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.

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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

Table of Contents

Appendices

Annexes

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 <u>not</u> 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]

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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

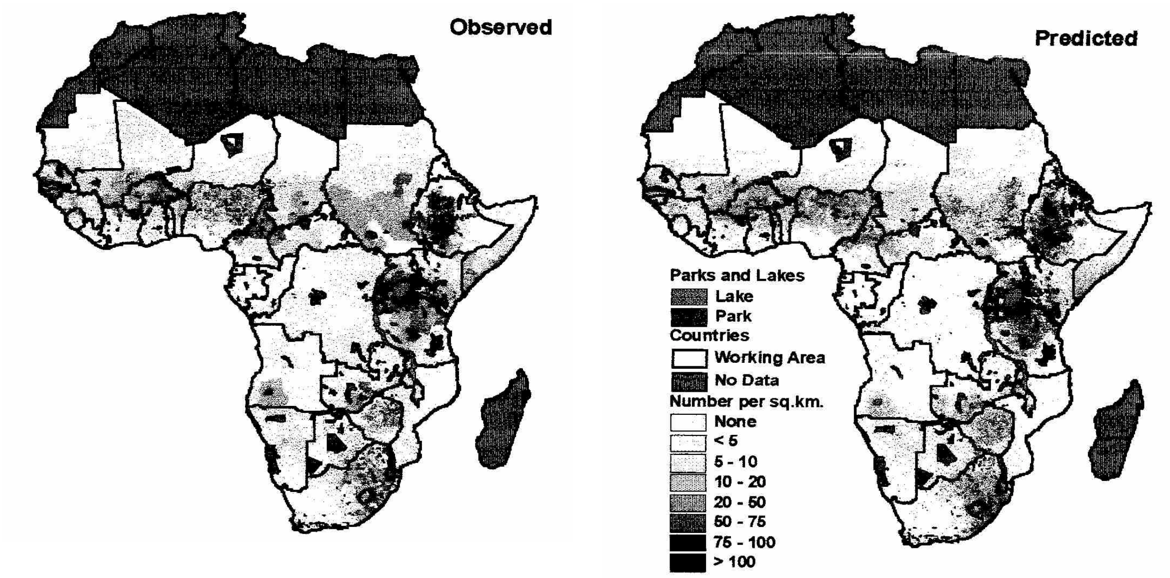
NDVI *	No	TALA
Observed Cattle *	No	Various – See text
Observed Cultivation *	No	Various – See text
Predicted Cattle *†	Yes	PAAT/TALA/ERGO
Predicted Cultivation *†	Yes	PAAT/TALA/ERGO
Length of Growing Period *†	Yes	FAO/AGL/ERGO/TALA
Mammal Biodiversity	Yes	PAAT/TALA/ERGO
Farming Systems	Yes	PAAT/TALA/ERGO
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)

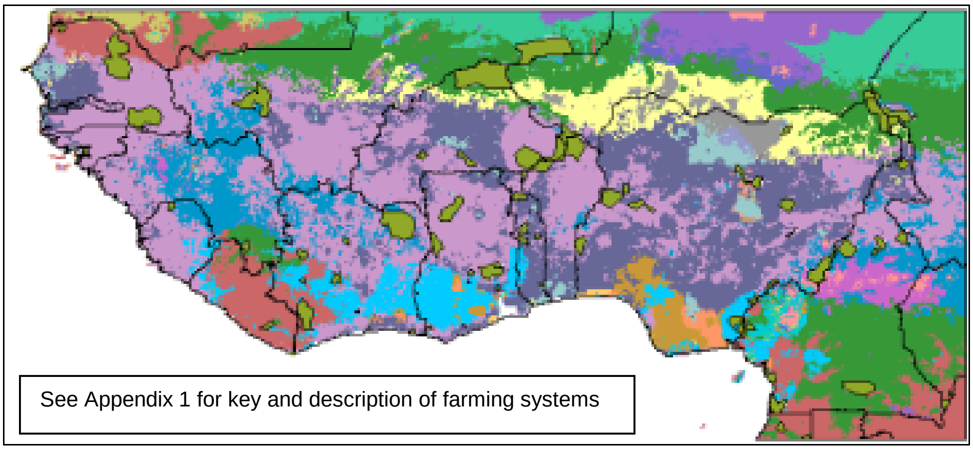


This 'observed' information is largely at the level of administrative units, some of which are very large (Figure 1, left). This resolution has been increased by using stepwise multiple regression to establish statistical relationships between these observed data and a range of predictor variables including: 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

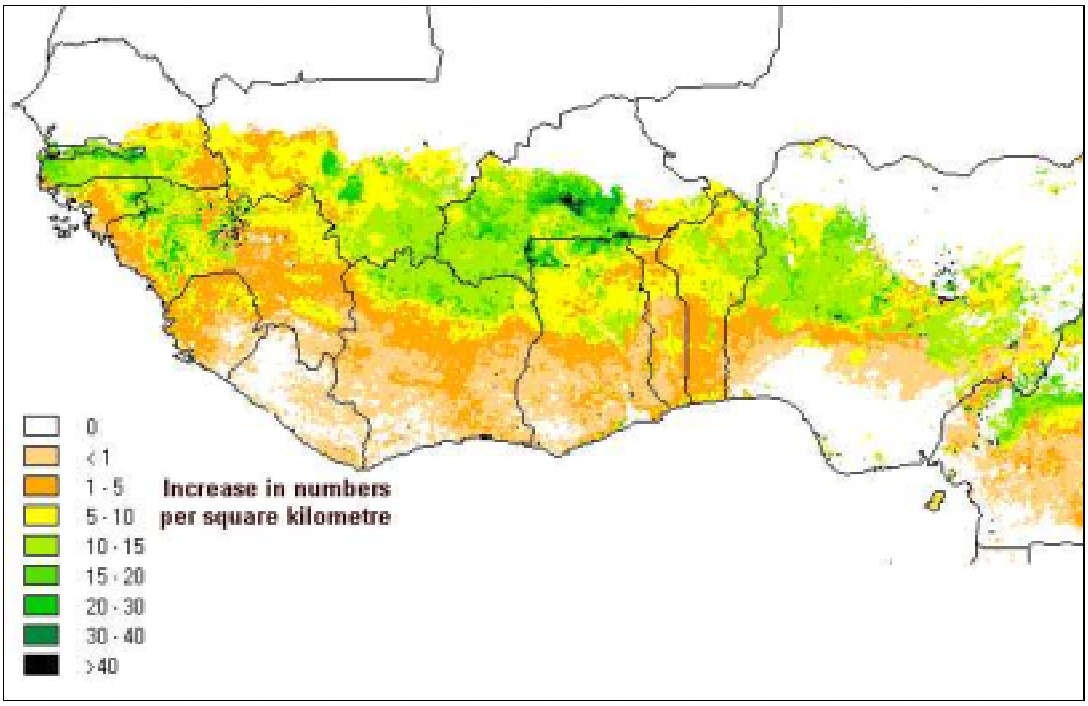
iii) export tasks to produce graphical or tabular outputs for use in external software.

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.

3.1 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.

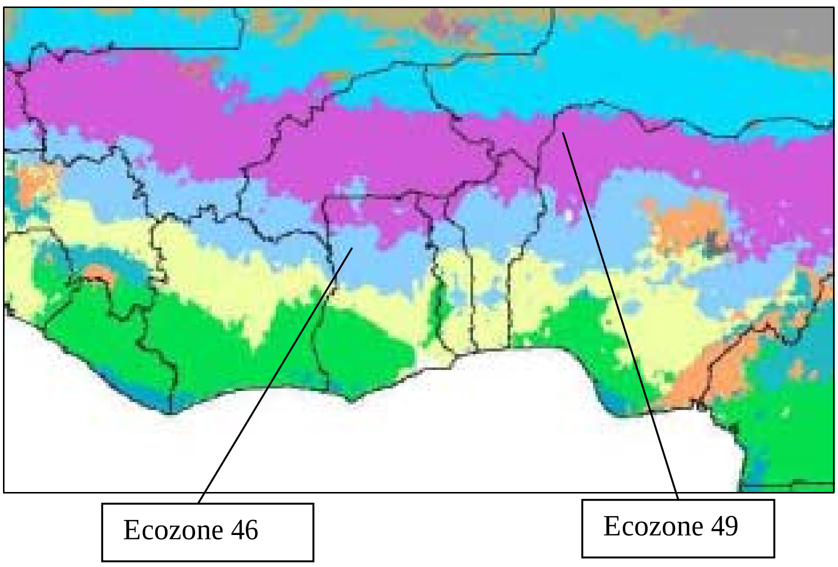
The means used to test these hypotheses was to develop a range of tsetse control projects of differing sizes throughout the 'Cotton Belt' and to estimate their costs and likely benefits. Consequently the projects so developed can only be regarded as hypothetical projects whose sole purpose was to provide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

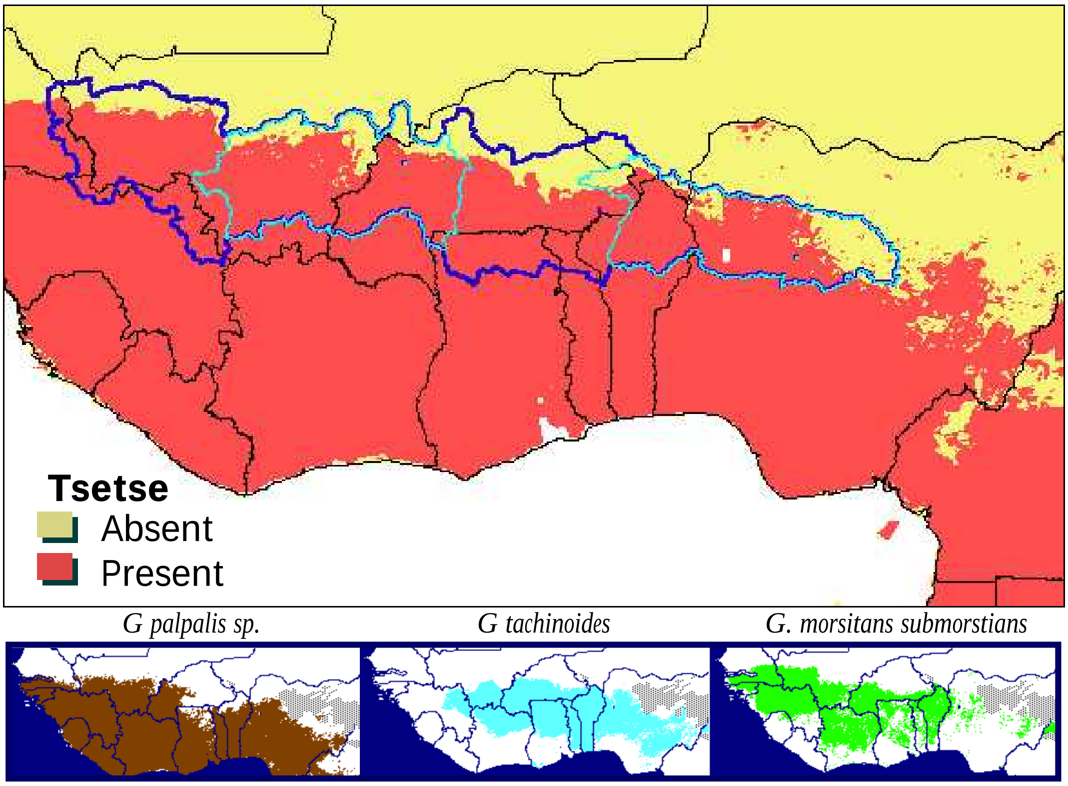
1 Normalised Digital Vegetation Index
2 Length of Growing Period (days)

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.

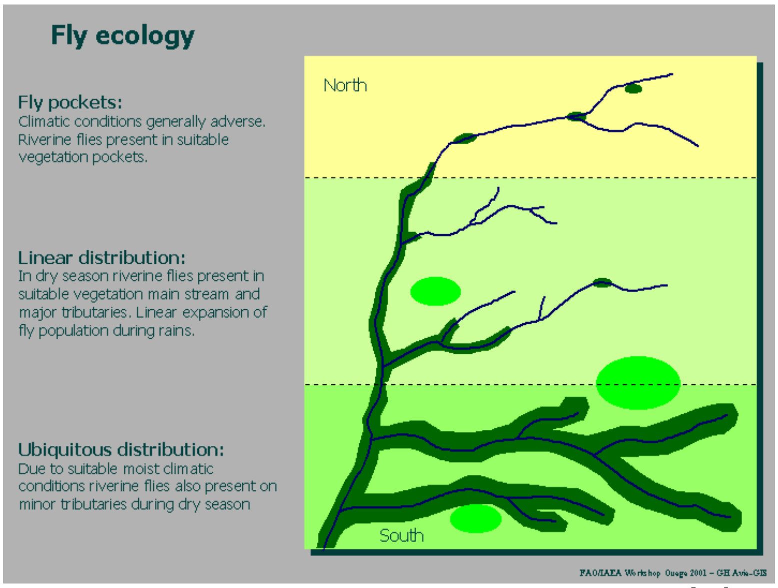
Figure 5 Tsetse Distribution within the Moist Savannah Zone



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



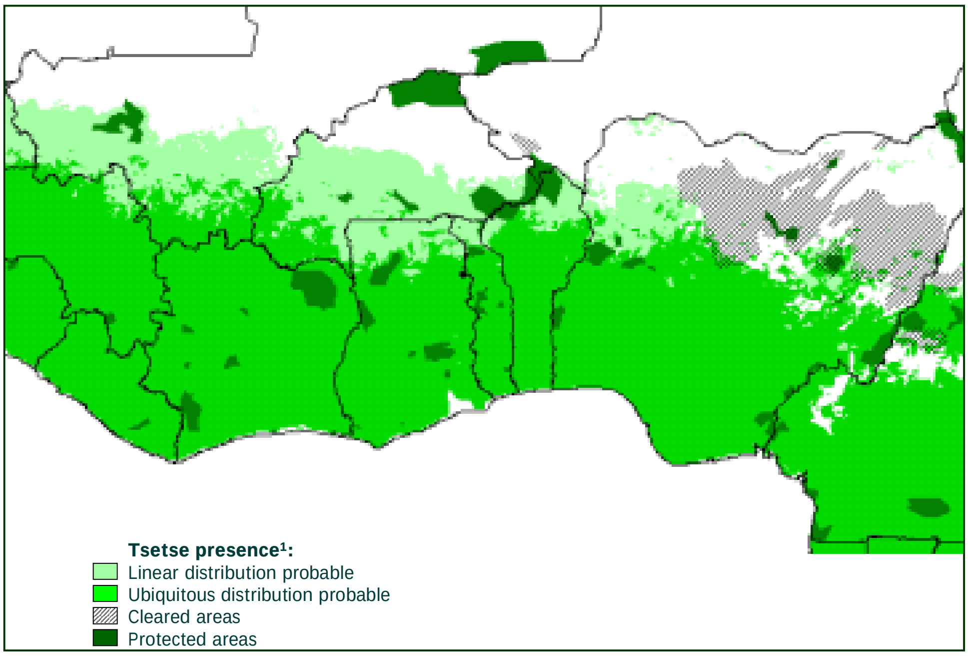
Source: Guy Hendrickx

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.

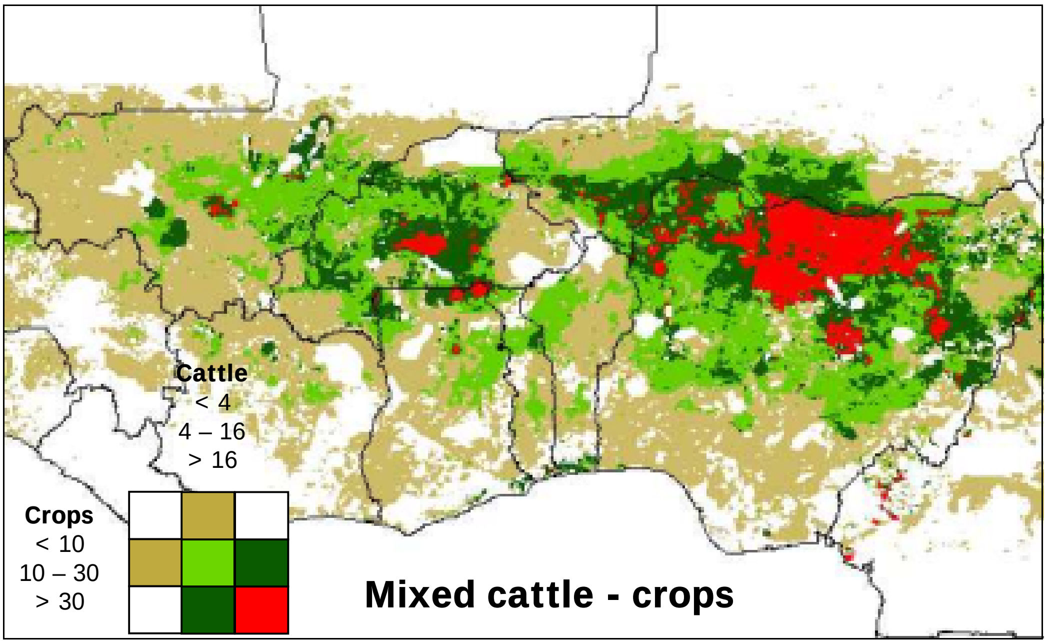
3.2.6 LAND TENURE

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



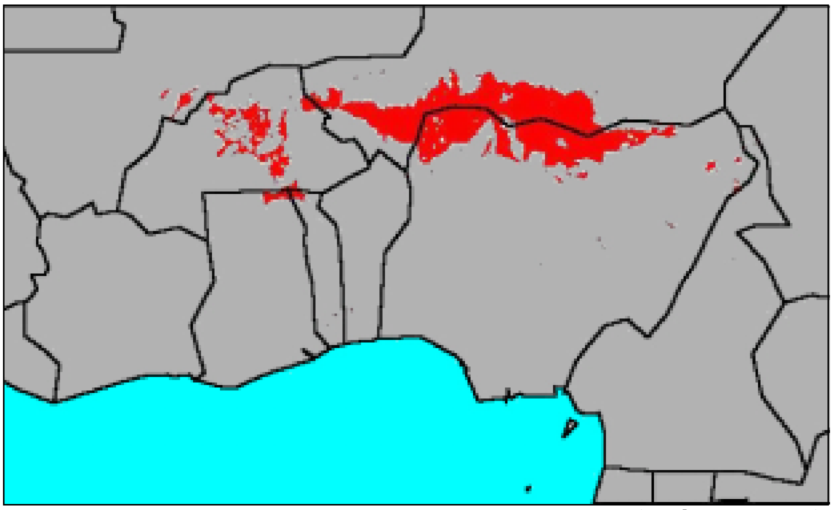
Whilst this designation of 'Land Pressure' only embodies two GIS layers it clearly demarcates (Fig. 8, areas in red and dark green) densely populated regions such as the Nigerian highlands and the effect of large towns, e.g. Bamako, Ouagadougou and Niamey on farming intensity in their hinterlands. More 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



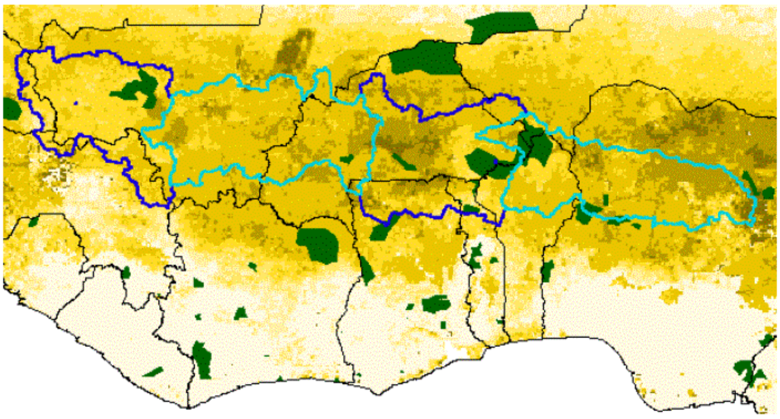
Source: FAO-AGAH (work in progress)

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.

