PROGRAMME AGAINST AFRICAN TRYPANOSOMIASIS

Options for Tsetse Eradication in the Moist Savannah Zone of West Africa

Technical and Economic Feasibility,

Phase 1 – GIS-Based Study

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Introduction

Trypanosomosis has long been regarded as one of the complex of constraints that is preventing most of sub-Saharan Africa from realising its full agricultural potential. In many areas the presence of trypanosomosis is linked to a low usage of animals for draught cultivation. In such areas cultivators continue to rely on hand cultivation which effectively restricts them to a subsistence existence, especially where the agricultural potential is not high. The removal of the trypanosomosis constraint not only improves the welfare, health and productivity of livestock but the wider availability of cattle will provide the opportunity for cultivators to use draught animals and graduate from the hoe to the plough to till the soil. As has been shown during the agricultural development of other parts of the world it is only when power for cultivation is provided through cattle, horses or, later, tractors that cultivators and farmers can produce surpluses which thereby allows them to move into the cash economy.

This study explores one of the current strands of thinking in relation to addressing the problems caused by trypanosomosis, namely the eradication of its vector, the tsetse fly, on a large scale in west Africa. Previously emphasis had been placed on addressing the problem through small-scale, community-centred schemes to control (rather than eradicate) the vector or through the usage of drugs and trypanotolerant breeds to combat the effect of the parasite itself. In some areas these strategies have been effective but such strategies involve on-going costs and management, both being factors which threaten their long-term sustainability. This study has not set out to assess the comparative merits of these alternative strategies but merely to tentatively assess the economic merits of the eradication strategy.

It is well understood that whilst addressing the trypanosomosis problem will remove one constraint, its full benefit will only be realised through the synergistic effect resulting from the parallel removal of other constraints to development. Malaria, lack of access to clean water, poor sanitation, poor education, poor communications, conflicts and poor infrastructure are among the major constraints. The focus of this study is, however, solely on the direct effects of tsetse removal on livestock and mixed farming development.

Jan Slingenbergh
Food and Agriculture Organization of the United Nations
Rome

Acknowledgements

This report is the result of the combined work of many people but first I would like to acknowledge the role of Dr. Jan Slingenbergh who recognised the role that even a basic study of the economics of tsetse eradication could play in raising the profile of the campaign to address the very scale of the trypanosomosis problem in sub-Saharan Africa. Jan initiated this study, was closely involved with its early stages and provided welcome support in the later stages.

I would also like to acknowledge the contributions of the leaders of the four small studies, namely, Dr. Oumar Diall, Mr. Zowinde Kougoudou, Dr. Victorin Codija and Prof. Albert Ilemobade who, each in their own way, went to great lengths in order to provide the databases on which part of this study is based. The ingenuity of Prof. Ilemobade's investigators, who travelled to study area 4 not once but twice during periods of severe petrol shortage, is acknowledged and appreciated. I also acknowledge Dr.. William Wint, Ms. Anita Erkelens and Dr. Guy Hendrickx for their contributions in the field of GIS not only during the early part of this study but also for their willing support during the analysis and writing-up stages. A particular thanks is due to Dr.. Guy Hendrickx for permitting a summary of one of his papers to be included in this report (Annex 6) and for being a ready and willing source of technical information and illustrations.

Mr. Guy Freeland, Dr. Issa Sidibe, Mr. George Chizyuka and Dr. Janet East have each contributed to this study at various points during its progress and I acknowledge the contributions that each of them has made.

Without funding this study could never have taken place and I acknowledge the role that the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, based at IAEA, Vienna, has played in this respect and, in particular, the support received from Dr. James D. Dargie and his staff.

Leonard Budd

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SUMMARY

This desk study was initiated with two objectives:

- To examine the economic costs and benefits of a range of different sized tsetse eradication projects in the Moist Savannah Zone of West Africa (MSZ), and,
- To test the hypothesis that larger tsetse control projects are more economically efficient than smaller projects in that region.

The limited nature of the study precluded detailed examination of the socio-cultural and environmental issues relating to controlling trypanosomosis although these are briefly considered; nor did it aim to compare vector control with other methods of combating trypanosomosis such as the therapeutic or prophylactic use of drugs. However, by computing benefits over just 10 years an indirect comparison is made with the strategy that maintains that eradicating tsetse flies is not justified as, sooner or later, rapidly increasing population pressure will autonomously eradicate tsetse flies and hence trypanosomosis. This analysis suggests that such a strategy is not justified economically.

As the basis of the economic evaluation was a study of projects in defined areas it was first necessary to iteratively examine the technical and economic issues relating to project selection and design. In this respect, the re-invasion issue was considered to be the major influence as it threatens both the sustainability and economic performance of tsetse eradication. Consequently, it was considered that the river basin was the smallest size of project that would optimise economic performance. This particular observation relates uniquely to the MSZ and may not apply to more southerly areas where fly distribution is more ubiquitous or to other parts of Africa.

By basing the economic analysis on an evaluation of projects, albeit hypothetical, it was possible to use real data as the baseline database and the projects could be designed in response to actual tsetse and trypanosomosis scenarios. The group of study areas were chosen to be representative of the whole of the MSZ and not in response to any project that is being planned by any organisation or government. Consequently the studies must be regarded as hypothetical and are termed 'shadow' projects in the report.

It was considered that the level 4 river basins were the most appropriate level in the MSZ and five study areas throughout the zone ranging from 13,000 sq km to 22,000 sq km were selected as the small shadow project areas. Adjacent pairs of small project areas formed the basis of two medium-sized project areas (170,000 and 187,000 sq km) and the whole zone (669,000 sq km) formed the large project. By examining these different project sizes it was hoped to test the hypothesis that larger projects are more economically efficient than smaller projects.

Baseline data for the large and medium projects was provided by the PAAT-IS database. This included predictions of increased cattle numbers and cultivated areas resulting from tsetse eradication. The small project studies were carried out by specialists in the field who used baseline data from a range of local government statistical information. In this respect, difficulties of interpretation were encountered as river basins do not form discrete boundaries for data collection purposes; one project even encompassed two countries. This inevitably led to the need to make estimates but, on the other hand, added to the reality of the exercise as similar statistical and, more importantly, operational problems will be encountered by real tsetse eradication projects in the future.

One of the selected small study areas had to be dropped at an early stage as, on visiting the area, it was found that population pressure had resulted in the area autonomously becoming free from tsetse flies. For the same reason it was not possible to substitute an adjacent river basin.

The results of the economic analysis (up to 10 years) are as follows:

	Costs $ Million	Benefits $ Million	Cost/Benefit Ratio (undiscounted)	Internal rate of Return (IRR)
Small Study Area 1	5.4	52.0	1:9.6	16.0%
Small Study Area 2	4.6	37.2	1:8.1	16.4%
Small Study Area 3	2.9	34.9	1:12.0	13.7%
Small Study Area 5	6.4	32.3	1:5.0	11.7%
Med. Study Area 1	42	407	1:9.7	18.2%
Med. Study Area 2	40	344	1:8.6	16.7%
Large Project Area	107	1153	1:10.8	19.0%

These baseline data and the presumptions on which the projects' costs and benefits have been estimated are not sufficiently secure to enable direct comparison between projects to be made. However, even though two different methodologies for the economic analysis were used, there is a reasonable degree of consistency in the results. Disregarding the somewhat anomalous result of Study Area 5, it can be inferred from these results that a tsetse eradication project in the MSZ is likely to have an IRR in excess of 15% and an undiscounted Cost-Benefit ratio of between 1:5 and 1:10. As such it is suggested that, in relation to the first objective of the study, that tsetse control in this region is economically worthwhile.

Although the data in the table above would tend to suggest that larger tsetse eradication projects would be slightly more efficient than smaller projects, the quality of the databases, the use of different computational methodologies and the need to replace missing data with estimates would preclude such a conclusion being drawn.

As such, the second objective hypothesis has not been justified in relation to the MSZ. Instead this analysis would suggest that, provided projects encompass a river basin (level 4), larger projects are not measurably more efficient than smaller projects. This conclusion is not surprising as the primary reason for larger projects being more economically efficient is that the costs involved with preventing re-invasion in the MSZ are low. The characteristics of riverine tsetse fly distribution mean that there is a much lower risk than in other areas where savannah tsetse flies are present.

1. INTRODUCTION

1.1 STUDY RATIONALE

The present economic study originates from the renewed interest in tsetse control on a large scale by PAAT and, more recently, by the Pan-African Tsetse and Trypanosomosis Eradication Campaign (PATTEC). Tsetse eradication is difficult to achieve but recent developments in the application of the Sterile Insect Technique (SIT) indicate that in some areas eradication is technically feasible. Because of the 'industrial' nature of sterile fly production, significant economies of scale are available and, in economic terms, the technique would appear increasingly attractive as the size of the control area increases. Larger projects would also have the advantages that: -

i) Re-invasion of flies from outside is less of a technical problem and;

ii) They address the scale of the trypanosomosis problem, in contrast to the micro-scale village level tsetse control schemes currently being operated.

However, large-scale tsetse control projects are inherently complex and would pose significant problems including: -

i) Indiscriminate clearing of fragile land which is not rewarding in terms of agricultural development and which may enhance degradation;

ii) Reconciling tsetse control with the integrity of protected forest and game reserves;

iii) Controlling up to eight species of co-existing flies;

iv) Securing the massive funding necessary for such an investment.

This current study seeks to embrace some of these considerations and to assess the hypothetical feasibility of small, medium and large-scale tsetse eradication projects within the West African moist savannah zone (MSZ) and to compare their relative economic viability. This area is recognised by countries in the region, the World Bank and FAO as harbouring a high potential for the integration of crop and livestock production, and with scope to significantly enhance cereal and cotton production in West Africa.

The study compares the costs and benefits of tsetse eradication and ensuing agricultural development for several small projects (20,000 sq. km), two medium size projects (200,000 sq. km) and much of the moist savannah zone (600,000 sq. km). The study is based on PAAT-IS data and field collected data from within West Africa, and will apply normal project planning strategies. The purpose of the study is to compare the viability of a range of hypothetical projects in as realistic situations as possible. It is not the intention of the study to assess the feasibility of actual projects in these areas but merely to predict the likely economic outcomes of a range of different project strategies with particular reference to project size. For that reason all projects in this study are hypothetical and, for convenience, termed "shadow" projects. The term "shadow" is to be implied even where, for brevity, it is omitted from the text.

2. INTRODUCTION TO THE PAAT INFORMATION SYSTEM

The following outline of the PAAT Geographical Information System (GIS) was extracted and adapted from: The Programme Against African Trypanosomiasis Information System (PAATIS) by M. Gilbert [1], C. Jenner [2 3] J. Pender [2], D. Rogers[4], J. Slingenbergh [3], and W. Wint [5]

[1] *Laboratoire de Biologie animale et cellulaire, CP160/12, Free University of Brussels, av. F.D. Roosevelt 50, B-1050 Brussels, Belgium*
[2] *Natural Resources Institute, Central Avenue, Chatham Maritime, Kent ME4 4TB UK*
[3] *Food and Agriculture Organisation, Via delle Terme di Caracalla, 00100, Rome*
[4] *Trypanosomiasis and Land Use in Africa Research Group, Dept of Zoology South Parks Road Oxford OX1 3PS UK*
[5] *Environmental Research Group Oxford Ltd, Dept of Zoology South Parks Road Oxford OX1 3PS UK – Author for correspondence.*

The PAAT Information System is made up of three interacting components: the **Geographical Information System** (GIS) providing the capability for storage, display and analysis of layers of spatial data; the **Resource Inventory** containing country level tsetse and trypanosomosis information and the **Knowledge Base** allowing the user to query an extensive database of accepted literature.

2.1 THE GIS

The GIS component of the PAAT-IS allows display and detailed analysis of geographical information related to African trypanosomosis, providing an integrated common platform for continental scale data. Data available in PAAT-IS (Table 1) were compiled from a wide variety of sources as detailed below. Raster data have a 0.05 degree resolution.

The **tsetse distribution** maps have been derived from those produced by Ford and Katondo in 1977, using remotely sensed satellite imagery of climatic indicators (such as temperature, rainfall and vegetation cover) to provide predicted distributions of the three species groups (*Morsitans, Palpalis* and *Fusca)*. A background layer of the **number of tsetse species** present is also provided. Details of the prediction methodology can be obtained from FAO (2000) or *ergodd.zoo.ox.ac.uk/tseweb/index.htm*.

Table 1 Data currently available in PAATIS Beta (v 1.0).

Data Description	Predicted	Source
Layers (Vector Polygons)		
Continental Regions	No	PAAT/ERGO
Countries	No	UNEP/GRID, Nairobi
Administrative Level 1 and 2	No	UNEP/GRID, Nairobi
Major Rivers	No	NRI
River Basins	No	USGS/EROS Hydro1K
Major Roads	No	NRI
Major Towns and Cities	No	NRI
National Parks	No	PAAT/ERGO
Forest Types	No	FAO
Lakes	No	PAAT/ERGO
Tsetse fly Distributions	No	ERGO/TALA/ILRI/FAO
Background (Images)		
Annual Rainfall *†	No	Cramer and Leemans
Human Population *†	No	Various – See text
Elevation *†	No	USGS
No Tsetse Species	No	ERGO/TALA/ILRI/FAO
Morsitans group	Yes	ERGO/TALA/ILRI/FAO
Fusca group	Yes	ERGO/TALA/ILRI/FAO
Palpalis group	Yes	ERGO/TALA/ILRI/FAO

