pathogenic effect of the disease in many parts of Africa, the problem of sleeping sickness is relatively less common than animal trypanosomiasis. Sleeping sickness will not

be part of the economic review here except to the extent necessary to highlight the overall tsetse problem and its qualitative effect on the economy.

The tsetse or A.A.T. problem is sometimes referred to as the land use problem. It does not make economic sense to speak of the problem unless it is related to some kind of land use system. The effect of the disease on land use and ecology can be seen from two differing aspects: (1) regulatory function and (2) production inhibiting results. Some people think [see Ormerod, 1970] that many of the ecologically fragile parts of Africa would have long been subjected to overcrowding and overgrazing in the past resulting in degradation and destruction of the ecosystem if they had not been infested with tsetse flies and thus unavailable for livestock grazing and crop production. Even the devastating Sahelian drought in the early 1970s is partly attributed by Ormerod [1976] to the seasonal overgrazing subsequent to tsetse control schemes which doubled in ten years the livestock population in the area. Similarly without tsetse infested sanctuaries wild life enclaves would have long succumbed to growing livestock and human population pressures.

The issue that has drawn much interest in the literature is however the production inhibiting effect of Trypanosomiasis on land. Potential agricultural lands are not exploited because they are mainly off limits for livestock grazing on the land cannot be more productively cultivated because tsetse infestation makes it either impossible or expensive to keep traction animals. Many people think that the gradual encroachment of cultivation practices into the tsetse infested areas has often succeeded. Thus, Ford [1971] says, ". . . the local peasantry [of Uganda] had developed, unaided, large areas of tsetse infected bushes" [p. 236]; Jahnke [1974] adds, "In principle the presence of tsetse flies would not directly impede agricultural development unless sleeping sickness is present" [p. 54]. Such successes while common are not however

universal. Thus, Jordan [1978] says, "African methods of cultivating land vary immensely from place to place . . . Results of cultivation can be either favorable or unfavorable to tsetse . . . in many parts of African shifting cultivation has resulted in the formation of much secondary thicket, frequently an ideal habitat for certain Glossina spp" [p. 126]. In some cases even cocoa, coffee and rubber plantations could serve as a temporary tsetse habitat. Nevertheless, the basic observation that expanding human populations and the resulting acquisition and cultivation of new areas as the major cause of decline for certain fly populations and habitats seems well established. This is particularly true mainly with the savanna type G. morsitans group tsetse. Other groups of flies, "can live in close association with man . . . particularly in wetter areas, man's activities can actually provide new habits for the fly" [Jordan, 1978].

Finally, the adverse effect of trypanosomiasis onthe economy is reflected on livestock production systems. Besides the costs pertaining to diagnostic surveys, drug purchase and treatment, and control expenses borne by the economy, livestock production suffers from four aspects: (a) increased morbidity (b) increased mortality, (c) reduced fertility and (d) reduced grazing areas. The seriousness of these problems depend, among other things, on the tsetse challenge a broad term referring to the level of tsetse infestation, the type of tsetse species, the frequency of tsetse bites, the kind of the disease organism involved, the susceptibility of the livestock involved [Jahnke, 1974] and the quality of management and husbandry practiced.

Morbidity among infected livestock results in reduced milk and meat production, inefficient use of feeds and poor work performance. Due to abortion and lethargic state, the ability of an infected herd to reproduce itself is also greatly diminished. For economic analysis, the morbidity loss

is usually estimated to be about 1-2 percent of the market value of the animal.

The greatest loss may be however, the mortality among infected animals. In accute forms of the disease, the death rate can go as high as 50 percent for untreated animals and up to 10 percent

B. Approaches and Techniques For A.A.T. Control/Eradication

Strictly speaking, there is a difference between the words control and eradication in the context of combating the A.A.T. disease. Control implies measures taken to limit the distribution and number of the tsetse fly (hence, the disease, trypanosomiasis); eradication implies the complete elimination of the fly (or the disease) from a given locality. The difference between the two is sometimes a function of the level of effort applied with a given control/eradication technique rather than differences in basic approach. Thus, insecticide spray could be used for both objectives. Furthermore, eradication in the sense of permanent national relief from any fly threat is only a possibility whose realization, if ever possible, is a long way off. Thus, any eradication measure at the local level amounts to a form of control from a national, regional or even continental point of view. Thus, the two words are usually used interchangeably unless it is contextually necessary to use their specialized meanings; such a convenience will be used in this review. Furthermore, except in a few isolated cases where the disease may be transferred mechanically by other flies from one host to another, the tsetse fly is the vector in all other cases. Therefore, a measure of (reference to) tsetse control or eradication implies a control or eradication of the disease.

Tsetse control is a complex program calling for an efficient and elaborate organizational structure whose sub-units are specialized in the accomplishments of various tasks. Such tasks constitute responsibilities such as surveying and monitoring the extent, pattern and effect of the disease, facilitating the actual control or eradication programe, the control/eradication activitiy itself and subsequent monitoring of the effect of tsetse control on the disease, the environment and on land utilization patterns. The success of the approach will thus depend on efficient coordination of units (and activities within units) and the availability of qualified expertise at

certain critical phases of the programe. Success in the present context implies the timing and cost per unit area cleared and maintained free of tsetse, the setting up of mechanisms (projects) to realize the consequent economic benefits and the feasibility of such projects.

Almost all the different techniques for controlling tsetse and A.A.T. can be divided into three basic approaches:

1. Attack the vector
2. Modify the habitat
3. Attack the trypanosomes or disease causing organisms (treat the disease)

Rarely will one of these basic control approaches be used by itself without being supplemented with at least one of the remaining two. What approach and technique to use is technically determined by the level of fly infestation, the nature of the habitat, the effectiveness (feasibility) of the approach and the associated costs in clearing. Beyond these issues however political considerations (e.g. employment creation) could greatly influence or modify the technical conclusions.

1. Attacking the Vector

There are about 30 species of the African tsetse fly (Glossina genus) of which 22 are capable of transmitting the disease of A.A.T. The fly feeds exclusively on the blood of vertebrates (man, wild and domestic mammals, reptiles and birds) and as a vector carried the trypanosome pathogens between livestock, human beings and wildlife as well as within the same species. There are different groups of flies characterized by habitat, geographical distribution, host preference and other behavioral traits. Both habitat and

distribution are determined by ecological, climatic and vegetational factors. The three main groups of flies are Glossina morsitans (savanna type), G. palpalis (riverine type) and G. fusca (forest type).

The most important techniques for attacking the vector, the fly, are the following:

a. Insecticide spray
   i) persistent versus non-persistent (aerosal) chemicals
   ii) ground vs. air spraying
   iii) Discriminitive versus blanket spraying
b. Genetic manipulation of laboratory reared vector
c. Biological attack of the vector
   i) Releasing fly parasites
   ii) Releasing fly pests or predators

The last two techniques are at the experimental stage (particularly the biological attack) and their feasibility (both technically and economically) have not been fully evaluated yet. The genetic manipulation is achieved by sterilizing laboratory reared male flies through gamma radiation. Since the female fly is assumed to mate only once in lifetime, releasing the sterile males into the open fly habitat so that they can seek and mate with the females will help to substantially reduce and even eventually eradicate the tsetse population from a given area. About 100 km^2 in Upper Volta (GTZ, n.d.) and 16 km^2 in Tanzania were cleared by this method. The use of sterile males has a number of advantages (Putt et al., 1980). Among the advantages are (a) since no insecticide is used it is environmentally attractive; (b) it is suitable at low levels or densities of fly population where fly detection is not so easy and yet the sterile male can actively seek out and sterilize the

female; (c) there is no problem associated with persistent control measures since the fly destroys itself in death; and (d) one sterile male is capable of sterilizing a number of virgin females. The approach has a number of disadvantages too: (a) it is not absolutely certain the female fly mates only once in a lifetime; (b) it may not be easy to rear and maintain a large fly colony in a laboratory condition requirement and to monitor the efficiency of the sterile flies in competition with the wild males for mating; (c) there is the danger of trypanosomiasis infection by sterile flies; (d) there is always the threat of re-invasion from neighboring areas; and finally (e) the technique is effective in low fly population densities so that initially it may be necessary to use some other techniques (usually fast degrading insecticide) to lower the population density, thus negating the environmental advantage and possibly creating a danger to the sterile fly itself from insecticides. Except some applications in Tanzania (Dame, 1979) and Upper Volta (Cuisance et al., 1978), the technique has not been extensively tested. In Tanzania, the cost per sterile fly released was estimated at about U.S. $0.22.

The most common technique of attacking the vector on a large scale has been insecticide spray. The application is usually made during the dry season when the fly distribution is most limited and its population level is at its lowest. Cost per unit area claimed can be further decreased by spraying only certain bushes and vegetations (discriminative spray) ideal for fly habitat (shade) and within these target areas only certain parts of a shrub or tree (selective spray). Success of eradication through spray is enhanced if natural fly barriers are incorporated in the construction of buffer zones or lines of "consolidation" which are absolutely necessary to contain re-invasion.

There are two kinds of insecticides: the persistent ones which retain their toxicity for 2 to 4 months after application and the non-persistent ones. Both of them can be applied from the ground or the air. Ground spray includes knapsack manual sprays and motorized mistblowers; aerial spray is applied by helicopter or fixed-wing aircraft. Both the kinds of insecticide form used and the methods of application employed have advantages and disadvantages. The residual effect of persistent chemicals could be highly destructive to non-target species; on the other hand, non-persistent insecticides may require repeated applications in thicket and riverine vegetations and thus could be relatively more expensive and possibly less effective. Because of the problem of applying discriminative spray with fixed-wing aircraft, they are usually not used for persistent insecticides. Both ground and aerial sprays could be used together to clear an area. All three must be followed with (a) the construction of buffer zones (through resprays or bush clearing), (b) both pre- and post-spray surveys to determine fly habitat, population and distribution and to check reduction and eventual disposition of the fly and (c) a continuous monitoring of the effect of the insecticide on the environment. Zambia is usually cited as having done extensive operation with fixed-wing aircraft; Niger, Cameroun, Nigeria and Upper Volta have successfully used the helicopter.

What technique of insecticide application to employ could be determined by characteristics of the terrain, the density of the vegetational cover, the kind of insecticides used, the ecological adverse effect of the technique and by political or policy decisions not necessarily based on economic or feasibility criteria.

Some of the advantages to ground spraying are the following: (a) training of staff; (b) creation of employment; (c) building of roads highly conducive and necessary for area development subsequent to tsetse clearance; (d) use of selective spraying for more effectiveness and less ecological damage; and (e) reduced demand for foreign exchange. On the other hand, the disadvantages include (a) large organizational unit prone to potential inefficiency, (b) unsuitable for large areas in a short time, (c) possibly expensive labor and infrastructural needs and (d) limited accessibility to difficulty areas such as thick forests, steep slopes and deep gullies.

The advantages of aerial spraying include (a) large area coverage in a shorter time, (b) physical inaccessibility not a problem, (c) less overhead costs such as roads and (d) effective use of persistent chemicals (helicopter only) in riverine forests. The disadvantages are mainly (a) the inability to apply discriminitive and selective sprays, increasing both environmental damage and the cost per unit area sprayed (b) usually requires ground spray or bush clearing to construct buffer zones and (c) it costs more foreign exchange.