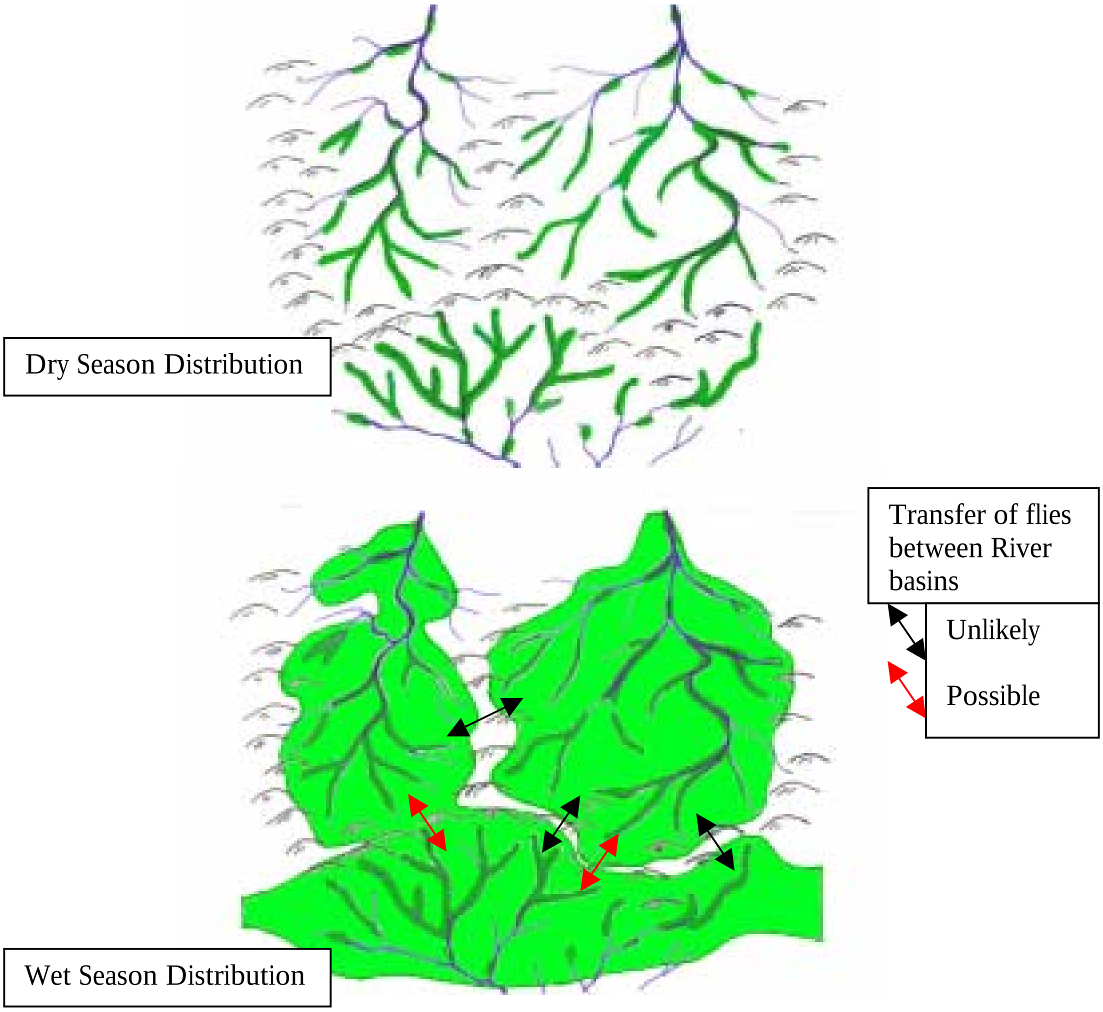
3.3 THE RIVER BASIN CONCEPT

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..

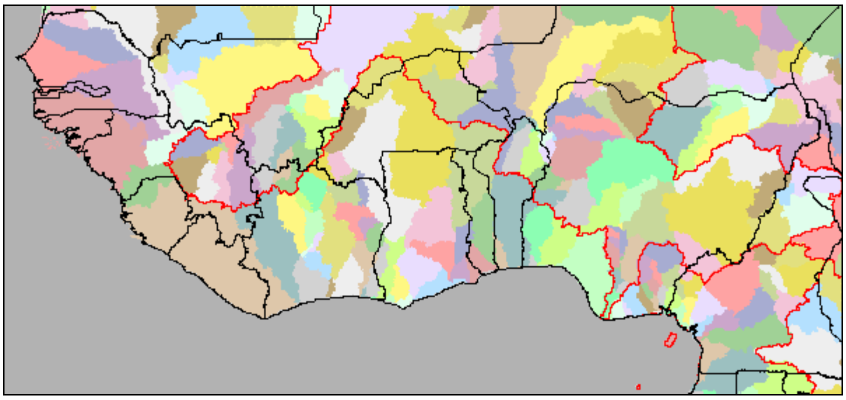
Figure 12 diagrammatically represents the dry and wet season distribution of *G. tachinoides* within the riparian vegetation close to watercourses. Such vegetation may be as little as a few meters either side of the smaller seasonal watercourses but can be as much as 250 meters either side of the main 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

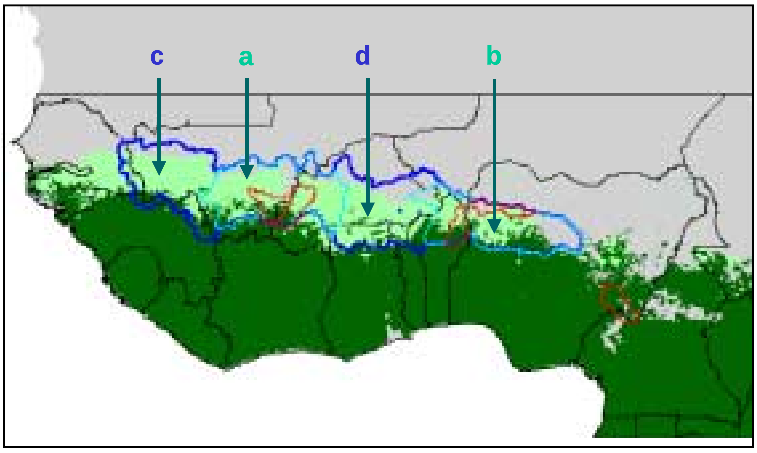


3.4 IDENTIFICATION OF STUDY AREAS

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.

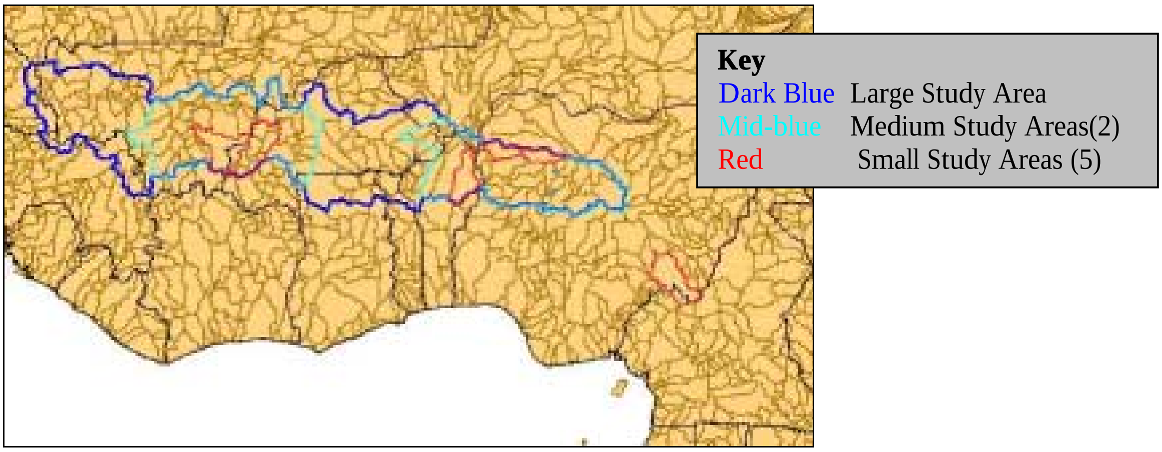
The small study areas are demarcated in fig. 14 and described in table 2. The medium-size GIS study areas were built-up from expansions of small study areas 1 with 2 and 3 with 4 and are combinations of adjacent river basins.

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 <u>not</u> 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

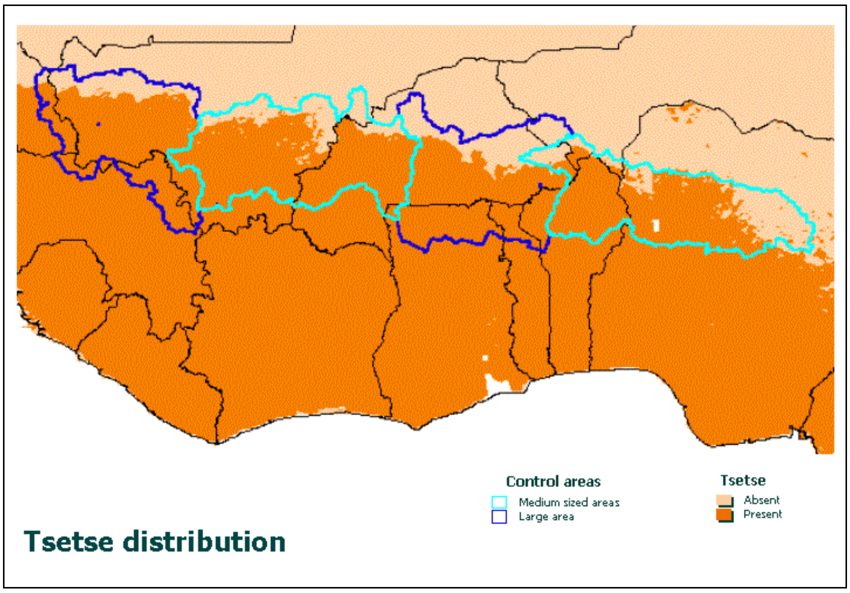
The data provided will also assist the basic data source for the studies of the 200,000 and 600,000 sq. km projects. Once all the technical data has been brought together, we will be in a position to calculate the likely costs and benefits of tsetse eradication projects on these 3 scales.

[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.

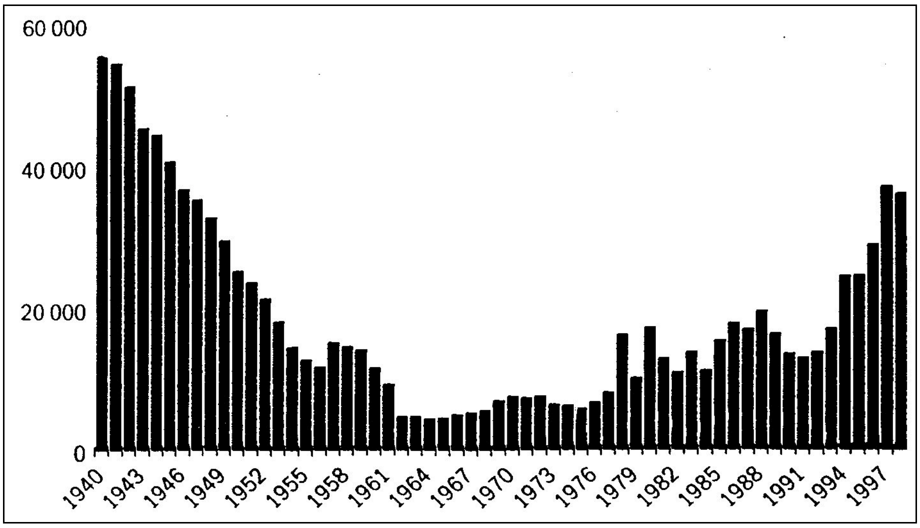
3.5 SHADOW PROJECTS – THE CONCEPT

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.).

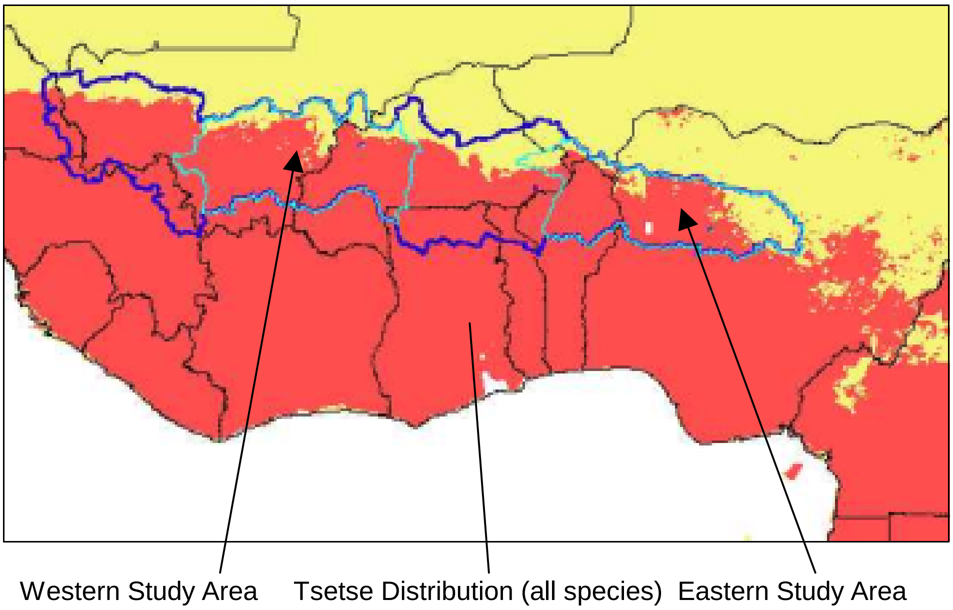
Bearing these factors in mind and the need for clarity and transparency in this study it is considered that maximum overall benefits will arise in year 10 and will be considered until year 15. Benefits will rise arithmetically from year 1 to year 10. This simplification of the benefits flow is not an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

5 MEDIUM-SIZE STUDY AREAS

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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Appendices

APPENDIX 1 PAAT GIS DESCRIPTION OF W AFRICA

Figure A1.1 Observed Cattle Density

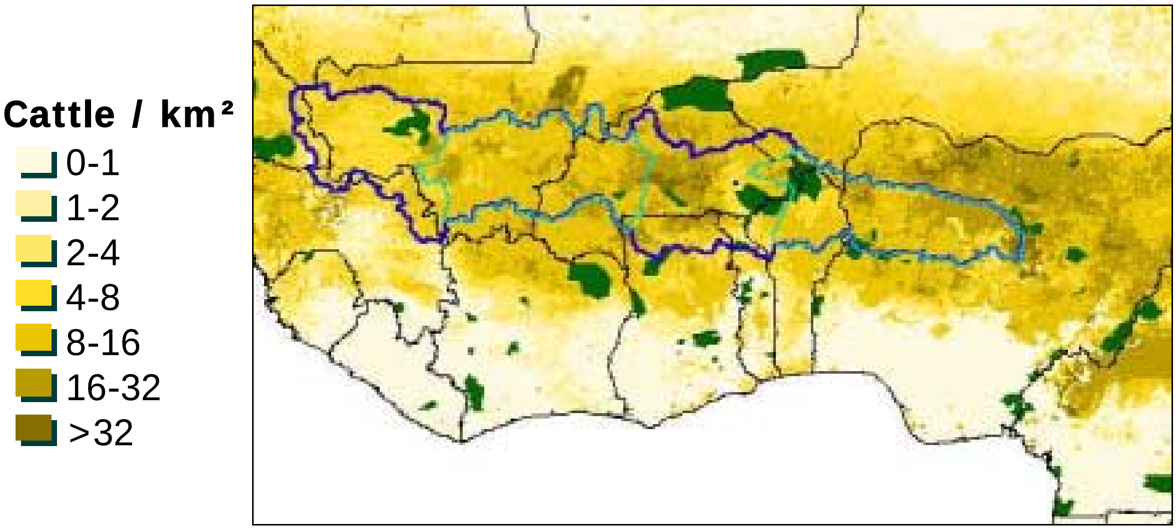


Figure A1.2 Predicted Cattle Density after Tsetse Control

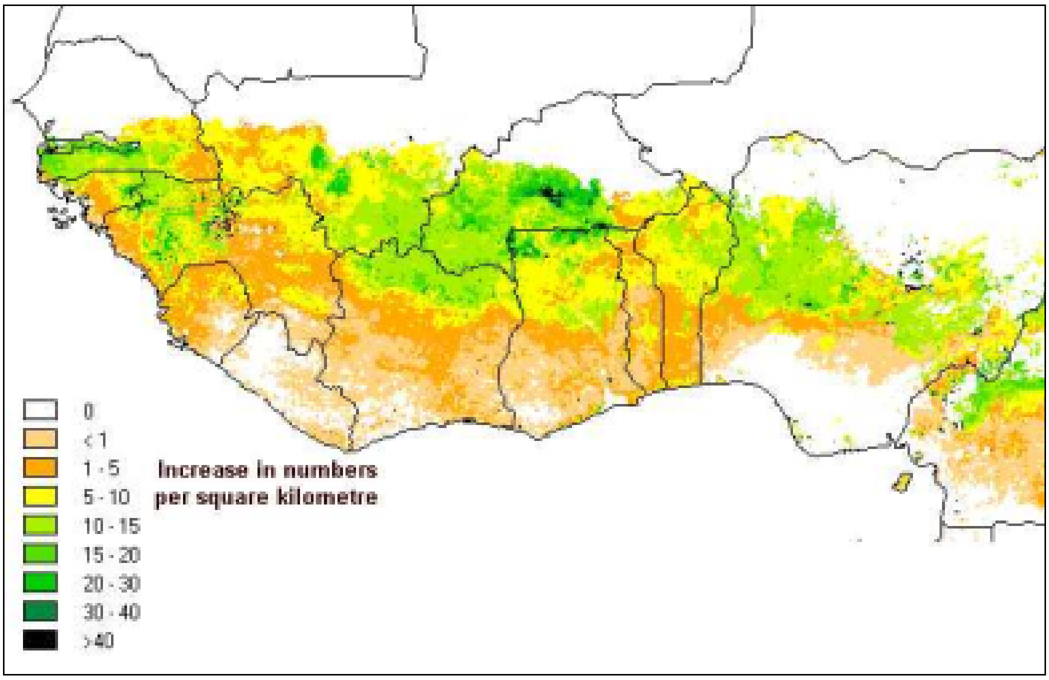


Figure A1.3 Digital Elevation Map

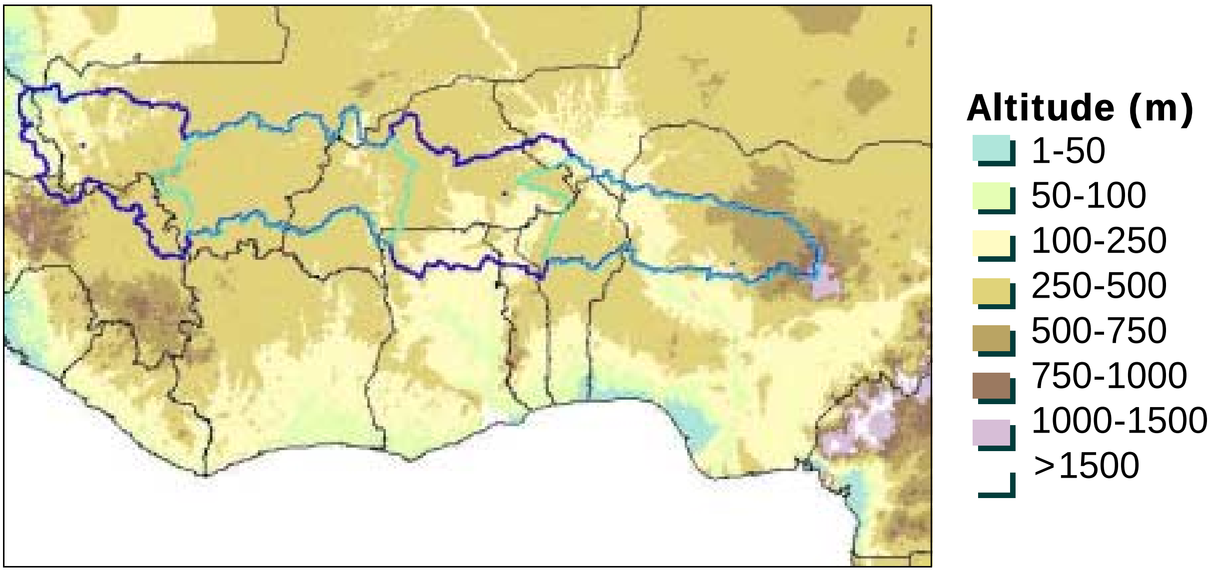


Figure A1.4 Ecozones

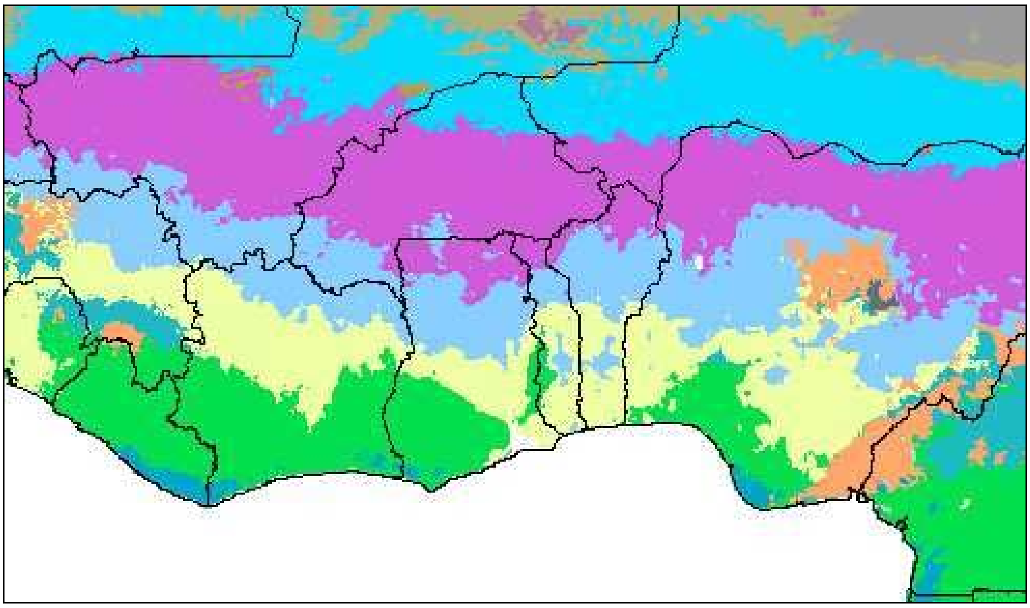


Figure A1.5 Length of Growing Period (LGP)