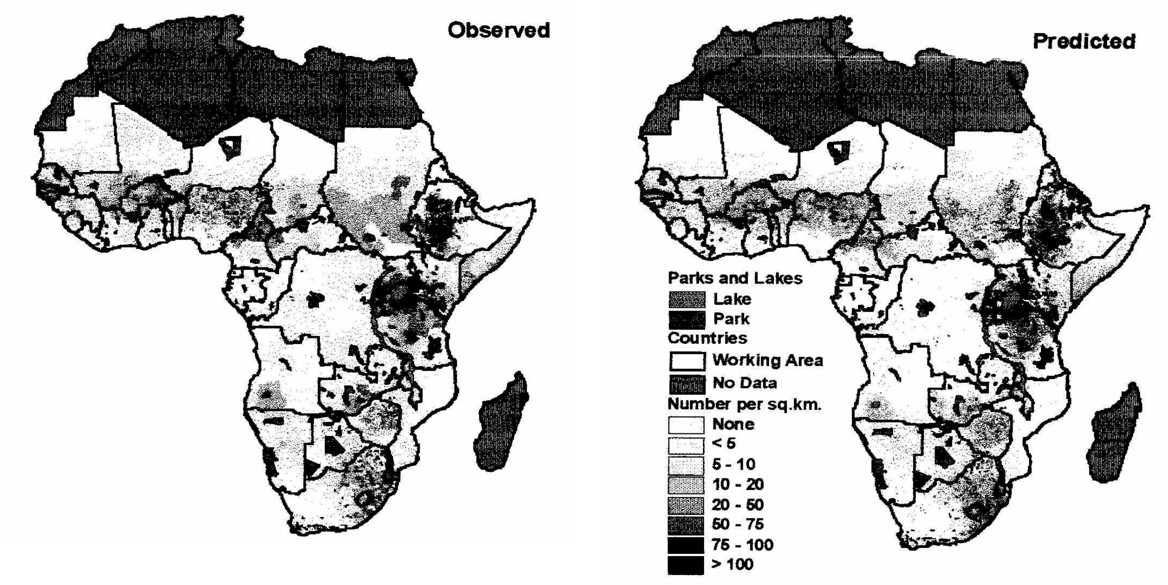
NDVI *	No	TALA
Observed Cattle *	No	Various – See text
Observed Cultivation *	No	Various – See text
Predicted Cattle *†	Yes	PAAT/TALA/ERGO
Predicted Cultivation *†	Yes	PAAT/TALA/ERGO
Length of Growing Period *†	Yes	FAO/AGL/ERGO/TALA
Mammal Biodiversity	Yes	PAAT/TALA/ERGO
Farming Systems	Yes	PAAT/TALA/ERGO
Ecozones	Yes	PAAT/TALA/ERGO
Data Reliability, Cattle	N/A	PAAT/ERGO
Data Reliability, Cultivation	N/A	PAAT/ERGO

*Raster data layers marked * are accessible for local statistical calculations and those marked † are available for statistics tabulated by Country and/or Ecozone and/or Farming Systems (Mean, Max, Mean and Total when applicable).*

The **human population** data given is combined from three sources: a global coverage of population number per image pixel from University of California at Berkeley provided by FAO; a population density coverage at the same resolution from the Consortium for International Earth Science Information Network (CIESIN: *www.ciesin.org*), derived from data collated by the National Centre for Geographic Information and Analysis (NCGIA: *www.ncgia.ucsb.edu*); and data from the Intergovernmental Authority on Drought and Development (IGADD).

Two sets of **cattle density** and **cropping percentage** data are provided: ‘observed’ and ‘predicted’ (Figure 1). The former represents the national and sub-national census data covering the period between 1985 and 1999, available from a wide range of sources. For cattle these include: the International Livestock Research Institute; ERGO aerial survey archives and Government Agricultural Census data. The observed cropping data were obtained from: the Africa Data Dissemination Service; FAO AGDAT as used in the FAO GEOWEB service, produced by FAO GIEWS (*geoweb.fao.org/*); ERGO/TALA aerial survey archives; transcribed Government Census data; and FAO GIEWS reports.

Figure 1: Observed and Predicted Cattle Densities (PAATIS, 2000)

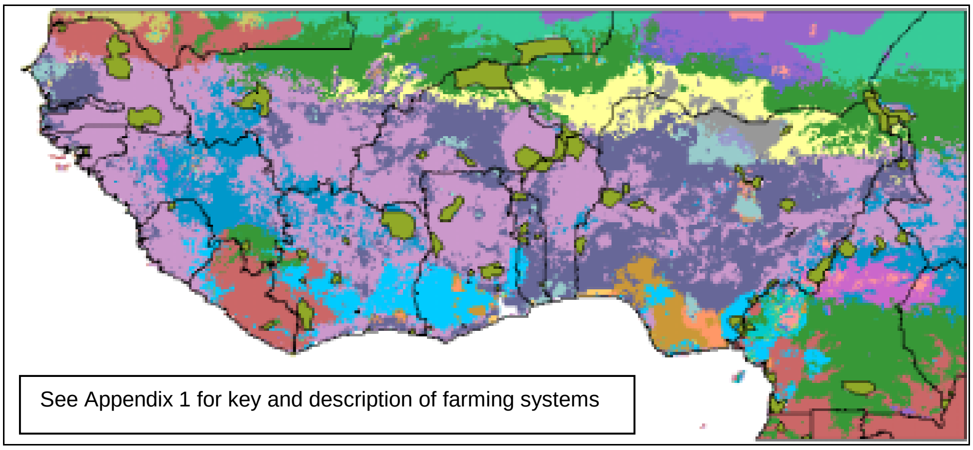


This ‘observed’ information is largely at the level of administrative units, some of which are very large (Figure 1, left). This resolution has been increased by using stepwise multiple regression to establish statistical relationships between these observed data and a range of predictor variables including: satellite imagery, provided by the TALA Research Group, related to rainfall, temperature, vapour pressure deficit, vegetation cover and elevation; potential evapotranspiration; length of growing period; human population; and the number of tsetse species present. These data were extracted for some 12,000 sample points covering sub-Saharan Africa, and a separate relationship established for each of a number of ecozones (see below) occurring within each country. The resulting equations were then applied to the high resolution imagery to provide **predicted maps of cattle and cultivation*** at a resolution of 5 kilometres. All the predictive equations used were formally significant to at least the one percent level ($p<0.01$), and most substantially more so. The predicted distributions can thus be taken to be statistically acceptable, providing, of course, that the underlying training ('observed') data are accurate.

The cattle prediction mirrors the observed distribution well (Figure 1 right), and picks out both major foci (e.g. East African and Zimbabwe highlands, Tanzania, semi-arid and dry sub-humid West Africa) and smaller concentrations such as in the Gezira, the Mali Delta, and south-eastern Zambia. Relatively high resolution spatial data that exist in the observed survey data for Nigeria and Botswana tend to be smoothed out by the regression methods used to generate the predicted map. Some of the contrasts between observed and predicted maps are due to minor differences between observed and predicted values falling into different mapping classes. There are also some minor anomalies in northern Chad, where very high predicted densities are obviously false, and are caused by extreme predictor values. The major predictor is human population density, which is primary in 30% of the equations.

PAATIS provides two zoning layers – **ecozones*** (used to subdivide the predictive analyses described above) and **farming systems**. Both are intended to show areas with similar (eco-climatic or agricultural) characteristics. They were produced using a statistical clustering technique available within the ADDAPIX software produced by FAO. The ecozones were defined using elevation, and remotely sensed imagery relating to temperature, rainfall, vegetation cover and vapour pressure deficit. The farming systems were identified using cattle, cropping and human population levels as well as elevation.

Figure 2 Farming Systems in West Africa



The layers for **Forests** and for **National Parks and Reserves** were obtained from FAO and NRI. The latter boundaries are for IUCN categories I to IV and supplemented by ERGO archive data for Botswana and Nigeria. It is stressed that these data are incomplete – for example neither the gazetted areas of South Africa, nor the forest information for the SADC countries are included.

Major rivers and river basins* were obtained from USGS EROS (*edcdaac.usgs.gov/gtopo30/hydro/africa.html*), and **roads** and **administrative boundaries** FAO, and NRI.

Digital Elevation Model (DEM)* data were obtained from the GTOPO30 1 km resolution surface for Africa, produced by the Global Land Information System (GLIS) of the United States Geological Survey, Earth Resources Observation Systems (USGS, EROS) centre.

The **length of growing period (LGP)*** and **mammal bio-diversity** layers are derived from low resolution data by the same predictive procedures used for cattle and cropping levels. The training data for LGP were provided by FAO AGL, whilst those for mammal distributions were extracted from the African Mammal Database compiled by the Istituto di Ecologia Applicata in Rome**.** **Rainfall** is derived from the maps published by Cramer and Leemans, provided by the Environmental Change Unit of Oxford University.

PAAT-IS also provides a background layer the **Normalised Difference Vegetation Index (NDVI)**, a widely used measure of 'greenness' allied to vegetation cover. This layer is derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery, from the Pathfinder Program, initially supplied by the NASA Global Inventory Monitoring and Modelling Systems (GIMMS) group, and further processed by the TALA research group.
* Maps for West Africa are included in Appendix 1

2.2 DESIGN AND FUNCTIONALITY

The GIS was designed using ArcView® (v 3.1) with the Spatial Analysis® Extension (v1.1) for analysis and data manipulation of raster images. This software was chosen because of its object-oriented scripting language (Avenue®) that allows complete customisation of the Graphical User Interface (GUI). The PAATIS design is modular which facilitates updating existing layers, the addition of new layers and customisation of the user interface to incorporate new modelling and statistics options.
The GIS was organised into three layers which correspond to three stages of the decision pathway:

i) defining and focusing on the study area,

ii) mapping priority control areas defined by cattle and crop levels and presence or absence of tsetse and

iii) mapping and evaluating predicted impact of control..

At each level, the user is provided with various options: mapping tasks to customise the view;

i) analysis tasks to extract geographical information and statistics

ii) navigation tasks to personalise the overall decision pathway

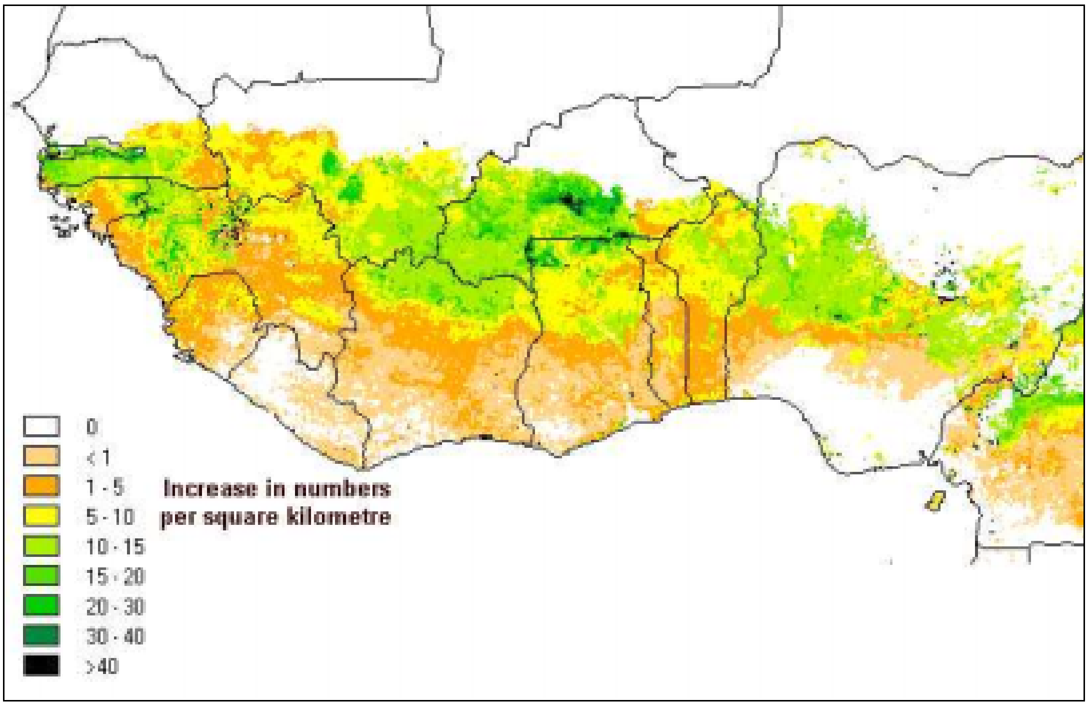
iii) export tasks to produce graphical or tabular outputs for use in external software.

Statistics, priority control maps and impact maps can be generated or calculated for a geographic area or for a shape defined by the user. Local statistics can be calculated for all data layers marked * in Table 1 and cross tabulated statistics by Country and/or Ecozone and/or Farming System can be calculated for all those marked †. All tabular results can be exported to table format files or straight to an Excel spreadsheet.

Two methods of calculating tsetse impact are provided in the GIS Level 3. Users have been provided with a means of setting their own impact levels (both positive and negative) which the programme then applies to the cattle and cultivation data. Secondly, a predicted impact of the removal of the fly on cattle (Figure 3) and cropping levels, is provided. This is derived using the predictive equations for cattle and crops, within which the number of tsetse species is set to zero, giving an estimate of the levels of these parameters in the absence of tsetse. This is subtracted from the original prediction to give a predicted impact.

It is fully appreciated that this is a rather simplistic way of calculating impact, as it assumes that all tsetse species have a similar effect on agriculture, and that this is constant for all areas and agro-ecological zones. The method does not take into account any possible increase in human population (and its possible impact on agricultural levels), nor does it predict any new agriculture where there is currently none. As such the predicted impact is likely to be an underestimate. The method does, however, highlight the areas where some agriculture is already found within the tsetse belt - and thus likely to be most immediately affected by tsetse control operations. In West Africa such areas are exemplified by parts of Burkina Faso and Mali; and in the East, Ethiopia, Tanzania and the Lake Victoria Basin.

Figure 3   Predicted impact of tsetse removal on cattle densities (PAATIS, 2000)



Whilst an estimation of the possible change in cattle and cultivation due to the removal of tsetse is central to the definition of impact, it is the economic value of these changes that often determines the feasibility of control operations. It was impractical to assign fixed ‘dollar values’ to the impact predictions provided so users have been provided with the facility for assigning their own (currency independent) values to a hectare of cultivation and a cattle density of one animal per square kilometre, which are then applied to the impact predictions, thereby providing an indication of economic impact that may be adjusted to local conditions.

Results from these impact maps can be extracted by any geographical region or shape. Present data indicates that there are approximately 175 million head of cattle, of which 45 million are within the area of tsetse infestation. From the predicted cattle impact map the PAATIS calculates that there would be an increase of approximately 50 million head of cattle (effectively a 100% increase in actual numbers) if all tsetse were removed.

2.3 FUTURE OF THE PAATIS SOFTWARE PACKAGE

Continental scale information could simply be replaced by a country or project specific geographical area with associated higher resolution data layers. Existing cattle layers could be supplemented with data for other animal species or trans-boundary disease occurrence, such as addressed by the EU funded PACE and FAO EMPRES. The economic importance of, for example, production systems, milking and calving offtake, could be incorporated into the analysis and impact modelling. A prototype of this approach has recently been tested for Kenya by FAO AGAH.

Whilst there are limitations in the validity of existing continental tsetse maps, it must be noted that there are currently developments in the field of predicting tsetse distribution and abundance using satellite imagery, which in turn would lead to more detailed and accurate analysis of impact by single tsetse species or groups.

A distinct advantage of the spatial approach within this customised environment, is the ability to obtain statistics, not only from administrative boundaries, but from a user defined shape reflecting a more realistic trans-boundary approach. For example, the extraction of any of the statistical outputs provided in the PAATIS menu could be applied to a natural watershed or some other terrain related system. In addition, statistics can also be calculated by selecting a cross-tabulation output by LGP category, Ecozone or Farming System. This not only allows more flexible data queries than available in the majority of information systems, but provides a decision tool that can be targeted precisely to specific project requirements. There is thus substantial potential for expanding the PAATIS to incorporate additional data, utilising its modular construction, to become more widely applicable as a source of agro-ecological and epidemiological information.