2. Modifying the Habitat

One way of controlling tsetse or reducing its harmful effect would be to destroy its habitat. Measures employed for this purpose include:

a. Mechanical bush clearing

b. Seasonal burning

c. Alteration of land use patterns

Bush clearing usually refers to indiscrimination of the vegetation including tree cuttings and de-stumping. This deprives the fly of shade and resting sites. The operation may involve manual labor and/or heavy machinery,

such as a pair of caterpillar tractors, pulling in parallel an enormous chain weighing up to 10 tons and up to 100 meters long. Depending on a number of factors, mechanized clearing could progress at the rate of 1 ha. to 4.4 ha. per hour (Jahnke, 1974) thus the cost ranged from U.S. $5.60 to $24.36 per ha. Manual total bush clearing (unlike partial which is suited for discriminative and selective clearing) took 6.5 to 30 man-days per ha. cleared and required U.S. $4.50 to $20.16 in Uganda (Jahnke, 1974). Nigeria also used manual bush clearing extensively. The advantage of bush clearing is that there is no adverse effect on the ecology from chemicals; the big disadvantage is of course bush clearing exposes the land to erosion and possibly to drought (Ormerod, 1976).

Seasonal burning of the infested area destroys both the fly and its habitat. Its advantage lies in killing other parasites and vectors such as ticks. Its greatest disadvantage lies in its possibility to destroy the ecological system and expose the land too to severe erosion. It does not afford permanent solution from the A.A.T. problem either.

The third approach to modifying the fly habit is the most important one in its rationale, feasibility and effectiveness. It mainly deals with bringing in infested areas under planned land utilization program and agricultural production or human settlement (assuming there is no sleeping sickness too). Both of them involve bush clearing and land development thus giving permanent relief from re-infestation. Its based (or should be) on genuine need for more settlement or agricultural land and it is effective since it will be maintained fly free as a by-product of the cultivational and settlement activities. Without a clear and strict land use plan however, the process will be haphazard, slow and probably destructive to an ecology that was protected so far by fly infestation.

Associated with modifying the habitat are the driving away or killing off game animals and the use of trypanotolerant livestock on infested areas. The first move is bound to occur as a result of settlement or agricultural cultivation encroaching on infested areas. The desirability of such an outcome will be determined by political and economic realities. Jahnke (1976) has also noted that elephants tend to lower fly populations by tearing down their resting sites of bushes and trees.

The use of trypanotolerant livestock such as the N'Dama, Keteku and Muturu humpless cattle of West Africa and the Baouli of Central Africa and even some zebu breeds in Southern Africa (Morrison et al., 1979) as well as seasonal grazing by susceptible cattle are some other responses to A.A.T. problem in otherwise agriculturally suitable area. (The last response is what livestock owners have done all along and thus may not be considered as special form of A.A.T. control.) The use of trypanotolerant cattle is advisable where it is not possible or economical to eradicate the tsetse or where the use of chemotherapy and chemophylasis cannot be followed either due to drug scarcity or trypanosome resistance. Under heavy fly challenge however, even the trypanotolerant cattle must be additionally protected by trypanocidal drugs. Better management and nutrition as well as initial exposure to A.A.T. at a younger age help to successfully withstand the infection.

Some of the complaints against trypanotolerant cattle are their small size, difficult herd instinct, alleged lower productivity, loss of A.A.T. resistance when crossed with improved local or exotic breeds (Jahnke, 1974) and even susceptibility to the disease when under stress such as from intercurrent disease infections and draft work. Size for size and both under similar tsetse-free environments, evidence shows that the small trypanotolerant cattle

are at least as productive as their bigger but susceptible breeds in beef production (Wissocq, 1980; Animal World, 1979; and Putt et al., 1980); under tsetse-infested environments, the dwarf cattle produce more, since the susceptible breeds are at a disadvantage. Although their small size may be an advantage in times of pasture and fodder shortage, Wissocq (1980) says even this can be improved through improved nutrition[1] and better management. He cites N'Dama in Zaire and Baoulé in Central African Republic which showed general increase in body size. The dwarf cattle also mature early compared with the zebu and have a shorter calving interval (Putt et al., 1980). Their poor herd instinct may be an asset too in introducing them to an economic system not accustomed to cattle production (Jahnke, 1974). Much economic and technical research needs to be done on the relative production efficiency of trypanotolerant cattle, the genetic or biological mechanism and basis of their tolerance, how it is affected by different levels of management, tsetse challenge and ecological systems and on their role as reservoirs of trypanosomes. People disagree on the direction of dynamic changes in the aggregate population size of the trypanotolerant cattle in West Africa. Table 3 shows a substantial proportion of the cattle population in many West African countries are trypanotolerant breeds. Finally, since trypanotolerant cattle are usually raised in heavy fly challenge, the use of curative and preventive drugs becomes almost always a necessity. This will be discussed in the following section.

3. Attack the Trypanosomes or Disease Causing Organisms (Treat the Disease)

There are three main species of trypanosomes or disease causing agents in livestock (and man). They are *T. vivax*, *T. congolense* and *T. brucei*.

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[1]The high mineral levels in the soils were responsible for the improvement in pasture nutrition.

Table 3 LIVESTOCK POPULATIONS

	Cattle '000 head		Goats '000 head		Sheep '000 head		Percent of Total area infested with tsetse
Benin +		800		450		950	100
Cameroun -	(2 197)	3 027		1 750		2 211	84
Central African Republic -		670	(450)	780	(63)	80	96
Congo +		71		119		66	100
Gabon +	(3.4)	3	(52)	90	(47)	100	100
Gambia +	(295)	280		92		95	88
Ghana +	(777)	930	(980)	2 000	(450)	650	100
Guinea +	(1 215)	1 700	(537)	395	(540)	430	100
Ivory Coast +	(483)	650		1 200			100
Liberia +	(25)	38	(119)	190	(45)	190	100
Mali o	(1 810)	4 457	(754)	5 757	(833)	606	16
Nigeria -		12 000		24 500		8 500	65
Senegal o	(1 353)	2 806		(1 606) 1 000		1 884	30
Sierra Leone +	(207)	270	(47)	175	(112)	60	100
Togo o	(214)	250	(730)	748	(792)	835	100
Upper Volta o	(2 550)	2 700	(100)	2 700	(4 142)	1 800	66
Zaire o	(1 078)	1 144	(2 216)	2 783	(762)	779	98

Figures in brackets from ILCA/FAO/UNEP Survey, 1980

+ = over 50 percent trypanotolerant livestock

o = under 50 percent but over 25 percent trypanotolerant livestock

- = under 25 percent trypanotolerant livestock

Source: Report of FAO/SIDA Workshop on the Breeding of Trypanotolerant Livestock, FAO, Rome, 1981.

The first two are the main causes of trypanosomiasis respectively in West and East Africa. T. brucei is less virulent to livestock; however, it has two sub-species, T. gambiense and T. rhodesiense, which are the causes of sleeping sickness in man. All of them complete their developmental cycle in flies of the genus Glossina;[1] one species however, T. evansi, which is related to the T. congolense does not use tsetse fly as a vector and is mechanically transmitted by other biting flies.

One way of raising livestock in infested areas (at least on a seasonal basis) and thus control trypanosomiasis is by using trypanocidal drugs against the above trypanosomes themselves (Bourn and Scott, 1978). Where the tsetse challenge is heavy such drugs are necessary even for the trypanotolerant cattle discussed earlier. There are two general purposes of the drugs: (a) chemotherapeutic or curative once infection has taken place and (b) chemophylactic or preventive against infection. No vaccination technique is available currently due to the ability of the infecting strain to produce a large number of antigenic variants every few days and thus evade the immune response it produces.

It is very difficult to raise even with drugs susceptible livestock in a year round heavy fly infestation without additional measures to control the vector. Thus, curative drugs are best used for the following purposes (adapted from Putt et al., 1980):

a) To mitigate losses from trypanosomiasis due to seasonal fly infestation or with other fly control measures in a year round infestation;

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[1]The fact that T. vivax in cattle in Latin America and T. evansi in many livestock in Latin America, Asia, Middle East, Far East and in Africa outside known limits of fly distribution show that there are means of trypanosomiasis transmission other than tsetse fly.

b) Early introduction of livestock into tsetse reclamation schemes;

c) The control of trypanosomiasis on the fly-infested margins of reclamation schemes;

d) To control of sporadic trypanosomiasis due to mechanical transmissions, seasonal fly dispersal and flies mechanically transported; and

e) The protection of livestock passing through fly belt.

Preventive or chemoprophylactic drugs could also be used for the above purposes. However, since blanket administration of the drug would be needed, the exercise would be very expensive. There are rather serious disadvantages (or potential dangers) to the use of both drugs. They include the following:

a) Application requires strict adherence to prescription or treatment regimen; otherwise there is danger of resistant strains of trypanosomes being developed;

b) It can be very expensive due to high frequency of treatments, surveying and monitoring of infected animals (for chemotherapeutic drugs) and blanket treatment of all cattle (for chemopro hylaetic drugs);

c) Due to the above two reasons, diagonistic facilities and well trained expertise are required thus making the application difficult in pastoral areas;

d) Drug may not be available (imported) on time or it may not be stored properly; and

e) Infection is very dangerous if it comes from animals that have been under prophylaxis.

Thus, for trypanocidal drugs to be effective, they require high veterinary supervision, sound management practices and an understanding of the epizootiology and epidimiology of the disease (Bourn and Scott, 1978).

C. FACTORS INFLUENCING THE CHOICE OF APPROACH TO AAT CONTROL AND/OR ERADICATION

The choice of approach to control and/or eradication of AAT depends on several interrelated physical and social factors which have important economic consequences. These fall into five broad categories.

1. Geographical Dimensions of the AAT Challenge

Where tse-tse infestations are relatively isolated, or in areas which can be protected from reinfestation with minimum effort, eradication programs may offer a more cost-effective solution to AAT problems than on-going control operations. River valleys in between heavily cultivated areas provide, perhaps, the most common setting for eradication programs. The need and the ability to control movements of livestock and people from infected areas into the newly claimed areas will usually be key variables influencing the long-term success of eradication programs.

2. Ecology

Terrain, vegetative cover, the type of fly, the presence of other life forms which might be affected by AAT control measures and climate are but a few of the ecological variables which influence the choice of approach to AAT control in a particular situation. This project addresses the ecological dimension of the choice of approach of expertise that increase the likelihood of careful consideration of all the nuances of this dimension.

3. Land Use

Inground, AAT intervention programs should assume that land use patterns following control and/or eradication measures will pretty much continue as before unless specific measures are taken to alter land use patterns, i.e. by moving people and/or livestock into the reclaimed areas. Where these is hope of rapid increases in human settlement, for example, extensive clearing operations might give way to increased cultivation and land use changes that help

control the fly's habitat naturally. This would only occur where population pressure is high and available land for cultivation is relatively scarce. At the same time, chemoprophylaxis and chemotherapy will be relatively more economic where heavy agricultural use of the land has greatly diminished the fly population and, at the same time, reduced the area available for livestock raising. In such circumstances ground spraying or helicopter spraying will often be more cost effective than spraying with fixed wing aircraft.