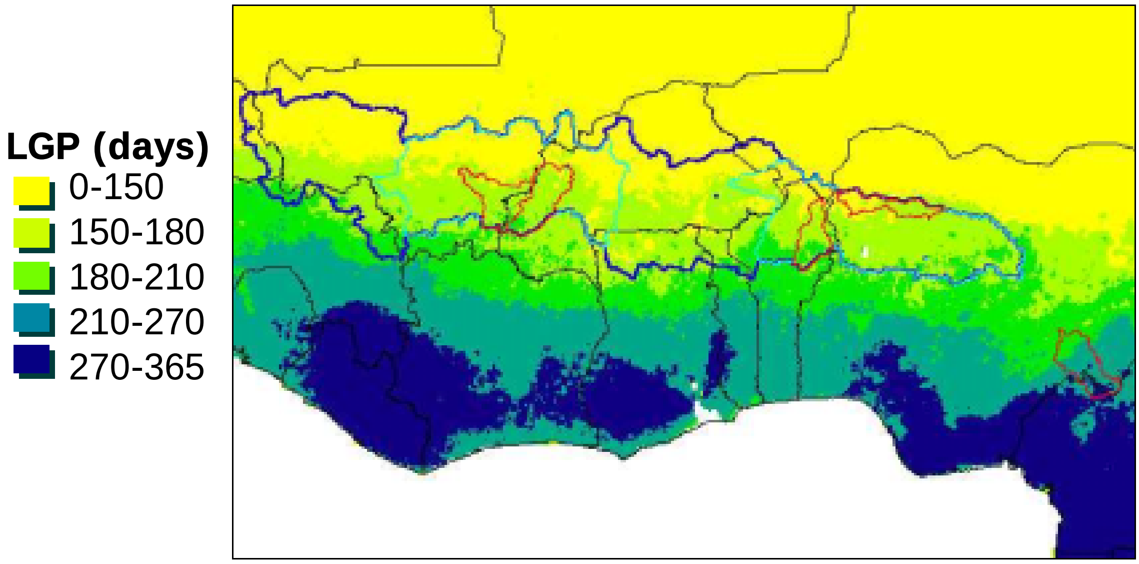


Figure A1.6 Human Population Density

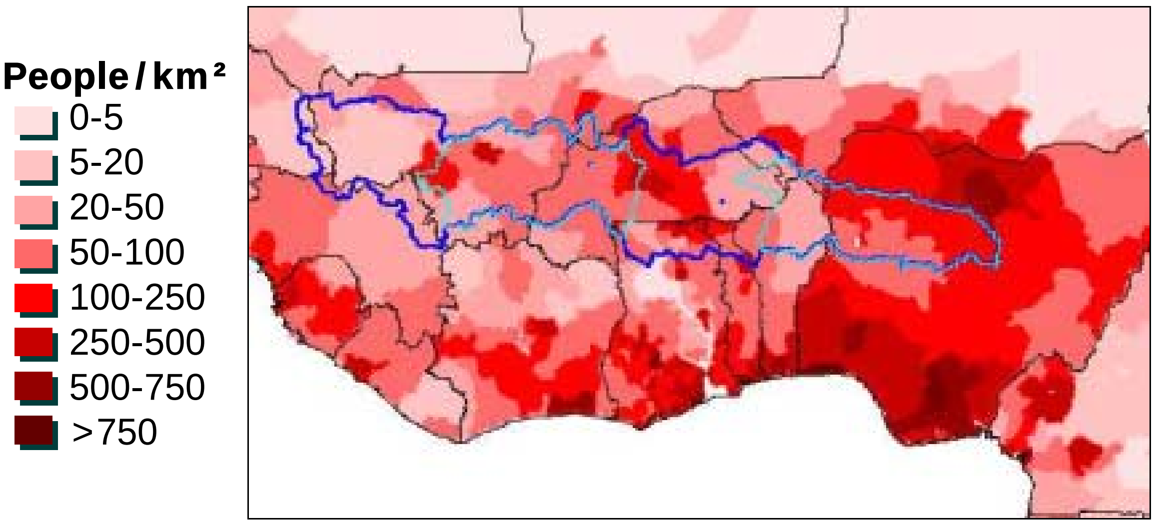


Figure A1.7 Percentage Areas Cultivated (based on 1 sq km pixels)

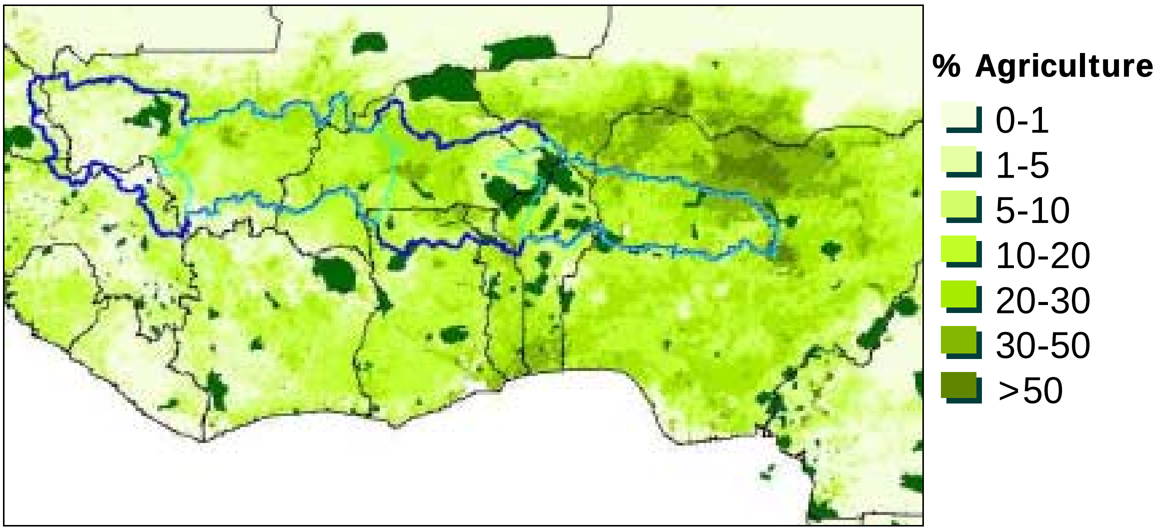


Figure A1.8 River Basins in West Africa Showing Study Areas

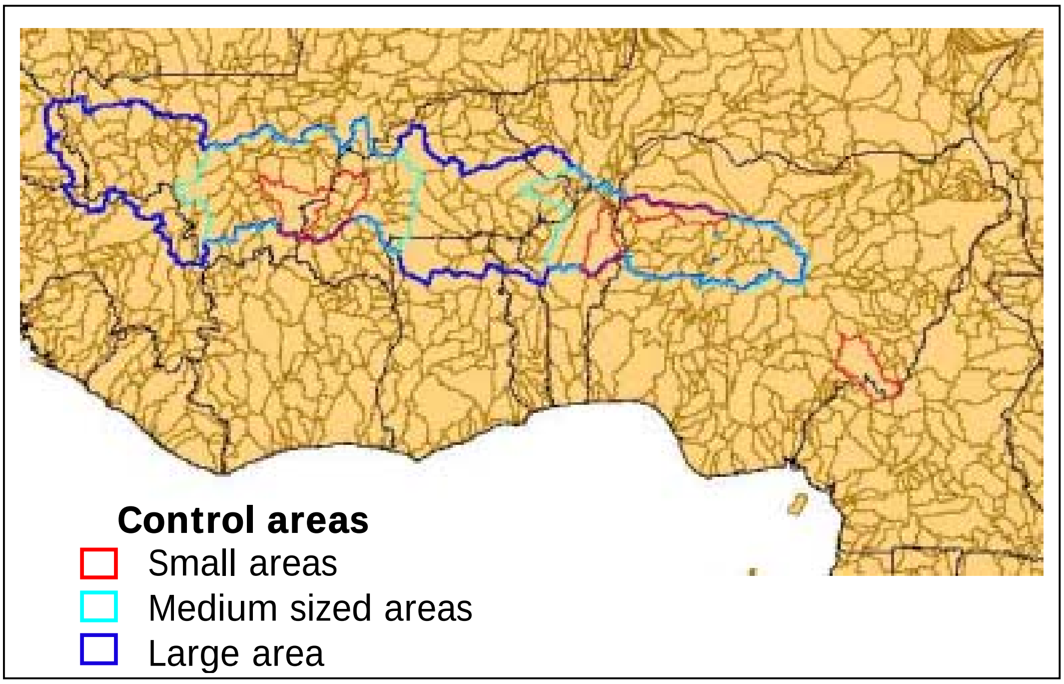


Figure A1.9   Farming Systems

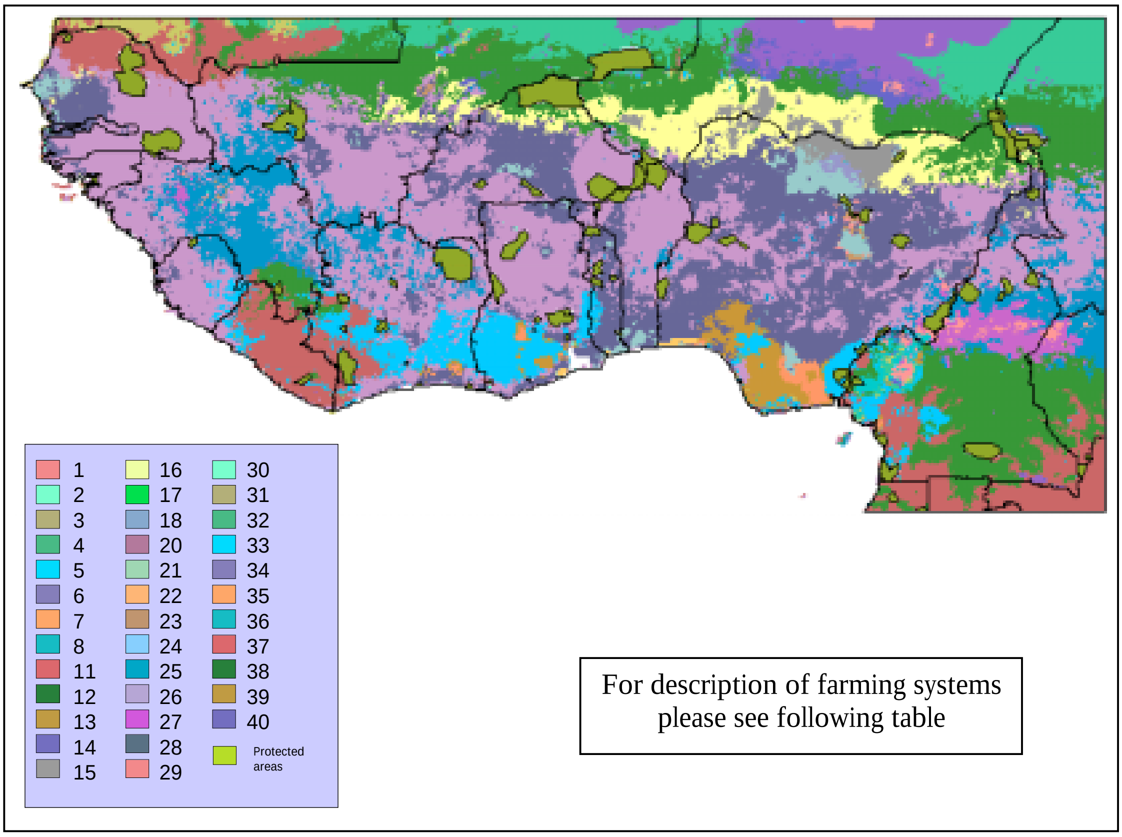


Table A1.1 Description of Farming Systems

System Ref. No.	Population density /km^2	% Cultivated	Cattle density /km^2	Elevation meters	LGP* days	TYPE	Ha. Cultivated / 100 people	Cattle /100 people
1	15	19	7	626	29	Agropastoral	569	177
2	778	6	1	172	18	Marginal	1	0
3	3	1	1	458	12	Marginal	49	156
4	49	3	34	369	28	Pastoral	18	464
5	3	0	2	258	14	Marginal	19	199
6	41	11	184	369	23	Int Pastoral	1112	72864
7	5	0	7	520	14	Arable	5	616
8	3	1	2	691	15	Marginal	58	97
9	4	1	2	1033	20	Marginal	50	418
10	3	1	3	1409	27	Marginal	35	370
11	31	9	15	313	97	Pastoral	38	117
12	9	3	6	222	85	Marginal	34	388
13	46	18	166	764	84	Int Pastoral	106	3693
14	10	3	4	542	85	Marginal	51	134
15	397	61	30	677	109	Mixed	21	9
16	52	32	11	357	98	Agropastoral	75	23
17	7	1	4	1020	92	Marginal	30	215
18	112	67	19	487	101	Mixed	124	33
19	40	9	22	1180	97	Pastoral	41	271
20	8	2	6	1403	88	Marginal	86	347
21	44	8	28	1392	175	Pastoral	41	166
22	142	84	39	933	167	Intensive	438	236
23	63	18	11	306	181	Mixed	54	29
24	139	11	68	1995	203	Int Pastoral	16	114
25	238	37	20	748	190	Mixed	38	18
26	23	5	8	276	182	Pastoral	35	80
27	13	2	4	666	202	Marginal	30	90
28	2145	30	39	608	201	Mixed	2	2
29	12	2	4	1250	185	Marginal	19	48
30	112	12	161	1377	188	Int Pastoral	37	1175
31	131	91	58	1486	308	Intensive	153	50
32	742	21	10	348	284	Agropastoral	3	1
33	23	2	0	264	300	Marginal	21	2
34	226	18	139	1834	288	Int Pastoral	20	968
35	269	15	0	189	291	Arable	6	0
36	133	20	32	1329	290	Mixed	22	34
37	10	2	1	516	324	Marginal	22	14
38	29	3	4	907	315	Marginal	14	30
39	90	11	1	230	289	Arable	21	2
40	63	3	15	1997	310	Pastoral	50	254

* LGP – Length of Growing Period

APPENDIX 2 COSTS AND BENEFITS OF SMALL PROJECTS

2.1 GEOGRAPHICAL DATA

Chapter 3 describes the small projects areas and outlines the principles of the shadow tsetse eradication projects. This appendix computes the costs and benefits of these projects in financial terms and Chapter 8 analyses them in economic terms.

Table A2.1 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.)

2.2 COSTS OF TECHNIQUES

The costs of implementing the various tsetse control techniques have only been computed in the Mali study area and these will be applied in the cost analysis of all of the study areas.

The cost of fabricating, deploying and maintenance of one target, at $25, is substantially lower than that reported by Barrett based on surveys in Zimbabwe. The difference can not be obviously accounted for by differences in the costs of deploying between riverine and savannah woodland.

The cost used for SIT, $800 per sq km, is a standard global cost estimate as there has been insufficient experience of operating SIT in field conditions to establish a reliable costs database. As the production of sterile male flies can be regarded as an industrial process, there are large economies of scale available. However, these would not be available to these small projects if they were operated on a one-off basis. On the other hand, the existing fly rearing facility at Bobo-Dialasso would be capable of supplying sufficient flies to each of the small projects. On balance, therefore, there does not seem to be sufficient reason not to use the standard cost estimate in this study.

In order to avoid underestimating the shadow projects' costs, a high proportion of actual costs has been added to take account of overheads (25%) and contingencies (25%). For the formulation of actual project plans and project tender documents a more normal figure of 10% would be used.

Table A2.2 Cost of Tsetse Control Techniques

	Area 1	Area 2	Area 3	Area 5
Target/Trap Make+deploy	15 US$	15 US$ (est.)	20 US$	20 US$ (est.)
Target/Trap Servicing	1$ per time (up to 6 times only)	1$ per time (up to 6 times only) (est.)	1$ per time (up to 6 times only) (est.)	1$ per time (up to 6 times only) (est.)
Pour-on	75c US per time	75c US per time (est.)	21,000 CFA/ litre	
Ground Spraying	-	-	-	500$ per sq km
Aerial Spraying (SAT)	-	-	-	500$ per sq km (1500$ per river km)
SIT (Standard cost)	800$ US per km^2	800$ US per km^2	800$ US per km^2	800$ US per km^2

2.3 SHADOW PROJECT COSTS

All costs are denominated in US Dollars converted at a rate appropriate to the date of the basic data.

2.3.1 STUDY AREA 1

Area: 20513 sq km
Length of infested watercourses: 2000 km
Length of re-invasion barrier: 100 km

<u>Phase 1 Project Planning:</u>

- Costs of initial surveys and project planning: 100,000 $

<u>Phase 2 Suppression:</u>

- Costs of construction and treatment of targets :
  2000 river miles @ 20 targets/river km =40,000 targets x 15$ = 600,000 $
  Costs of servicing targets (6 times @ 1$ per time) 240,000 $
  Cost of replacing 20% of targets (8,000) @ 15$ each 120,000 $
- Costs of 2 insecticide treatments of cattle (15cattle/km^2):
  2(15cattle/km^2 x 20,000 km$^{2)}$ = 600,000 cattle treatments
  600,000 x 0.75$/ treatment = 450,000 $

  Sub-Phase 2a *G.M Morsitans* 10% of above (nominal) 141 000 $

<u>Phase 3 Eradication</u> - Costs of SIT in years 2 and 3
2,000 river linear km x 800$/sq km = 1,600,000 $

Sub-Phase 3a *G.M Morsitans* 10% of above (nominal) 160,000 $

<u>Phase 4 Protection</u> - Costs of barrier establishment and maintenance(100 linear km over 20 years)
1600 targets: Purchase, maintain and replace (20%) on 2 year cycle
1600 targets x 5 cycles @ 24$ per target 192,000 $

Sub-total 3,603,000$

<u>5. Overheads</u>: 25% of total = 900,750$

<u>6. Contingency</u>: 25% of total = 900,750$

Total: 5,404,500 $

2.3.2 STUDY AREA 2

Area: 21,630 sq km
Length of infested watercourses: 1408 km
Length of re-invasion barrier: 350 km (estimated)

Phase 1 Project Planning:

- Costs of initial surveys and project planning: 100,000 $

Phase 2 Suppression:

- Costs of construction and treatment of targets :
  1408 river miles @ 20 targets/river km =28,160 targets x 15$ = 422,400 $
- Costs of servicing 28,160targets (6 times @ 1$ per time) 168,960 $
  Cost of replacing 20% of targets (5,632) @ 15$ each 84,480 $

  Sub-Phase 2a *G.M Morsitans* 10% of above (nominal) 67,578 $

Phase 3 Eradication - Costs of SIT in years 2 and 3
1408 river linear km x 1000$*/ km = 1,408,000 $

Sub-Phase 3a *G.M Morsitans* 10% of above (nominal) 140,800 $
* fly numbers released increased by 25% as live-bait technique not feasible

Phase 4 Protection - Costs of barrier establishment and maintenance (350 linear km over 20 years)
5600 targets: Purchase, maintain and replace (20%) on 2 year cycle
5600 targets x 5 cycles @ 24$ per target 672,000 $

Sub-total 3,064,218 $

5. Overheads: 25% of total = 766,054 $

6. Contingency: 25% of total = 766,055$

Total: 4,596,327 $

2.3.3 STUDY AREA 3

Area: 14125 sq km
Length of infested watercourses: 552 km
Length of re-invasion barrier: 275 km

<u>Phase 1 Project Planning:</u>

- Costs of initial surveys and project planning: 100,000 $

<u>Phase 2 Suppression:</u>

- Costs of construction and treatment of targets :
  552 river miles @ 20 targets/river km =11,040 targets x 20$ 220,080 $
  Costs of servicing targets (6 times @ 1$ per time) 66,240 $
  Cost of replacing 20% of targets (2208) @ 20$ each 44,160 $
- Costs of 2 insecticide treatments of cattle (15cattle/km^2):
  2(15cattle/km^2 x 14,000 km$^{2)}$ = 420,000 cattle treatments
  420,000 x 0.75$/ treatment = 315,000 $