Finally, PAATIS is intended to provide an extensive and standardised set of agro-ecological and tsetse related data to a wide audience. It is hoped that this will stimulate recipients of the system to assist PAAT in updating and revising the many data layers included, as well as to refine and improve the capabilities of the system itself.

NB Maps of W Africa are included in Appendix 1.

3 THE STUDY

3.1 INTRODUCTION AND OBJECTIVES

This study is a PAAT initiative and jointly funded by the Joint FAO/IAEA Division and FAO. It was carried out in several phases and a wide range of people were involved during each phase; participants for each phase are noted in Appendix 6. The study was initiated at a 1½-day workshop held in Geneva (WHO) in November 2000 with a follow-up two-centre workshop in Rome (FAO) and Vienna (IAEA) in December 2000. This was followed by a stage during which a bilateral approach was adopted. The partners from the west Africa countries each carried out a study of their own country's study area, drew up plans for a tsetse control project there and predicted the consequences. At the same time the consequences of tsetse control projects in the medium and large study areas were predicted using the PAAT-IS. These were all then co-ordinated in this final report which includes an economic analysis.

The objectives of this study were to test the hypotheses that:

1. tsetse control and eradication in the 'Cotton Belt' of west Africa is economically worthwhile
2. that larger projects are likely to be more economically efficient than smaller projects.

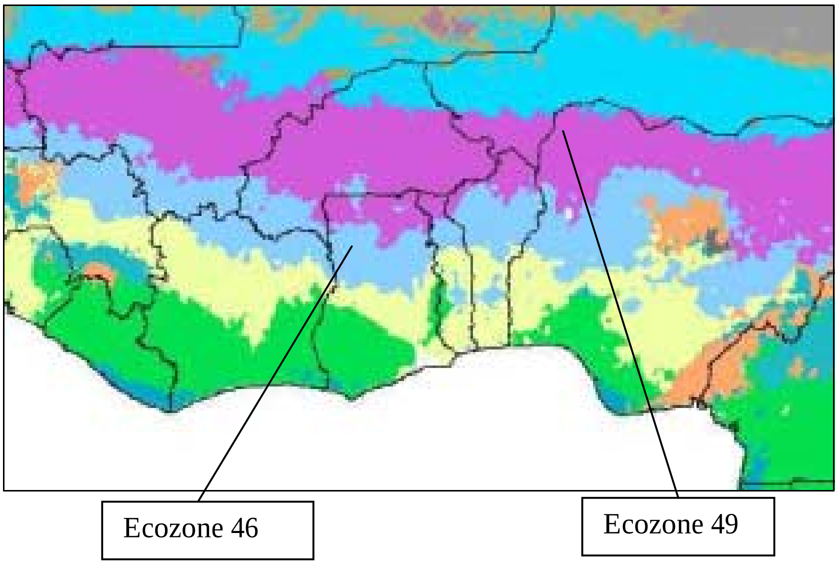
The means used to test these hypotheses was to develop a range of tsetse control projects of differing sizes throughout the 'Cotton Belt' and to estimate their costs and likely benefits. Consequently the projects so developed can only be regarded as hypothetical projects whose sole purpose was to provide the database to test the hypotheses.

3.2 SIGNIFICANT ISSUES

3.2.1 ECOZONES

For some time the PAAT has identified the 'West African Cotton Belt' as a high priority region for tsetse control. For the purposes of this study it was first necessary to express this colloquial term more accurately in terms of agro-ecological zones. Using the PAAT-IS the agro-ecological zones that best coincided were zones 46 and 49. The term 'Moist Savannah Zone' was the preferred descriptor of this region and is used throughout this report.

Figure 4 Ecozones in West Africa



ZONE	46	49
NDVI[1]	0.12 to 0.45	0.09 to 0.45
Av.Temp	40.8ºC	44.4ºC
LGP[2]	186	162
Average Rainfall (mm)	1370	1092

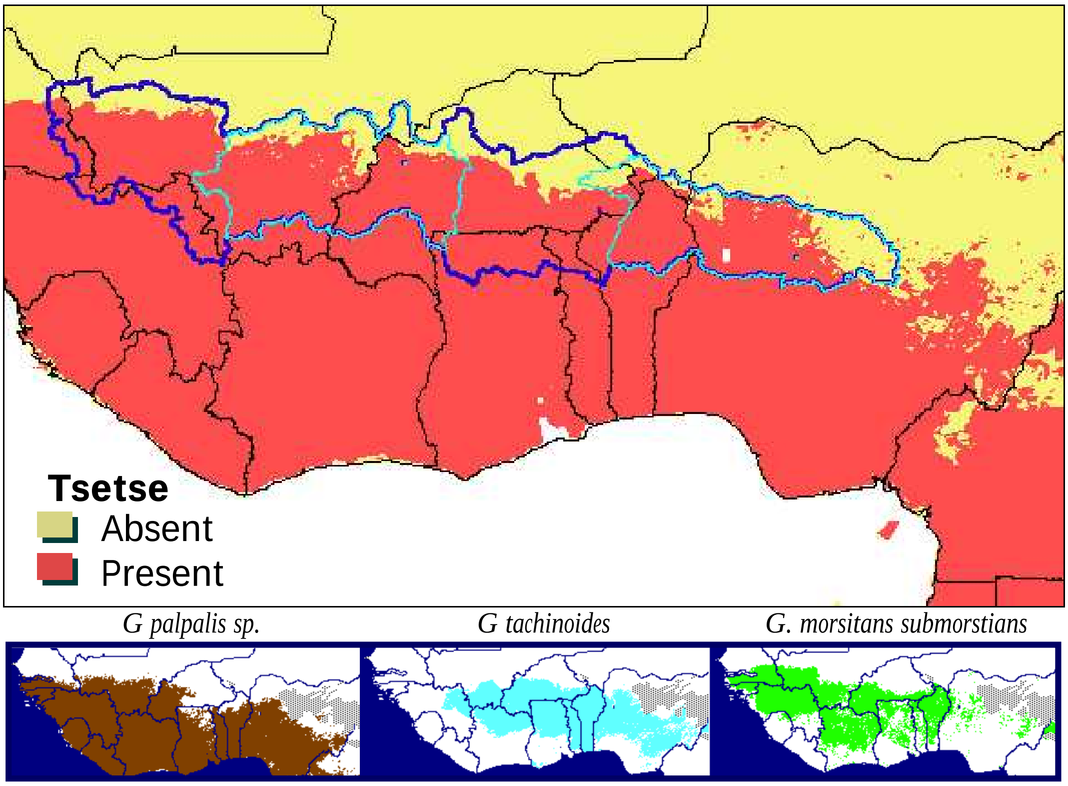
1 Normalised Digital Vegetation Index
2 Length of Growing Period (days)

3.2.2 TSETSE FLY SPECIES

Within the Moist Savannah Zone (MSZ) the three most significant species of tsetse fly are *Glossina morsitans morsitans*, *Glossina palpalis palpalis* and *Glossina tachinoides*. The first is predominantly a savannah species inhabiting woodland of sufficient density to provide sufficient shade. *G. palpalis* and *G tachinoides* are riverine species which, like all tsetse flies, prefer to rest in cool shady areas and in the dry season are rarely found outside the narrow strips of riparian vegetation bordering water courses in the dry season. During the wet season when the natural vegetation grows up to provide sufficient shade these riverine species spread out from the watercourses for some distance. In this respect *G tachinoides* tends to move further than *G palpalis*, the latter rarely moving far from standing water, either in the wet or the dry season.

Previous surveys had indicated that in this region *G. tachinoides* was responsible for transmitting at least three-quarters of trypanosomosis infections (J Slingenbergh, *personal communication*). In the Moist Savannah Zone *G. Morsitans* is at its northern ecological limit and so the mere removal of its habitat by human settlement and the introduction of agriculture is generally sufficient to cause its eradication. Consequently *G Morsitans* is not only a minor agent for transmission of trypanosomosis but its eradication by artificial means is considered to be relatively straightforward in comparison with the riverine species. *G palpalis* is so restricted in its habitat that it rarely comes into contact with livestock, even at watering and crossing points, and thereby also presents only a minor transmission risk. An eradication programme targeting *G. tachinoides* would, with little extra effort, simultaneously eradicate *G palpalis*. For these reasons it was felt that *G. tachinoides* would be the major target for any eradication programme and that tsetse control programmes should primarily be designed with that objective in mind.

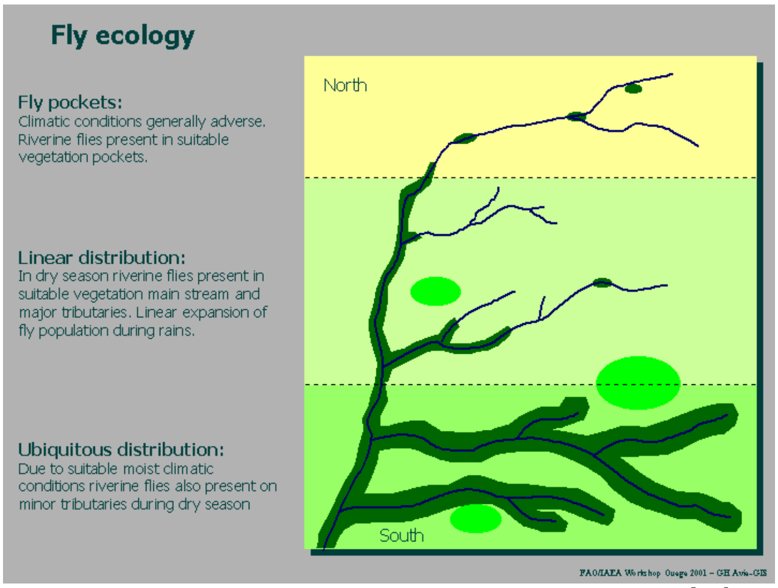
Figure 5 Tsetse Distribution within the Moist Savannah Zone



3.2.3 LOCATION OF TSETSE FLY SPECIES AND THEIR VULNERABILITY

Within the MSZ the three significant tsetse fly species have somewhat different distributions as shown in figure 6.

Figure 6 Schematic Diagram of Tsetse Fly Distribution in the MSZ



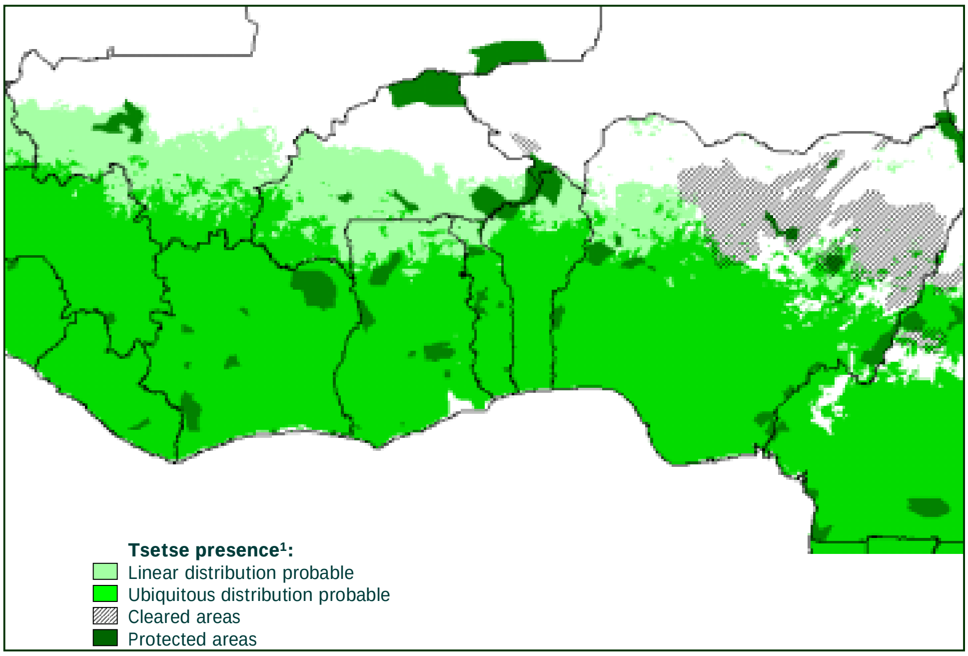
Source: Guy Hendrickx

In figure 6 the distribution patterns of the three tsetse fly species are demonstrated diagrammatically. Starting from its northern limit the west-African fly belt can be divided into three almost horizontal and parallel bands. A northern band where riverine tsetse species (*G. tachinoides* and *G. palpalis*) distribution is very patchy, a middle band where they become more evenly spread along the major river systems and finally a southerly band where they invade secondary and tertiary tributaries. This distribution is explained in more detail in Annex 6.

The savannah fly species (*G. Morsitans*) do not inhabit riverine vegetation but the drier savannah woodland. In the MSZ the pressure of farming and human habitation has now restricted their presence to pockets dispersed throughout the zone. Whilst this distribution is based on observations and experience in the west of the zone it should be noted that *G. morsitans* and *G. palpalis* were the primary target species during the tsetse control campaign in northern Nigeria during the 1960's and 1970's (Putt *et al*, 1980).

As may be expected, discrete fly populations, when identified, should be more easily eradicated than ubiquitous populations in the more humid southern parts of west Africa. Unfortunately, the tsetse fly is a very strong flier, and can move long distances. Therefore cleared areas can easily be reinvaded from neighbouring areas remaining infested by flies. Arguably clearing tsetse from the drier northern parts might be achieved with minimal re-invasion risks. When combined with increased agricultural activity and proper land management there might even be no need for extended artificial protective barrier systems in the more southerly zones.

Fig 7 Riverine Tsetse fly Distribution Patterns



The riverine tsetse fly distribution pattern map (figure 7) was derived from field observations made in Burkina Faso and extended using GIS techniques to the whole of west Africa. It clearly shows the band where riverine flies are distributed linearly along watercourses and that the areas in Nigeria from which tsetse have been eradicated as a result of previous campaigns (hatched) would consistently fall into this category.

3.2.4 TECHNICAL FEASIBILITY

In this study it was acknowledged that, even though the projects to be formulated and analysed were 'hypothetical', they still had to be technically feasible. As such it was acknowledged that it would not be possible to eradicate tsetse flies from the thick gallery forests of the forest and coastal zones of west Africa where fly distribution is ubiquitous. Consequently projects would have to be in areas where there would be a good chance of eradicating flies using the currently available techniques, i.e. in areas where *G. tachinoides* were distributed linearly along watercourses or in discontinuous pockets. This process is explained in more detail in annex 6.