Land use considerations go beyond the immediate choice of technique for AAT control. Existing land tenure systems may prevent the realization of key long-term economic development benefits from AAT control/eradication measures unless land use is planned and followed with institutional reforms necessary to ensure that such plans can be implemented. Careful attention to land use variables will frequently spell the difference between cost-effective AAT interventions and uneconomic ones. One of the purposes of this AAT project is to increase the returns to tse-tse control and/or eradications measures of all types by providing the skills necessary for effective land use planning relating to the newly opened areas.

4. Organizational Infrastructure

The data on the cost of various kinds of AAT control/eradication measures which are summarized in Section E show wide differences in cost per unit. Partly this reflects accounting differences and the difficulty of correctly identifying all the various cost components. Partly these differences reflect differences in terrain, vegetative cover, fly species and other variables which have a major impact on site specific unit costs. But the differences also, no doubt, reflect wide differences in organizational infrastructure, operations and management control and public sector wage, employment and pricing policies. The length of an actual working day (as opposed to an official work day) for a

civil servant or veterinary assistant in Mid-Saharan Africa, for example, varies between two and seven hours per day. The supply of materials with which to work ranges between usually non-existant to generally available. Obviously the number of treatments or area sprayed per day per person will vary enormously under such circumstances, as will unit costs. Where organizational infrastructure or work discipline is particularly weak it would be foolish to approach AAT eradication/control in any way requiring careful ongoing monitoring or control of movements.

5. Level of the AAT Challenge

Both the absolute level of the AAT challenge and the importance of AAT relative to other diseases will influence the choice of approach to AAT control and/or eradication. Where no human settlement or livestock production currently exists - usually in areas where human sleeping sickness is also a problem - the challenge will generally be high. In such situations chemotherapy and chemoprophylaxis do not offer visible approaches both because of the large number of treatments which would be required and the danger of stimulating the development of drug resistant strains which could reduce the effectiveness of otherwise successful chemotherapy operations elsewhere. If, on the other hand, some cropping and livestock production activities are already taking place, trypanosomiasis may be one of many diseases against which producers need to protect their animals. In such circumstances, treatment and prophylactic measures will usually make more economic sense than afrontal attach on the vector itself. Treatment programs also fit more easily into ongoing veterinary programs.

D. Benefits of A.A.T. Control/Eradication

A.A.T. is characterized by a complex manifestation of variability and interactions. Similarly, the identification and quantification of benefits and costs are bound to be equally complicated. Some benefits and costs such as the saving of human life and the loss of an ecological system cannot be measured at all. The extent of their worth to society are usually based on (limited by) political or policy decisions. Because of such problems and the uncertainty inherent even in the quantifiable variables, it is better to use boundary or range values rather than single figures. Thus, individual benefits could be estimated at the worst possible scenario and at the best possible outcomes. An economic analysis of A.A.T. control measure on such an approach helps the decision maker to weigh the stakes at different levels of the outcome.

The benefit-cost approach to projects such as A.A.T. control evaluation has the following limitations:

1. The benefit/cost ratio analysis is biased toward quantifiable financial measures; any direct cost or benefit that cannot be quantified is not accounted for;

2. Indirect economic, social and ecological effects from control measures are not considered; and

3. Political objectives such as income distribution at an inter-sectoral, interregional or even at a local level are not accounted for.

Furthermore the following points need to be considered: (a) Whether to evaluate costs and benefits in market prices or accounting (world) prices--the former includes transfers between individuals which are not real costs and benefits to the economy as a whole; and (b) in the case of A.A.T. control, some people do not include potential benefits (and hence associated costs) not spontaneously pursued by the residents either because the system of production is new to the area (and is doubtful whether it would have been adopted in

the absence of tsetse) or such flow of costs and benefits are best analyzed in development project type of approach where the problem of tsetse would be internalized in the project's intensive input and output configurations. Ranch development and large scale irrigation schemes are sometimes identified as projects with such categories of costs and benefits [see Putt et al., 1980]. Any project or production system whose adoption was constrained by the presence of A.A.T. should be part of the A.A.T. control economic analysis. This is the approach in the Nigeria A.A.T. control economic analysis. Jahnke's [1974] economic analysis in Uganda however, views A.A.T. costs and benefits in much broader perspective.

An attempt to list the major cots and benefits from A.A.T. control or eradication program is presented below. Which ones will be present in a substantial way and which ones absent is something which is project specific. Even among those which are expected to be present and quantifiable, a decision must be made whether the expected improvements are worth the additional calculations.

1. Qualitative Listing of Benefits

   a. Direct Benefits

      1. Affecting humans

         - Reduction in human sleeping sickness diseases
         - Reduction in mental and physical discomfort from fly bites

      2. Affecting livestock production through,

         - Reduced mortality
         - Reduced morbidity
         - Improved pasture in both previous and newly opened areas (may not be sustainable over long run)
         - Use of more productive breeds formerly restricted by A.A.T.
         - New production technologies heretofore not feasible (fattening operations in river valleys, permanent ranching, etc.)

- Increased livestock carrying capacity of the land due to dry season crop residue

3. Affecting agricultural production through,

   - Opening up newer, more productive areas
   - Increased cropping intensity in areas already under production
   - Adoption of animal traction not feasible or efficient prior to control/eradication measures
   - Greater productivity of human and draft animals arising from control or eradication measures

b. Indirect Benefits (externalities or by-products)

1. Improved nutrition from,

   - Greater availability of animal products where protein deficiency is otherwise or problem and where livestock production is increased
   - Increased availability of food energy where nutrient intake is inadequate and production increases

2. Increased incomes arising from improvements in livestock and agricultural production (livestock alone rising by up to 18 percent [FAO, 1981]

3. Reduced government expenses through lower expenditures on treatments for human and animals (provided not offset by higher costs elsewhere)

4. Increased government revenues through direct taxes on incremental agricultural production

5. Increased foreign exchange through,

   - Savings on imports of agricultural commodities due to greater supply domestically
   - Earnings on exports of agricultural commodities in greater supply because of A.A.T. control or eradication measures
   - Savings on import of drugs and lab facilities (provided not offset by foreign exchange costs of control or eradication measures)

6. Increased economic integration of traditional livestock herds through increased commercial offtake of livestock and livestock products

2. Quantitative Estimates of Benefits from AAT Control/ Eradication

Though not easily quantifiable, clear and often times substantial benefits accrue to society from elimination of human sleeping sickness. In recognition of the difficulty of valuing this benefit, however, this analysis will concern itself only with quantifying those benefits relating to increases in agricultural production which result from AAT control eradication programs.

a. Livestock Production Benefits

There is little doubt that, historically, the principal production benefits of eliminating trypanosomiasis has been increased supplies of meat, milk and hides. As livestock move into the newly zoned areas grazing pressure elsewhere is reduced. Meat and milk production from livestock remaining in the former grazing areas increases, often by enough to offset the previous production of those animals moving to the new tsetse free areas. As a result, the total output of livestock in the newly opened areas will, in general, constitute a net increment to agricultural production. The value of these benefits will be proportional to the quality of the land opened up as well as the demand for, and consequently the price of, livestock production. For this reason, each eradication/control program will have to be analyzed in its particular context in order to determine its economic viability.

Available data permit limited generalizations concerning the magnitude of the technical responses one can expect from effective trypanosomiasis control programs in areas already containing livestock. In comparing various trypanotolerant herds of cattle in sub-Saharan Africa with non-tolerant breeds under medicine, light and zero levels of trypanosomiasis risk, FAO [1980] found only slightly higher (5-10 percent) productivity per 100 kgs. of cow maintained (in effect, per unit of feed resources) for Zebu herds under zero

risk, station management conditions. The Zebu maintained their productivity edge under low risk, village management conditions but the absolute levels of productivity for both tolerant and non-tolerant breeds were only about 40 percent as much as under the zero risk station management conditions. Under medium risk village management the tolerant breeds achieved productivity levels that were about 45 percent greater than those for non-tolerant breeds. From these data, limited as they are, we can conclude that aggregate production of meat and milk from cows on a given unit of posture is about 20 percent lower in the presence of medium tsetse challenge as compared to a low risk or no risk environment. This results primarily from differences in calving percentages (i.e., calving interval) and calf viability. Assuming 40 percent of the herd consists of cows overall losses in production range between 0 and 8 percent, depending on levels of tsetse challenge.

Adelhelm [1980] reviews two studies done in the Ivory Coast. One finds losses due to death for trypanosomiasis amounting to .5 percent of the value of the herd. Based on the prices used to value the dead animals it is clear that the study cited assumes that none of this meat is salvaged for local consumption or sale. On the other hand, losses due to death represent only one dimension of economic losses due to trypanosomiasis. Morbidity which reduces overall herd productivity must be much more important than outright death.

A second study reviewed by Adelhelm attempts to address this question by showing what the impact of higher mortality is on total herd size over a ten year period. The herd infested with trypanosomiasis has about 2 percent greater mortality overall, leading to about 19 percent fewer animals in the herd at the end of 10 years. From this Adelhelm calculates losses due to trypanosomiasis at 5 percent of the value of the herd. This probably

constitutes a slight overestimate since the age structure (and consequent value per animal) would be lower in the larger herd because mortality due to trypanosomiasis is higher under one year of age.

Taken together these data suggest aggregate losses due to trypanosomiasis of 0-8 percent of the value of the herd, depending on the levels of exposure. Two to four percent probably represents a reasonable range for light to medium levels of infestation. The absolute level of benefits from AAT control operations will depend on stocking rates and cattle prices in addition to reductions in herd losses. The higher the carrying capacity of the land, the greater will be the absolute savings. The economic analysis section assumes stocking rates based on a standard stocking unit (S.U.) of 250 kilograms liveweight. The estimated value assumed for one stocking unit for 1980 is 300 or 1.40 per kilogram liveweight, based on prices in Bouché, Ivory Coast, less 50 handling and transport.

b. Crop Production Benefits

Crop production benefits arising from eliminating AAT can sometimes be substantial. In Nigeria, for example, Putt et al. [1980] found that from 20 percent to 50 percent of the benefits of tsetse eradication arose from crop production, including the use of draft animals. The large benefit was substantially due to the fact that the presence of human sleeping sickness was preventing settlement of highly productive riverine land adjacent to areas of land scarcity and high population densite. Once the source of the disease was eliminated new settlement on highly productive land occurred rapidly.

In areas where land pressure is less intense, not all new agricultural production represents a net gain to society. The new land may indeed be more productive but at least a part of the new production only offsets output lost where farmers abandon old, depleted production areas in favor of the

often more fertile virgin areas. The net gain in output will vary from case to case but only in the unusual case of high adjacent population pressure will it be immediate and dramatic.

In general we can say that land that can support crops will be more valuable in crop production than in livestock production, assuming of course it does not serve as a crucial dry season feeding reserve. Under prices prevailing in the Sahelian region, for example, the total value of grain produced on a hectare of land would be 7-8 times the value of meat and milk produced by the average traditionally managed herd on the same land. Labor inputs, however, are much higher for the cereal crop and, in most cases, only the increase over previously used depleted soils--perhaps 25 percent of total production--would be attributable to the removal of trypanosomiasis. The remaining 75 percent would merely replace the production which would have occurred in the former producing area.