  Sub-Phase 2a *G.M Morsitans* 10% of above (nominal) 64,620 $

<u>Phase 3 Eradication</u> - Costs of SIT in years 2 and 3
552 river linear km x 800$/sq km = 441,600 $

Sub-Phase 3a *G.M Morsitans* 10% of above (nominal) 44,100 $

<u>Phase 4 Protection</u> - Costs of barrier establishment and maintenance (275 linear km over 20 years)
4100 targets: Purchase, maintain and replace (20%) on 2 year cycle
4100 targets x 5 cycles @ 30$ per target 615,000 $

Sub-total 1,907,520 $

<u>5. Overheads</u>: 25% of total = 476,880 $

<u>6. Contingency</u>: 25% of total = 476,880 $

Total: 2,861,280 $

2.3.4 STUDY AREA 5

Area: 19856 sq km
Length of infested watercourses: 2000 km
Length of re-invasion barrier: 350 km

Phase 1 Project Planning:

- Costs of initial surveys and project planning: 100,000 $

Phase 2 Suppression:

1. Construction and treatment of targets :
   1000 river miles @ 20 targets/river km = 20,000 targets x 20$ = 400,000 $

1a. Servicing targets (6 times @ 1$ per time) 120,000 $
    Cost of replacing 20% of targets (4,000) @ 20$ each 80,000 $

2. Ground spraying 500 river km (=100 sq km)
   100 sq km @ 500 $ per sq km 50,000 $

3. Fixed-wing Aerial spraying 500 river km (=1500 sq km)
   1500 sq km @ 500$ per sq km 750,000 $

   Sub-Phase 2a *G.M Morsitans* 10% of above (nominal) 140,000 $

Phase 3 Eradication - Costs of SIT in years 2 and 3
   2000 river linear km x 800$/sq km = 1,600,000 $

   Sub-Phase 3a *G.M Morsitans* 10% of above (nominal) 160,000 $

Phase 4 Protection - Costs of barrier establishment and maintenance (350 linear km over 20 years)
   5600 targets: Purchase, maintain and replace (20%) on 2 year cycle
   5600 targets x 5 cycles @ 30$ per target 840,000 $

Sub-total 4,240,000$

5. Overheads: 25% of total = 1,060,000 $

6. Contingency: 25% of total = 1,060,000 $

Total: 6,360,000$

2.3.5 SUMMARY

Table A2.3 Summary

Phase	Area 1 $	Area 2 $	Area 3 $	Area 5 $
Pre-project surveys and project planning:	100,000	100,000	100,000	100,000
Suppression	1,551,000	743,418	710,820	1,540,000
Eradication	1,760,000	1,548,800	481,700	1,760,000
Protecting against re-invasion (10 years)	192,000	672,000	615,000	840,000
Overheads	900,750	766,054	476,880	1,060,000
Contingency	900,750	766,055	476,880	1,060,000
Total	**5,404,500**	**4,596,327**	**2,861,280**	**6,360,000**
Equivalent to:	256 / km^2	212 / km^2	202 / km^2	320 / km^2

Table A2.4 Cost Categories by Percentage

	Area 1	Area 2	Area 3	Area 5	Average
Pre-project surveys and project planning:	1.9	2.2	3.5	1.6	2.1
Suppression	28.7	16.2	24.8	24.2	23.6
Eradication	32.6	33.7	16.8	27.7	28.9
Protecting against re-invasion (10 years)	3.6	14.6	21.5	13.2	12.1
Overheads	16.7	16.7	16.7	16.7	16.7
Contingency	16.7	16.7	16.7	16.7	16.7

2.4 THE BENEFITS OF TSETSE AND TRYPANOSOMOSIS PROJECTS

Based on a wide range of observations throughout the continent a generalisation has been developed with regard to the relative performance of cattle herds living in trypanosomosis risk and no-risk environments, viz. that herds in no-risk situations are twice the size and produce 20% more milk and meat than herds in areas infested with tsetse flies (Swallow, Budd). However, an examination of the particular characteristics of the shadow projects areas suggests that the moist savannah zone has a lower than average trypanosomosis risk (see table A2.5).

This assertion is supported by the empirical observation that, although they are present throughout the area, trypanotolerant cattle are not present in great numbers. Twenty per cent of the cattle in study area 1 and 70% in study area 3 are reported as being trypanotolerant. However, virtually all of the cattle in area 3 are reported as being crosses between trypanosusceptible Zebu types and West African Shorthorn, the latter being regarded as a trypanotolerant breed. It has been observed by Gbodjo Zakpa *et al* that cattle-owners owning trypanotolerant breeds tend to use Zebu bulls during periods of low trypanosomosis challenge and trypanotolerant bulls during times of high trypanosomosis challenge. Thus an extrapolation of this observation would suggest that the moist savannah zone is a below average trypanosomosis challenge area.

Table A2.5 Tsetse and Trypanosomosis Incidence

Trypanosomosis	**Area 1**	**Area 2**	**Area 3**	**Area 5**
Trypanosomosis Prevalence	0-15% (1977-87)		*T. vivax* 11.3% *T. c'lense* 10.1% *T. b.brucei* 1.1% Overall 19% (1989)	16-47%
Average Herd PCV			20%	
Tsetse				
Flies/trap/day *G Palpalis* *G Tachinoides* *G Morsitans* ((	3 (1989) 5 (1989) 0.07 (1989) 0.0? (2001)		0.05 - 1.07 0.27 – 20.0 0.06 – 0.5 (1989)	Present Present Present

Table A2.6 Estimated* Livestock Populations in the Study Areas

	Area 1	**Area 2**	**Area 3**	**Area 5**
Total No. Cattle/density	308,690 =17 per km^2 Mali 5 /km^2 B/Faso ?	109,084 =5 per km^2 ?	342,236 =24 per km^2	*210,000* (Est.) = *11* per km^2
Of which: Trypanosusceptible /Trypanotolerant	80% / 20%		30% / 70%* *mainly crossbreds	
No Draught cattle	107,518 (35%)		19,984 (6%)	*35,000* (Est) (15-18%)
Sheep	238,350 (includes goats)	297,357	166,731	-
Goats		391,550	172,207	-

* Extrapolated from government statistics relating to (larger) local government districts

The implications of this observation are that eradicating tsetse flies from the MSZ may bring less benefits than the continent-wide average. The PAAT-GIS data predicts that the cattle numbers will increase by between 52% (in the eastern MSZ) and 72% (in the western MSZ). However, the presumed cattle density with tsetse flies is significantly lower than reported in the individual shadow project area reports.

Table A2.7 Cattle Herd Data (Estimated figures in *Italics)*

	Area 1	Area 2	Area 3	Area 5
Male/Female Ratio	38% / 62%	36% / 64%	27% / 73%	
Offtake (gross)	7.2%		13.8%	
Introduction Rate	2.5%		2.5%	
Offtake (net) =Slaughter	4.6%		11.8%	10%
% of herd adult females	15%		35%	
Calving Interval (months)	18	22	18	
Total Milk Yield/Lactation	*180*/106 litres (*gross*/net)	*180*/108 litres (*gross*/net)	530/200 litres (gross/net)	520/*200* litres (gross/net)
Calf/human consumption			62.5%/37.5%	
Mortality Rate < 1 year Total Herd	16% 5.6%	23%	23% 7.5%	

Trypanosomosis significantly affects the reproductive systems of cattle thus increasing calving intervals through increasing abortions. The calving intervals reported in table do not suggest that, except for study area 2, this is a significant factor. However, calf mortality (16 - 23%) is relatively high which suggests that the disease is causing mortality in live animals. This suggestion is backed up by herd mortality figures of 5.6 and 7.5% (areas 1 and 3) which when the calf mortality rate is deducted suggest a mortality rate of animals over one year-old of 4 to 5%. In the case of study area 1 this is similar to the net offtake rate in numerical terms.

Whilst cattle densities in the MSZ are not as high as those in the zones to the north a significant increase would bring them up to levels that would be sufficient to cause potential overgrazing as has occurred in the Sahelian regions (see section 3.2.8). Bearing this in mind, it is possible that productivity increases resulting from tsetse control will arise from a combination of pastoralists becoming settled, upgrading of cattle breeds, improved cattle health and welfare and a moderate increase in cattle numbers.

TABLE A2.8 LIVEWEIGHT VALUES OF CATTLE

	Area 1	Area 2	Area 3	Area 5
Young Male (**160 kg?**)		70,000 CFA =450CFA/Kg	70,000 CFA =450CFA/Kg	
Mature Male (**350 kg?**)		135,000 CFA =390 CFA/kg	180,000 CFA =500 CFA/kg	
Cow (**240 kg?**)		90,000 CFA =375 CFA/kg	120,000 CFA =500 CFA/kg	
Heifer (**120 kg**)	65,000 CFA =540 CFA/kg		60,000 FCFA =500 FCFA/kg	
Oxen (**320 kg**)	65,000 CFA =540 CFA/kg		160.000 FCFA = 500 FCFA/kg	

Using the example of Area 1, herd numbers will inevitably increase as calving intervals fall and calf mortality is almost eliminated, estimated at 2% per year. Adult mortality will be reduced by half from 6% to 3%. As a result of better health and welfare, a change of management styles from transhumant to sedentary, animals offered for sale will be heavier (est. +5%) and have a better confirmation and killing-out percentage thus increasing their value per kg liveweight (est. +5%) (see table A2.8).

Current Annual Offtake / Productivity (Area 1):

Mature Males (5 years-old)	2% of herd	= 6200 animals (300 kg) at 150$ each =	930,000 $
Mature Females (8 years-old)	3% of herd	= 9300 animals (240 kg) at 120$ each =	1,115,000 $
Adult mortality	6% of herd		nil
		Total	2,045,000 $

Trypanosomosis-free Offtake / Productivity

Mature Males (5 years-old)	3% of herd	= 9300 animals (315 kg) at 165$ each	=1,535,000 $
Mature Females (8 years-old)	5% of herd	=15500 animals (252 kg) at 132.5$ each	=2,055,000 $
Adult mortality	3% of herd		nil
		Total	3,590,000 $
		Increase	**1,575,000 $** (+77%)

From the above calculation it is evident that even modest improvements in the health of livestock results in significant increases in the income of livestock owners. To this figure of 77% improvement in the value of herd sales must be added the increase in herd size through the reduction of calving interval and lower calf mortality. It is estimated that together these factors would raise the increase in the offtake value to 90%.

2.4.1 MILK

The production of milk will undoubtedly increase as the health of livestock increases. However, it is estimated that this extra production will be required to sustain the increased number of calves due to a reduced calving interval and improved calf survivability. Consequently it is assumed there will be no increase in the supply of milk but its value will be reflected through the increased number of animals that is able to be sold as herd offtake.

2.4.2 SUMMARY - LIVESTOCK

By applying the same formula and percentage increase (90%) to the livestock data of other projects areas predictions can be made as follows:

Table A2.9 Value of Extra Livestock Production in Study Areas after Tsetse Eradication

	Area 1	Area 2	Area 3	Area 5
Estimated Current Output	2,045,000 $	720,000 $	2,260,000 $	1,390,000 $
Predicted increase in output (90%)	1,840,000 $	650,000 $	2,030,000 $	1,250,000 $

The prediction for study area 2 seems to be much lower than would be expected. This is due to the low number of cattle reported, approximately one third of that in the neighbouring study area 2.

However, the area contains almost three times the number of small stock, i.e. sheep and goats, most of which are trypanotolerant breeds. This pattern of livestock ownership may be a response to trypanosomosis. Small stock tend to be more tolerant to trypanosomosis than cattle and the removal of this disease will not benefit them, and hence overall livestock production increase will be lower than in predominantly cattle areas. On the other hand farmers might respond to the eradication of trypanosomosis by 'grading-up' from small stock to cattle. It is beyond the scope of this study to predict the effect of such a move from small stock to cattle. The effect of trypanosomosis on small stock is something that needs further investigation.

2.4.4 CROPS

The PAAT GIS predictions for the increase in area cropped as a result of eradicating trypanosomosis are 6.5% in the west and 5.1% in the east of the MSZ (see appendix 3, table A3.1). This would seem to be a modest increase, particularly for areas 3 and 5 where the proportions of draught animals is low. In study area 1, however, there are sufficient draught animals to plough most of the cultivated area (based on the premise that a pair of oxen can cultivate 5 ha (see annex 1). Indeed, any increase in cultivation in that study area would further violate the local policy of keeping a reserve of 2 sq km for every sq km that is cultivated. Already the ratio is 1:1.4 and it is reported that the increase in area cultivated is already 6% per annum.

TABLE A2.10 CROPPING DATA

	Area 1	**Area 2**	**Area 3**	**Area 5**
Area (sq km)	20513	21630 (Actual)	14125	19858
Human Population /density	629,408 Total 31 per km^2	543,750 (1985) 25 per km^2	226,000 16 per km^2	643,043 32 per km^2
Cultivatable Area (sq km)	8411		-	
Cotton (sq km)	781 22%		569 36%	
Maize (sq km)	544 16%	411 44%	380 24%	
Sorghum+ Millet (sq km)	1101 32%	390 42%	263 17%	
Rice (sq km)	125 4%	-	14 1%	
Groundnuts (sq km)	-	-	103 7%	
Others (sq km)	932 26%	129 14%	259 15%	
Total/ Proportion of Study area	**3484** 19%(Mali)	**930 ?** 4.3%?	**1588** 11%	**2100** *11%*(Est)
Proportion of Draught cattle	35%		6%	15-18%
Proportion of household using draught animals				10-40%

However, the cultivated areas for study areas 2 and 3 are much lower as is the proportion of cattle that are used for draught purposes. In study area 5 the proportion of families that have access to draught power for cultivation is between 10 and 40%.

Individual project area reports did not predict the likely impact of tsetse eradication on cropping patterns. In the absence of such data the PAAT GIS data (see chapter 1) will be used in calculating the value of increased cropping resulting from eradicating tsetse flies.

2.4.5 VALUE OF CROP OUTPUT

It is reported in the Study Area 1 report that in terms of food security cereal production in Mali in 2000-2001 exceeded the FAO norm of 250 kg per person by 116 kg, a margin of 46%. It is therefore presumed that any increase in the cropping area will be predominantly used for cash crops in order to generate a cash income. In the study areas 1, 2 and 3 this is most likely to be cotton and in study area 5, groundnuts.

Table A2.11 Outputs, Costs and Margins per hectare

	Cotton*	***Maize* (Est)**	***Groundnuts* (Est)**
Yield	1250 kg/ha	1500 kg / ha	900 kg / ha
Price	170 CFA /kg	90 CFA / kg	300 CFA / kg
Gross Output	212,500 CFA / ha	135,000 CFA / ha	270,000 / ha
Less			
Machinery Costs	20,000 CFA / ha	7,500 CFA / ha	5,000 CFA/ ha
Employed labour	15,000 CFA / ha	10,000 CFA / ha	35,000 CFA / ha
Fertilizer, Pesticides etc.	54,000 CFA / ha	47,500 CFA / ha	20,000 CFA / ha
Net Output / ha (Return to family labour)	123,500 CFA	70,000 CFA	210,000
Equivalent to	175 $ US	100 $ US	300 $ US

* based on Project Area 1 Report (Annex 1)

Using the PAAT GIS predictions for increases in areas cropped along with the above net output figures it is possible to predict the total value of the extra crop production resulting from eradication of trypanosomosis and the consequent increase availability and usage of draught oxen. For simplicity only cattle and oxen are considered in this prediction although donkeys are already being used and without the risk of trypanosomosis it is quite feasible that horses could be introduced into this area for draught purposes.

(The figure for the proportion of the total area cultivated in study area 2 in the above table is sufficiently different from that of the adjacent study area 1 that it is likely that it is under-reported, especially as no figure for the area planted to cotton is given. A more likely figure is estimated in the table below.)

Table A2.12 Value of Extra Crop Production in Study Areas after Tsetse Eradication

	Area 1	Area 2	Area 3	Area 5
Current Area Cropped (sq km)	3484 19%(Mali)	*3250*(Est) *15%*(Est)	1588 11%	*2100*(Est) *11%*(Est)
Predicted Increase after Project - %	+ 6.5%	+6.5%	+5.1%	+5.1%
Predicted Increase after Project - Sq km	225	210	80	105
Extra area by crop and net output per sq km	67% Cotton @ 17500 $ 33% Maize @ 10000 $		50% Maize @ 10000 $ 50% Groundnuts @ 30000 $	
Average net output per sq km	15,000 $	15,000 $	20,000$	20,000 $
Predicted Total Extra Output	3,375,000 $	3,150,000 $	1,600,000	2,100,000

2.4.6 OVERALL BENEFIT FROM TSETSE ERADICATION

By adding the predicted benefits in terms of livestock and crop production together (see table A12.13) an estimate the benefit to the farming community is obtained. However, this benefit should not be seen purely in financial and numeric terms but in human terms. Most members of the farming community in the MSZ are living well below the 'Dollar-a-day' poverty level and this increase in productivity resulting from eradicating trypanosomosis will increase their income by 5-10%. Some will benefit as farmers and livestock owners in their own right, others will benefit from increased opportunities to work and the wider economy will benefit from the significant increase in economic activity resulting from activities downstream of the farm, e.g. marketing, storage, transport, processing etc.

Table A2.13 Predicted Overall Benefit of Tsetse Eradication by Study Area per Year

Predicted production increases per year	Area 1	Area 2	Area 3	Area 5
Livestock	1,840,000 $	650,000 $	2,030,000 $	1,250,000 $
Crops	3,375,000 $	3,150,000 $	1,600,000 $	2,100,000 $
Total	1 $	2 $	3 $	5 $

APPENDIX 3 COSTS AND BENEFITS OF MEDIUM PROJECTS

3.1 IMPACT OF TSETSE CONTROL IN MEDIUM-SIZE STUDY AREAS

The PAAT GIS is able to predict the consequences of a tsetse control project by resetting the number of tsetse species to zero. In this way it is able to predict the herd size and quantity of land being cultivated as a result of eradicating tsetse flies and trypanosomosis. Inevitably, these changes will take some time to occur an, as such, the new predictions reflect the new equilibrium situation. These predictions use formula and are based on the current *with tsetse* situation. They do not take account of any dynamic changes over time arising from movements of human and animal populations from adjacent areas of high land pressure. As this is one of the primary reasons for selecting these particular study areas it is considered that the GIS predictions are likely to be exceeded in real project situations.

In addition it is presumed that there are no factors acting as constraints on the transition to the new equilibrium. This is an oversimplification of the situation. It was reported in the Geneva workshop that without reform of the legal framework for land tenure which recognises the need for pastoralists and sedentary farmers and livestock keepers any change in the *status quo* could lead to conflicts resulting from the use of the land in newly created tsetse-free areas. In this way tsetse control projects could be counter-productive although whether in the long-term this would inhibit the optimum use of the land in terms of productivity is not possible to predict for these projects which are anyway hypothetical.

Table A3.1 Increase in Cattle Numbers and Cultivated Areas Predicted by PAAT GIS

	Western Project Area	**Eastern Project Area**
Cattle Population Increase after Tsetse Control (head)	1,798,000	1,233,000
Population Increase(%)	71%	53%
Cultivated Area Increase (ha)	163,000	138,000
Proportional Increase	6.5%	5.1%

3.2 COSTS FOR THE MEDIUM-SIZE TSETSE ERADICATION PROJECTS

For planning of real projects detailed surveys will be carried out before commencement of any tsetse eradication project. For the shadow project areas which are the subject of this study this is not feasible and simplifications need to be made in predicting the cost of such projects. The three main headings into which costs fall are:

i. The area which needs to undergo control measures where tsetse flies occur linearly and in pockets along watercourses

ii. The area which needs to undergo control measures where flies are distributed universally

iii. The area which needs to undergo measures to protect against re-invasion

The first category is based on the watercourse length in km. In the more northerly parts of these study areas the watercourses may be as little as 50 meters wide and in the south they may be as much as 500 meters wide. For the purposes of this exercise it will be assumed that for the whole of this category an average of 250 meters will be used. Whilst this is a correct estimate for ground-based measures it is probably an underestimate for air-delivered control measures (SAT and SIT) for which precision delivery is not possible.

For the second category control measures will need to be applied throughout and so no adjustments need to be made. For the barrier category it is assumed that an area of 4 sq km will need to undergo control measures on a permanent basis for every linear km of boundary that has to be protected. This 4 to 1 ratio is half that used against *G morsitans* in Zimbabwe with barriers based on target technology. Bearing in mind the lower risk of re-invasion from riverine flies and the consensus regarding the risk of re-invasion (see section 3.2.5) half the Zimbabwean rate of provision is considered adequate.