In the long-term, i.e. after flies have been cleared from the MSZ, there will be no risk of re-invasion from the north and projects in the more southerly areas where flies are distributed more widely are more likely to be successful than at present. It is also a reasonable expectation that during the MSZ eradication phase the usage of existing techniques will have been refined and that new tsetse control techniques will have been developed.

3.2.5 RE-INVASION

It was considered by those with a detailed knowledge of tsetse flies in west Africa that re-invasion was not likely to be a significant problem in the moist savannah zone. Such intuition is supported by the experience in northern Nigeria where areas freed from tsetse flies in the 1960's and 1970's have only suffered minimal re-invasion until now. The possible risk of re-invasion by flies being carried on animals undergoing transhumance journeys was also considered to be minimal as any flies moving from the southern forests would not be able to survive in the more arid conditions of the MSZ.

However, because the cost of taking measures to prevent re-invasion is likely to be a, or even 'the', major cost element in any tsetse control programme this factor has been retained in evaluating the economic performance of the shadow projects. By its inclusion the conservative nature of the economic analysis is retained.

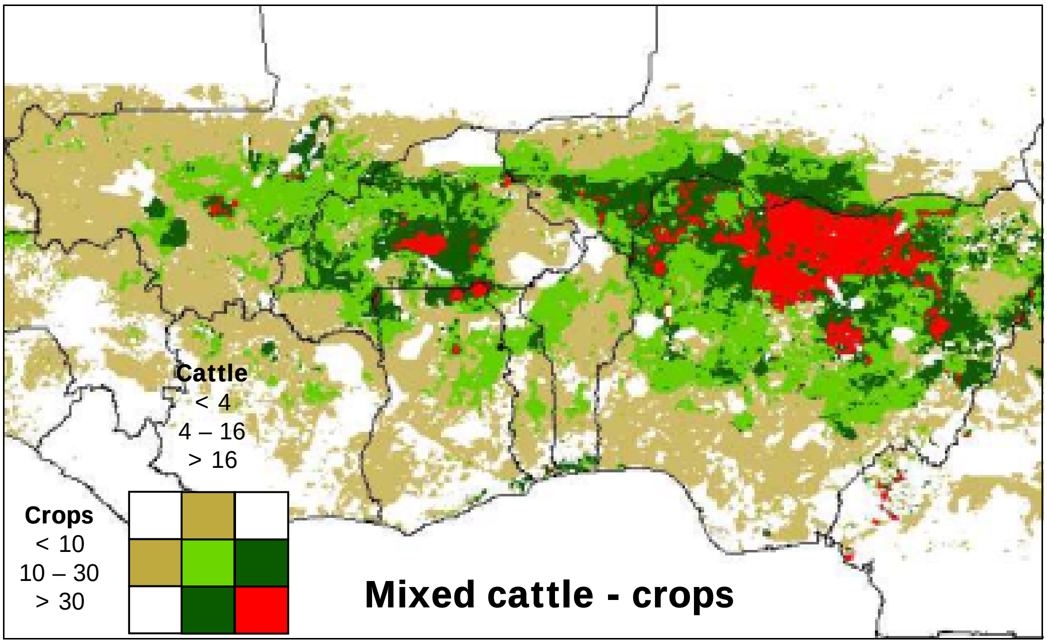
3.2.6 Land Tenure

Bearing in mind the existing competing demand for the use of land by arable farmers, agropastoralists and transhumance pastoralists, the combination of the lack of a more modern land tenure system and the eradication of tsetse flies enabling land to become livestock-friendly was recognised as having the potential to heighten tension between these groups. The need for a more equitable legislative framework for land tenure was considered to be a vital pre-requisite for tsetse control projects.

3.2.7 Economic Benefit and Land Pressure

It was considered that the greatest or the quickest economic benefit would be most likely to arise in areas where there was land pressure in adjacent areas resulting from the presence of tsetse flies and trypanosomosis. For the purposes of this study 'land pressure' was determined by the level of intensity of a combination of cropping (> 10% of the land being cultivated) and cattle density (> 4 cattle per sq km). The regions around such areas which are infested by tsetse were therefore regarded as high priorities for tsetse control on the assumption that trypanosomosis is the major constraint to the intensification of farming.

Figure 8 Land Pressure in West Africa



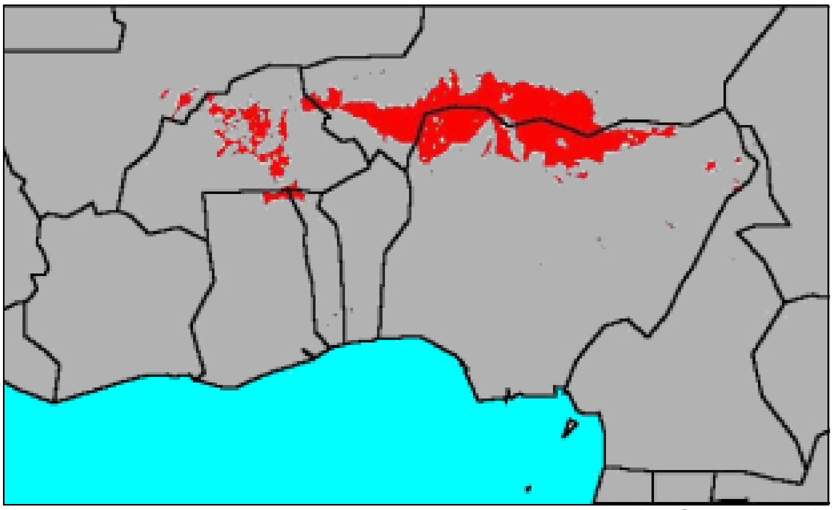
Whilst this designation of 'Land Pressure' only embodies two GIS layers it clearly demarcates (Fig. 8, areas in red and dark green) densely populated regions such as the Nigerian highlands and the effect of large towns, e.g. Bamako, Ouagadougou and Niamey on farming intensity in their hinterlands. More importantly, figure 8 also shows areas where land pressure is low and it is when these areas are also infested with tsetse flies that the greatest benefits from tsetse control programmes are likely to occur.

However, the situation is complicated by the diverse nature of farming in the MSZ and which is not evident from this map. There are basically three groups of farmers in the MSZ: firstly, arable farmers who grow both subsistence and cash crops; secondly, settled agropastoralists who keep livestock and, thirdly, pastoralists who practise transhumance and who move basically north or south according to the season. Although this is an over-simplified description of farming in this zone it demonstrates that the level of integrated crop/livestock farming is low. One of the causes is that cultivation predominates in areas where it is difficult to keep cattle due to trypanosomosis. By removing this constraint the significant advantages of crop/livestock farming could benefit farming productivity, particularly with regard to the expansion of the availability and use of draught animals for cultivation and transport.

3.2.8 THE POTENTIAL FOR LAND DEGRADATION

The causes of land degradation and soil erosion are a complex combination of physical, climatic, socio-economic and climate change factors. However, it was recognised that in some areas the benefits arising from increasing numbers of livestock resulting from the removal of the constraint of trypanosomosis will be outweighed by the negative effects on the land surface and the soil and its fertility.

Figure 9 Primary Land Degradation Risk - West Africa



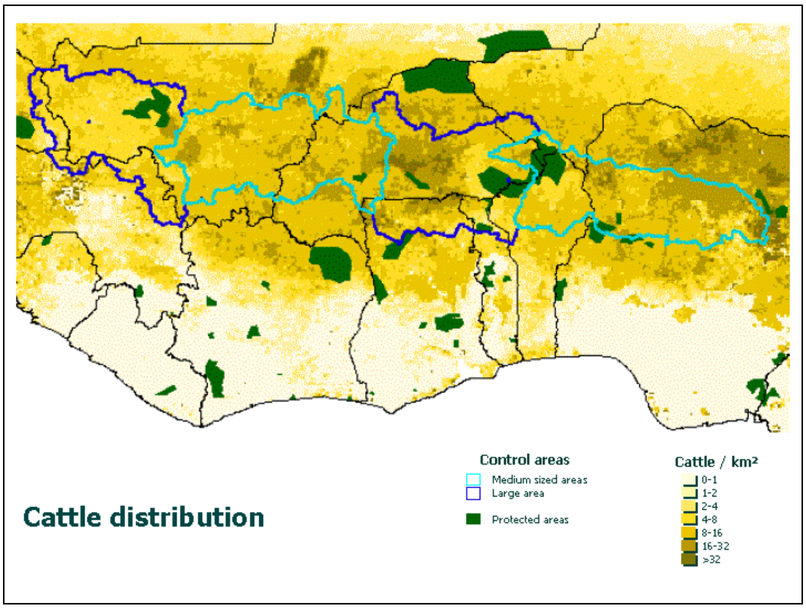
Source: FAO-AGAH (work in progress)

Because of the limited nature of this study it was not possible to embrace this factor in great detail but areas where there was a high risk of environmental degradation (see fig. 9) were precluded from becoming target areas for study.

The criteria for assessing risk areas was areas which were identified from the Global Assessment of Human Induced Soil Degradation (GLASOD) map which was conducted by the International Soil Reference and Information Centre (ISRIC) at Wageningen, The Netherlands, as commissioned by the United Nations Environment Programme (UNEP). ISRIC produced a 1:10 million scale wall chart in 1990 and subsequently produced a digital data set.

In essence, the GLASOD database contains information on soil degradation within map units as reported by numerous soil experts around the world through a questionnaire. It includes the type, degree, extent, cause and rate of soil degradation. From these data, digital and hardcopy maps were produced and area calculations were made.

Figure 10 Cattle Distribution in west Africa



From figures 9 and 10 it can be seen that the primary areas at risk of environmental degradation also coincide with areas with cattle densities of over 16 per sq km. Most of these occur in the northern arid savannah regions and thus fall outside the tsetse belt, apart from the region around Ougadougou in Burkina Faso. This is an area where the distribution of riverine species of fly is patchy and consequently trypanosomosis is unlikely to be a significant constraint on cultivation or livestock keeping.

3.2.9 ERADICATION OF THE WHOLE *G. TACHINOIDES* BELT

The possibility of eradicating the whole *G tachinoides* belt was considered as an alternative to protecting cleared areas of the MSZ from re-invasion from the south. It was recognised that the benefits that would accrue to areas to the south of the target areas would not be as great as in the MSZ as other species would still be capable of transmitting trypanosomosis. Consequently, the benefits might not outweigh the costs especially as trypanosomosis might not be the major constraint to livestock productivity in most areas. Diseases such as Dermatophilosis and babesiosis were considered to be greater constraints in those areas. In addition the density of the vegetation was considered likely to preclude effective suppression of the flies as this will increase the difficulty of deploying traps and targets and aerially applied insecticide is likely to be intercepted by vegetation before it reaches the bottom metre or so which tsetse flies inhabit.

Bearing in mind the technical difficulties involved in eradicating the whole *G. tachinoides* belt it was concluded that such an aspiration could not be embraced within the first phase of tsetse control programmes in west Africa. However, it was recognised that removal of the whole *G. tachinoides* belt would become more feasible once tsetse flies had been eradicated from the MSZ and, as a result, an artificial barrier against re-invasion from the north would already have been created.

3.2.10 HUMAN SLEEPING SICKNESS

The west African form of human sleeping sickness is a chronic disease caused by *Trypamosoma brucei gambiense* which may take several years to become fatal if left untreated. This is in contrast to the acute form of the disease found in east Africa which can prove fatal in as little as six months in similar circumstances. Both forms of the disease tend to break out in foci (see fig. 11) rather than universally and are transmitted by tsetse flies. However, because of the chronic, rather than acute, nature of the disease it is generally considered that in order to combat the west African form of sleeping sickness it is more effective in the short term to reduce the human reservoir of the disease by surveillance and treatment than to remove the vector as most of the transmission occurs from person to person (Welburn, 2001). For the east African form cattle act as a reservoir of the disease and so controlling the vector is considered to be an effective control measure.

Fig 11 Historic Foci of Human Sleeping Sickness

Map: Trends in Parasitology, Jan 2001

For these reasons the exclusion or inclusion of historic foci was not considered to be an important factor in determining the location of the study areas.

3.2.11 SOCIO-CULTURAL FACTORS AND LIVELIHOODS

The limited nature of this study prevented the incorporation of an analysis of the impact on the culture and livelihoods of people affected by the removal of livestock and human trypanosomosis resulting from tsetse eradication projects except in financial terms. However, it is considered in this early stage of planning there are no socio-cultural or gender issues that would need to be incorporated in this study. It is further considered that until the project implementation stage such factors will probably not influence the direction of a project; and even then only in relation to the application of ground-based control techniques.