In general, actual crop production benefits will be even lower than this. Except where human sleeping sickness prevents cultivation, much of the land in crop production during the 10 years immediately following elimination of the tsetse challenge will be land in production prior to control measures. Where population density is sufficient to promise significant land use changes once the tsetse threat is removed, it will also be sufficient to push cultivation into the infested area in spite of the presence of tsetse. Control/eradication may reduce human discomfort but it is likely to increase substantially the area under cultivation over the short to medium term.

Elimination of tsetse may facilitate use of animal traction, leading to an increase in agricultural production. However the generally marginal returns to animal traction throughout much of Africa suggest that these

production increases barely cover the increased production costs associated with use of animal power. Therefore, the net gain due to tsetse eradication/control will generally not amount to much in practical terms.

c. Other Benefits

Treating the reduced costs of treatment for AAT is a benefit for eradication programs presents similar problems. In order to avoid double counting of benefits, the without project situation needs to be kept clearly in focus. For example, in the case where a treatment program is underway prior to project implementation the increase in livestock production attributable to the project will not be as great as where no treatment program is operating. Maximum production gains will accrue where no treatment program is operating--other things being equal--with the result that savings in treatment costs will be nil. Thus it is appropriate to count either savings in treatment costs, or increases in production, but not both--unless, of course, the treatment program is totally ineffective.

In summary, then, the major benefits of trypanosomiasis eradication programs will come from increased livestock production. To this can be added crop production benefits amounting to, perhaps, and additional 1 percent of the livestock production benefits for each 1 percent of area put into crops as a result of the eradication/control program. More accurate measures of benefits will be possible only by considering the specific with and without project agricultural production patterns particular to a proposed project area. This will be one of the functions of the technical assistance terms financed under this project.

E. Costs of A.A.T. Control or Eradication

1. Qualitative Listing of Costs

a. Direct costs

1) Overall administration costs
2) Entomological and protozoological surveys
3) Personnel training and area preparation
4) Initial control or eradication measures (labor, equipment, overhead or administration and supplies)

a) Bush clearing

- manual
- mechanized

b) Insecticide spray

- ground manual spray
- ground motorized mistblowers
- aerial helicopter spray
- aerial fixed-wing spray

5) Ongoing treatment and control

a) Chemoprophylaxis and chemotherapy

- drugs
- drug application
- screening surveys
- drug resistance by trypanosomes

b) Maintaining physical barriers

- keeping clean with herbicides, burning, periodic clearing, hunting
- policing movements of livestock and people
- respraying

c) Trypanotolerant livestock

- acquiring and breeding animals

b. Indirect costs

1) Negative environment impacts

a) Killing non-target population
b) Reduced game reserves
c) Elimination of dry season grazing reserves
d) Possible overgrazing and uncontrolled land use in opened areas

2) Negative developmental impact

   a) Uneconomical or sub-optimal land use patterns may become established which cannot be easily altered

3) Cost of planning for the use of opened areas

4) Cost of inducing population to take advantage of potential created by control or eradication measures (else re-invasion by the fly may take place)

   a) Infrastructure
   b) Incentives: inputs, credit, vet. service, etc.
   c) Improved technologies mode available

2. Quantitative Estimates of Costs

By far more information is available on the costs of various trypanosomiasis control/eradication operations than on the benefits. However, much of the empirical data is out of date and reflects widely different accounting practices, operating consumptions and public policies.

In an attempt to determine control tendencies for costs of AAT control/eradication programs across countries, Table 4 summarizes quantitative information contained in studies of programs in several African Countires. Because the yen in which the studies were done varies, the results are expressed both in current dollars and in 1980 dollars. To the extent possible given available information, these costs are then adjusted to correct for accounting differences and differences in the area covered in order to arrive at operating cost estimates for 1980. Where the data included sufficient detail, the costs of administration, entomological surveys and post-control surveillance have been broken out separately. Often, however, the reports did not indicate exactly which costs were included in the estimates, what percentage of the area was resprayed nor whether costs referred to the area sprayed initially or the area sprayed overall including respraying. Other sources of variation include differences in operating efficiency and host country pricing, wage and other policies.

Bearing in mind these limitations, the wide range of cost estimates for given eradication/control techniques summarized in Table 4 is not surprising. In general, however, upper and lower ranges are identifiable for most of the techniques. These figures refer to the area actually treated; not the area reclaimed - a separate middle that has an enormous impact on the economic viability of a given eradication/control program.

Looking first at helicopter spraying, we see comparably based 1980 operating costs centering around 1500 per square kilometer on the lower end

to 4500 per km^2 on the upper end. Administration, which is low for helicopter programs (usually financed more or less as package operations), entomological surveys and post-control surveillance would add another 500 per square kilometer to unit costs. Thus, we have 2000 - 5000 per km^2 as the total cost of helicopter spraying programs per km^2 of area actually sprayed to completion.

Ground spraying follows helicopter spraying in terms of cost. Administration and other fixed costs constitute a higher proportion of total costs than for helicopter spraying since necessary ground support greatly complicates the logistical picture and the administrative burden. Available data on ground spraying permits separation of costs by type of terrain, a key variable influencing costs for all eradication/control techniques. In terms of operating costs only, square kilometer ground spraying costs range from 150 - 300 in favorable terrain to 400 - 700 in difficult terrain. Administration, surveys and surveillance add another 600 - 1000 per km^2 of area actually sprayed. On a total cost basis 800 - 1600 per km^2 probably represents the normal range of costs between favorable and difficult terrain.

The observation from Zambia for fixed wing aircraft spraying does not specify the number of passages included in the cost figures. None of the data breaks out administration and other costs. These should be much lower than for the other techniques since fixed wing aircraft usually blanket on entire area rather than selectively spray as do helicopters and ground spray units in general. Operating costs range between 150 and 450 per km^2 for five to six flights per year, though the higher figure is adjusted from very old data and is much less reliable than the lower figure. Administration, entomological surveys and post-control surveillance would probably add another 250 per km^2, though this is only a crude guess based on costs for the more selective ground and helicopter spraying operations. Overall, we are probably looking at total costs for fixed wing serial spraying operations amounting to 400 - 700 per km^2.

Cost figures for mechanical bush clearing and game elimination are very old. These techniques are no longer used with the frequency that was common in the late 60's and early 70's. The difficulty of keeping barriers clear and the ecological consequences and expense of eliminating game have shifted control methods toward spraying and chemotherapy and chemoprophylaxis operations. Moreover, the follow through in terms of more intensive use of land for agricultural purposes is not likely to be very great in areas where these techniques are the most effective short-term approaches to tse tse eradication/control.

Costs of chemotherapy and chemoprophylaxis vary even more than costs per unit for the other approaches to AAT eradication/control. Actual drug charges account for only a small part of total costs. Drug administration adds at least as much to costs as the drug itself. Central administration and fixed costs add still more, though we have no hard data on just how much. These are real costs, nonetheless, since the more time and attention veterinary assistants devote to trypanosomiasis the less time they will have available for other diseases unless central and field staff are increased accordingly. This is an important issue since chemotherapy and chemoprophylaxis programs are usually just additions on reinforcements to existing disease control services. Overall, total costs per injection appear to average around $1.50. The total cost of chemotherapy is then linearly related to the number of treatments required to provide the necessary protection in a particular environment.

TABLE 4a: Alternative Operating and Other Cost Estimates for Selected AAT Eradication and Control Techniques in Sub-Saharan Africa

($ U.S.)

Eradication/Control Technique	Estimate			Unit of Measure	Type of Cover	Operating Costs		
						Cost per Unit		Percent Resprayed
	Source	Country	Year			Current	1980[a]	
Application of Insecticides								
Helicopter Spraying	FAO/UNDP [1977]	Nigeria	1975-76	km^2	Sudan-Northern Guinea	2940	4626	n.s.
	IBRD [1980]	Cameroon	1980	km^2	Savannah	2362	2362	n.s.
	FAO [1982]	Zambia	1980-81	km^2	Miombo	190	190	n.s.
	PUTT et al [1980]	Nigeria	1977-78	km^2	Savannah/ Riverine	347[e]	461	46%
Fixed Wing Aircraft	FAO/UNDP [1977]	Botswana	1976	km^2	Acacia Woodland	100	155	0
	FAO/UNDP [1977]	Zambia	1972	km^2	n.s.[g]	210	450	0
Ground Spraying	FAO/UNDP [1977]	Botswana	1976	km^2	Acacia Woodland	1125	1770	0
	PUTT et al [1980]	Nigeria	1977-78	km^2	Sarma/ Riverine	127[e]	170	46%
	FAO/UNDP [1977]	Nigeria	1975-76	km^2	Sudan Sub-Sudan Northern Guinea	66-136 136-238 109-124	110-227 227-397 182-207	n.s. n.s. n.s.
			1975-76	km^2	Sudan Northern Guinea Southern Guinea Average	83 170 419 140	138 284 699 234	n.s. n.s. n.s. n.s.
	FAO/UNDP [1977]	Chod	1971-73	km^2	n.s.	3274	7570	n.s.
	JAHNKE [1974]	Uganda	1972	km^2	Favorable Difficult	411[h] 660[h]	880[h] 1412[h]	n.s. n.s.
Mechanical Bush Clearing	JAHNKE [1974]	Uganda	1972	km^2	Favorable Difficult	700[h] 2100[h]	1500[h] 4500[h]	- -
Game Elimination	JAHNKE [1974]	Uganda	1972	km^2	Favorable Difficult	487[h] 701[h]	1043[h] 1500[h]	- -
Treatment and Prophylaxis	PUTT et al [1980]	Nigeria	1977-78	injection	-	.81[e]	1.08	-
	FAO/UNDP [1977]	Botswana	1976	injection	-	3.04	4.78	-
	JAHNKE [1974]	Kenya	1972	Treatment cycle	high challenge med. challenge low challenge	1.26 .77 .14	2.69 1.64 .30	- - -
	FAO [1977]	Ivory Coast	1976	Dose		.52-.59	.82-.93	-

TABLE 4 b: Alternative Operating and Other Cost Estimates for Selected AAT Eradication and Control Techniques in Sub-Saharan Africa

($ U.S.)