Table A3.2 Actual Areas Requiring Control Measures

	Western Shadow Project Area	**Eastern Shadow Project Area**
Project Area in Tsetse Belt	151,231 sq km	122,139 sq km
Linear and Pocket Tsetse distribution - Watercourse Km	13075	9618
Ubiquitous Distribution - km	3172	6312
Total Boundary - km	11,950	9900
Boundary to be Protected - km	3125	2700

Using these adjustment factors the basic areas in table A3.3 are converted into areas in which tsetse control measures need to be applied within a shadow tsetse control project.. These areas are based on the dry season distribution of tsetse flies. It is presumed that control measures would commence at the beginning of the dry season and that by the end of it populations would be sufficiently suppressed that the eradication stage using SIT could commence. The amount of sterile flies released is proportional to the number of flies present. Consequently, when the flies are more widely distributed in the wet season it is not necessary to release a greater number of flies but merely to release them over the wider area. As a result, there is only a marginal difference in costs of SIT between dry and wet season. Male tsetse flies have the characteristic that they actively seek out females for mating and the fact that females are more widely distributed during the wet season merely means that the released males have to fly further in order to mate with females. Provided that they are healthy this poses no problem for the male flies and the technique remains as efficient.

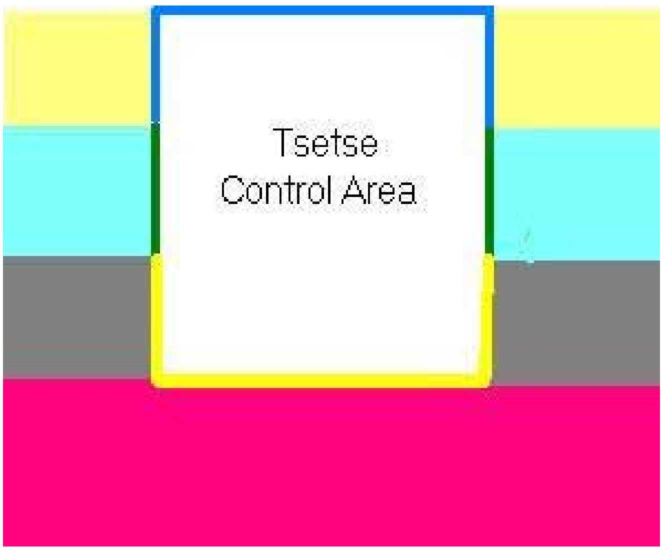
Table A3.3 Adjusted Areas Requiring Control Measures (sq km)

	Adjustment Factor	Western Shadow Project Area	Eastern Shadow Project Area
Linear and Pocket Tsetse distribution - Watercourse Km	0.25	3269	2404
Ubiquitous Distribution - km	1.00	3172	6312
Boundary to be Protected - km	4.00	12,500	10,400
Control Programme Total (sq km)		6441	8,716
Protection Programme Total (sq km)		12,500	10,400

During the wet season *G tachinoides* is widely distributed over most of the whole region where it is able to transmit trypanosomosis to animals and humans. However, during the dry season the whole population retracts back to the watercourses where its population density increases. By concentrating together in this way *G tachinoides* populations become vulnerable to control measures.

Table A3.3 uses the adjustment factors to calculate how large the areas are that will need to undergo control measures during the suppression and eradication phases as well as on an ongoing basis to protect the freed area from re-invasion by flies from areas in the south remaining tsetse-infested. The boundaries have been calculated using the PAAT GIS and are considered to represent the likely maxima.

Figure A3.1 Schematic Diagram of Barrier Location in relation to Tsetse Fly Distribution Zones



Key
Yellow = no tsetse flies present
White = area where fly is eradicated, no pockets left within area
Light blue = fly present but very fragile, no dispersion
Grey = distribution linear
Red = fly gradually more ubiquitous towards South
Blue lines = perimeter of medium sized project area where no barriers will “ever” be necessary
Green lines= perimeter where barriers very unlikely (in the light blue area no significant fly dispersion occurs)
Yellow lines = perimeter where barriers might be necessary.

In practice the linear distribution and the consequent increase of agriculture will reduce the areas in which a re-invasion barrier is required.

3.3 SUPRESSION AND ERADICATION TECHNIQUES – DISCUSSION

3.3.1 SUPPRESSION PHASE

Without the level of detail that can only be provided by ground-based surveys it is not possible to detail which of the appropriate techniques will be used in which locations based on GIS data alone. Using insecticide-treated cattle as **live baits** may be appropriate when targeting *G. morsitans* but it is unlikely to be used widely against *G tachinoides* or *G palpalis*. In the dry season livestock only move into the riverine habitat in order to drink and where they may come into contact with these species it is only for 15-30 minutes per day.

Ground spraying with organochlorines has previously proved effective and environmentally-benign in the medium term and may be used in limited areas provided that the this group of chemicals, or alternatives, is acceptable to host countries on environmental grounds.

Traps and targets have proved to be both technically and cost-effective against riverine species. However, access has often proved to be a problem for both installation and maintenance.

The **Sequential Aerosol Technique** (SAT) is effective but night-flying fixed-wing aircraft are only able to operate in straight lines rather than follow watercourses. As a result much larger areas need to be covered, much of which will be wasted as large proportions of these areas will not contain any tsetse flies in the dry season. Whilst this does not necessarily present an environmental hazard it does increase the cost in such a way that the adjustment factor used in table A3.3 would not apply.

Helicopters are more easily able to follow the line of watercourses, even at night, but they are 2-3 times more expensive than fixed-wing aircraft per sq km and would probably not be able to deliver a sufficiently even distribution of insecticide.

Bearing in mind the above it is considered that the most widely used technique for the suppression phase of a tsetse control programme is likely to be traps deployed within the watercourse and as near to the water as possible. Live baits will be deployed strategically and against *G morsitans* pockets. SAT will be used in remote areas where access is difficult.

Eradication Phase

Although in practice eradication of tsetse flies may be achieved in some of the areas through the application of the above population suppression techniques it will be assumed for the planning and costing of these hypothetical studies that a SIT campaign will be required to ensure complete eradication.

Post-eradication Phase – Prevention of Re-invasion

Once the flies have been eradicated from the project area it will be necessary to implement actions to prevent re-invasion of flies from areas from which flies have not been eradicated, predominantly from the south. It is hoped that once the infrastructure is in place for eradicating flies from the shadow project areas they will be applied to pushing the fly limit further and further south until the *G tachinoides* belt is completely eliminated. Such a ‘rolling programme’ would be the most positive way of preventing re-invasion. However, for the purposes of this study the projects can only be considered as stand-alone projects.

Figure A3.1 indicates schematically where barriers are most likely to be required. Whilst all of the techniques could be deployed as barriers, either individually or in combinations, it is most likely that traps will be the mainstay of the strategy to prevent re-invasion. One of the advantages of this method is that they can also provide information on fly distribution within the barrier zone as flies that have been caught are retained within the structure of the trap itself.

There is a body of opinion based on empirical evidence which considers that even in the areas where fly distribution is ubiquitous re-invasion will not prove to be a major threat. However, it is generally acknowledged that it will be necessary to continue to monitor the situation even after the threat is perceived to be nil.

At the maximum level of provision traps will need to be deployed in the same way that targets have been deployed for this purpose in Zimbabwe, albeit at the lower rate of 16 traps per linear km. This is considered to be the maximum level of provision required. In time, farmers will settle in this area and change the habitat in such a way that makes it uninhabitable for tsetse flies. Bearing this in mind, it is considered that a cost estimate based on a 50% barrier provision is considered to best represent the likely provision required over the whole life of the project. It is beyond the scope of this project to indicate whether such provision would allow for a full-width barrier for half the barrier length, a half-width barrier for the whole length or a full–width, full-length barrier reducing to nil over the project period, or indeed any other combination.

3.4 SHADOW PROJECT STRATEGY

It is envisaged that the basic strategy will be to commence the suppression phase at the commencement of the dry season when all *G tachinoides* are concentrated along the watercourses. Experience of previous control programmes indicates that using targets populations are likely to fall by more than 95% within 3 months. At this point SIT will be deployed through the release of flies on a weekly basis. It is anticipated that this release will need to continue through the wet season and into the next dry season if eradication is to be assured. During the wet season the pattern of release will be adjusted to the distribution of flies.

Once the control phase is over it will be necessary to implement measures against re-invasion probably using a trap-based strategy. This strategy will inherently include a monitoring component which will need to be continued well after the threat has been reduced to zero.

3.5 COST OF SHADOW CONTROL PROGRAMMES

Because GIS rather than survey data based on ground observations is being used as the data source for these shadow projects only an approximation of the costs of the medium-size projects can be possible in this study.

3.5.1 PROJECT PLANNING PHASE

Before any tsetse control project commences it will be necessary to carry out detailed surveys detailing tsetse distribution, cattle distribution, farming patterns and likely changes in addition to an environmental impact assessment before the project can be planned in detail. Provision will be made for these aspects of the shadow projects at the level of $10 per sq km; this level of provision is sufficient to cover the survey, project planning and financing phases.

3.5.2 SUPPRESSION PHASE

Based on the costs of control methods included in Budd, (1999 p33), the costs of ground spraying, aerial spraying using fixed-wing aircraft (SAT) and traps are each likely to be in the region of $300 - $400 per sq km. Treating cattle with insecticides is likely to cost about one-quarter of that and the use of helicopters rather than fixed wing aircraft is likely to increase the cost by 2-3 times.

Bearing in mind the conclusion in 3.1.8.1 above that traps will be the predominant technique and in order to simplify calculations one single cost of $300 per sq km will be used as the basic cost for the suppression phase. This figure is more conservative than that used for the small projects as planning at a greater level of detail has been possible for them.

3.5.3 ERADICATION PHASE

For the purposes of this study it is assumed that the Sterile Insect Technique (SIT) will be used throughout the control area in order to eradicate the remaining population of flies after the suppression phase. This technique has not been used against tsetse flies on this scale previously and, because the production of sterile flies is an ‘industrial’ process, very significant economies of scale apply to larger scale production. At the moment the technology for large-scale production has not yet been refined nor proven. It is predicted by IAEA that maximum economies of scale are likely to occur for projects of 25,000 sq km or larger. This programme will, therefore, enjoy the maximum benefit from economies of scale.

Because SIT has not been carried out on this scale before there are no precedents on which cost predictions can be made. A cost of $800 per sq km is used for the small projects. It is IAEA’s prediction that this cost can be reduced to $400-$500 per sq km for large projects but against this must be set the higher cost of using more expensive helicopters rather than fixed-wing aircraft for distribution in order to be able to follow the course of the rivers and streams. Bearing this in mind a figure of $800 per sq km will be used which is considered to reflect local situations, be conservative and also embody a contingency element.

3.5.4 BARRIERS

Monitoring the dynamic situation of tsetse distribution along the boundary sensitive to re-invasion is an integral part of the phase during which action to prevent re-invasion is being taken. By using traps as the control technique the normal procedures of deployment and maintenance can easily encompass the monitoring function. Whilst it is acknowledged that there may be some extra costs involved it is considered that the basic cost estimate used for the suppression phase of $300 per sq km per year will be a sufficient provision. This is equivalent to $75 per trap per year. As the cost estimate is based on 50% of the maximum likely provision the total cost will be the equivalent of $150 per year over the whole barrier area where re-invasion might occur.

3.6 SUMMARY

Table A3.4 Summary

	Western Shadow Project Area	**Eastern Shadow Project Area**
Planning Phase (Total Project Area)	187,014 sq km	170,247 sq km
Project Planning @ $10 / sq km	$1,870,100	$1,702,500
Control Programme (Tsetse Area)	6,441 sq km	8,716 sq km
Suppression Cost @ $300 / sq km	$1,932,300	$2,614,800
Eradication cost @ $800 / sq km	$5,152,800	$7,587,200
Protection Programme (Barrier Area)	12,500 sq km	10,400 sq km
Total Cost over 10 years @ $150 / sq km / year	$18,750,000	$15,600,000
Contingency and Overheads (50% of above costs)	$13,852,600	$13,445,000
Total	$41,558,800	$40,335,000
Tsetse-infested Area*	151,231 sq km	122,139 sq km
Cost per sq km (Tsetse-infested Area)	$275	$330
Cost per sq km (Areas of control activities)	$6450	$4640

* Equivalent to the area that will benefit from tsetse control.

3.7 BENEFITS OF THE TSETSE CONTROL PROJECTS

3.7.1 CATTLE HERD AND CULTIVATION

Level 3 of the PAAT GIS encompasses a facility that allows a prediction to be made for an area of the consequences of tsetse control in terms of changes in cattle population and the amount of area cultivated. This is explained in detail in section 2.1. This facility has been applied to the two areas and the results are included in table A3.5.

Table A3.5 GIS Predictions for Cattle Population and Cultivated areas in Tsetse-free Scenario

	Western Project Area	Eastern Project Area
Cattle		
Present Population (with tsetse)	2521563	2322939
Predicted Cattle Population (without tsetse)	4319643	3556239
Difference	+1798080 (+72%)	+1233300 (+53%)
Crops		
Area Cultivated (with tsetse)	24963 sq km	26829 sq km
Predicted Area Cultivated (without tsetse)	26595 sq km	28212 sq km
Difference	+1632 sq km (+6.5%)	+1383 sq km (+5.2%)

The predictions resulting from the application of this PAAT GIS data layer are based on the current size of the cattle herd and level of cultivation to which a formula is applied. However, it is known that to the north of these areas there is a high degree of land pressure and that there is likely to be a movement of all types of farmers and their cattle into this area once the constraint of trypanosomosis is removed. The consequences are two-fold:

- Although it takes only a short time for the tsetse population to be eradicated and the trypanosomosis risk removed the slow rate of domestic animal reproduction means that it takes 10-15 years for the size of the *in situ* cattle herd to reach a new equilibrium. The GIS prediction indicates the level of herd size in this new equilibrium. Bearing in mind the anticipated influx of farmers and animals into these project areas it is anticipated that the new equilibrium will be reached in a much shorter period. (Whether this will result in the cattle population exceeding equilibrium level with the consequent risks of environmental degradation is a factor that must be considered in real project situations but is beyond the scope of this study of hypothetical shadow projects.)

- With regard to cropping levels the improved health and numbers of cattle will allow more cattle to be made available for draught purposes. This factor is not embodied in the GIS and so the increases in cultivated areas are, in real project situations, likely to be several times greater than predicted in table A3.5.

3.7.2 FINANCIAL

Assuming an on-farm liveweight value of animals of 500 CFA/kg (70 cents US/kg) and a 50% killing-out rate an on-farm value of meat of 1000 CFA/kg ($1.40 US/kg) is used in this part of the analysis. This compares well with a retail beef value of between 1000 and 1800 CFA/kg ($1.40 to 2.60 US/kg) reported in study area 3 (Annex 3, section 4.5) and $2019/tonne reported by Kristjanson. This would allow an approximate 30% marketing margin which is a normal level where a degree of processing, i.e. slaughtering, butchering, transport and possibly refrigeration, is involved.

Calculations are based on those used previously by Budd (1999) except for making the same assumption with regard to milk as used for the small project calculations, i.e. that all the extra milk produced is used for sustaining the increased number of calves.

3.7.1.1 Meat

Table A3.6 Increased meat productivity and on-farm value of existing herd per year

	Current No. Cattle	Increase in meat production Kg per animal per year	Total increase in meat production Tonnes/year	Value Per tonne $	Value of increased meat production $ per year
Western Project Area	2.5 m	3.5 kg	8823t	1400	12.4 m
Eastern Project Area	2.3 m	3.5 kg	8050t	1400	11.3 m

Table A3.7 Increased production and on-farm value from increased cattle herd size

	Increase in no. cattle	Meat output per animal per year	Total increase in meat production Tonnes / year	Value Per tonne $	Value of increased meat production $ per year
Western Project Area	1.8 m	18.5 kg	33262	1400	67 m
Eastern Project Area	1.2 m	18.5 kg	22806	1400	46 m

3.7.1.2 Crops

Using a net output value for crops of $15,000 per sq km and $20,000 for the Western and Eastern shadow project areas respectively (the values used in the analysis of the small projects), the value of the increased crop production resulting from the increased area cultivated is calculated in table A3.8. This is a purely arbitrary value and reflects an average value for the mix of crops that are grown in the MSZ. This is a net value thus taking into account the costs of purchased inputs. It is also considered that the increasing use of draught animals will enable timeliness to be improved with a consequent increase in crop yields. This factor has not been included in these predictions as there is no data available which quantifies this benefit.

Table A3.8 Value of Increased Crop Production

	Increased Cultivated Area sq km	Value of output per sq km $	Total increase on crop output $
Western Project Area	1632	15,000	24.5 m
Eastern Project Area	1380	20,000	27.6 m

3.8 FINANCIAL SUMMARY

Table A3.9 Total value of increased livestock and crop output (per year)

	Extra meat output from existing herd million $	Extra meat output from larger herd million $	Value of increased crop production million $	Total value of increased crop and livestock production million $
Western Project Area	12.4	46.6	24.5	83.5
Eastern Project Area	11.3	31.9	27.6	70.8

APPENDIX 4 COST AND BENEFITS OF LARGE PROJECT

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 appendix. The same format for tables is used as in the previous appendix.

Table A4.1 Increases in Cattle population and Areas Cultivated after Tsetse Control

	Large Project Area
Cattle Population Increase after Tsetse Control (head)	5,314,000
Population Increase(%)	64%
Cropped Area Increase ha	4,975,000
Proportional Increase	6%

4.1 COST OF TSETSE CONTROL PROJECT

Table A4.2 Actual areas requiring control measures (Source PAAT GIS)

	Large Shadow Project Area
Project Area in Tsetse Belt	540,000 sq km
Linear and Pocket Tsetse distribution - Watercourse km	46044
Universal Distribution - km	6054
Total Boundary - km	29,200
Boundary to be Protected - km	7550

Table A4.3 Adjusted areas requiring control measures (sq km)

	Adjustment Factor	Large Shadow Project Area
Linear and Pocket Tsetse distribution - Watercourse Km	0.25	11,511
Universal Distribution - km	1.00	6,054
Boundary to be Protected - km	4.00	30,200
Control Programme Total (sq km)		17,565
Protection Programme Total (sq km)		30,200

Table A4.4 Summary

	Large Shadow Project Area	
Planning Phase (Total Project Area)	669,440 sq km	
Project Planning @ $10 / sq km		$6,694,400
Control Programme (Tsetse Area)	17,565 sq km	
Suppression Cost @ $300 / sq km		$5,269,000
Eradication cost @ $800 / sq km		$14,052,000
Protection Programme (Barrier Area)	60,400 sq km	
Total Cost over 10 years @ $150/sq km/year		$45,300,000
Contingency (25%) and Overheads (25%)		$35,658,000
Total		$106,974,000
Tsetse-infested Area*	540,000 sq km	
Cost per sq km (Tsetse-infested Area)		$200

* Equivalent to the area that will benefit from tsetse control.

4.2 BENEFITS OF THE TSETSE CONTROL PROJECTS

4.2.1 CATTLE HERD AND CULTIVATION

Table A4.5 GIS Predictions for Cattle Population and Cultivated areas in Tsetse-free Scenario

	Large Project Area
Cattle	
Present Population (with tsetse)	8,282,791
Predicted Cattle Population (without tsetse)	13,596,736
Difference	+5,313,945
Crops	
Area Cultivated (with tsetse)	81,150 sq km
Predicted Area Cultivated (without tsetse)	86,125 sq km
Difference	+4,975 sq km

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4.2.2 FINANCIAL

Applying the same values for meat and milk ($2019 per tonne for meat) and the format used applied in Budd (1999), the above physical values are translated into financial values in tables A4.6 and A4.7.

4.2.2.1 Meat

Table A4.6 Increased productivity and on-farm value of existing herd per year – Meat

	Current No. Cattle	Increase in meat production Kg per animal per year	Total increase in meat production Tonnes per year	On-farm value Per tonne $	Value of increased meat production $ per year
Large Project Area	8.3 m	3.5 kg	28,988t	1400	40.6 m

Table A4.7 Increased production and on-farm value arising from increased cattle herd size

	Increase in no. cattle	Meat output Kg per animal per year	Total increase in meat production Tonnes per year	Value Per tonne $	Value of increased meat production $ per year
Large Project Area	5.3 m	18.5 kg	78,294	1400	110 m

4.2.2.2 Crops

Using an average net output value for crops of $17,500 per sq km the value of the increased crop production resulting from the increased area cultivated is calculated in table A4.8. This is a purely arbitrary value and reflects an average value for the mix of crops that are grown throughout the MSZ.

It is also considered that the increasing use of draught animals will enable timeliness to be improved with a consequent increase in crop yields. This factor has not been included in these predictions.