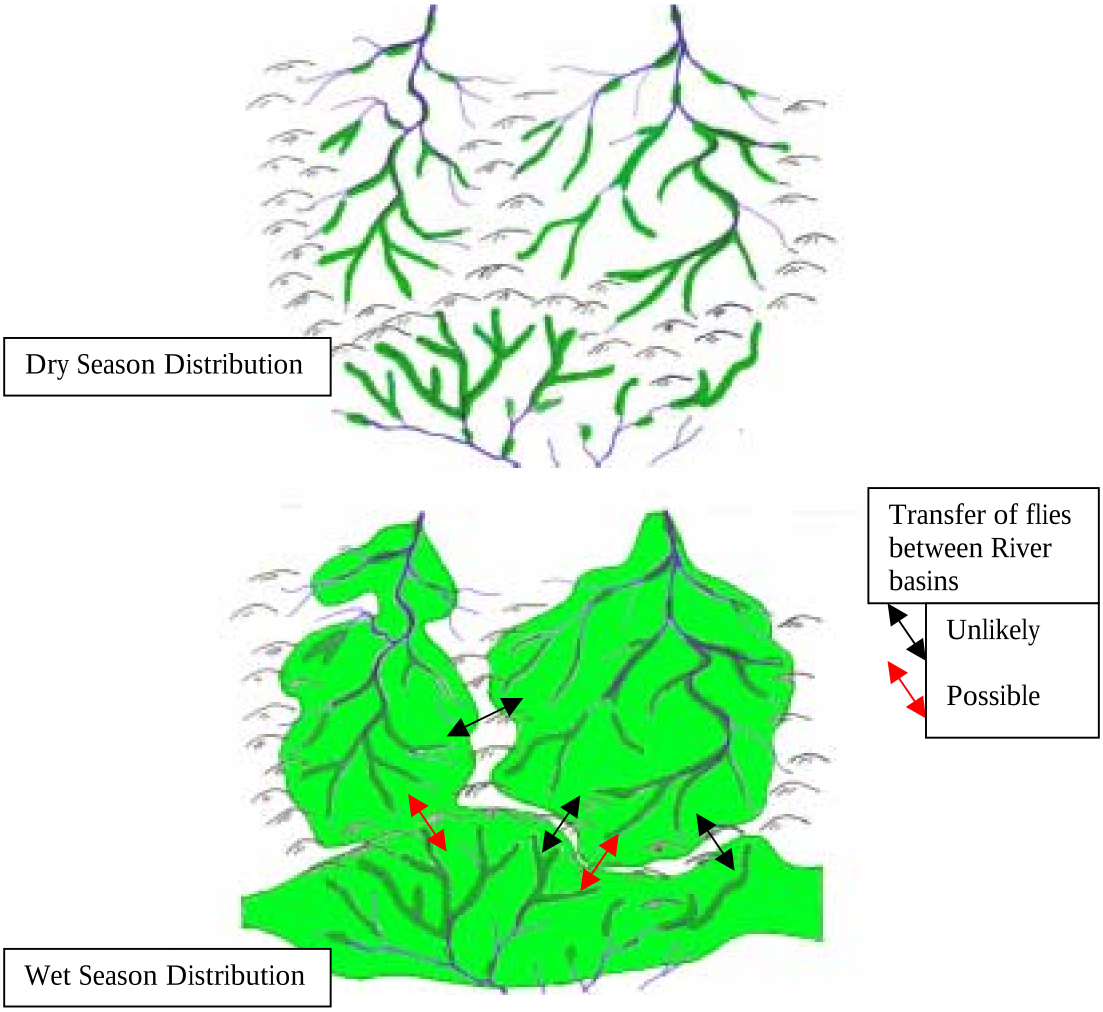
3.3 THE RIVER BASIN CONCEPT

Bearing in mind the need to minimise the risks, and the consequent prevention costs, of re-invasion and the fact that *G. tachinoides* is the major transmitter of trypanosomosis in the MSZ it was considered that the lowest density of these flies, even during the wet seasons, would be along the watersheds between the various river basins. It has been suggested that flies travel as little as 4 km from a watercourse in the wet season although research will be needed to verify this distance.

Consequently it was considered that river basins would most likely be the topographical feature that could be the smallest size unit for tsetse control projects. Whilst the watersheds could provide an effective barrier from neighbouring river basins to the east and west, in the west of the MSZ rivers systems run northwards. This provides the potential for the southern watershed boundaries of the river basins to act as a full or partial natural barrier against re-invasion from the more heavily wooded south where *G. tachinoides* distribution is ubiquitous. Below this unit size tsetse eradication would not only be more technically difficult and less sustainable but also less economically viable because of the increased cost of preventing re-invasion..

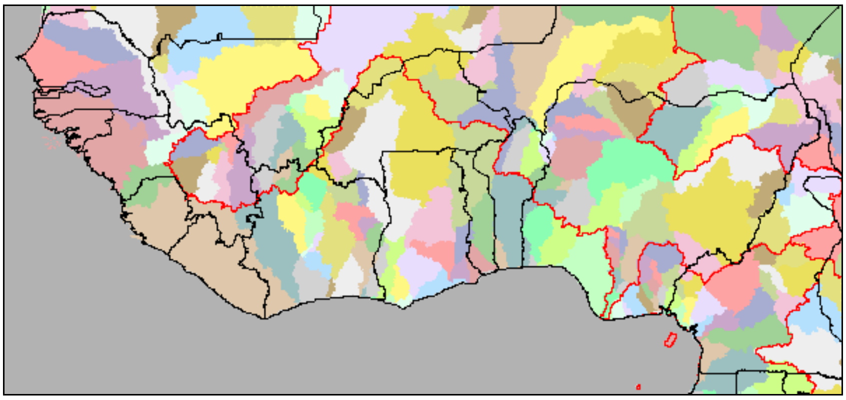
Figure 12 diagrammatically represents the dry and wet season distribution of *G. tachinoides* within the riparian vegetation close to watercourses. Such vegetation may be as little as a few meters either side of the smaller seasonal watercourses but can be as much as 250 meters either side of the main perennial rivers. During the wet season vegetation that can provide cool shade for resting tsetse flies grows up in the treeless areas between watercourses and this allows flies to disperse away from the watercourses. Whether flies disperse sufficiently to reach and cross the watersheds is not fully understood but the study considered that, even if they did, these boundaries would be the easiest place to implement measures to protect areas from which tsetse flies had been eradicated against re-invasion. It was also noted that main roads had often been routed to follow watersheds in order to minimise the need for bridges across rivers and streams.

Figure 12 Diagrammatic Representation of Dry and Wet Season Distribution of *G. tachinoides* in relation toRiver Basins



For these reasons it was concluded that a river basin should be regarded as the smallest optimal unit for a tsetse control project. Whilst this does not rule out smaller projects being economically viable and technically feasible it was considered that the need to implement measures against re-invasion in perpetuity would not only render them more costly but also less sustainable. Thus the small projects were designed around a single river basin and the medium sized projects were multiples of river basins. A consequence of this was that these projects were larger than originally intended (see 3.4 below). Accordingly there remains a need to compare the economic performance of a project of less than river basin size, i.e. about 2000 sq km. Fig. 13 denotes the level 4 river basins of west Africa.

Fig 13 Level 4 River basins of west Africa

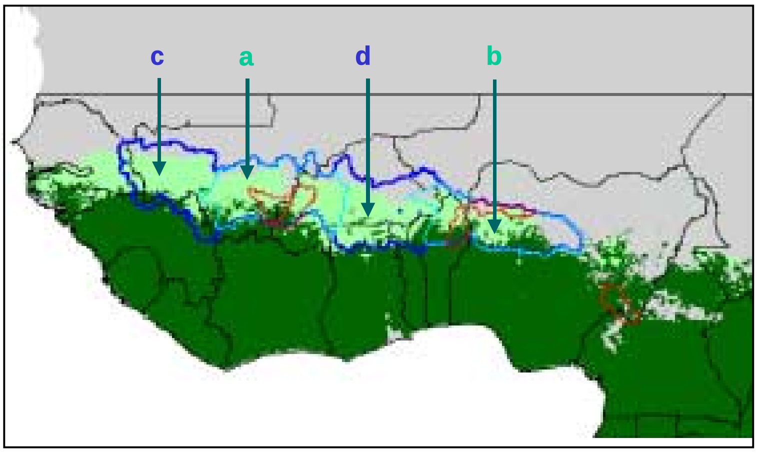


3.4 IDENTIFICATION OF STUDY AREAS

It must be emphasised that all the study areas are hypothetical and have been selected in order to ascertain in general terms the costs, benefits and social consequences of tsetse control projects in the MSZ of west Africa. These studies are not in response to specific requests from governments or agencies to draw up project proposals but are designed to provide a range of models which could form the basis for designing actual projects. The MSZ has been identified by PAAT as one of the priority areas for tsetse control and this project has been initiated by PAAT as a representative of all international interests in the field of tsetse flies and trypanosomosis.

One of the objectives of this project was to test the hypothesis that larger tsetse control projects would not only be more effective in cost/benefit terms than smaller projects but would also be more sustainable in the long-term. As the whole of the MSZ area identified as capable of being freed from tsetse flies was measured (using GIS techniques) as 600,000 sq km, projects of one-tenth (60,000 sq km) and one-hundredth (6000 sq km) of that size were required to test the hypothesis. In order to provide coherence and make the comparisons more valid it was considered that the 6000 sq km projects should be within the medium sized (60,000 sq km) projects. The medium sized projects would inherently be within the whole area.

Figure 14 Selected project areas for study in relation to the LGP <170 days band



Key

Small study areas marked in red

a = Western medium-size area
b = Eastern medium-size area

c+a+d+b = Large study area

Bearing all the factors outlined above in mind, four small areas were selected for study and drawing up of hypothetical tsetse control projects (see fig. 14). In addition the Mambilla plateau in eastern

Nigeria was selected for study in order to investigate the parameters for tsetse control in this area bordering central Africa. Whilst the original intention was to select areas of about 6,000 sq km as the small study areas, regarding a river basin as the smallest unit for tsetse control resulted in selecting study areas that were at least two to three times that size.

Selecting river basins rather than administrative boundaries as shadow project areas meant that collection of data became more difficult as the boundaries of river basins are not contiguous with district or even national boundaries. One project even crosses the national boundary between Mali and Burkina Faso. However, this complication does reflect the true nature of designing and implementing projects in the real world (a fact which has been recognised by PATTEC for whom the very need to conduct tsetse control across international boundaries is part of their *raison d'être*) and was accepted as being an integral part of the models.

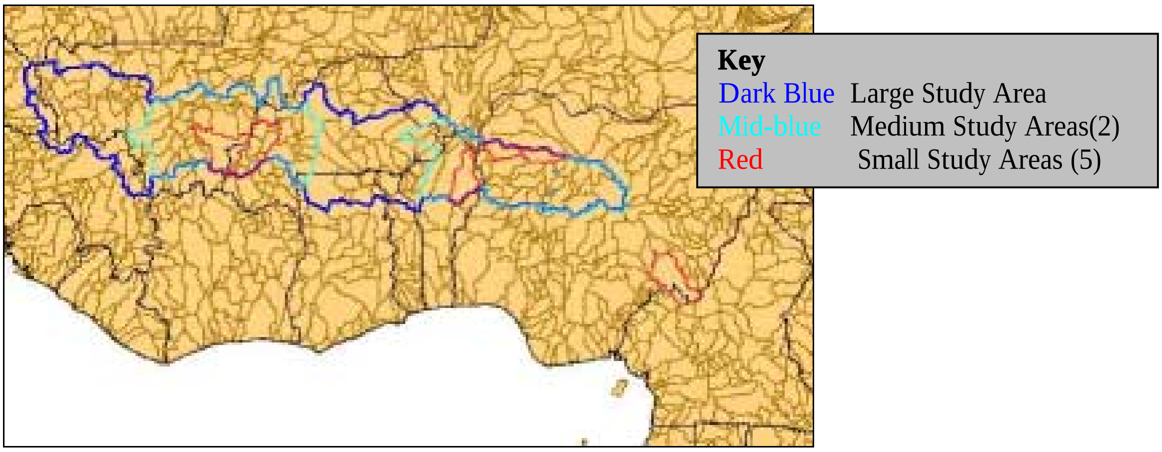
The small study areas are demarcated in fig. 14 and described in table 2. The medium-size GIS study areas were built-up from expansions of small study areas 1 with 2 and 3 with 4 and are combinations of adjacent river basins.

Table 2 Small shadow study areas (13,000-22,000 sq. km)

Project Area	Description	Study Leader
1. Broader San River Basin, directly north of Sikasso (Mali) Area 20513 (4415) sq km Perimeter 1162 (438.2) km	This is a river basin in which trypanosomosis is a major constraint to improvement of the livelihoods of the rural population. This area already has considerable levels of mixed farming with cotton as a cash crop, and it is believed to only contain 2 tsetse species which are mainly concentrated in riparian vegetation	Dr. Oumar Diall
2. Mouhoun River System (Burkina Faso) Area 21630 sq km Perimeter 1053 km	This area of high agricultural potential was selected because it suffers high land pressure from cotton areas to the East. The area contains both savannah and riverine species, both of which are easily controlled.	Zowinde Koudougou
3. Northern Benin Area 14125 sq km Perimeter 820 km	This area was chosen because it is towards the northern fly limit, has high agricultural potential and there are wildlife factors (National Parks) to consider.	Dr. Victorin Codjia
4. Ka River (Sokoto River system) Nigeria Area 13161 sq km Perimeter 1170 km	This area was chosen because of the persistence of riverine species at the ecological limit, the high demographic pressure and a high level of resource exploitation.	Prof. Albert Ilemobade
5. Mambilla Plateau Eastern Nigeria Area 19858 sq km Perimeter 1034 km	This area was chosen to represent the particular land use and socio-economic aspects of the eastern part of the moist savannah zone. There is also pressure on cattle in transit to the Mambila Plateau and expansion pressure for cultivation from areas associated with the Benue River system.	

A framework for the analysis of these five study areas was developed and is included as Section 3.4.1

Figure 15 Map showing selected study areas and Level 5 River Basins



3.4.1 FRAMEWORK FOR ANALYSIS OF SMALL STUDY AREAS

A framework to guide the colleagues in west Africa who would actually carry out the analysis for the small study areas selected was drawn up. Data from the PAAT GIS was extracted for each of the five areas and provided to them digitally in either a PowerPoint® or ArcView® format depending on the software available locally. The purpose of the framework was to indicate the type of background data required in order to be able to quantify the shadow projects in numeric terms and thereby make an economic assessment. By providing a format in which to supply the information it was hoped that this would enable a common report format to be developed for all the studies so that the final composite report would be more easily readable.

SMALL SHADOW PROJECT ASSIGNMENTS

Each project area has been pre-selected on the basis of two principle considerations:

i) Small projects are vulnerable to re-invasion except when situated at the northern dry/hot fringes of tsetse distribution, and;

ii) The area must receive sufficient rainfall and have sufficient mixed farming (present and potential) to qualify as a priority area. Hence, the following set of criteria were used as the basis for area selection:

- tsetse fly ecology and behaviour
- the presence of and potential for mixed farming
- vegetation patterns, ecozones and drainage systems
- risks of land degradation
- risks of other diseases in man, livestock and crops.

The study is based on a range of data selected from the PAAT-GIS and additional data available to FAO and PAAT; i.e. ecozones, farming systems, predicted tsetse distribution by species, elevations, human population density, cattle density, proportion of land cultivated and administrative boundaries.

CONTRIBUTIONS FROM WEST AFRICA BASED EXPERTS

In order that all the reports are similar in approach, and are thereby comparable, it is suggested that the following report template is used:

1. Database Creation. Whilst the PAAT-GIS contains a wide range of basic data it may need to be improved by the inclusion of more detailed local information in order to create an adequate database for designing and evaluating the hypothetical tsetse control projects. It is suggested that the PAAT-GIS information provided is carefully checked and, where applicable further detail added.

Human Factors – Human population and settlement patterns (especially migration as a response to Onchocerciasis control), sleeping sickness foci, the importance of crops and livestock to rural incomes, food security and poverty reduction.

Crop Production – Proportion of land cropped, ranges of crops being grown and trends, yields, prices and level of inputs used.

Herd Composition – Proportions of different breeds in cattle herds, proportion and usage of draught oxen, mortality rates (calves and adults), calving rates, milk production, herd growth, off-takes (sales), milk and meat prices and the importance of other diseases.

Other Livestock – The role of other livestock, including equines, small ruminants and pig plus poultry keeping.

Tsetse Flies and Trypanosomosis – Tsetse fly distribution by species and seasonal dispersal from water courses, prevalence of trypanosomiasis.