Eradication/Control Technique	Proportion of Cost Due to: Drugs/Chemicals	Aircraft	Other	Adjusted 1980 Cost per km² [b]	Other Costs (1980 Prices): Administration Off-season and Other Indirect Costs as Percent of Operating Costs	Entomological Surveys	Post-Control Surveillance
Application of Insecticides							
Helicopter Spraying	.45	.55	0[c]	4626	n.s.		
	.41	.37	.22	2078	n.s.		
	.60	.40	0	1357[d]	n.s.		
	.35	.52	.13	1537[f]	230		
Fixed Wing Aircraft	.33	.34	.33	155	n.s.		
	n.s.	n.s.	n.s.	450	n.s.		
Ground Spraying	.53	-	.47				
	.17	-	.83	567[f]	1021		
	n.s.	-	n.s.	110-227	n.s.		
	n.s.	-	n.s.	227-397	n.s.		
	n.s.	-	n.s.	182-207	n.s.		
	n.s.	-	n.s.	138			
	n.s.	-	n.s.	284			
	n.s.	-	n.s.	699			
	n.s.	-	n.s.	234			
	n.s.	-	n.s.	7570	7000		
	n.s.	-	n.s.	458[1]	343[1]	94[1]	148[1]
	n.s.	-	n.s.	739[1]	396[1]	94[1]	148[1]
Mechanical Bush Clearing	-	-	1.00	2141[1]			
	-	-	1.00	6422[1]			
Game Elimination	-	-	1.00	664[1]	367[1]	94[1]	148[1]
	-	-	1.00	379[1]	378[1]	94[1]	148[1]
Treatment and Prophylaxis	n.s.	-	n.s.	1.08	.50		
	n.s.	-	n.s.	4.78	-		
	1.00	-	0	2.69	4.00		
	1.00	-	0	1.64	2.00		
	1.00	-	0	.30	.50		
				.90	.50		

Footnotes for Tables 4a and 4b.

a/ Cost appreciation is projected at 8% per year up to 1976 and 12% per year thereafter.

b/ Adjusted to allow for differences in the basis of estimating costs. In general, adjusted basis includes financial cost of chemicals, ground support, aircraft and vehicles, but doesn't include pre-survey, technical assistance, project administration or senior level personnel costs. No adjustment i made to correct for differences in the proportion of the area which is resprayed.

c/ Already allocated to drugs/chemicals and aircraft.

d/ Current cost figure is based on spraying of woodland edge/dambo ecotones, the edges of roads and as as 30 meter parallel swaths at intervals of 330 meters across uniform woodlands. Assume overall discrimination is 14% based on data provided in the study.

e/ One Naira = 1.80 $ U.S.

f/ Assuming 30% discrimination based on data provided in the study.

g/ Not specified.

h/ Using accounting rather than market prices. Costs using accounting prices are about 30% lower than costs using market prices.

i/ Market prices rather than accounting prices.

F. Factors Influencing the Level of Benefits and Costs

The levels of benefits and costs that determine the economics A.A.T. control are influenced by a large number of factors. The most important ones are listed below.

1. Benefits

   a. The timing or incidence of benefit flows and the level of discount rate chosen or applied
   b. Effectiveness of land use develoment
   c. Productivity of new lands opened up,

      1) Values of animals and crops grown or to be grown
      2) Realizable stocking rates

   d. Magnitudes of losses avoided (or the level of fly challenge .. encountered before control operation)
   e. Availability of new and improved inputs to exploit new lands efficiently
   f. Magnitudes of costs saved due to control measures

2. Costs

   a. Area treated relative to area opened up or improved
   b. Timing of intervention with respect to human population pressure, fly distribution and density
   c. Level of fly infestation and challenge
   d. Intensity of ground cover, nature of vegetation and topography
   e. Choice of approach and technique for control or eradication measures
   f. Cost of maintaining barriers
   g. Organizational efficiency with respect to timing, coordination and manpower training

Finally whether a tsetse or A.A.T. project will be economically viable or not will depend on the relative incidence of costs and benefits in time and the profitability of all other investments in the economy which give rise to the prevailing discount rate. A project that earns an internal rate of return higher than the prevailing discount rate or a benefit/cost ratio greater than 1 is then conventionally considered profitable.

G. Economic Analysis of Typical Eradication Control Interventions

Strictly speaking the costs and benefits of eradication/control programs should be adjusted to reflect transfers and real resource scarcities before an analysis of them can be expected to give a clear picture of the net impact of a project on the national economy. In practice, the data do not permit more than very rough adjustments which do not add measurably to our confidence in the results.

Jahnke [1974] did a fairly comprehensive analysis of the economic cost of AAT programs in Uganda. His is the only one of the studies cited which did this. He found that economic costs using accounting prices were about 70 percent of financial costs. Both costs and benefits were measured in border prices. Zalla [1972] did a similar analysis in Tanzania and found economic costs amounting to 85 percent of financial costs.

Most African countries have overvalued exchange rates, wage levels for low skilled and unskilled labor that exceed its opportunity cost, and high taxes on fuel and vehicles. However many offer special exchange rates or waive taxes on donor financed agricultural projects. In addition livestock products are either exported or substituted directly for imports. The net difference between costs and values based on accounting prices and those based on prevailing prices concern primarily unskilled labor costs and transfers arising from taxing policies. The former are often a small proportion of total costs and the latter may or may not be substantial. Indiscriminately adjusting published cost figures for these unknown parameters is frought with more danger than using existing figures. For this reason our analysis is based on financial costs as reported in the reference studies. Given the structure of costs of tsetse control/eradication projects economic returns will probably be somewhat higher than financial returns where the

latter are positive and lower than financial returns where these are negative. Apart from these generalizations we make no distinction between economic and financial prices in the analysis.

The analysis in this section is divided into two broad sub-sections. The first sub-section uses a methodology developed by Adelhelm [1980] to compare costs and benefits under a wide range of alternative assumptions concerning costs, stocking rates, number of treatments and offtake rates. This section gives the reader a feel for the interactions between several key variables that, in the final analysis, determine the largest proportion of costs and benefits associated with specific techniques of AAT control/ eradication in a particular context. No adjustments are made to allow for the time distribution of benefits and costs. In effect, costs and benefits using this approach embody an implicit discount rate of zero. The advantage of the approach is its simplicity and clarity.

The second part of this analysis projects the costs and benefits of a typical control/eradication program over a ten year period and compares the costs and benefits using discounted cash flow analysis.

1. Cost and Benefit Interactions

a. Cost of Chemotherapy Versus the Benefits

Figure 1 summarizes the relationship between the number and cost of treatments, assuming $1.50 per injection, in financial terms, and the value of herd losses avoided at different rates of loss. The left and right vertical scales are coordinated so that the left axis measures the value of loss per stock unit given the percent herd loss due to trypanosomiasis on the right axis. The left axis, therefore, measures both costs and benefits per stocking unit.

Figure 1

COSTS AND BENEFITS OF CHEMOTHERAPY AND CHEMOPROPHYLAXIS UNDER VARIOUS ASSUMPTIONS CONCERNING THE PERCENTAGE OF HERD LOSSES DUE TO TRYPANOSOMIASIS

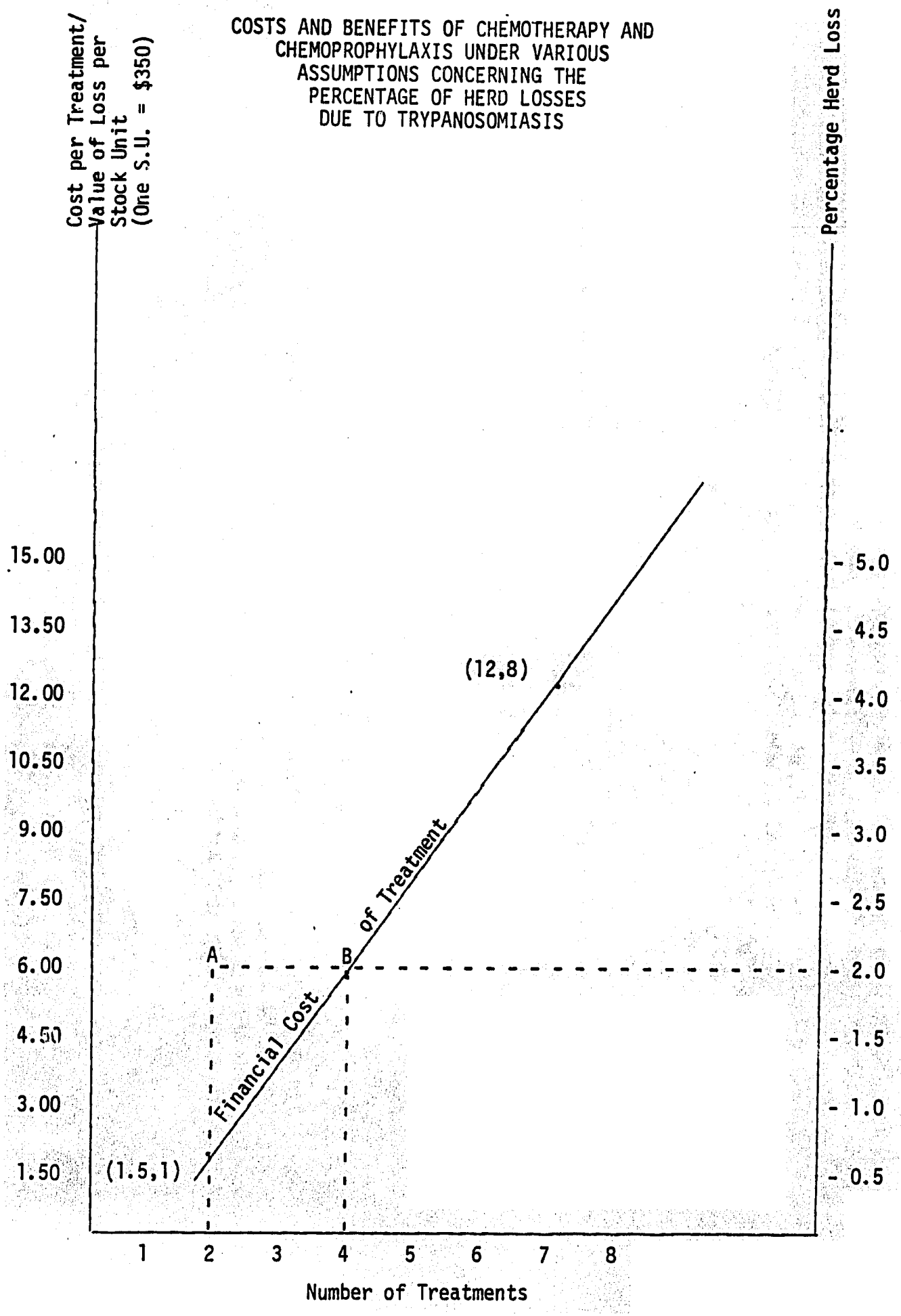


Figure 1 shows that with herd losses due to trypanosomiasis running at 2 percent, governments would find any treatment program requiring less than four injections per stocking unit financially beneficial. The value of the benefit is the vertical distance between the coordinate corresponding to the losses due to trypanosomiasis and the total cost line at what ever level of treatments are required to reduce losses on treated animals to zero. AA, for example, measures the financial benefit of a treatment program that reduces AAT losses to zero with two treatments. As the tsetse challenge increases higher levels of treatment become economic because losses from not treating also increase. However the danger of developing resistant strains also increases and other approaches to control become more cost effective.