Table A4.8 Increased value of crops arising from increased Cultivation

	Increased Cultivated Area Sq km	Value of output per sq km (net) $	Total increase on crop output $
Large Project Area	4971	17,500	87.0 m

4.2.3 SUMMARY

Table A4.9 Total value of increased livestock and crop output (per year)

	Extra output from existing herd Meat million $	Extra output from larger herd Meat million $	Value of increased Crop Production million $	Total value of increased crop and Livestock Production million $
Large Project Area	40.6	110.0	87.0	237.6

Narrative	Objectively Verifiable Indicators	Means of Verification	Assumptions and Risks
Super Goal – Improvement of livelihoods and reduction of poverty in rural areas through the opening up and/or realization of full potential of extensive areas of land currently infested by tsetse fly.			
Goal – Rational selection and implementation of tsetse elimination programmes enables increased agricultural productivity.	-Improved livestock productivity -Improved crop/livestock integration -Increased crop yields -Increased areas under cultivation		Marketing systems enhanced to reflect the increased supply of crop and livestock products.
Purpose – To provide a sound technical and economic basis for the identification and selection of areas in which the removal of the tsetse/trypanosomosis constraint may provide a real and sustainable benefit to agricultural development.			Animal health and husbandry services will be facilitated to secure the new opportunities open to livestock production through the removal of this key constraint. Draught animal extension, training, and equipment programmes will be introduced in synchrony with tsetse elimination. Equitable and sustainable land tenure, usufruct and common property rights can be agreed and implemented.
Outputs – 1. Insight into the economics of tsetse elimination projects, with particular reference to project size.	A range of cost benefit analyses supported by sensitivity analyses, produced by March 2001	Phase 1 Final Report.	That the quality and margin of error of data garnered (through GIS for the large and medium sized 'shadow' project areas, and that ground truthed by West African Experts for the smaller and smallest areas) is sufficiently narrow to allow valid analysis and comparison.
2. Initial development of methodologies for identification, selection, demarcation, and planning of tsetse elimination programmes in the MSZ of West Africa.	Check list of factors, and their parameters, for consideration and evaluation in project planning, produced by March 2001.	Phase 1 Final Report.	
3. Proposal for further development of the methodology and associated capacity building in West Africa.	Concept Note (C.N.) and skeleton log-frame prepared by 20.12.2000	C.N delivered to FAO and IAEA.	

The second phase of the project will extend and develop the methodologies for strategic planning for tsetse elimination formulated in Phase I, and facilitate human and infrastructural capacity building and technology transfer to the West Africa Region.
Duration – 9 months Budget – Up to US$ 100,000.

Narrative	Objectively Verifiable Indicators	Means of Verification	Assumptions and Risks
Super Goal – Improvement of livelihoods and reduction of poverty in rural areas through the opening up and/or realization of full potential of extensive areas of land currently infested by tsetse fly.			
Goal – Rational selection and implementation of tsetse elimination programmes enables increased agricultural productivity.	-Improved livestock productivity -Improved crop/livestock integration -Increased crop yields -Increased areas under cultivation		-Marketing systems enhanced to reflect the increased supply of crop and livestock products
Purpose – Securing the infrastructural requirements and the human resource capabilities, at national and regional levels, adequate for the selection, definition and planning of tsetse elimination programmes.			- Animal health and husbandry services will be facilitated to secure the new opportunities open to livestock production through the removal of this key constraint. - Draught animal extension, training, and equipment programmes will be introduced in synchrony with tsetse elimination. - Equitable and sustainable land tenure; usufruct and common property rights can be agreed and implemented.

Outputs – **1** Further development and refinement of the strategic planning methodology **2** 'XX' staff trained and competent in strategic planning for tsetse elimination **3** Preparation of a Phase 3 proposal. (See section below) **4** The strategic planning group is co-ordinated and empowered under the auspices and authority of an appropriate regional organization.			Political and financial support for continuation of the process is forthcoming from national governments, PATEC, OAU and the donor community. Appropriate staff/personnel are, willing, able and available for training and subsequent involvement in the strategic planning process. Invitations are forthcoming from East and Southern Africa to extend this project into their areas in the third phase. A regional stream of funding is agreed for the operation of the group
Activities **1** Re output 1 – Preparation and implementation of a multi-disciplinary workshop, in Ouagadougou, on strategic planning methodology **2** Re output 2 – Identification or design, of training programmes to enhance the capacity of West African specialists to contribute to multi-disciplinary planning and decision making processes **3** Re output 2 – Suitable staff identified and enrolled in training. **4** Re output 4 – Consultation within the region to identify and agree an appropriate regional organization.			

Phase III

Outputs:

- Initiation of real location planning in sites selected as an outcome of the methodologies and capacities developed in Phases I and II.
- Extension of the programme to East and Southern Africa.

Activities:

- Preparation of a similar set of Phase I and II proposals relevant to extension of the programme into Eastern and Southern African regions.

APPENDIX 6 PARTICIPANTS IN THE STUDY

GENEVA WORKSHOP

Prof Albert Ilemobade, George Chizyuka, Dr. Guy Hendrickx, Dr. Issa Sidibe, Dr Oumar Diall, Dr. Victorin Codija, Dr Jan Slingenbergh, Guy Freeland and Leonard Budd.

Some preparation for the meeting had been carried out by Anita Erkelens (FAO / IAEA) and Leonard Budd.

ROME/VIENNA WORKSHOP

Dr. Guy Hendrickx, Dr. William Wint, Dr Jan Slingenbergh, Dr. Janet East, Guy Freeland, Anita Erkelens, Zowinde Kodougou and Leonard Budd.

INDEPENDENT WORKING SECTOR

Prof Albert Ilemobade, Dr Oumar Diall, Dr. Victorin Codija, Zowinde Kodougou, Leonard Budd. (Co-ordinator) with assistance from Dr. Guy Hendrickx and Dr. William Wint.

Annex 1 Study Area 1 (Mali) Report

Programme Against African Trypanosomosis

Options For Tsetse Fly Eradication in the

Moist Savannah Zone of West Africa:

Technical and Economic Feasibility Study,

Phase 1 (Mali)

Dr OUMAR DIALL

March 2001

Introduction

Mali is a landlocked country which covers 1,211,238 km² and contains around 10 million people.

Mali is cited among the less advanced countries with GDP of 156,264 CFA(220 US Dollars) per person. At least 75% of the population live in the rural areas and depend mainly on agriculture for their livelihood. The contribution of agriculture to GDP is about 50%. The population increase rate is 3.4% , while the GDP increase rate is about ----------. One of the major constraints to the integrated rural development in the portion of Malian territory (240,000 km² or 16%) infested with tsetse flies is the presence of trypanosomosis

Mali is infested with only three types of tsetse flies: a regressing *G.morsitans submorsitans* in the declining savannah and the persisting *G.palpalis gambiensis* and *G.tachinoides* alongside the river systems. *G.morsitans submorsitans*, being continuously pushed by the cultivation of new lands, tsetse control in Mali is likely to be restricted to a battle against reverine tsetse flies.

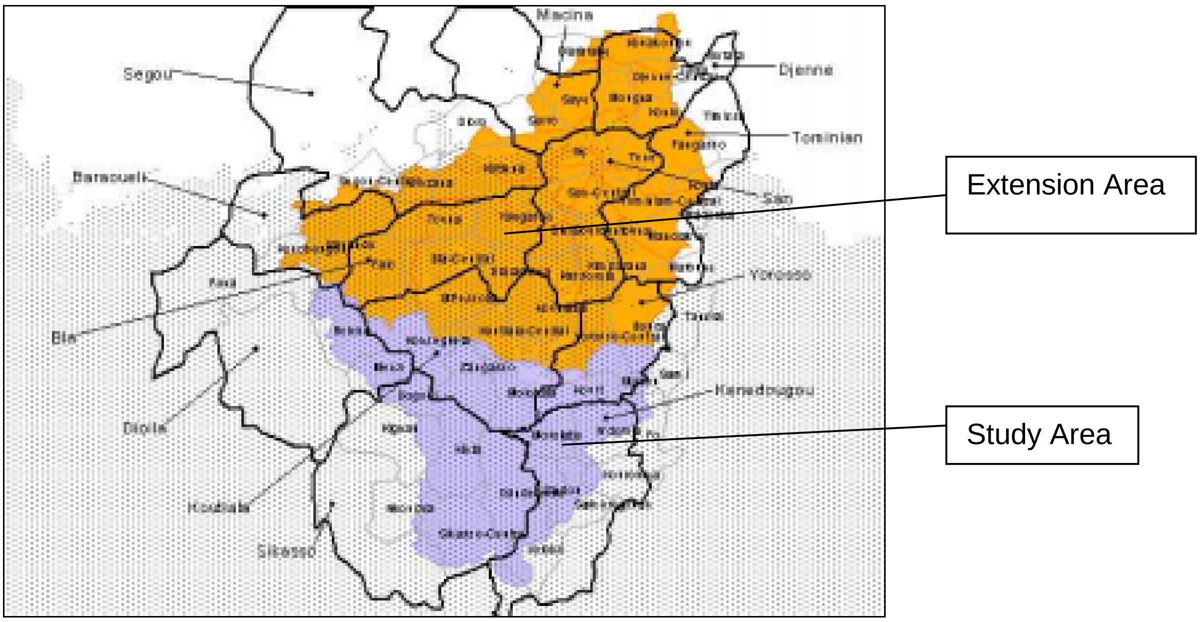
According to the criteria set up by PAAT, the cotton belt in the southern part of Mali which has a high potential for agricultural and livestock production, has been identified as a priority area for tsetse control. The development of this area is the responsibility of the "Compagnie Malienne pour le Développement des Textiles" known as CMDT. CMDT is a society owned by the Government of Mali (60%) and the "Compagnie Française pour le Développement des Textiles" known as CFDT (40%). Its primary mission was the promotion of the cotton business. Nowadays its activities have diversified and cover many other domains of socio-economic development such as food security, rural infrastructure (roads and bridges), public health, education, community organisation, etc.

The present work is a contribution to a study examining the costs and the benefits of tsetse eradication and ensuing agricultural development for a small project (17,000 sq km) at the Mali - Burkina Faso border.

Definition of the area

The area covers about just over 17,000 km² and represents the basin of the River Banifing which is a tributary of the River Bani. The area borders with Burkina Faso in the east. It is made of several territorial entities which are subject to both Government and CMDT nomenclatures. The government subdivisions are from the smallest to the biggest: arrondissement, cercle, region and those of CMDT are: secteur CMDT and region CMDT.

Figure 1 The Project Area



So the study area is made of 13 arrondissements scattered between different subdivisions as shown in table 1.

Table 1 Government and CMDT area demarcations within the study area

Arrondissement (abreviation: ar.)	Government		CMDT	
	Cercle	Region	Secteur CMDT	Region CMDT
1.Zangasso	Koutiala	Sikasso	Koutiala	Koutiala
2.Konseguela	Koutiala	Sikasso	Koutiala	Koutiala
3.Molobala	Koutiala	Sikasso	Molobala	Koutiala
4.Kouri	Yorosso	Sikasso	Yorosso	Koutiala
5.Mahou	Yorosso	Sikasso	Yorosso	Koutiala
6.Yorosso	Yorosso	Sikasso	Yorosso	Koutiala
7.Sikasso	Sikasso	Sikasso	Sikasso	Sikasso
8.Denderesso	Sikasso	Sikasso	Sikasso	Sikasso
9.Klela	Sikasso	Sikasso	Klela	Sikasso
10.Kignan	Sikasso	Sikasso	Kignan	Sikasso
11.Dogoni	Sikasso	Sikasso	Kignan	Sikasso
12.Beleko	Dioila	Koulikoro	Beleko	Fana
13.Mena	Dioila	Koulikoro	Beleko	Fana

For data collection purposes, we have summarized this figure considering the fact that some data are from the government and others from CMDT and also the fact that some entities are entirely included in the study area and others only partially (fractions):

This gives us the following figure with only seven (7) territorial entities:

CMDT region of Koutiala
1. 1/2 sector of Koutiala(=arrondissement Zangasso + arrondissement Konseguela)
2. Total sector of Molobala(=ar. Molobala)
3. 1/2 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)

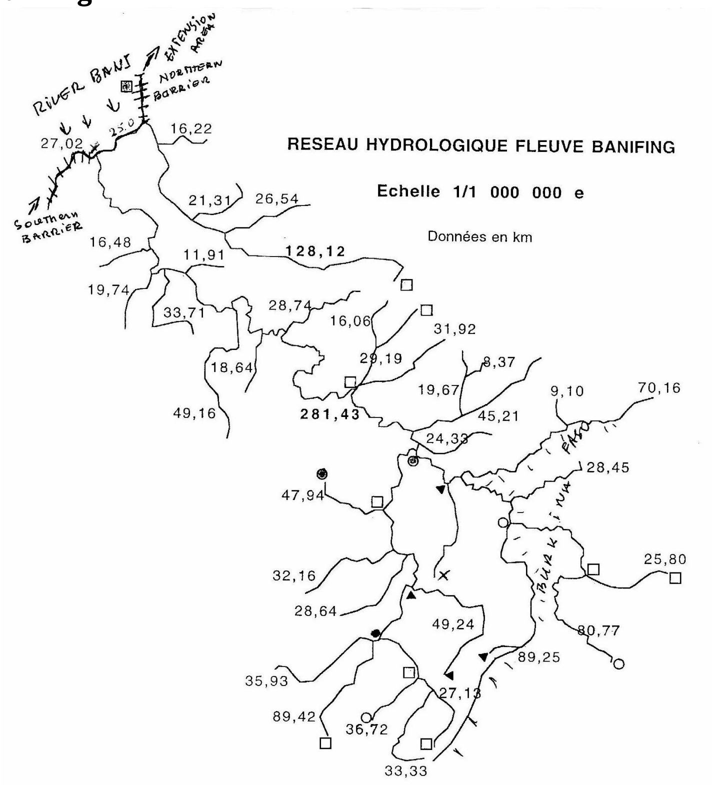
Relief:

The study area is a typical sudanian peneplain made of different types of soils(alluvio-sandy, lateritic and clayey) and sandstones. In the southern part of the area one can distinguish some escarpments of sandstones forming chains of hills disrupting the monotony of the landscape.

In its northern part (Koutiala), these sandstones called "grès koutiala" form a rocky chain going from N'Tosso (west) to Ourekela passing by Zangasso. Further north the peneplain goes down suddenly and disappears into the alluvions of the River Banifing (Monographie Cercle de Koutiala, 1997. Rapport Annuel de la Direction Régionale de la Statistique, 1986).

Hydrography:

Figure 2 The River Banifing



The main river, River Banifing, comprises two main arms, one coming from the east and serving as a natural border with Burkina Faso and the other coming from the south from inside Burkina Faso territory. The Banifing is reinforced inside the Malian territory by the River Lotio, which starts at the level of Sikasso. Several small rivers are draining rain waters from the chains of hills into the river bed of the Banifing. The length of the whole Banifing river system is about 2,000 km

Climate:

The study area is entirely inside the sub-humid zone between the isohyets 750 mm (in the north) and 1150 mm (in the south).

There are two main seasons: rainy (5-6 months) starting form May-June and dry (6-7months).starting from October-November.

The mean annual temperature is 27°C with maxima of 32 °C in April- May and minima of 24°C in December- January.

Hygrometry:

The mean relative humidity is under 50% from December - April and under 75% from June- October.

Vegetation:

The vegetation is represented by scarce forests, wooden and grass savannah and riparian vegetation. As one goes north or north-east, the vegetation becomes rare due to excessive exploitation of wood resources either for firewood or the extension of the cultivated lands. The dominant tree species are shea tree (*Vitellaria paradoxa*), Cailcédrat, *Tamarindus*, *Parkia biglobosa* (kapok).

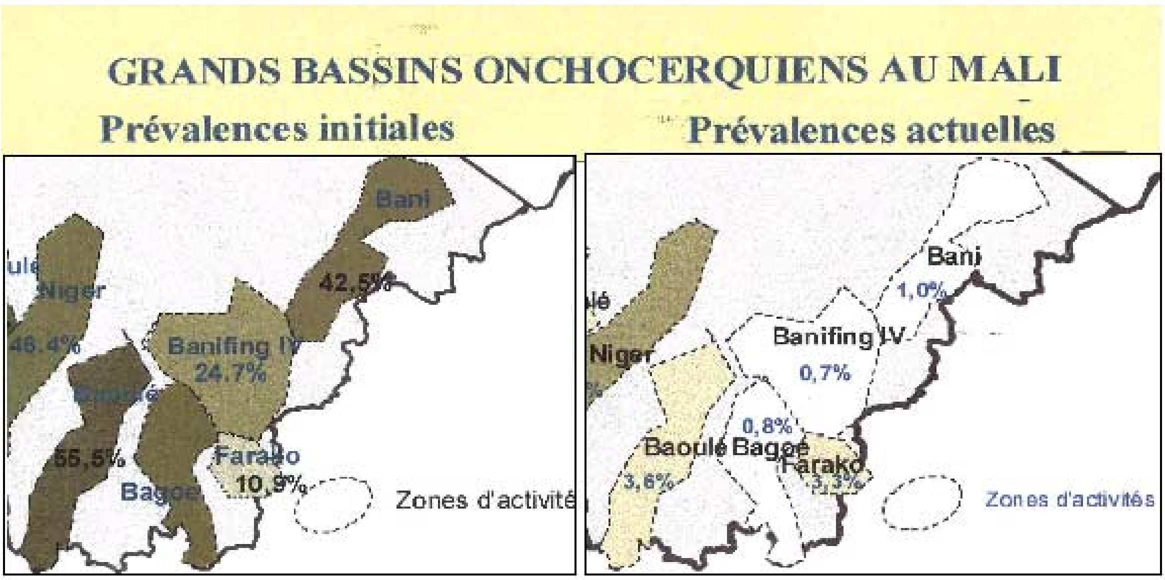
Human Factors:

The human population study area is around 769.225 people with a density of 48 hts/km2 et and rate of population increase of 3.0% per year. The study area is predominantly populated by the Minianka and the Bobo in the north and the center and by the Senoufo in the south. The Bambara and the Peuhl are present in all the parts of the study area. Except for the Fulani, the activity of all those tribes is agriculture; as for the Peuhl, pastoralism is the main activity. The cotton business has attracted many people into the area. They settle either as agropastoralists or as rented manpower. Many pastoralists also came in the area to look for better pastures and water. Some come there only temporarily while others settle for ever. Migrations out of the area do occur but young people to migrate seasonally to Cote d'Ivoire to look for small jobs. This has progressively changed attitudes and even the social structure of the area.

History of Onchocercosis and Human African Trypanosomosis (HAT)

The last cases of this disease were reported in the 1970's and are related to the southern part of the study area. Presently no new cases are being reported, despite the presence of the vector. It is generally admitted that the Onchocerciasis programme succeeded in cutting down the epidemiological chain by clearing the parasite but leaving the vector.

Figure 3 Onchocerciasis Control Campaign in SW Mali



As far as HAT is concerned, no cases have ever been officially reported and the disease seems to be completely unknown in this area. If this is not enough to rule out the presence of HAT, it may indicate at least, its extremely low incidence.

Importance of Agriculture and livestock:

The rural population get their subsistence and other resources mainly from agriculture and livestock production:

Agriculture: the main crops are: **cotton**, peanut , soya, bennissed (commercial), **corn, millet, sorghum, rice**, hungry rice (subsistence) and others like lemons, oranges, mangoes, yams, cassava, onions, peppers etc..

The cattle in the study area comprises two systems:

- sedentary herds belonging to the local populations with the vocation for draught oxen production. They also serve as "living banks" for the peasants who invest their incomes from selling agricultural products in cattle. These savings are mobilized and sold in case of bad harvests to enable the peasant to buy cereals from elsewhere or whenever more cash is needed.

- transhumant herds belonging to Sahelian cattle rearers who moved into the sub-humid areas as result of the drought in the 1970's and 1980's and have stayed ever since. There are also some seasonal transhumants.

Besides the cattle there are many other species of domestic animals: sheep, goats, poultry, donkeys and a very few horses and pigs (see table 12)

Food security

Food security is assured by the local production of subsistence products (cereals and others). For example in 2000-2001, the cereal production in all the CMDT areas was 1,132,000 tons which represents 366 kg/person, while the FAO norm is 250 kg/person. In case of cereal deficits, the sale of cotton and other commercial products combined with cattle offtakes give the peasants enough purchasing power to procure cereals from more "lucky" areas.

Crop Production

The **total land** surface of theMalian part of the study area according to our calculations (addition of all territorial units inside the study area) is **17,361 sq. km**. The non arable lands are represented by river beds, hills and mainly eroded lateritic lands.

The **arable** land covers **8,011 sq. km** (46% of the total area). The cultivated area is **3,318 sq. km** (41% of the arable area). The difference between arable and cultivated land gives a **reserve** of **4,693 sq. km**. This reserve divided by the cultivated land gives us the so-called 'agro-demographic potential' of the land which is 1.4 in our study area. This means that for each cultivated 1 sq. km there is a reserve of 1.4 sq. km. It is important to note that the norm recommended by CMDT is a reserve of 2 sq. km for each cultivated 1 sq. km. The progression of cultivated surface is about 6% yearly. There are efforts being conducted through anti-erosion measures to convert some non-arable to arable lands.