Land Use - Pastoral, agro-pastoral and sedentary patterns, local movement of animals and transhumance patterns.

Natural Resources – Soil quality (for cropping), environmental risks, (over grazing, land degradation etc.), national parks.

This information will be needed for the economic evaluation of the project. Please provide data source and date even if it has not been published and where possible geo-reference all data or, at least, provide the name of the district or the nearest village.

2. Describe how you propose to eradicate tsetse flies taking into account the ecology and behaviour of the fly species involved. All of the current tsetse control techniques may be included, i.e. ground spraying, targets, traps, live baits, SAT[2] and SIT[1].

3. Describe what provision you would make, if any, to prevent re-invasion of tsetse flies from outside the project area. If the cleared area were to be left unprotected, what would be the pace of re-invasion, supposing a 20-year time horizon?

4. a) The tsetse control project assignment (sections 2 & 3 above) presumes that eradication of tsetse flies is feasible in your project area.

   b) Assuming that eradication is not possible, outline what strategy you would adopt in order to keep the tsetse fly population, and/or the disease at an acceptable level.

5. Predict what would be the short, medium and long-term effects of eliminating tsetse flies from your project area in relation to:
   a) Animal health, production and productivity
   b) Herd demography and proportion of draught oxen
   c) Crop productivity and production (yield and areas grown)
   d) Land use within the study area (especially the proportion of land brought into the cultivation cycle)
   e) In-migration of people
   f) Land degradation (over-grazing) and recuperation (of overstoc[2]ked drylands)
   g) Other factors (including small stock)

6. Outline what constraints you anticipate may prevent farmers realising the full benefits of the new tsetse-free status of your area; e.g. supply of implements, veterinary services, extension, credit and marketing infrastructure. Describe how these could be overcome.

7. Outline how the current land tenure system within the project area would influence the benefits arising from the project.

N.B. It is suggested that you need not carry out this task alone but that you do so in conjunction with colleagues who know the project area.

THE NEXT STEP

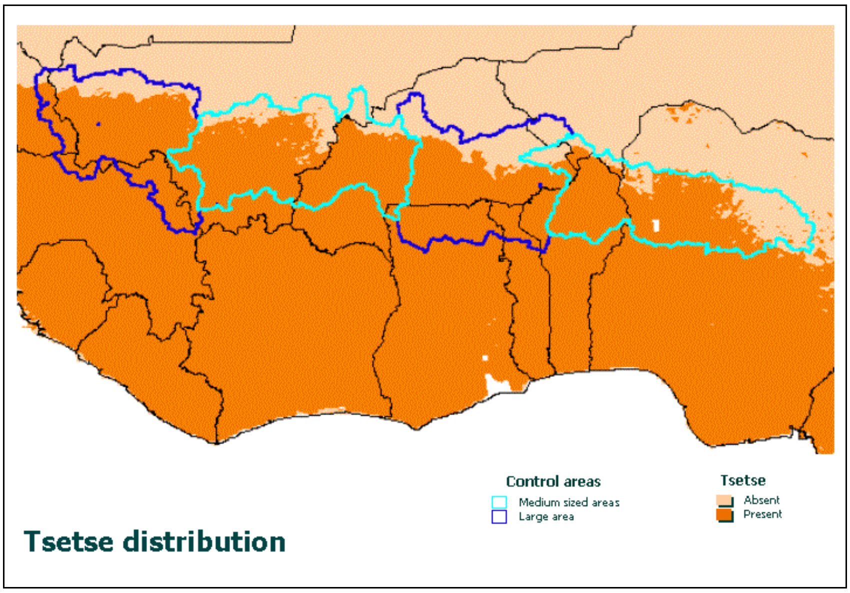
The data provided will also assist the basic data source for the studies of the 200,000 and 600,000 sq. km projects. Once all the technical data has been brought together, we will be in a position to calculate the likely costs and benefits of tsetse eradication projects on these 3 scales.

[1] The use of helicopters may be considered in addition to or instead of fixed-wing aircraft.

3.4.2 DEMARCATION OF MEDIUM-SIZE STUDY AREAS

The two medium-size study areas are expansions of the San and Mouhoun River basins and Northern Benin/Ka River study areas. This part of the study was based solely upon the information and its interpretation included in the PAAT GIS.

Figure 16 Medium-size areas and tsetse distribution



It can be seen from figure 16 that the northern part of each of these two shadow project areas does not appear to be within the tsetse belt. This is because, whilst it was feasible to embrace a degree of re-invasion protection from the north in the small shadow project areas, it was felt that this would not be appropriate for larger projects. Consequently as the northern boundary of the study area has been demarcated using the GIS on the basis of river basins, a large degree of 'safety' has been included in the project areas, thus somewhat enlarging them beyond reality. However, the GIS system precludes any benefits arising from tsetse control in this area and the calculations below exclude any costs of tsetse control in this area. In reality actual projects would need to carry out preliminary surveys in this part of the area in order to determine the actual margin of tsetse flies.

3.4.3 LOGICAL FRAMEWORK ANALYSES FOR PHASES 1 AND 2

A Logical Framework Analysis for Phase 2 was developed. This next phase is designed to build on this current study and not only embrace more detail but also enable more local participation by experts in the field. It is envisaged that most of the inputs would be made through a workshop held in west Africa. An outline for Phase 3, which envisages applying the same systematic approach in other priority areas, i.e. the Ethiopian Highlands and S Kenya/N Tanzania, was also developed. The logframes for this phase and phases 2 and 3 form appendix 5.

3.4.4 SOME INTERIM LESSONS FROM THE STUDY

Although the original objective of this project was to carry out an economic analysis of a range of tsetse control scenarios it became evident from an early stage that the only means by which any accuracy and reality can be introduced into the quantitative analysis is to **mirror the project planning process**. It is necessary to plan how and where and in what quantities control measures will need to be applied, in what sequence and in what time-scale in order to estimate costs. Benefits can only be calculated from baseline data which has been drawn from local sources and PAAT GIS. In a real project planning situation extensive ground-based surveys would be carried out which would be more accurate than the data used here and for that reason a very high level of contingency (50%) has been applied to the basic estimates used in the medium and large projects.

It was also the original intention to increase the scale of the project by a factor of 10, i.e. 6,000 sq km, 60,000 sq km and 600,000 sq km. However, on examination of the projects areas it became clear from empirical observation and experience that a **river basin** was the smallest unit of project that could be both most economically efficient and also most sustainable as this unit minimises the risk of re-invasion from outside. Consequently it was not possible to adhere to the original size comparisons.

It also became evident that the process of collecting **baseline data** is far from straightforward. Firstly, whilst there is some up-to-date information regarding the current pattern of tsetse fly distribution there is little information available in relation to the prevalence of cattle trypanosomosis and very little about the degree of infection as expressed by the PCV. Secondly, what background information there is available in relation to livestock and cropping has been collected and made available on the basis of local government boundaries. In Mali this is further complicated by the fact that some agricultural data have been collected by the central government on one basis and the Compagnie Malian pour Developpement de Textiles (CMDT) has collected data based on their own boundary demarcation system. But as the project areas chosen for study have been based on river basins then it has been necessary to deconstruct and reconstruct the available data so that it coincides with study area boundaries. This was only a problem for the small projects as the larger projects relied on data from the PAAT-GIS which already had been deconstructed into 1 to 5 sq km pixels.

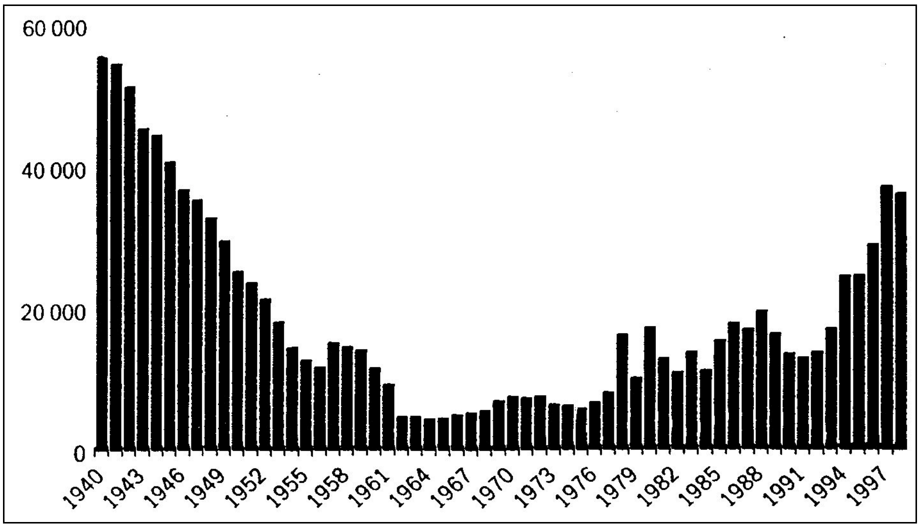
3.5 SHADOW PROJECTS – THE CONCEPT

The growing awareness of environmental issues that arose in the 1970's led to so much concern about the use of insecticides on a large scale that eventually it was not possible to operate tsetse control schemes on the same large scale as previously. Instead, emphasis was placed on the application of trap and target technology allied to small-scale projects in which the community participated in one way or another. One exception to this pattern was in Botswana where a project based on targets operated in 20,000 sq km of the Okavango Delta. An alternative strategy, which predominated in west Africa, was to combat the disease itself by a more professional usage of drugs facilitated by the development of a cadre of private veterinary surgeons.

At the end of the 20th century there was a growing realisation that the tsetse control strategy based on small-scale projects was insufficient to combat the very scale of the continent-wide problem. This was particularly evident with regard to sleeping sickness; whilst the number of deaths had fallen from a level of over 60,000 in the 1930's to almost zero in 1960 it has risen to almost 50,000 in 2000 (see fig. 17). At that time a number of studies indicated that the disease was causing a loss of agricultural potential and production that the continent could not afford. Not only was the existing livestock herd rendered less productive in terms of fecundity and milk and meat production but the lack of availability of animals for draught cultivation also hampered the productivity of the continent's millions of subsistence farmers such that they were unable to lift themselves from their subsistence existence.

It was realised by the international agencies that form the secretariat of the Programme Against African Trypanosomosis (PAAT), i.e. FAO, IAEA, WHO and OUA/IBAR and its membership that it was their duty to take the initiative to re-examine the case for large scale intervention based on tsetse control. Accordingly, this study was commissioned to analyse the economic implications of a range of options for one of the areas that had been identified as a high priority, i.e. the moist savannah zone of west Africa. One of the primary issues was to examine the implications of project size as one of the previous studies had suggested that there were significant economies of scale not only in economic performance terms but also in relation to sustainability.

Figure 17 Sleeping Sickness Fatalities, 1940 to 1998



Source: WHO

In order to make this study as accurate and realistic as possible it was decided to use real data from the MSZ itself both from the PAAT GIS and from local sources. Five small study areas were selected using the criteria outlined in this chapter and these were built up into the medium size areas. The largest scale of project embraces the whole of the MSZ. These areas have been selected in order to provide decision-makers with a quantitative analysis of the concept of tsetse control on a significant scale in that part of west Africa. As such, these analyses should not be regarded in any way as any stage of project preparation. Although representatives from the region are members of PAAT this does not signify that the governments of the region are currently considering any such projects.

A range of strategies were considered in order to demonstrate that the study projects were hypothetical, e.g. creating 'hypothetical' data or masking the presentation of the areas by horizontally mirroring data. These were rejected as being too complicated or distorting the integrated nature of the three project sizes.

If significant tsetse control projects are to be brought back onto the agenda of individual governments and donor agencies a series of preparatory technical and economic investigations will need to be carried out. This study forms the first of these studies and its results will guide the decision-making process that will be undertaken by PAAT and PATTEC in conjunction with the individual governments and donor agencies. It is only when all the signs appear to be positive that the actual project planning phase can be undertaken based on parameters and methodologies developed in the previous studies.

In order to avoid the suggestion that using background data from real areas of west Africa indicates that actual projects are being planned the term '**shadow**' project has been used in this report to demonstrate that these studies are completely hypothetical. In order to avoid repetitiousness the term 'shadow' has not been used whenever the terms 'project area' or 'study area' are used but its usage should be implied.

4 SMALL PROJECTS

4.1 BASELINE DATA

It is customary that agricultural data is collected on a spatial basis orientated around local government areas with defined boundaries. However, the areas used for this study are based on river basins and it is rare that their boundaries coincide with local government ones. Accordingly, in order that baseline data, and hence projections, were as accurate as possible data based on local boundaries had to be adjusted to reflect the situation in the actual study areas. For each study area the adjustments needed to be made in different ways.

4.1.1 STUDY AREA 1

In Mali information is collected by both the government and the Compagnie Malienne pour le Développement des Textiles (CMDT), with each using different hierarchies of nomenclature for grouping the various arrondissements, the smallest local government area. This was rationalised by taking different proportions of the CMDT Secteurs as follows:

CMDT region of Koutiala

1. ½ sector of Koutiala(=arrondissement. . Zangasso + arrondissement. Konseguela)
2. Total sector of Molobala(=ar. of Molobla)
3. ½ sector of Yorosso(=ar. Kouri +ar. Mahou+ ar. Yoroso central)

CMDT region of Sikasso

4. Total sector Sikasso(=ar. Sikasso central +ar. Denderesso)
5. Total sector Klela(=ar. Klela)
6. 1/3 sector Kignan(=ar. Kignan +ar. Dogoni)

CMDT region of Fana

7. Total sector Beleko(=ar. Beleko+ar. Mena)

In order to compute the human population of the study area the population of Sikasso town was added.

The Mali section only comprises 17,361 sq km of the total study area of 20,513 sq km, leaving 3152 sq km at the Burkina Faso end of the River Banifing basin. In order to obtain the production characteristics of the whole study area the Mali figures could merely be increasd by 18%. However, this assumes that the pattern of agriculture in the Burkina Faso part of the study area is as intensive as that in Mali. However, in Burkina Faso the cropping intensity is less than one-quarter and cattle density is less than one-third of that in Mali. Bearing this in mind, production and output for the whole of the study area is considered to be only 105% of that in Mali.

4.1.2 STUDY AREA 2

Production data was provided for all Départementes with part or all of their area within the study zone. Such Départementes totalled 30,380 sq km, compared with the actual study area of 21,630 sq km. In order to reduce the 'data source area', working from the north, Départementes with less than 40% in the study area were iteratively disregarded until an area of 21,898 sq km remained. This was considered sufficiently close to the size of the study area to be regarded as an equivalent 'data source' for the purposes of this exercise. The exclusion of these Départmentes is balanced by including all the data from others with less than 100% in the study area.