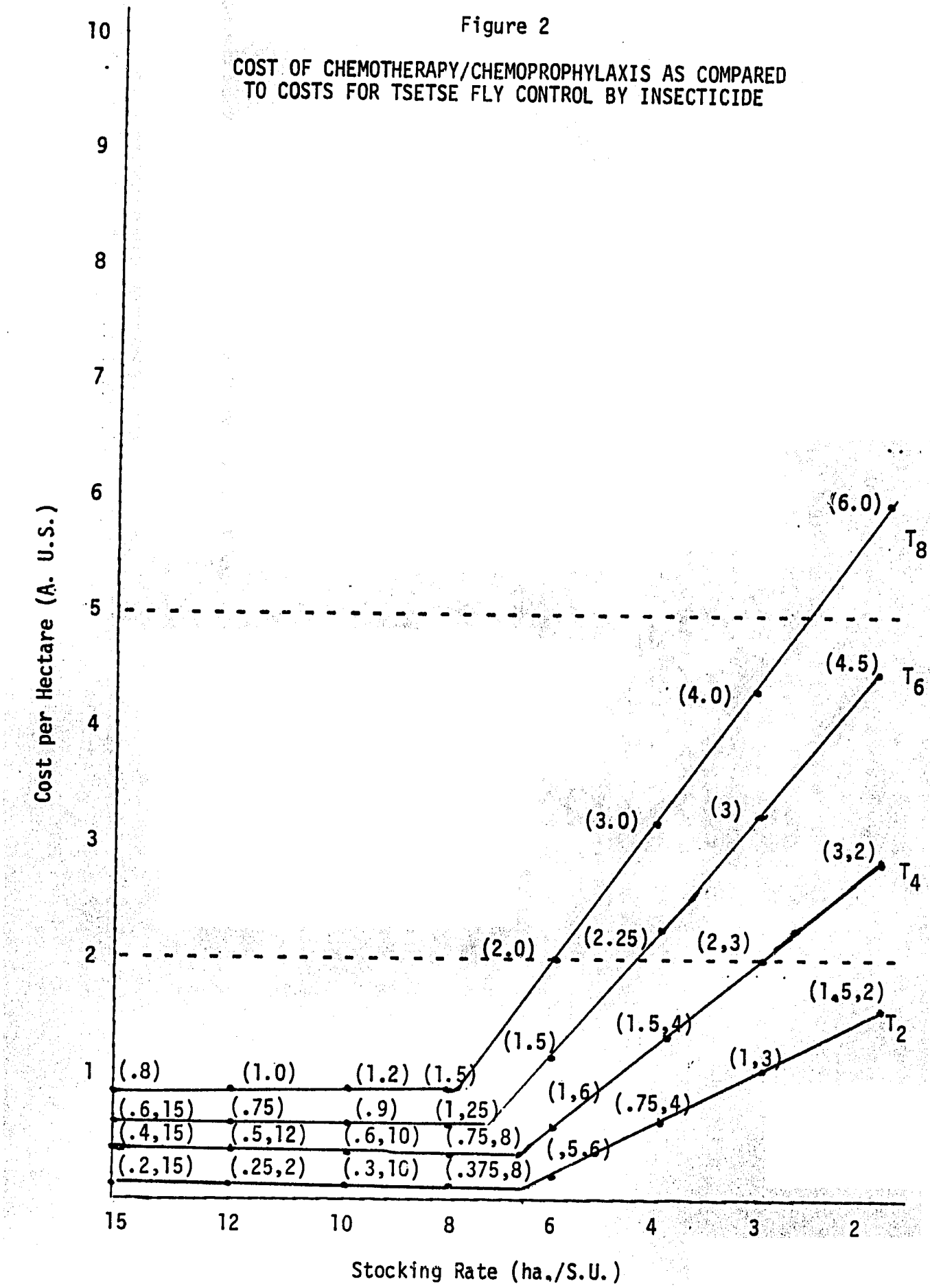
b. Cost of Chemotherapy/Chemoprophylaxis as Compared to Tsetse Fly Control With Insecticides

On a unit area basis, operating costs of a treatment program are proportional to the stocking rate. At some point it becomes more economic to control the fly instead of treating more animals or treating a given number of animals more frequently. Figure 2, an update of a similar figure discussed by Adelhelm [1980], demonstrates this relationship quite clearly.

The lines T_2 - T_8 represent the cost per hectare associated with 2-8 treatments per S.U. (at $1.50 per treatment) and various stocking rates. The dotted lines I_l and I_m represent the cost per hectare of control by insecticide using low (I_l) and medium (I_m) cost assumptions, assuming a discrimination percent (area actually sprayed as a proportion of area reclaimed) of 25 percent. Obviously, the greater the area reclaimed relative to the area sprayed the lower will be the cost per hectare of controlling with insecticides. Only at fairly high stocking rates or fairly high levels of infestation will spraying of any kind be more economical than chemotherapy unless the area reclaimed relative to the area treated is unusually fovorable.

Figure 2

COST OF CHEMOTHERAPY/CHEMOPROPHYLAXIS AS COMPARED TO COSTS FOR TSETSE FLY CONTROL BY INSECTICIDE



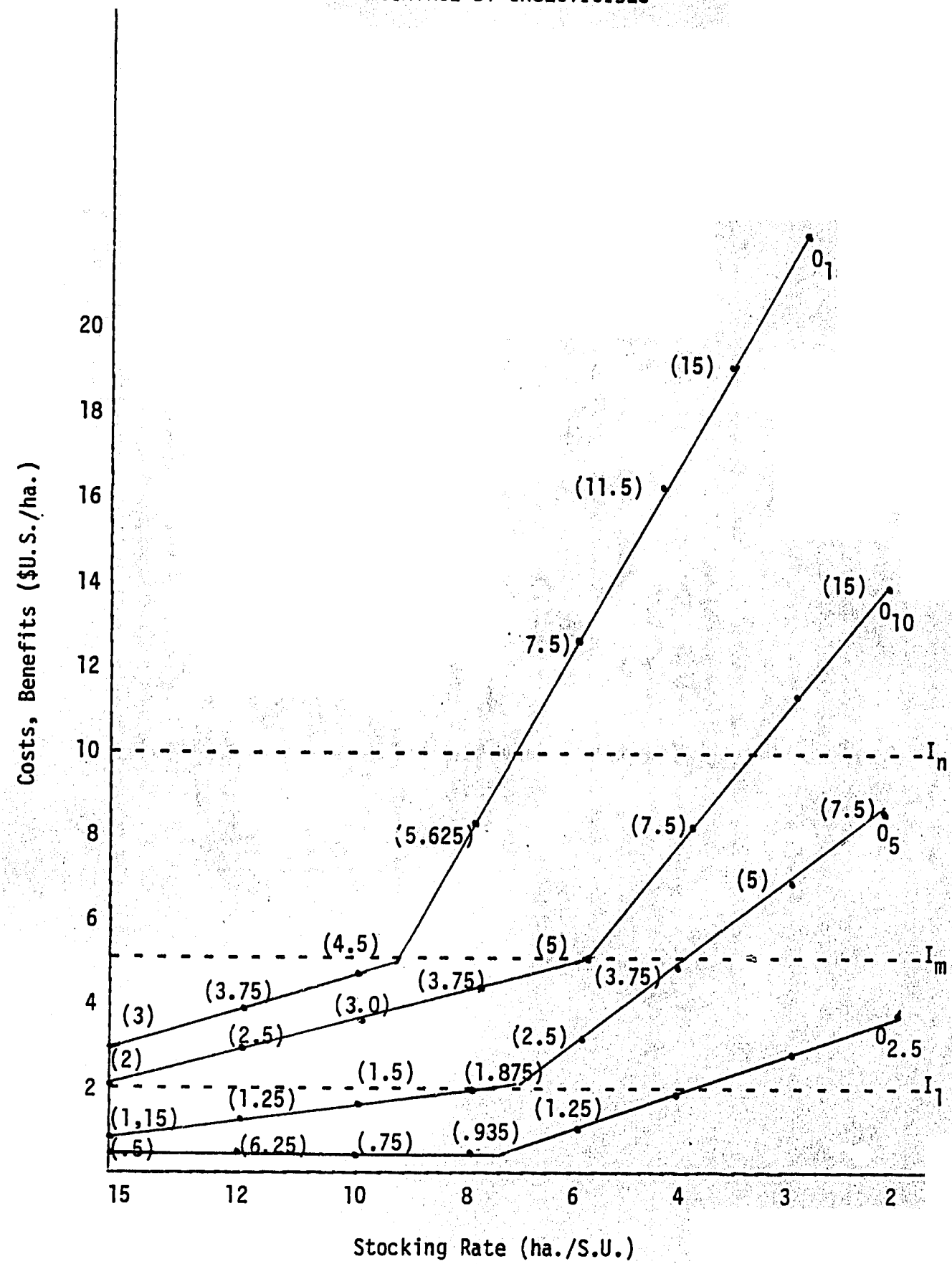
Where eradication is possible or control can be maintained with less than annual spraying then spraying becomes relatively more attractive. The higher initial cost per hectare needs to be weighed against the lower annual treatment cost. Deciding which course of action makes the most economic sense in light of the probabilities of successful eradication or longer term control will be one of the functions of the technical assistance teams financed by this project. Such a decision will require careful consideration of a wide array of ecological, biological and human performance data.

c. The Cost of Control of Tsetse Flys With Insecticides Relative to the Benefits

Whatever the costs of tsetse fly control with insecticides the benefits will be greater the greater is the rate of offtake from the herd. Figure 3 shows the relationship between stocking rate, offtake rate and the level of benefits and compares this with the cost of control with insecticides. Where stocking rates are high and offtake as a result of the spraying program increases by 10 percent (O_{10}) or more, even quite high spraying costs per hectare reclaimed (I_h) can be justified economically. On the other hand, where stocking rates are medium to low and the level of challenge is also low so that the increase in offtake due to the spraying operation is under 5 percent (O_5), even relatively low spraying costs per hectare reclaimed (I_1) cannot be justified in economic terms. What is economic in a given situation depends on the local circumstances. One of the most important benefits of the technical assistance terms provided under this project will be in helping African governments make this kind of analysis so as to improve the identification, selection and design of tsetse eradication/control projects. African governments should then realize greater returns from their tsetse related expenditures than at present.

Figure 3

COSTS AND BENEFITS OF TSETSE FLY CONTROL BY INSECTICIDES



2. Cost-Benefit Analysis of a Typical AAT Intervention

Given the large number of factors influencing the costs and benefits of AAT control/eradication programs the most sensible way to approach a cost-benefit analysis is perhaps to define a more or less typical situation and analyze the results. The purpose of this analysis is to confirm that investments in AAT eradication/control make economic sense when compared to alternative investment opportunities available to African governments over time.

For the sake of analysis we will take a hypothetical 400 square kilometer area of tsetse infestation. The land is relatively sparsely populated but new settlement is increasing because of growing population pressure. Sleeping sickness is not a problem. Previous settlement has been restricted mostly because of the availability of more suitable soils and rainfall patterns elsewhere. The analysis is based on the following set of assumptions:

Project life	10 years
Project area reclaimed	400 km^2
Area sprayed	120 km^2
Method of spraying	Helicopter
Terrain	Favorable
Cost of spraying per km^2 actually sprayed	$2500
Current stocking rate	10 ha./S.U.
Post-spraying stocking rate	6 ha./S.U.
Grazing conditions outside project area	heavy overgrazing
Current losses due to trypanosomiasis	2%
Annual offtake without project	8%
Annual offtake with project	10%
Proportion of cows in herd	40%
Value of milk production per cow per year	$50
Current area under cultivation	5%

Projected area under cultivation:

Year	Without Project	With Project
5	8%	12%
10	12%	20%

Incremental crop production on new land	25%
Value of incremental production related to new cropland under cultivation	$25/ha.
Value of livestock production now occurring on old abandoned crop land	
Livestock offtake	$5/ha.