Table 2: Land cultivation 1999-2000 (data from CMDT report 2000)

Sectors	Area . sq. km Total (1)	Cultivable sq. km (2)	Cultivated sq. km (3)	PAT (4)	People (5)	Human density / sq km (6)	Cultivated sq. km/100 people (7)
1/2 koutiala:	2,097	1,034.62	533.37	0.93	67,515		0.79
Molobala	1,665	1,052.56	522.69	1.01	66,163		0.79
1/2 Yorosso	2,552	1,458.80	559.39	1.60	70,809		0.78
Total Koutiala R.	**6,314**	**3,545.98**	**1,615.45**	**1.20**	**204,487**	**32**	**0.79**
Sikasso	6,245	2,149.00	801.32	1.68	148,393		0.53
Klela	1,370	564.00	322.85	0.75	59,786		0.54
1/3 Kignan	1,537	613.00	142.68	3.3	26,422		0.54
Total Sikasso R.	**9,152**	**3,326.00**	**1,266.85**	**1.62**	**234,601**	**25.6**	**0.54**
Beleko	1,895	1,139.00	436;16	1.61	70348		0.62
Total Fana R	**1,895**	**1,139.00**	**436.16**	**1.61**	**70,348**	**37**	**0.62**
Ville (C) Sikasso					**90,000**		
Total general	**17,361**	**8,010.98**	**3,318.46**	**1.41**	**599,436**	**34.5**	**0.55**
		46.14%(1)	41.4%(2)				

PAT(4)= (2)-(3):3 = ratio of uncultivated over arable land

Table. 3: Yields and Production 1999-2000 campaign: main crops

Sectors	Corn			Millet-sorghum			Rice			Cotton		
	Cultiv. sq.km.	Yield Ton/ Sq.km	Prod. Ton	Cultiv. sq.km	Yield Ton/ sq.km	Prod.	Cultiv. Sq.km	Yield Ton/ Sq.km	Prod.	Cultiv. sq.km	Yield Ton/ sq.km	Prod. Ton
1/2 koutiala:	48.42	-	-	244.12	-	-	7.10	-	-	107.74	-	-
Molobala	45.11	-	-	210.74	-	-	1.11	-	-	105.58	-	-
1/2 Yorosso	24.33	-	-	124.89	-	-	.54	-	-	113.00	-	-
Tot Koutiala R.	**117.86**	**188.7**	**22,240**	**579.75**	**108.0**	**62,613**	**8.75**	**157.8**	**1,381**	**326.32**	**131.0**	**42,748**
Sikasso	174.39	-	-	122.45	-	-	41.34	-	-	185.91	-	-
Klela	98.08	-	-	147.45	-	-	34.16	-	-	74.90	-	-
1/3 Kignan	33.67	-	-	49.27	-	-	8.87	-	-	33.10	-	-
Tot. Sikasso R.	**306.14**	**236.6**	**72,433**	**319.19**	**103.5**	**22,686**	**85.37**	**181.8**	**15,520**	**293.91**	**139.8**	**41,089**
Beleko	94.82	-	-	150.92	-	-	24.80	-	-	124.30		-
Tot. Fana R	**94.82**	**186.6**	**17,693**	**150.92**	**103.2**	**15,575**	**24.80**	**153.2**	**3,799**	**124.30**	**130.2**	**16,184**
Total general	**518.82**	**204.0**	**112,366**	**1049.86**	**104.9**	**100,874**	**118.92**	**164.3**	**20,700**	**744.53**	**133.7**	**100,021**

Source: CMDT year 2000 Report

Table 4 Yields for the main crops over 10 years (kg/ha):

Years	Millet	Sorghum	Rice	Corn
1987/88	875	956	1248	1383
1988/89	1030	756	898	1310
1989/90	893	851	1672	1386
1990/91	1143	1024	963	1566
1991/92	1086	974	1569	1715
1992/93	618	714	1439	1026
1993/94	542	618	1591	1153
1994/95	770	679	1344	1350
1995/96	781	806	1367	1574
1996/97	988	1271	1460	1897
Average	**793**	**768**	**1232**	**1305**

Source: Recueil des Statistiques du Secteur Rural Malien, March 1998

Table 5 Prices to the Producer for 100kg in CFA(1999-2000)

Product	Millet	Sorghum	Corn	Rice(brut)	Cotton	Peanut
Price	8,000	7,400	6,900	8,900	17,000	24,900

The main cereals occupy 51 % of the cultivated land and the main cash crop (cotton) occupies 22.4% of cultivated land. It is generally accepted that the respective shares of subsistence and cash crops is 70% and 30%.

Table 6 Cotton yields from 1992 - 2000 in the sectors included in the study area (data from CMDT):

Sector/year	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Koutiala	1331	1256	1137	1280	1285	1289	1295	1301	1310	1276
Sikasso	1357	1260	1067	1367	1372	1376	1384	1391	1398	1330.22
Fana	1302	1142	1098	1280	1283	1287	1290	1294	1302	1253.11

Animal work and agricultural machinery:

Draught oxen: The total estimate of working oxen in the study area is 102,394 which represents 51,197 pairs. One pair of oxen is enough to cultivate 5 hectares. This means that for cultivating 1 sq km 20 pairs of oxen are needed. The total culivated land in 2000 was 3,318 sq km, which requires about 66,637 pairs. The apparent deficit of oxen according to that calculation may be compensated by tractors and donkeys.

Donkeys: The study area has an estimate of 25,896 donkeys. Those animals are used either for driving carts (rural transport) or for cultivation where the structure of the soil does not require oxen force.

Table 7 The number of agricultural machinery is summarized as follows:

Tractors	Ploughs	Multicultors	Drivenhoes	Harrows	Seeders	Carts	Spray pumps
91	35,499	27,033	1,660	600	17,532	21,340	29,578

INPUTS:

Artificial Fertilizers:
In the study area three types products are used:
- Complex fertilizer which contains azote, phosphorous and potassium, or its substitute called DAP (Diammonium phosphate)
  Urea
- PNT: this a local and natural product called "Phosphate Naturel de Tilemsi"

The recommended dose is 150 kg/ha of each product. Those products are sold in bags of 50 kg each.

Organic fertilizers:
They are mainly cow manure. 5 tons of manure represent 50 kg of complex artificial fertilizer.
Only 14% of all the cultivated land receive organic fertilizers and about 70% of it goes to the cotton.

Insecticides:
They are used on 100% of cotton fields and seem to be reserved to cotton.

Herbicides:
They are used on both cotton and cereals.

Plant diseases
Two main diseases are reported endemic: la phylodie et le déssechement. Some other parasitic diseases are also prevalent.

Table 8 The percentage of cultivated land receiving fertilizers and other inputs:

Culture/product	Complex Or DAP	Urea	PNT	Organic Fertilizer	Herbicides
Cotton	99.90	99.88	1.86	34.00	40.0
Corn	88.00	88.00	0.70	32.00	25.0
Millet/sorghum	13.33	18.66	0.06	4.10	3.0
Rice	32.00	34.33	0.20	3.30	3.4

The insecticides are used only for cotton. The volume used was 450 liters per sq.km of cotton occupied land which is 744.53 sq km making a total volume of 335,038 liters. The price of 1liter of insecticide is 3,190CFA.

Table 9 The prices of inputs are as follows in CFA (720CFA=1.00$ US)

Input (unit)	Price
Complex fertilizer(cotton, bag of 50kg)	9,550
Complex fertilizer(cereals,bag of 50kg)	9,250
DAP (bag of 50kg)	12,250
UREA (bag of 50kg)	7,950
PNT (bag of 50kg)	1,750
Herbicides(l), cotton, corn, rice	4,600, 3,370 6,500
Fungicides(thyrame-lindane),sachet (cotton)	290
Insecticides(l)	3,190

Table 10 Price and depreciation of agricultural machinery

	Price	Life span	Maintenance	Depreciation Rate	Depreciation/ hectare
Ploughs	25,000	12	5,832	8,587	1,484
Multicultor	36,778	15	8,011	10,776	2,195
Seeder	52,500	13	8,200	13,263	737
Cart	161,875	22	17,081	24,616	3,039
Pump insecticide	27,500	4	2,538	11,074	2,393
Pump herbicide	35,760	9	740	5,896	182
Oxen	211,250	9	6,200	32,165	8,438
Donkey	52,500	9	0	6,458	897
Total					19,365

Table 11 Manpower costs for different crops

	Cotton	Corn	Sorghum	Millet	Peanut
Man/day	128	109	110	109	204
Cost /day	514	514	514	514	514
Total cost	65,792	56,026	56,540	56,026	104,856

Table 12 An example of calculation of the cost of one hectare of cotton and cost of 1kg of cotton

Nomenclature	Value
Depreciation	19,365 CFA
Manpower(rental)	14,778 CFA
Input	54,322 CFA
Total	88,465 CFA
Production	1,337 kg
Cost of 1kg of cotton(1)	**66.1 CFA**
Manpower familial	46,967 CFA
Cost of 1kg of cotton(2)	**101.3 CFA**

Livestock Data:

The study area was populated with Ndama and Méré cattle (all humpless and trypanotolerant) until early 1960s. But in early independence years the promotion of cotton culture and the use of animal traction have encouraged the introduction of Zebu oxen into all the CMDT (cotton) areas. Rich peasants also started investing in Zebu herds as a means of producing oxen but also as a means of savings, i.e. "living banks". As a result, the local breeds of cattle were progressively absorbed by Zebu. These days more than 80% of the cattle are Zebu Peuhl (trypanosusceptible) and the rest are crosses with trypanotolerant breeds. Sheep and goats are mainly of local breeds (Djallonke sheep and dwarf goat). Poultry is also very important in the economy of this area. Its essentially made of indigenous stock but in the peri-urban areas of Sikasso and Koutiala there are some industrial farms dealing with exported breeds.

Livestock production systems:

-Semi-sedentary system: practised by the local people in the villages; the main goal of this system is the production of working oxen and meat

-Transhumant system: practised by the Peuhl whose main goal is the production of meat and milk

and more recently,

- Semi-intensive systems in the peri-urban areas of Koutiala and Sikasso: the main goal is milk but also eggs(poultry)

Tab.13. Livestock 2000

Sectors	Cattle (1)	Sheep Goats	Donkeys	Horses	Pigs	Poultry	Draught Oxen
1/2 Koutiala:	50957	49146	7459	34	479	117760	17252
Molobala	43642	25622	4023	45	823	91579	15947
1/2 Yorosso	27700	26224	2055	219	5213	88000	9420
Total Koutiala R.	**122299**	**100992**	**13537**	**298**	**6515**	**297339**	**42619**
Sikasso	50713	37600	3993	6	169	237116	18816
Klela	41173	21327	3802	6	395	106550	14878
1/3 Kignan	22492	24037	1776	7	70	55157	6952
Total Sikasso R.	**114378**	**82964**	**9571**	**19**	**634**	**398823**	**40646**
Beleko	57313	43041	2788	37	782	102513	19129
Total Fana R	**57313**	**43041**	**2788**	**37**	**782**	**102513**	**19129**
Total General	**293990**	**226997**	**25896**	**354**	**7931**	**798675**	**102394 34.83% (1)**

Source: Fiche Technique No. 23.2 , octobre 2000, CMDT.

Table 14 Herd Productivity Parameters

Parameters	Région of Sikasso agropastoral/cash culture system
Herd size	39 +/-21.7
Male	50% <1 year:: 6% 1-4 years:12% >4years:32%
Female	*(50%) <1 year:: 7% 1-4 years:17% >4years:26%
Ratio females/ male	8,46*
Age first calving(years)	4.8
Calving rate(%)	51
Calving Interval (months)	21
Total offtake(%)	3.9
Sales(%)	2.5
Herd growth(%)	2.9
Annual numeric yield(%)	6.8
Age for selling males(years)	5
Age)for selling females(years)	8
Mortality rate 0-1 year General	 16% 5.6%
Milk production % milked cows/ total herd mean production/cow(liter) length of the lactation period(j)	 15% 0.64 164

Source: Bosma et al.1996, Yaya Konaté 1997

Prices of livestock and livestock products:
Data from OMBEVI, 1995 for the town of Sikasso
Bovine meat:

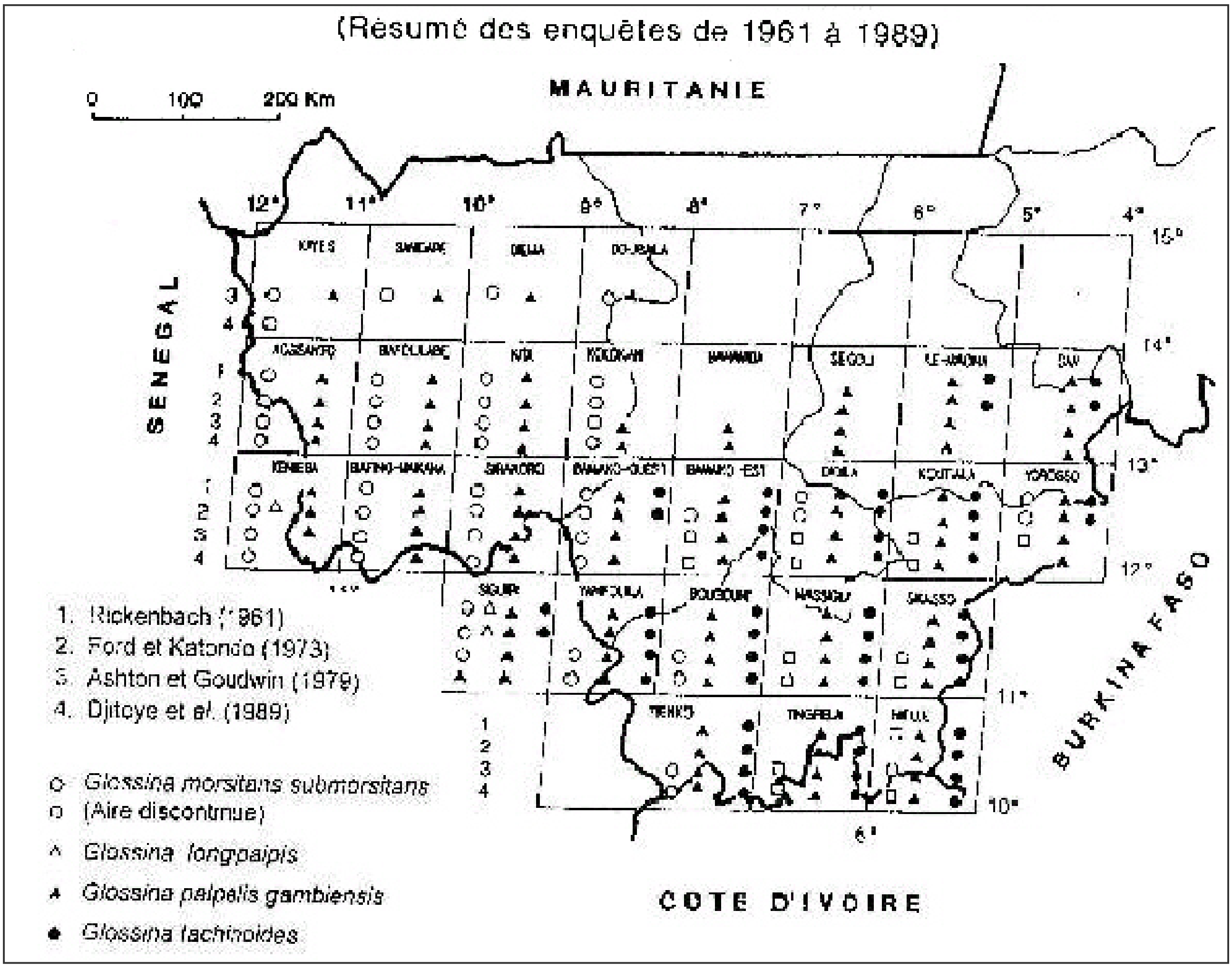
with bones:	900CFA/kg
without bones:	1,100CFA/kg
Sheep and goat meat:	900CFA/kg
Milk:	200CFA/l
Oxen:	50,000-80,000CFA
Heifers:	50,000-80,000CFA

Tsetse/Trypanosomosis Situation

Tsetse species and densities

There are two reference documents on tsetse distribution in Mali which are Ford and Katondo maps(1979) and Djitteye *et al* maps, an update of the first ones by CVL (1989). In those last maps apparent densities (DAP=number of flies/trap/day are indicated).

Figure 4 Tsetse Distribution in SW Mali



There are only two species of tsetse and both are riverine: *G.palpalis gambiensis*(mean DAP:3) and *G.tachinoides* (mean DAP:5), according to Djitteye *et al*.,1989.

As for *G. morsitans submorsitans* which used to be present in the area, it is now virtually absent as its density in the area according to the 1989 maps (see fig. 4) was very low (DAP:0.07). With the progressive occupation of the land and the destruction of the savannah, this species has regressed and should not be considered in this project.

Trypanosome Species and Prevalences:

The reference document here is a note compiling survey data from 1977 -1987 and prepared in 1990 by Diall et al. According to those surveys in this area there are two major species which are: *T.congolense* and *T.vivax*. The prevalences ranged from 0 to 15%. *T.brucei* is present but rarely detected and has less impact on cattle than the first two species.

Animal Hosts:

The study area was populated with Ndama and Méré cattle (all humpless and trypanotolerant) until early 1960s. But in early independence years the promotion of cotton culture and the use of animal traction have encouraged the introduction of Zebu oxen into all the CMDT (cotton) areas. Rich peasants also started investing in Zebu herds as a means of producing oxen but also as a mean of saving "live banks". This way, the local breeds of cattle were progressively absorbed by Zebu. These days more than 80% of the cattle are Zebu Peuhl (trypanosusceptible) and the rest are crosses with trypanotolerant breeds. Sheep and goats are mainly of local breeds (Diallonke sheep and dwarf goat).

The pathologic and economic importance of the disease

There is a strong people's belief that trypanosomosis was introduced in the area with the Zebu cattle and is related to the use of animals in cultivation. This is to say that the disease became noticeable mainly when the genotype of cattle shifted towards the Zebu breed. In the early 1980's outbreaks of trypanosomosis left many villages without working oxen. This was perceived as a big disaster in the region. In the two villages selected for parasitological investigations 65% of the cattle were found to be infected with trypanosomosis. The diagnosis was confirmed by the chemoprophylactic programme which was implemented in these villages and which stopped the problem temporarily.

Tsetse Eradication Project Outline

The Project Strategy:

From a theoretical point of view trypanosomosis control is based on parasite control (drugs), tsetse control and exploiting trypanotolerance, or any combination of those methods. In the study area the reintroduction of Ndama cattle would not be acceptable to the people. A large scale programme based on chemotherapy is expensive and may be dangerous in terms of the chemoresistance risk as its not easy to achieve a rational use of those drugs in the absence of precise diagnosis in field situations.

So the best technically feasible and probably the most cost-effective approach would be tsetse control.

The control of tsetse in this area should be resumed for the control of riverine flies exclusively.

Therefore we are dealing only with linear fly habitat which corresponds to the network of the **River Banifing**. The length of this network inside Malian territory is 1,428 km rounded to 1,500 km. The control of the tsetse in this area should aim to eradicate the tsetse populations by SIT after a population suppression phase using targets and insecticide-treated animals. The phases of this control programme would be as follows:

Survey and Planning Phase: Baseline assessments through parasitological and entomological surveys. This will help generate up-to-date baseline data on tsetse distribution and densities and on trypanosomosis prevalence (Cost - $100.000).

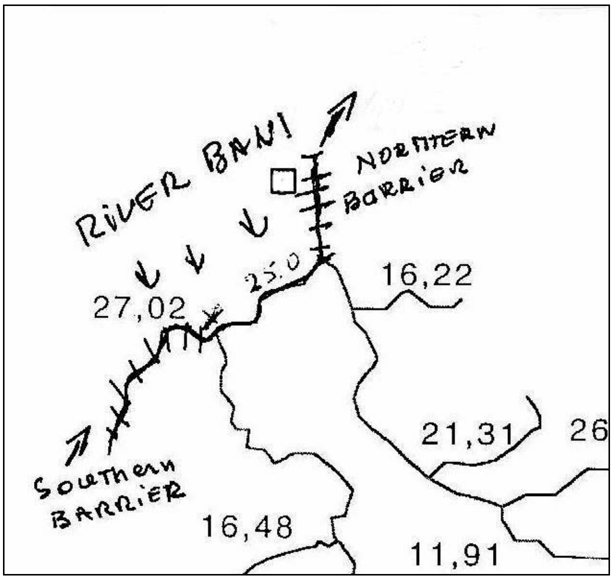
Phase 1(years 1 and 2): Population suppression using targets and insecticide treated animals.

Use of targets alongside all the river network (on both sides) in dry seasons as follows:

- end of rainy season (end of October): first deployment of targets at intervals of 100m (50m for the barriers)
- end of January: re-impregnation and redeployment of targets in the same condition as the initial one
- end of May: withdrawal of targets on the rivers for storage until the end of the rains in October (and so on); but the barrier targets should be left in place where possible.