4.1.3 STUDY AREA 3

The study area is covered by seven sous-préfectures covering a total of 25,923 sq km. This compares with 14,125 sq km for the study area. As the whole district is considered to be relatively homogeneous it was considered that proportionally reducing the total cropping and livestock statistics for the seven sous-préfectures would provide a sufficiently accurate baseline data source for the study area. Statistics provided in annex 3 have been condensed to provide price and yield data.

4.1.4 STUDY AREA 4

During the course of this study it was found by the surveyors that study area 4 was now free of tsetse flies and that although trypanosomosis infections were suspected to be present in two districts it was presumed that transmission occurred whilst the animals had moved to tsetse-infested regions during the dry season (see table 3). The PAAT GIS indicates that human population density falls within the 50 – 100 persons per sq km throughout the study area and population has risen by 30% over the last 10 years (see table 1 of Annex 6). This population density is much higher than in the other study areas and probably has passed the threshold for being able to sustain a habitat amenable for the flies (see Annex 6) during the last 10 years or since the tsetse distribution used by PAAT GIS was mapped. This study area illustrates the dynamic nature of tsetse distribution in response to the rapidly increasing population in west Africa.

Table 3 Absence of Trypanosomosis and Tsetse Flies

LGA	Trypanosomosis	Prevalence	Year	Vector
Dandi	Suspected	-	2000	None detected
Suru	None	-	-	-
Maiyama	None	-	-	-
Sakaba	Suspected	-	2000	None detected
Anka	None	-	-	-

Details of this study area are reported in Annex 4. Because there is no longer any trypanosomosis problem it is not included in the following parts of this study.

4.1.5 STUDY AREA 5 MAMBILLA PLATEAU, NIGERIA

Annex 5 provides data for only four of the five Nigerian Local Government Areas (LGA) and none for the part of the study area in the Cameroons; these areas amount to approximately one-quarter of the study area. Accordingly the data from the four LGAs has been increased by 30% in order to provide a total data source for the whole study area.

Table 4 Study Area 5 – Data Source Adjustment Scheme

Local Government Area (LGA)	% of total project area a	% of LGA in Study area b	Information available c	Inflation Factor d	Adjustment Factor b x d
Bali	10	20	Yes	1.3	26%
Dunga	15	100	Yes	1.3	130%
Takum	5	40	Yes	1.3	52%
Sarduana	47	90	Yes	1.3	117%
Wakiri	8	50	No	-	
Cameroon	15	?	No	-	
Total	100	-	77%	-	

4.1.6 SUMMARY

Table 5 Small Shadow Project Area Data

	Study Area 1	Study Area 2	Study Area 3	Study Area 5
Area (km^2)	17361 Mali 3152 B/Faso 20513 Total	21630 Actual 21898 Nominal*	14125	19858
Perimeter (km)	1162 (Mali+BF)	1054	820	1034
Barrier length required (km)	100	350	275	390
Length of River infested	2000 km (Mali+BF)	1408	552	2000 (Est.)

4.2 TSETSE CONTROL PROJECTS – MODUS OPERANDI

Of the small area studies only the report for Study Area 1 (Mali/Burkina Faso) outlines and costs a project for eradicating tsetse flies. It envisages a suppression phase based on targets deployed along fly-infested watercourses at a distance of 100m on each side of the watercourse supplemented by two treatments of cattle with an insecticide pour-on. SIT is subsequently deployed along the watercourses in order to eradicate the residual fly population. A barrier against re-invasion, based on targets, is deployed and maintained along sensitive parts of the project area border on a permanent basis.

For the purposes of the economic analysis the *modus operandi* of the other three projects are variations of that of Study Area 1. However, the characteristics of the other areas are somewhat different and the projects will need to be varied to address these differences:

- **Insecticide-treated cattle** In order for the 'live bait' technique to be an effective suppressing technique not only does a threshold cattle density needs to be reached (generally taken as 15 cattle per sq km) but also the cattle need to be relatively evenly distributed. It is therefore unlikely that this technique could be used effectively in study areas 2 or 5. Without the application of the 'live bait' technique fly densities after the suppression phase are likely to be higher than otherwise. Accordingly the SIT-based eradication phase is lengthened by one-quarter in study area 2. In study area 5 half of the length of the river is difficult to access and so ground spraying and aerial spraying (50/50) are used to replace both targets and live baits. This *modus operandi* is based on experience of previous tsetse control projects in a similar location in Nigeria.

- **Barriers against re-invasion** It was considered that the risk of flies re-invading the study areas after a tsetse eradication project was minimal (see 3.2.5) and that, where there was a risk, it would be on the southerly borders of the area. Consequently, for the purposes of the economic analysis, it is considered that, unless otherwise stated, a barrier will be required for one-third of the perimeter and in perpetuity. It is assumed that for the study areas a re-invasion barrier of 16 targets per linear km will be sufficient. This is half the target density of barriers used in Zimbabwe against re-invasion by *G. Morsitans* but is considered to be sufficient to protect against the riverine species.

- ***G. morsitans*** As previously stated the tsetse control projects will be primarily focussed towards the eradication of *G. tachinoides*. However, pockets of *G morsitans* exist in all of the areas and it is considered that these can be eradicated through the use of targets or insecticide-treated cattle. A nominal 10% of suppression costs is added to take account of this.

- **Sequential Aerosol Technique** The application of the sequential aerosol technique during the dry season was considered in the context of these small projects. However, it is difficult for fixed-wing aircraft to follow meandering watercourses with the result that they would have to operate within rectangular sectors containing the rivers. This would mean that for each km of river at least 3 sq km of land would need to be sprayed. This would elevate the cost substantially. The use of helicopters would appear to be more operationally efficient but their high operating cost would save little compared with the fixed-wing cost. In addition, it is more difficult for helicopters to generate an even and overlapping pattern of drift than fixed-wing aircraft. It is also considered that the size of the areas that would actually need to be sprayed aerially are not sufficient to secure the available economies of scale available to SAT operations.

4.3 SUMMARY OF COSTS AND BENEFITS

The computations for the costs and benefits form appendix 2 and an economic analysis is included in chapter 8 but a basic view of the economic performance of the shadow projects can be obtained by comparing the total cost of the project with the maximum annual benefit to the agricultural community as outlined in table 6.

Table 6 Shadow Project Costs and Project Benefits in Year 10

	Area 1	Area 2	Area 3	Area 5	Total	Total Areas 1,2 and 3 only
Total Project Costs	5.3m $	4.6m $	2.7m $	6.4m $	18.9m $	12.5m $
Benefits in Year 10	5.2m $	3.8m $	3.6m $	3.4m $	16.0m $	12.6m $

Whilst the total figure for all four project areas indicates that the costs for the tsetse eradication projects are slightly higher than the maximum annual value of benefits, i.e. at year 10, the difference is mainly accounted for by the inclusion of Area 5, for which the database was not complete and the estimates that were made were conservative. By excluding Area 5 a total of $12.5m for the costs of the projects and a year 10 benefit of $12.6m is computed. This latter relationship is considered to be a more accurate representation of the likely performance of tsetse control projects in the MSZ of a size that embodies one single Level 4 river basin.

The summary in table 6 assumes that the benefits of the tsetse eradication projects will continue in perpetuity and therefore computes the benefits on the basis of actual sales. However, the argument that increased human population pressure will autonomously eradicate tsetse flies is valid (see below) and the implication is that the benefits of the projected should only be computed until such time as autonomous control would have happened anyway. However, using the sales method of assessing benefits delays the timing of benefits and if a specific period (in this case 10 years) is used benefits in terms of meat growth occurring within the 10 year period are disregarded. For that reason the economic analysis in chapter 8 capitalises all the benefits accruing during a 15-year period into the 10-year period and hence provides a different assessment to that in table 6.

This basic conclusion that the cost of a tsetse control project is about the same as the highest year's benefits roughly coincides with the conclusions of the medium and large-scale projects even though the database and computational methodology were significantly, though not completely, different.

4.4 TIMESCALE AND AUTONOMOUS TSETSE CONTROL

Tsetse flies are very sensitive to temperature and are only able to survive where there is sufficient cool shade where they can rest. Such resting places are afforded by trees and the removal of trees for farming, and the consequent loss of wild animal hosts for trypanosomosis, effectively makes the habitat unsuitable and tsetse flies are consequently eradicated. This process of autonomous control and its parameters is very well described in Bourn *et al* and Annex 6.

The pressure to cut down trees for agriculture is generated by the rapidly increasing human population. An annual rise of 3.4% is reported for Mali, 2% for Benin and 3% for study area 5. Within this study this phenomenon has resulted in the exclusion of study area 4 in this study because it was found no longer to contain tsetse flies. The MSZ is at the northern limits of the tsetse fly zone and some observers suggest that within 10-20 years tsetse flies will have been eradicated autonomously.

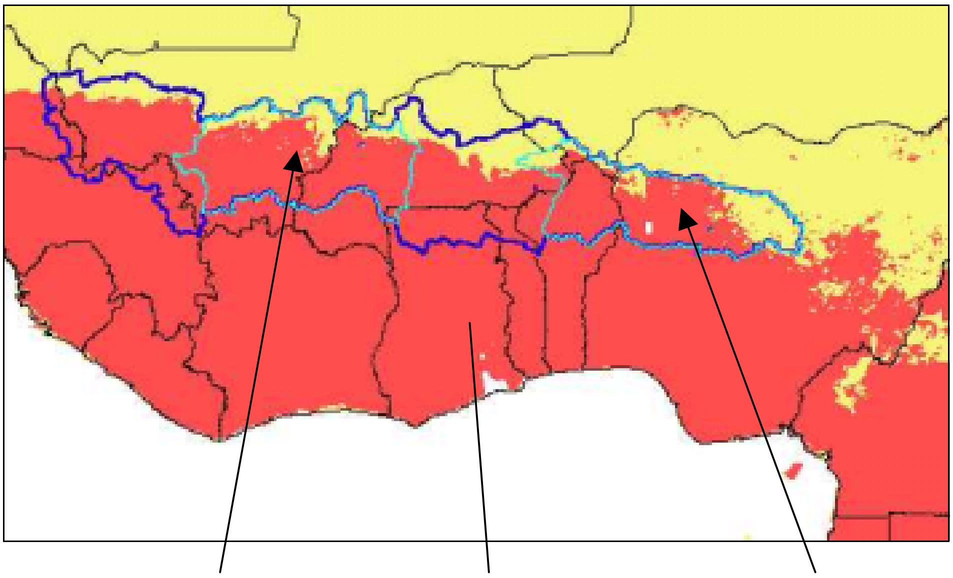
For this reason it is appropriate that, in the study areas, benefits resulting from tsetse eradication are not considered after a point in time at which tsetse flies would have disappeared autonomously. In this respect a period of 10 years would seem to be appropriate. However, by expressing the benefits in terms of mature animal offtake for slaughter a long lead time is embodied in the calculations. Adult males are not sold until they are 5 years old and females not until they are 8 years old. Thus any increase in offtake resulting from reduced calf mortality after year 5 (males) and 2 (females) will be disregarded as a benefit resulting from a tsetse eradication project. On the other hand, the capital value of the total herd will increase fairly soon after tsetse flies are eradicated as the health of the animals improves, the abortion rates falls and calf survivability increases. For a few livestock owners this increased capital value will be realised by selling calves but in a socio-cultural environment where livestock are mainly regarded as assets or savings, their capital value will only be converted into cash income when there is a need for purchasing power (weddings, hard times, children's education etc.).

Bearing these factors in mind and the need for clarity and transparency in this study it is considered that maximum overall benefits will arise in year 10 and will be considered until year 15. Benefits will rise arithmetically from year 1 to year 10. This simplification of the benefits flow is not an exact replication of likely reality but sufficiently accurate to reflect the combination of economic, financial, temporal and herd dynamic factors.

5.1 DESCRIPTION OF MEDIUM SIZE STUDY AREAS

Figure 18 Medium-size study areas in relation to tsetse distribution

Source: PAAT GIS



Using the PAAT GIS it was possible to obtain the following information about the medium size study areas:

Table 7 Statistical Outline of Medium-size Shadow Project Areas

	Western Project Area	Eastern Project Area
Human Population	6,650,000	8,427,000
Average length growing period	152 days	162 days
Total Project Area	187,014 sq km	170,247 sq km
Project Area in Tsetse Belt	151,231 sq km	122,139 sq km
Project Area within Tsetse Belt	81%	72%
Cattle Population (head)	2,522,000	2,323,000
Cattle Density In Tsetse Area Outside tsetse Area	13.7 per sq km 13.0 per sq km	12.4 per sq km 19.4 per sq km
Crops Present (sq km)	24,960 sq km	26,830 sq km
% of Total Area Cropped	13.3%	15.8%

The computations for assessing the costs and benefits of these projects forms appendix 3. An economic valuation of these changes is made in chapter 8.

5.2 SUMMARY OF COSTS AND BENEFITS

Without detailed ground-based information and relying on GIS predictions on which to base both costs and benefits only an approximation of the relationship between costs and benefits over time can be made. It has been the policy not to underestimate the costs nor overestimate the benefits. Whilst more sophisticated analytical techniques can be applied to the basic data it is felt that any such results will give a spurious impression of the degree of accuracy of this study that is not justified.

Table 8 is considered to provide an easily understood description of the financial performance of the two shadow medium-sized projects studied in west Africa. It indicates that the level of benefits that will accrue to the community in year 10 of the project will be significantly greater than the cumulative cost of the whole tsetse control programme up to that point.

Table 8 Project Costs and Project Benefits at Year 10

	Project Preparation, Tsetse Suppression, Tsetse Eradication (SIT) and Protection against Re-invasion Total Costs over 10 years ($)	Benefits at Year 10 $ Per Year
Western Project Area	41.6 million	83.5 million
Eastern Project Area	40.3 million	70.8 million

There are several factors which will alter the accuracy of the previous sentence:

- **Costs** It has been assumed that all control areas will require a full SIT programme to achieve eradication. This is the maximum level of provision as in many areas eradication will be achieved by suppression techniques alone. In other areas a full SIT programme will not be required. A high cost for SIT has been used – a cost reduction of one-third for this scale of operation is considered feasible. A very high contingency level (25%) has been built in to the calculations. The provision for measures preventing re-invasion can be considered to be generous bearing in mind experience in previous control programmes in Nigeria. Consequently it is considered that the costs in table 8 are much more likely to be an overestimate than an underestimate..

- **Benefits** Because the GIS is not able to take into account dynamic movements of the human and cattle population that may occur after an area is freed from tsetse flies and trypanosomosis it underestimates the changes in the extra areas that will be cultivated. This estimate could underestimate this factor by 100% which would increase the overall level of benefits by 15-20%.