Milk production	$3/ha.
Total value of incremental production related to new land under cultivation	$33/ha.

These are all quite reasonable assumptions throughout many tsetse infested areas for which eradication/control operations might be considered in sub-Saharan Africa--not particularly optimistic or pessimistic. Costs are based on the data in Table 4 as discussed in section F. The results of the projections based on these assumptions are detailed in Table 5.

The overall internal rate of return from this hypothetical data set is 23 percent. The economic rate of return would probably be slightly higher as some costs would be lower in economic terms. This compares quite favorably with rates of return available from other agricultural investments in sub-Saharan Africa, especially those with equally realistic input-output assumptions. The return would be higher where population pressures are greater and crop production increases more rapidly as was the case in northern Nigeria.

Table 5 INPUT/OUTPUT ASSUMPTIONS, COSTS AND BENEFITS, ASSOCIATED WITH TEN YEAR TSETSE ERADICATION/CONTROL PROJECT COVERING 400 KM^2

	Project Year										
	0	1	2	3	4	5	6	7	8	9	10
Area Measures (km^2)											
Project Area	400	400	400	400	400	400	400	400	400	400	400
Area Sprayed		120			30			30			
Area Under Cultivation:											
With project	20	22	29	36	42	48	54	60	66	72	80
Without project	20	22	24	27	30	32	35	38	41	44	48
Incremental Cultivated Area	0	0	5	9	13	16	19	22	25	28	32
Livestock Population (S.U.)											
With Project	3800	3780	6138	6067	5967	5867	5767	5667	5567	5467	5333
Without Project	3800	3780	3760	3730	3700	3680	3650	3620	3590	3560	3520
Incremental Livestock Population	0	0	2423	2337	2267	2187	2117	2047	1977	1907	1813
Offtake (S.U.)											
With Project	304	302	618	607	597	587	577	567	557	547	533
Without Project	304	302	301	298	296	294	292	290	287	285	282
Incremental Offtake	0	0	317	309	301	293	285	277	270	262	251
Project Benefits (1000)											
Incremental Crop Production	0	0	16.5	29.7	42.9	52.8	62.7	72.6	82.5	92.4	105.6
Incremental Offtake	0	0	95.1	92.7	90.3	87.9	85.5	83.1	81.0	78.6	75.3
Incremental Milk Production	0	0	48.5	46.7	45.3	43.7	42.3	40.9	39.5	38.1	36.3
Total Incremental Benefits	0	0	160.1	169.1	178.5	184.4	190.5	196.6	203.0	209.1	217.2
Project Costs											
Entomological Survey	40.0	-	-	-	-	-	-	-	-	-	-
Spraying	-	300.0	-	-	75.0	-	-	75.0	-	-	-
Administration	-	30.0	-	-	-	-	-	-	-	-	-
Post-Control Surveillance	-	-	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Total Costs	40.0	330.0	60.0	60.0	135.0	60.0	60.0	135.0	60.0	60.0	60.0
Net Benefits	-40.0	-330.0	101.1	109.1	43.5	124.4	130.5	61.6	143.0	149.1	157.2

H. When AAT Eradication Control is Economic

The preceeding analysis has concentrated on the benefits of AAT eradication/control for crop and cattle production. The results would be similar for small ruminants. What the analysis shows is that the net economic benefits of AAT eradication/control depend on a wide range of ecological, social, political and economic factors than need to be assessed and measured in a particular context. In some situations AAT control/eradication can be a highly profitable investment even where reinfestation occurs over a period of time. In other situations, with low stocking rates and/or low levels of tsetse challenge, on-going treatment and prophalaxis programs will make more economic sense than a frontal assault on the tsetse fly itself. Helping African governments to identify just what interventions are appropriate in given situations is the purpose of this project. It should make a substantial difference in the total economic benefits realized from tsetse eradication/control expenditures.

I. Brief Review of Actual Cost-Benefit Analyses

In the following pages, a brief review of the economic analysis on A.A.T. control or eradication programs in Uganda and Nigeria are briefly presented. The objective is to show differences and similarities in methodological approaches and the profitability of A.A.T. control when integrated with an efficient land use plans. Some of the difference are, for example, the use of accounting (world) prices in Uganda while market prices are used in Nigeria (although it is suggested that all expenses that use foreign change be increased by 50 percent to reflect its scarcity); the Nigeria analysis uses "with" and "without" A.A.T. control or eradication approach while there is no such approach in Uganda; only those costs and benefits that would be incurred by producers as a result of their spontaneous movement (without a national plan to help to motivate them) into a cleared area are considered in Nigeria--all costs and benefits whether affected by national development projects or not are included in the Uganda case; finally, for the Nigerian case only A.A.T. eradication projects and their effects on livestock and crop production systems are considered--the Ugandan analysis looks at different techniques of A.A.T. control or eradication and the economic viability of each technique followed by livestock production.

1. The Economics of Controlling Trypanosomiasis in Uganda

The economic research into the Ugandan tsetse and trypanosomiasis control program was done by Hans E. Jahnke.[1] His objective is, in his words, "to introduce a cost-benefit thinking into the approaches to the tsetse and

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[1]The study was funded by the Fritz Thyssen Foundation, Cologne and organizationally supported by the Afrika-Studienstelle of the Ifo-Institute, Munich.

trypanosomiasis problem which is at present mainly dealt with from a bio-technical standpoint" [p. 2]. To do this, he goes through mainly three cost-benefit analyses [p. 223]:

(1) Controlling the tsetse flies and establishing forms of cattle production;

(2) Keeping cattle with the aid of trypanocidal drugs;

(3) Utilizing the wildlife potential in tsetse-infested areas; and

(4) Finally, a very rough economic analysis on introducing trypanotolerant cattle from West Africa.

The tsetse control or eradication technique employed in Uganda consisted mainly in blanket insecticide ground spray and wildlife elimination through hunting (both supplemented with establishing buffer zones through manual and mechanical bush clearing).

On account of their national potentials, the use of the infested areas for cropping purposes are considered unsuitable. Where they are suitable, Jahnke says trypanosomiasis has not been a direct hinderance to agricultural (crop) development unless there is also sleeping sickness in the area; and he is not concerned with sleeping sickness in the study. Because of the distance between the market (demand) and production sites, the potential for dairy production on infested areas is also ruled out.

Uganda had long experience in tsetse control through groundspraying of insecticides and the elimination of wildlife as fly hosts and carriers of trypanosomes. Aerial spray was not used in Uganda. Jahnke says it was tried as early as 1956 and "the method was found to be too expensive and more harmful to the environment and less effective against tsetse than ground application on insecticides" [p. 61].

As for game elimination through hunting, Jahnke says it "has been effective over larger areas than any other method . . . 20,000 square kilometers

in Uganda have been reclaimed almost exclusively by hunting" [p. 89]; this compares with 11,000 km^2 for groundspray. Jahnke addresses himself to the controversial issue of using game elimination to control tsetse. He points out that since wildlife recover "amazing fast" the danger to them is not so much from hunting as from pushing them from their habitat for settlement and agricultural land use purposes. "Wildlife conservation," he says, "is mainly a matter of habitat conservation . . . A hunting campaign against tsetse will then, in most cases, only initiate the process of game elimination which is then rapidly completed by land use . . . In summary indirect costs of game elimination are more apparent than real" [pp. 90-91].

For the cost-benefit analysis, Jahnke approaches the issue on "model-like schemes" (as opposed to on a national level of actual experience) of an area scale suitable and economical for tsetse eradication and replication purposes. His "typical" scheme is 1,500 km^2 in size. Information on tsetse clearance cost per unit area comes from historical experiences. Benefits are calculated from production coefficients available on Uganda or else from the surrounding countries. All values are expressed in accounting or world prices so as to reflect the costs and benefits to the economy as a whole.

Livestock (beef) production is examined under two systems: pastoral (or traditional) and ranching, the latter analyzed over a 20-year horizon of herd building

His cost and benefit calculations do not include the "with and without" scenerio, presumably on the grounds that traditional livestock producers for the most part successfully avoided fly infested areas in the past and as there was no land shortage in Uganda, they would have continued to do so for the near future. For similar reasons livestock mortality, morbidity and treatment costs avoided do not enter into his cost-benefit analysis.

Thus, his approach is what the profit would be if a piece of land cleared of tsetse is exploited as a tsetse-free land used for pastoral grazing.[1] He is very careful to stress however that any tsetse eradication program must be based on geniune population pressure for more land and integrated with a long term land use plan and ecological protection consistent with a country's economic develoment.

In the Ugandan cost-benefit analysis, Jahnke finds the following results:

1. Traditional or pastoral livestock production in fly cleared areas is highly profitable (Table 6);

2. Compared with beef ranching characterized by high management and intensive inputs,[2] traditional livestock production in cleared areas was more profitable in Uganda. In fact, tsetse clearing for ranching purposes could be described as uneconomical (see Table 6)

3. Comparing the economics of tsetse eradication with trypanosomiasis control through drug application, the latter was markedly inferior if the trypanosomiasis disease incidence and the carrying capacity of the land are both high (see Tables 7 and 8);

4. The economics of alternative uses of tsetse infested areas for wildlife utilization and conservation depends on a number of factors. The national policy or wildlife conservation, which is difficult to subject to cost-benefit analysis, the feasible forms of wildlife utilization (e.g., game viewing, hunting, cropping and farming) in a given area and the potential of the infested area for livestock and crop production are some of the important issues. Jahnke found that, political land designations

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[1]Some parameters used by Jahnke are the following: annual offtake rate of 5.9 - 7.6 percent, 270 kg. liveweight of a mature aniaml (20 percent less than found in experimental stations), a mortality rate of 10 percent for yearlings and 5 percent for all other age groups, production cost amounting to about 20 percent of gross value of offtake (on herd basis) and an accounting price of Ush. 350 per animal (i.e., net of transportation costs).

[2]Some of the parametric coefficients used in the beef ranching include commercial offtake of 18 percent, 640 stock units worth 900 head of cattle at full ranch capacity (1,200 ha.) mortality rate of 5 percent, calving rate of 75 percent and an accounting price of Ush. 652 for a mature animal. (In the pastoral or traditional livestock raising, Jahnke uses 100 indigenous cattle as equivalent to about 50 stock units (S.U.) using the following conversion factors: 0.75 for mature cattle, 0.5 for immature cattle and 0.2 for calves.)

Table 6 **Profitability of Tsetse Control with Subsequent Cattle Production[a]**

	Net Present Value at a Discount Rate of 8% (Ush/ha)	10% (Ush/ha)	12% (Ush/ha)	Internal Rate of Return[c]
Tsetse Control (Ush 25/ha) with subsequent				
Pastoralism (2 ha/SU)	120	67	51	g.t. 12%
Pastoralism (4 ha/SU)	47	20	0	12%
Ranching (2 ha/SU)	0	b	b	8%
Ranching (3 ha/SU)	b	b	b	l.t. 8%
Tsetse Control (Ush 50/ha) with subsequent				
Pastoralism (2 ha/Ush)	95	40	26	g.t. 12%
Pastoralism (4 ha/SU)	22	b	b	9%
Ranching (2 ha/SU)	b	b	b	l.t. 8%
Ranching (3 ha/SU)	b	b	b	l.t. 8%
Tsetse Control (Ush 75/ha) with subsequent				
Pastoralism (2 ha/SU)	70	15	1	12%
Pastoralism (4 ha/SU)	b	b	b	l.t. 8%
Ranching (2 ha/SU)	b	b	b	l.t. 8%
Ranching (3 ha/SU)	b	b	b	l.t. 8%

a On the basis of accounting values.

b Implies negative result.

c l.t. = less than g.t. = greater than.