- **Timespan** For simplicity a project timespan of 10 years has been used. It is presumed that the level of benefits will gradually increase after tsetse control has taken place and begin to level out by year 10. Consequently the cumulative total of benefits up to and including year 10 will not be 10 times the figure stated in table 8, but probably 5-7 times that figure, depending on the dynamics of population movement.

The projects will create a permanent level of benefit in the area at approximately the level of year 10. However, these benefits have not been taken into account even though the projects, as planned, are considered to be sustainable. After the initial control phase the only costs that are likely to be incurred are those of monitoring and preventing re-invasion of flies from adjoining areas remaining infested by flies. On the other hand it could be correct to completely discount any benefits occurring after year 10 as autonomous control resulting from increased populations might have eliminated tsetse flies and trypanosomosis anyway (see section 4.4).

Unlike the calculations for the small project areas the computational methodology, by valuing meat growth per year, assesses benefits in the year that they occurs and thus inherently capitalises the benefits.

- **Discounting** This economic technique expresses the time value of money and is considered to be an important factor by funding institutions. It has the effect of devaluing 'future' money and benefits in relation to 'present' money, e.g. $100 in year 1 is considered to be equivalent to $39 in Year 10 if a 10% 'discount' rate is used. As such the application of a discount rate undervalues the benefit to potential beneficiaries of long-term projects such as these shadow tsetse control projects where the full level of benefits take a time to build up but then continue to exist in perpetuity.

  Discounting in this study will be expressed by the use of the internal rate of return (IRR). See Chapter 8

For these reasons it is considered that table 8 expresses in readily understood terms as good a prediction of the likely economic performance as is possible for these shadow projects based on the quality of the information currently available.

6 LARGE SCALE STUDY AREA

The same GIS techniques and cost and benefits calculation methodology that were applied to the medium size shadow project areas are applied to the large project area. Consequently the narrative for the large project is not repeated in this chapter. The same format for tables is used as in the previous chapter.

6.1 SHADOW PROJECT AREA DESCRIPTION

Table 9 Project Area Description

	Large Project Area
Human Population	24,453,695
Length growing period	155 days
Total Project Area	669,440 sq km
Project Area in Tsetse Belt	516,160 sq km
Proportion Project Area in Tsetse Belt	77%
Cattle Population (head)	8,283,000
Cattle Density Tsetse Area Non-Tsetse Area	12.5 per sq km 14.4 per sq km
Crops Present (sq km)	81,150

6.2 COMPARING COSTS AND BENEFITS

Table 10 Project Costs and Project Benefits at Year 10

	Project Preparation, Tsetse Suppression, Tsetse Eradication (SIT) and Protection against Re-invasion Total Costs over 10 years ($)	Benefits at Year 10 $ Per Year
Large Project Area	107 million	238 million

7 STUDY AREA 4 (KA RIVER, NIGERIA)

During the course of this study area 4 has been found to be free of both tsetse flies and trypanosomosis. In addition, the area south (which was also investigated) has also been found to be essentially free of tsetse and trypanosomosis. This finding is if significance and justifies the concept of autonomous elimination of tsetse flies resulting from human and agricultural encroachment into tsetse habitats and demonstrates how quickly it happens.

Details of this project area are to be found in annex 4 and a summary of this phenomenon and its parameters is contained in annex 6 by Guy Hendrickx. This work was not a fundamental part of this study but was instigated as a result of it and is included in full in the report of the Workshop held in Ougadougou in May 2001, which formed Phase 2 of the project to investigate the technical and economic feasibility of tsetse eradication in West Africa.

8 ECONOMIC INTERPRETATION OF PROJECTS

8.1 INTRODUCTION

The scope of this study was limited and one of the primary purposes was to provide the first overview of the likely economics of addressing the problem of trypanosomosis in the MSZ through tsetse eradication projects. It was beyond the scope of the study to compare this strategy with a strategy of tsetse control or trypanosomosis control through drugs or the promotion and extension of trypanotolerant cattle. In order to investigate the feasibility of actual projects as proposed a much more accurate database of agricultural, economic, socio-economic, socio-cultural, tsetse distribution and trypanosomosis prevalence will be required. This study relied on existing information and, as such, much of the basic data had to be adapted into a format that was common across all study areas. Where information was not available or obviously incorrect data was provided estimates were made. Bearing this in mind the detailed analysis in the latter part of this chapter should be not be regarded as definitive but rather as a guide to the likely relationship between the costs of tsetse eradication projects and the likely benefits that will flow from them.

In order to provide a succinct and readily understood summary of the conclusions of this study a comparison between the costs of projects and the maximum level of benefits, expressed as Year 10 benefits, is made in table 11.

Table 11 Shadow Projects Costs and Benefits at Year 10

	Area Sq km	Cost of Projects $	Benefits at Year 10 $
Study Area 1	20,513	5,255,000	5,215,000[1]
Study Area 2	21,630	4,600,000	3,800,000[1]
Study Area 3	14,125	2,715,000	3,635,000[1]
Study Area 5	19,858	6,360,000	3,350,000[1]
West Medium Study Area	179,800	41,600,000	83,500,000[2]
East Medium Study Area	123,300	40,300,000	70,800,000[2]
Large Project Area	669,440	107,000,000	238,000,000[2]

Notes 1) Based on value of annual sales of livestock
2) Based on annual increase in capital value of livestock

The above table indicates that, as a generalisation, the annual value to the farming community of tsetse eradication projects at their maximum level is likely to be at least similar to the total cost of the projects over a 10 year period.

These generalisation appear to apply to all of the projects throughout the MSZ and all sizes of projects even though the methodologies used and assumptions made were different for the medium/large and small projects. In addition the database source for the medium/large projects and the small projects was different, i.e. PAAT-GIS and local government data respectively. The only shadow project that does not conform to this pattern is area 5. However, the database for this area was incomplete and the estimates used in the computation were conservative. This area

(Mambilla Plateau, SE Nigeria) is strictly outside the MSZ and has characteristics more like areas south of Areas 1 and 2 with greater ubiquitous tsetse distribution. The low level of draught animal usage would indicate that the increase in cropping after tsetse eradication may be significantly greater than the 5.1% norm used in the computations. The high cost of the project per ha. is probably realistic because of the higher risk of re-invasion from the Cameroons although the length of river infested by flies may have been over-estimated.

The smaller projects appear to be less economically efficient than larger projects and hence justify the assertion that larger projects are more economically efficient than smaller projects. However, the different performances of project size categories shown in table 11 are more likely to have arisen from the use of different datasets for the different project sizes and/or different computational methodologies employed than any inherent characteristics.

Having established such a *caveat* there could be justification for asserting that larger projects are not less efficient than smaller projects on the basis that the largest project is the most economically efficient and the smallest projects, as a group, the least efficient.

8.2 INTERNAL RATE OF RETURN

The computational methodology used for the small projects values the benefits in terms of the increased value of animals sold. As such the value of the extra meat production which is present in the herd as a result of the removal of trypanosomosis is not considered in a time-limited analysis such as used in an internal rate of return calculation. For the medium and large scale projects a different computational methodology was used which assessed the increased capital value of the herd through extra meat production on a continuous basis. In order to provide a more realistic comparison between the methodologies and project sizes the sale values of livestock from the trypanosomosis free herd in years 11 to 15 have been capitalised into the 10 year period of project assessment.

Table 12 Internal Rates of Return

Study Area 1	(Values in $1,000)										
Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-2000	-2500	-616								5,116
Barrier	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	288
Total Costs	-2029	-2529	-645	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-28.8	-5404
Benefits	0	1002	1403	3608	4810	6013	7215	8217	9320	10452	52040
IRR	**16.0%**										

Study Area 2											
Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-1000	-1700	-888								3,588
Barrier	-108	-100	-100	-100	-100	-100	-100	-100	-100	-100	1,008
Total Costs	-1108	-1800	-988	-100	-100	-100	-100	-100	-100	-100	-4596
Benefits	0	716	1003	2579	3438	4298	5158	5874	6662	7471	37200
IRR	**16.4%**										

Study Area 3

Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-700	-900	-342								1,942
Barrier	-92	-92	-92	-92	-92	-92	-92	-92	-92	-92	922
Total Costs	-792	-992	-434	-92	-92	-92	-92	-92	-92	-92	-2864
Benefits	0	672	941	2420	3226	4033	4839	5511	6251	7010	34904
IRR	**13.7%**										

Study Area 5

Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-1500	-2700	-900								5,100
Barrier	-126	-126	-126	-126	-126	-126	-126	-126	-126	-126	1,260
Total Costs	-1626	-2826	-1026	-126	-126	-126	-126	-126	-126	-126	-6360
Benefits	0	622	871	2239	2986	3732	4478	5100	5784	6487	32300
IRR	**11.7%**										

West project (Values in $ million)

Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-8	-4	-2								-14
Barrier	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-28
Total Costs	-10.8	-6.8	-4.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-42
Benefits	0	7	12	24	34	44	56	68	78	84	407
IRR	**18.2%**										

East project

Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-10	-4	-3								-17
Barrier	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-23
Total Costs	-12.3	-6.3	-5.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-40
Benefits	0	6	10	21	29	37	47	57	66	71	344
IRR	**16.7%**										

Large project

Year	1	2	3	4	5	6	7	8	9	10	Total
Plan/Sup/Erad	-20	-12	-7								-39
Barrier	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-68
Total Costs	-26.8	-18.8	-13.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-6.8	-107
Benefits	0	21	34	69	96	124	158	193	220	238	1153
IRR	**19.0%**										

Apart from study area 5 there is a broad consensus in the IRRs of the projects. (The database for study area 5 contains several figures that were estimated and hence the result should be regarded with caution.). However, the IRR of a project is very influenced by cash flows in the very early years and only slightly influenced by cash flows in the later years. For instance, if the costs and benefits of year 10 of area 1 are ignored then the IRR increases to 16.2%. Even small changes in the flow of costs and benefits at the beginning of the period can alter the IRR significantly.

Paying due regard to the IRR is an important consideration for projects where the 'investor' is also the beneficiary and who may have alternative investment possibilities. However, where a project's prime purpose is to alleviate poverty and promote development it is more appropriate to consider parameters that also express both the permanence and sustainability of benefits.

8.3 COST-BENEFIT ANALYSIS

For most areas of Africa where there is not as high level of population pressure as in the MSZ of west Africa autonomous control of tsetse flies and trypanosomosis is unlikely to occur in the foreseeable future. In these area the most important factor is that the eradication of trypanosomosis is permanent and sustainable in order that the full potential of livestock is realised in the absence of that constraint. In these areas therefore an assessment of a project that involves discounting and hence the downgrading of long-term income, e.g. the IRR, underestimates the developmental worth of a project. For such projects an assessment of their developmental value may be better expressed by an undiscounted cost/benefit analysis but for a limited period, e.g. 15-20 years. This would seem to balance the long-term value of a project against the inevitable uncertainty of long-term sustainability. For the MSZ where there is a real possibility of autonomous control as shorter period of assessment, 10 years, is more appropriate.

Table 16 Cost Benefit Analysis of Projects (undiscounted)

	Costs (up to 10 Years) $ Million	Benefits (up to 10 years*) $ Million	Cost/Benefit Ratio (undiscounted)
Study Area 1	5.4	52.0	1:9.6
Study Area 2	4.6	37.2	1:8.1
Study Area 3	2.9	34.9	1:12.0
Study Area 5	6.4	32.3	1:5.0
West Med. Study Area	42	407	1:9.7
East Med. Study Area	40	344	1:8.6
Large Project Area	107	1153	1:10.8

The cost-benefits as computed in table 16 are significantly higher than the 1:2.5 put forward by Budd as a continent-wide prediction for continent-wide removal of the trypanosomosis constraint and justifies the identification by PAAT of the MSZ as a priority target for tsetse control.

Even though autonomous control of tsetse flies and hence trypanosomosis is a possibility in this region the above cost/benefit and IRR results indicate that tsetse control projects are still economically worthwhile.

8.4 THE EFFECT OF PROJECT SIZE

These IRR results could be interpreted as justification of one of the assertions (See section 1.1) to be tested by the study, namely that larger projects are more economically efficient than smaller projects. The main factor supporting this assertion is the cost of re-invasion barriers and the increasing 'perimeter to area' ratio for increasing areas. However, this study has assumed that in the MSZ the need for barriers only exists to the south of the projects, if at all. This is reflected in this study by assuming a higher proportion of the project perimeter for the small projects (approximately one-third) needs to be protected compared with the larger projects (approximately one-quarter). In addition, whilst all the available economies of scale for the control techniques used in the medium and large projects have been built into the calculations this factor has not been made for the small shadow projects. In the absence of detailed project analysis overheads have been assumed to be a fixed proportion, 25%, of eradication costs.

However, bearing in mind the inadequacy of the datasets used, the multiplicity of assumptions made and the different computational methodologies used the slightly increasing performance the larger the project size cannot be regarded as justification of the original assertion as applied to the MSZ. In other regions of Africa, particularly those where the need to protect against re-invasion, the result is likely to be quite different. It should also be noted that in terms of tsetse control over the last 20 years even the smallest project size used in the analysis is larger than most projects which have been carried out during that period.

8.5 CONCLUSION

This study is not capable of justifying the assertion (see section 1.1) that, in the moist savannah zone of west Africa, larger projects are more economically efficient than smaller projects. However, in this study the smaller projects are between 13,000 and 20,000 sq km which, in current terms, is very large. The reports suggests that projects which do not adopt the river basin concept will be less efficient or less sustainable as they do not inherently adopt strategies that minimise the cost of preventing re-invasion.

An extrapolation of the results of these shadow projects to real projects within the moist savannah zone of west Africa suggests that they are likely to have an IRR of between 15% and 20 % and that (undiscounted) benefits flowing to the rural community will exceed costs by between six and twelve times. This suggestion remains true over a period of time as short as 10 years; the inference being that tsetse eradication is economically worthwhile even though tsetse flies may disappear in 10 years autonomously as a result of human population pressure. This conclusion remains true for projects of any size larger than a level 4 river basin. The study did not investigate smaller projects or projects not adhering to the river basin concept and this conclusion cannot be applied to them.

Bearing in mind the current lack of funding support for large-scale tsetse control it is proposed that the technical and economic feasibility of projects smaller than a level 4 river basin be carried out.

N.B. As these are hypothetical projects the economic results should be considered as a integrated group rather than comparing one particular project against another; the limited nature of the study and the quality of the databases used precludes making assumptions from such comparisons.

8.6 SENSITIVITY ANALYSIS

As stated in this document the quality of the datasets available means that the computations must be regarded as best estimates. Bearing this in mind it was considered that sensitivity analyses were inappropriate as they would, in these circumstances, be merely 'less-than-best' estimates.

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