Source: Adopted from Table 26 of Jahnke [1974].

Table 7 Capitalized Cost[a] of Drug Application per Hectare in Relation to the Trypanosomiasis Incidence and the Carrying Capacity
- in Ush per hectare -

Trypanosomiasis Incidence	Carrying Capacity 2 ha/SU	4 ha/SU	6 ha/SU
Very high	100-180	50-90	33-60
High	60-120	30-60	20-40
Medium	30-80	15-40	10-27
Low	10	5	5

a Net present value of an indefinite cost annuity discounted at 10%.
Source: Adopted from Table 33 of Jahnke [1974].

Table 8 The Effect of Tsetse Control Costs and of the Costs of Drug Application on the Internal Rate of Return of Ranching Development[a]

	Tsetse Control Costs 25Ush/ha	50Ush/ha	75Ush/ha	Annual Drug Costs 6.5 Ush per animal	14 Ush per animal
Internal Rate of Return	8.0%	7.2%	6.5%	8.9%	7.8%

Without any costs for tsetse and trypanosomiasis control the internal rate of return is 9.2%.

a As described in Jahnke [1974] Chapter II.2.c. of Section B and in Appendix V (carrying capacity of 2 ha/SU).

Source: Adopted from Table 35 of Jahnke [1974].

aside, except in those cases where the infested area was naturally suited for wildlife conservation (e.g., poor fertility potential), wildlife utilization of infested areas was comparatively unprofitable (a return of Ush. 2.6 - 4/ha). Without a proper wildlife management scheme to monitor and control the movements, number, and health of game animals the danger of maintaining wildlife which are effective hosts of tsetse fly and permanent reservoir for human and animal traypansomes must be carefully weighed.

In conclusion Jahnke says,

> "In summary tsetse control for cattle production may be called an investment of marginal profitability for the Ugandan economy. It may be justified if one or more of the following conditions hold
>
> - Tsetse control operations can be carried out at low cost.
> - A high proportion of the cleared area is actually available for subsequent cattle production.
> - The timing of tsetse control and subsequent cattle production is as efficient as possible.
> - The carrying capacity of the land for cattle is high.
> - The rate of retrun of investment to the economy as a whole is not expected to be much higher than 10%" [p. 124].

2. Cost-Benefit Analysis of Tsetse Control in Nigeria

The cost-benefit assessment report on tsets control in Nigeria was carried out by UEERU (the Veterinary Epidemio'og ınd Economics Research Unit) of the University of Reading. An interdisciplinary team of 5 people worked for 2 years (between 1978 and 1980) to produce the document.

Their objective was to look into and analyze the "social and economic effects" of tsetse control on traditional agricultural systems. They go into an extensive review of the effects of tsetse problem in Nigeria and the measures taken to control or locally eradicate the fly. Their cost-benefit

analysis refers to clearing of tsetse by insecticide spray which was the technique used since 1955 to reclaim about 196,400 km^2 of northern Nigeria. Of the total area 94 percent was reclaimed by groundspray and the rest mainly by helicopter aerial spray.

Using a discount rate of 12 percent the team calculates three benefit/cost ratios: two at a district level (Sokwa and Burra) to see the economic effect of tsetse control at a local level and one at the national level.

Expectedly, the major problem the team faced was lack of appropriate data on cost but particularly on benefits. They had to use a number of assumptions or guesses as well as the outcome of land use and livestock raising system models. The livestock growth models were for 20 and 25 years, the latter for the national cost-benefit analysis. Their analysis uses a "with and without" scenario of tsetse control and employs conservative figures to avoid overestimation.

Their cost configuration of average clearing expense per unit area come from actual or historical expenditures of ground and helicopter spraying adjusted to 1977/78 market prices. Benefits are calculated from livestock mortality and morbidity losses avoided (diminished), livestock and human treatment (and surveillance) costs saved, and increases in livestock and crop productions due to removing tsetse from an infested area. Understandably, no valuation is made of human death avoided.

Their analysis in ex-post and identifies the following for production systems: pastoral livestock production and land cultivation integrated with livestock. No analysis is made for beef ranching nor separately for durg application.[1]

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[1]Furthermore, the following major parameters were used to estimate benefits and costs: Initial mortality rate of 5 percent latter falling

The calculated benefit/cost ratios in clearance investment at the national level are 3.34 and 5.01 respectively for a pessimistic and optimistic assessments (see Table 9).[1] The corresponding ratios for the Sokwa and Burra districts are respectively 2.66 and 7.97, and 4.67 and 6.51 (see Tables 10 and 12). Thus, tsetse control or eradication program in Nigeria were highly profitable ventures. In concluding their findings, Putt et al., [1980, p. 509] say,

> "However, these figures [the B/C ratios] do point to the fact that it appears that simply in terms of extra meat produced, tsetse eradication excercises were very profitable and still remain so even if the price of cattle voluntarily sold for slaughter is reduced by 50 percent; when the benefit-cost ratios yielded are 1.99, 2.53, 1.34, and 1.69, depending on the assumptions used."

The assumptions they are referring to are whether the fly species G. morsitans is expected to eventually disappear naturally from the cleared areas or not and whether one-half or one-third of the carrying capacity of the reclaimed (and usable) area is utilized for cattle raising. Furthermore, it should be pointed out, as Putt et al. do, that even though benefit-cost analysis at the national level masks regional interactions and is also fraught with data deficiency, the calculations here do not include increased milk produced for subsistence consumption or for sale nor beef slaughtered for subsistence consumption.

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off due to fly recession salvage value of a livestock dying from A.A.T., 50 percent of market value for healthy animal), morbidity rate, 1 percent of the market value of a healthy animal, commercial offtake rate of 9.5 percent, drug treatment costs saved ₦0.45/treatment per year, crop output from cleared fadama (irrigated lowland) areas 2-3 times higher over the tsetse-free highland areas, grazing area lost to crop cultivation about 2 percent of crop value and the market value of a healthy, mature cattle at ₦420.

[1] If the fly species G. morsitans is expected to eventually disappear from the cleared areas through natural recession or retreat, then the benefit/cost ratios are 2.63 and 3.94 depending what proportion of the cleared area is utilized in time.

Table 9

SUMMARY OF COSTS AND BENEFITS AT THE NATIONAL LEVEL

Costs	Benefits From Various Sources							Present Value (Benefit-Costs)	Benefit-Cost Ratio
	Morbidity Losses Avoided	Treatment Costs Saved	Extra Slaughtering of Cattle for Meat						
				G.morsitans eliminated in :					
7,551,169	152,218	22,833	1/2 of extra CC* used	5 years	C_{11} :	29,772,297	PV_{11} : 22,221,128	BC_{11} : 3.94	
				10 years	C_{12} :	37,844,439	PV_{12} : 30,293,270	BC_{12} : 5.01	
			1/3 of extra CC*used	5 years	C_{21} :	19,839,741	PV_{21} : 12.288.572	BC_{21} : 2.63	
				10 years	C_{22} :	25,221,169	PV_{22} : 17,670,000	BC_{22} : 3.34	

Note: Due to the different assumptions affecting the benefits arising from extra meat production from cattle which do not affect costs and savings on morbidity and treatments, four different values for these benefits and consequently for the present value and benefit-cost ratio are derived.

The assumptions made are explained in the text above and are, briefly :-

- that either half or one-third of the extra carrying capacity released each due to tsetse clearance operations taken up by an increase in cattle numbers over a period of time
- that in the absence of tsetse clearance operations, *G.morsitans* would have disappeared of its own accord within either 5 or 10 years after the areas were in fact cleared in the areas so affected.

* CC = Carrying Capacity.

Source: Adopted from Table 9.11 of Putt et al., [1980].

Table 10 SOKWA DISTRICT : COSTS AND BENEFITS SUMMARY

	Low Level Assumptions		High Level Assumptions	
Costs	C	104,466	C	104,466
Cattle Mortality Avoided	LB_1	58,169	HB_1	111,379
Cattle Morbidity Avoided	LB_2	2,909	HB_2	5,569
Treatment Costs Saved	LB_3	700	HB_3	1,338
Extra Slaughter for Meat	LB_4	162,573	HB_4	278,920
Additional Income of Immigrants	LB_5	6,824	HB_5	6,824
Additional Income from Fadama Crops	LB_6	21,398	HB_6	319,903
Increased Use of Work Cattle	LB_7	24,822	HB_7	108,932
Present Value	LPV	172,929	HPV	728,399
Benefit/cost	LBC	2.66	HBC	7.97

C = cost LB = low benefit HB = high benefit

LBC = low benefit/cost ratio HBC = high benefit/cost ratio

LPV = low level present value HPV = high level present value

Prices given in 1977/78 Naira

Source: Adopted from Table 9.11 of Putt et al., [1980].

Table 11 SOKWA DISTRICT : PERCENTAGE BREAKDOWN OF BENEFITS

Category	% of Total Low Level Benefits	Category	% of Total High Level Benefits
LB_1	21.1	HB_1	13.4
LB_2	1.0	HB_2	0.7
LB_3	0.2	HB_3	0.2
LB_4	58.6	HB_4	33.5
LB_5	2.5	HB_5	0.8
LB_6	7.7	HB_6	38.4
LB_7	8.9	HB_7	13.0

Source: Adopted from Table 9.12 of Putt et al., [1980].

Table 12 BURRA DISTRICT : COSTS AND BENEFITS SUMMARY

	Low Level Assumptions		High Level Assumptions	
Costs	C	1,009,321	C	1,009,321
Extra Slaughter for meat	LB_4	4,109,107	HB_4	5,694,678
Additional Income of Immigrants	LB_5	572,403	HB_5	747,822
Increased use of work cattle	LB_7	33,253	HB_7	132,499
Present Value	LPV	3,705,442	HPV	5,565,678
Benefit/Cost Ratio	LBC	4.67	HBC	6.51

Source: Adopted from Table 9.16 of Putt et al., [1980].

Table 13 BURRA DISTRICT : PERCENTAGE BREAKDOWN OF BENEFITS

Category	% of Total Low Level Benefits	Category	% of Total High Level Benefits
LB_4	87.2	HB_4	86.6
LB_5	12.1	HB_5	11.4
LB_7	0.7	HB_7	2.0

Source: Adopted from Table 9.17 of Putt et al., [1980].

In conclusion, the benefits from tsetse or A.A.T. eradication depend on a number of factors which are specific to each cleared locality or region Whether the benefits can be realized in time and at a level efficient enough to justify investment expenditures on them will depend on a number of technical, social and economic variables. Among these, those relating to technical issues such as the availability of well trained personnel will be the most crucial factors. Thus, the benefits (either direct or via cost reductions) will depend on people who can assess the tsetse problem correctly and devise ways of eradicating it and implementing subsequent developmental projects.

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