The linear distance to be treated will be rounded up to 2,000 km to take into account the Burkina side of river. With 100m intervals we need 10 targets per km. As both sides are to be dealt with we will need in total 2,000 x 10 x 2= 40,000 targets. The total size of the area being 20,000 km^2 this will make it equivalent to 2 targets/km^2.

Figure 5 Location of Barriers against Re-invasion



The barrier against re-invasion will be 100 km length on the river Bani with a southern portion and a northern portion as shown in figure 1. As each and every river will be treated from its source there is no need of barriers on those ends.

- Use of insecticide-treated cattle: this is done only in year one in the rainy season before the SIT. It helps kill both tsetse and ticks, therefore cattle owners may be willing to contribute both financially and physically. The minimum cattle density required for this technique to be effective is 15 cattle/km^2. This almost corresponds to the cattle density in the studied area. The insecticide to use is Deltamethrine Pour-on, Spot-on or Butox Pour-on. Two treatments should be done at 6 weeks intervals.

Phase 2 (years 2 and 3): Use of SIT during the rainy seasons in years 2 and 3.
Sterile males of both species (*G.palpalis gambiensis and G.tachinoides*) will be produced at CIRDES in Bobo Dioulasso. We can consider the release dose of 75 flies/km^2/week for each species over a period of 16 weeks.

The distance between Bobo-Dioulasso and Sikasso the main town of the area is about 200 km (2-3 hours drive). Sikasso will have a real airport by the end of 2001, thus allowing closer aerial support for the project.

Monitoring: During phases 1 and 2 (years 1, 2 and 3) tsetse and parasite monitoring will also be conducted in some selected villages or points to assess the efficacy of the control operations.

Project Budget Outline

The Costs

1. Project Planning: Costs of initial surveys and project planning: **100,000$**

2. Suppression:

- Costs of purchase and deployment of targets :
  40,000 targets x 15$ = **600,000 $**

- Costs of servicing those targets (6 times +replacement of 20% of them)
  60% of (1) = **360,000$**

- Costs of 2 insecticide treatments of cattle (15cattle/km^2):
  15cattle/km^2 x 2 x 20,000 km^2 = 600,000 treated cattle
  600,000 x 0.75$/ animal = **450,000 $**

3. Eradication

- Costs of SIT(years 2 and 3): 2,000 sq km x 800$/sq km = **1,600,000 $**

4. Protection

- Costs of barrier establishment and maintenance(100 km over 20 years)

  400 targets @ 20% of (1)+(2) = **128,000 $**

5. Overheads: 25% of above total = 779,500**$**

6. Contingency: 25% of above total = 779,500**$**

Summary:

Costs of pre-project surveys and project planning:	100,000$	
Costs of suppression:	1,410,000$	
Costs of eradication	1,600,000$	
Costs of protecting against re-invasion	128,000$	3,238,000
Overheads (25% of project costs)	809,500$	
Contingency: (25% of project costs)	809,500$	
Total:	**4,857,000$**	
Equivalent to	$ 240/km^2	

The Impact of Tsetse and Trypanosomosis Eradication

In this study area, the human population pressure is mainly high in the north where the degradation of natural resources is therefore the most advanced. The pressure on land is driving the livestock production towards intensification. In both agriculture and livestock, the efforts to increase the productivity should be combined with natural resources conservation measures in order to limit erosion. The erosion problem is not fully perceived by the peasants and so the anti-erosive methods need to be less demanding in terms of labour, money, and investments in order to be adopted.

The tsetse eradication project as outlined will likely increase the productivity of small milk farms around the cities and reduce the mortality rate in both village and pastoral herds. These pastoral herds will be pushed towards the south where pressure on land is less important or towards marginal lands unsuitable for agriculture.

This study area is not meant to support huge number of herds so what is needed here is better individual productivity and higher herd offtake

The Benefits:*(as summarized in DFID doc)*

The benefits from tsetse eradication in this area comprise normally:

Direct benefits:

1. improvement in milk and meat production from the present cattle herd

2. increase in production resulting from a combination of enlarged cattle herds and higher offtakes

3. improve in the productivity of other animals

Indirect benefits:

1. increase in productivity resulting from mixed farming and better application of draught power

2. savings on the costs of trypanocidal drugs

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Complement on the Burkina Faso Portion:

The Burkina portion is 3152 km² and comprises partially 4 departments already described in the Burkina study and with different rate of inclusion into study area no. 1 (Mali). In the main report these data from these areas has been incorporated extrapolating the Malian data proportionately. This is considered sufficiently accurate for this study as there is a high degree of similarity throughout the study area.

Data on agriculture, livestock, human population and the physical environment are provided in the Study Area 2.

The costs of the tsetse control in the Burkina Faso portion have been included in the calculations above. The benefits of the project have been calculated in the main report by extrapolating the Mali data.

Annex 2 Study Area 2 (Burkina Faso) Report

Programme Against African Trypanosomosis

Options For Tsetse Fly Eradication in the Moist Savannah Zone of West Africa: Technical and Economic Feasibility Study, Phase 1 (Burkina Faso)

Zowinde Koudougou

March 2001

Study Area 2 (Burkina Faso) Report

1. THE STUDY AREA

Table 1 Burkina Faso Study Area No.2 – Administrative Areas

Province	Departement			Human Population 1985	Cattle Population	Proportion within Study Area (%)
	Name	Ref. No.	Size (Sq km)			
Houet	Badema	21	939	30936	3403	100
	Bama	22	1325	36305	7261	100
	Bobo-Dioulasso	24	2540	62715	6899	60
	Fo	25	1174	47461	9967	90
	Kourignon	26	559	9726	1070	100
	Satiri	28	1169	25837	2584	80
	Toussiana	29	557	12382	0	40
Kenedougou	Djigouera	30	585	14242	5839	100
	Koloko	31	1248	23835	1907	50
	Kourouma	32	978	13560	2848	80
	N'dorola	34	1455	26743	8023	40
	Orodara	35	427	18326	3848	100
	Samorogouan	38	1132	13193	1451	60
Kossi	Balave	40	521	9246	2866	100
	Dokui	44	782	22543	4734	100
	Kouka	47	779	35372	7428	100
	Sami	50	686	5798	1739	90
	Sanaba	51	917	20388	4078	100
	Solenzo	52	1952	71582	15032	100
	Tansila	53	1100	20646	4129	90
Mou Houn	Ouarkoye	57	1073	22914	13978	60
	Total		**21898**	**543750**	**109084**	

Figure 1 Departements within the Study Area with Reference Nos. (see table 1)

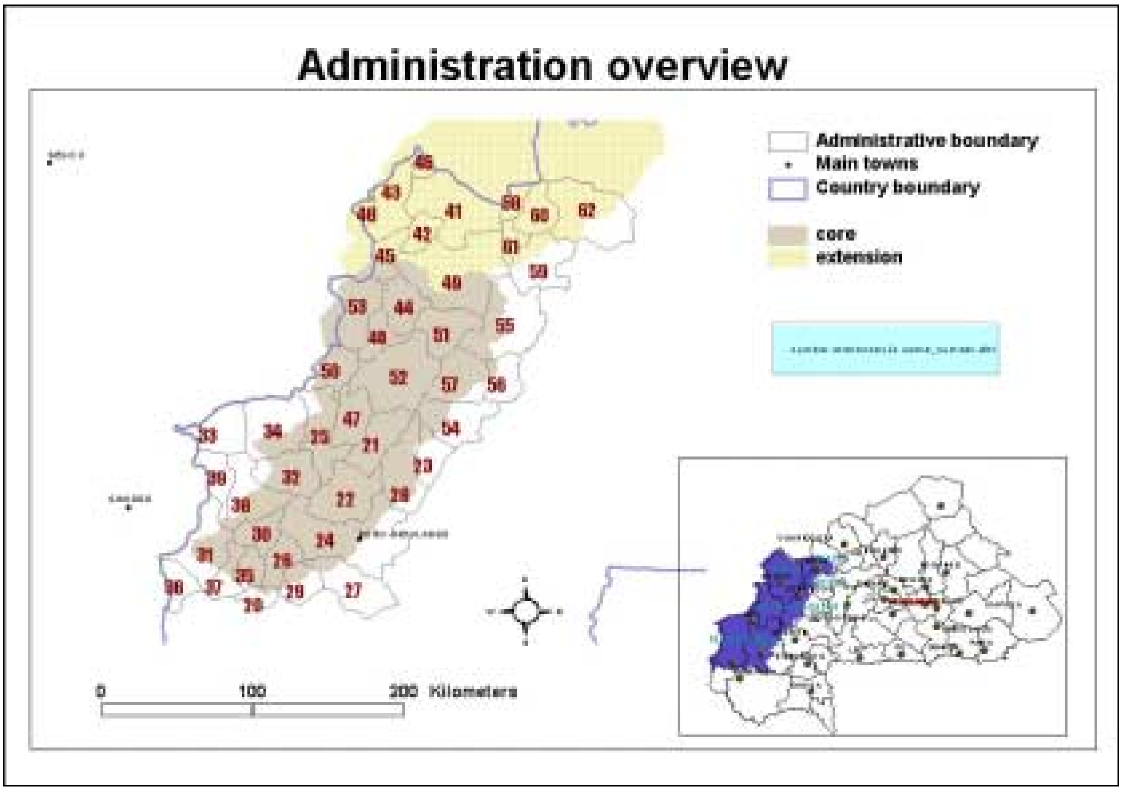


Figure 2 Provinces within the Study Area

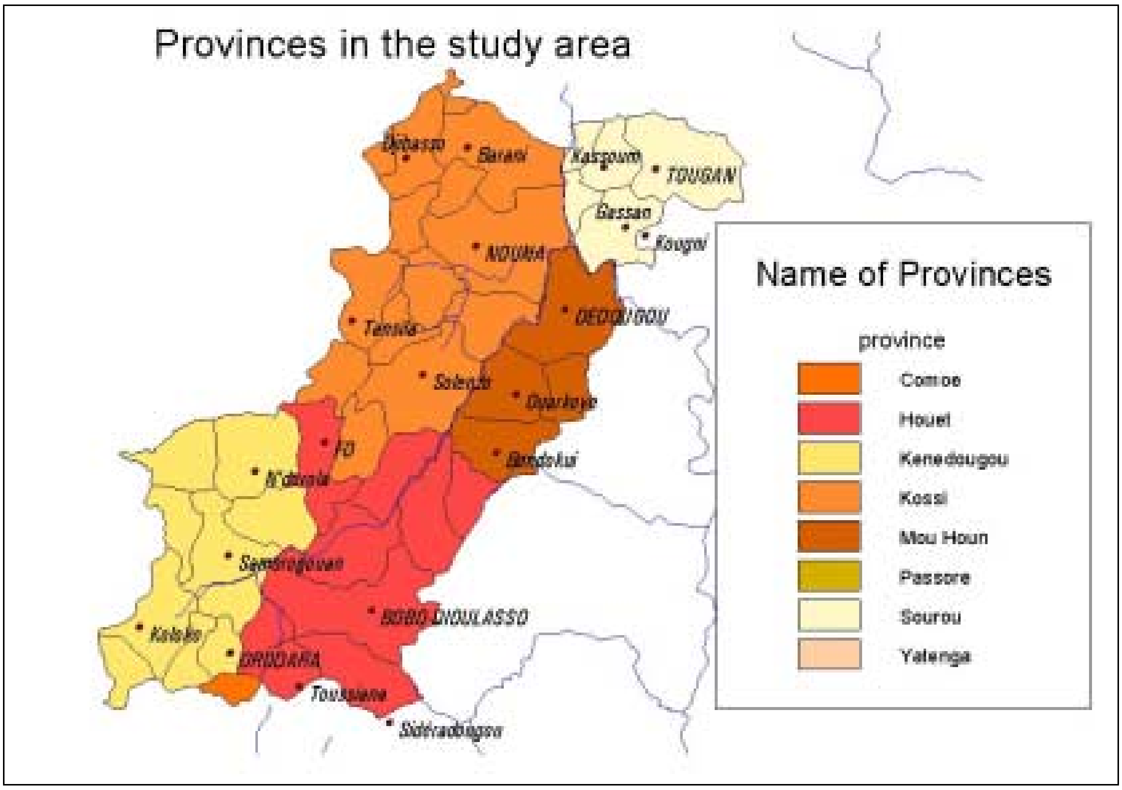


Table 2 Human Population Profile by Departement

Province / Département	Ref no.	Size Sq km	Population 1985	% in study area	% female	Family size	% in agriculture	No. of active age
Houet								
Badema	21	939	30936	100	51	9.8	56.9	5.69
Bama	22	1325	36305	100	49	10.2	58.7	5.87
Bobo-Dioulasso	24	2540	62715	60	48	9.5	51.3	5.13
Fo	25	1174	47461	90	47	9.0	50.9	5.09
Kourignon	26	559	9726	100	43	8.8	51.5	5.15
Satiri	28	1169	25837	80	50	10.3	50.2	5.02
Toussiana	29	557	12382	40	54	8.1	40.9	4.09
Kenedougo								
Djigouera	30	585	14242	100	48	12.3	66.7	6.67
Koloko	31	1248	23835	50	49	14.5	87.9	8.79
Kourouma	32	978	13560	80	48	11.4	49.4	4.94
N'dorola	34	1455	26743	40	48	11.8	46.5	4.65
Orodara	35	427	18326	100	45	11.3	64.7	6.47
Samorogouan	38	1132	13193	60	49	11.1	59.0	5.90
Kossi								
Balave	40	521	9246	100	51	7.9	43.8	4.38
Dokui	44	782	22543	100	51	9.4	56.6	5.66
Kouka	47	779	35372	100	48	10.9	61.4	6.14
Sami	50	686	5798	90	44	8.7	56.3	5.63
Sanaba	51	917	20388	100	48	10.3	63.9	6.39
Solenzo	52	1952	71582	100	51	10.4	61.9	6.19
Tansila	53	1100	20646	90	53	9.5	56.5	5.65
Mou Houn								
Ouarkoye	57	1073	22914	60	47	9.8	54.5	5.45

To refine the actual study area, the "small shadow project 2" has been overlaid by the tsetse fly distribution map. We get for the present study a new limit (See maps) corresponding better to the actual area. In order to collect data the smallest administrative units are used: "Department" (the large administrative unit is "Province"). These administrative units have been changing; so there are two maps covering the same exact study area which have a different number of "Departments" and different names. Some data are collected based on both delineations. Most existing data are in the oldest delineation.

2. HOUSEHOLD INCOME

The household is a socio-economical unit including the members of the same family or not living in the same compound, sharing the same resources under the responsibility of a **head of household (hH). The Household income** is a monetary and non-monetary income used by all the members of the household, i.e.

Global income = Monetary income + Non-monetary income

2.1 Structure of Global income

The average estimate of a household is 7.8 persons.
An average income of a household is 532 045 FCFA per year; that is to say 68.210 FCFA a person.

Table 3 : Structure of Global income per year.

Type of income	Amount In FCFA	%
Non-monetary	268 150	50.4
Monetary	263 895	49.6
Total	532 045	100.0

2.1 Structure of monetary income.

Table 4 : Structure of monetary income

Origin	Amount CFA	%
Crop, Livestock, fruit picking	79 960	30.3
Crop:	49 612	18.8
cotton	21 639	8.2
millet-sorghum	5 014	1.9
groundnut	6 861	2.6
Market gardening	5 805	2.2
fruit picking	2 111	0.8
Livestock	22 431	8.5
Business and non agricultural activities	98 169	37.2
Salaries and non agricultural activities	34 306	13.0
Gifts etc..	51 197	19.4
Total	263 895	100.0

2.2 Detailed structure of monetary income.

Table 5: Agricultural income structure (monetary income)

Origin	%	
CROP		62.0
Goundnuts	8.5	
Cotton	27.2	
Millet-sorghum	6.4	
Rice	10.7	
Maize	5.0	
Niébé	1.5	
Fonio	0.2	
Sesame	0.9	
Other crops	1.7	
MARKET GARDEN PRODUCE		7.2
Market gardening	5.3	
Fruit gardening	1.9	
FRUIT PICKING PRODUCE		2.8
Shea	1.1	
Néré	0.5	
Others	1.2	
LIVESTOCK PRODUCE		28.0
Cattle sale	16.6	
Goat sale	5.2	
Sheep sale	3.3	
Pig sale	1.0	
Other animals sale	2.0	
TOTAL		100.0

2.3 Detailed average monetary income

Table 6 : Structure of detailed average monetary income according to the sex of the head of the household (%).

	Male	Female	Total
CROPS	61.9	66.4	62.0
Groundnuts	8.5	16.1	8.5
Cotton	27.2	20.0	27.1
Millet-sorghum	6.2	19.2	6.4
Rice	10.8	4.0	10.7
Maize	5.1	1.7	5.0
Niébé	1.5	2.9	1.5
Fonio	0.2	0.0	0.2
Sesame	0.9	0.2	0.9
Other crops	1.6	2.2	1.7
MARKET GARDENING PRODUCE	7.2	2.6	7.2
Market gardening	5.4	2.5	5.3
Fruit growing	1.9	0.1	1.9
FRUIT PICKING PRODUCE	2.8	2.4	2.8
Shea	1.1	1.6	1.1
Néré and derived produce	0.5	0.3	0.5
Other fruit picking produce	1.2	0.5	1.2
LIVESTOCK PRODUCE	28.0	28.7	28.0
Cattle sale	16.6	11.0	16.6
Goat sale	5.2	6.6	5.2
Sheep sale	3.3	5.1	3.3
Pig sale	0.9	5.2	1.0
Sale of other animals	2.0	0.6	2.0
TOTAL	100.0	100.0	100.0

2.4 Structure of food related expenses

Table 7 : Structure of the household food expenses

OUTCOME	Annual average consumption expenses (CFA)	Food consumption shares (%)	Budget shares (%)	Self consumption rate (%)
Cereal, products	101.214	41.6	9.7	66.2
Leguminous (niébé)	7.856	3.2	0.5	73.5
Meat, fish, eggs	23.466	9.6	5.5	10.5
Milk-dairy	3.940	1.6	0.7	36.5
Oil and fat content	15.766	6.5	2.7	36.2
Fruit and vegetables	15.680	6.4	2.7	33.7
Sugar	5.770	2.4	1.5	0.3
Coffee, tea, cola	7.140	2.9	1.9	1.0
Drinks	10.567	4.3	2.5	10.0
Tobacco	6.773	2.8	1.7	3.3
Others	45.313	18.6	9.8	17.6
TOTAL FOOD	243 488	100.0	38.7	40.1

Table 8 : Structure of total expenses relating to cereal products

	Annual average consumption per household en CFAF	Share (%)	Self consumption rate
Rice	22.093	21.8	27.1
Millet-sorghum	58.220	57.6	84.8
Maize	15.896	15.7	68.7
Flour	628	0.6	15.6
Bread	4.376	4.3	1.8
TOTAL	101.214	100.0	68.5

3. Poverty

The following data of the current study are taken from two detailed national inquiries on household life conditions: the first inquiry was carried out from October 1994 to January 1995 and the second one from May to August 1998. Both used a standard model of questionnaire (Marchant *et al* 1987) with very slight differences. The first inquiry collected data from 8642 households while the second inquiry collected data from only 8478 households.

The main element that makes the difference between the two origins of the data is the period of observation. The second priority inquiry took place from May to August, a period during which food provision in rural area is not easy and a crucial issue.

The above difference implies some differences as far as household expenses are concerned. The equipment and materials are not affected by these differences, consequently, the analysis is based on these elements.

3.1 How to measure the well-being state: building the indicators

It is very difficult and complex to define, measure and estimate poverty very precisely. What appears in the publications is that poverty implies human well-being. Building an indicator of well-being will allow comparisons between people in terms of satisfaction of their needs. There are two categories of people: poor people, i.e. those who cannot reach the indicator of well-being and non-poor people, i.e. those beyond this indicator.

As explained previously, it is difficult to measure human well-being because of subjective and multi-dimensional items such as non-quantifiable components and the usefulness of a person. Nevertheless, it is generally acknowedged that individual well-being can be represented by a monetary unit. Considering this complexity, it is suggested that the unit of measurement of human well being the quintile :

Table 9 : The quintile of individual life styles

Quintiles	Total average expenses per capita and per year (CFA F)	Life style
1st quintile	Less than 49 706	Extremely poor
2nd quintile	From 49 706 to less than 68 220	Moderately poor
3rd quintile	From 68 220 to less than 91 530	Acceptable life style
4th quintile	From 91 530 to less than 140 331	Not poor
5th quintile	140 331 and more	Rich

Annual rate of population increase: 2,37%

Having established parameters for measurement, the following issues can be examined:

- What are the characteristics of people who move from the state of poverty to the one of non poverty with special reference to the socio-economical group, sex, etc. ?.

- What are the specific influences and contribution of poor and non-poor people on the global characteristics of the population ?

Figure 3 Soil Suitability in in the Study Area

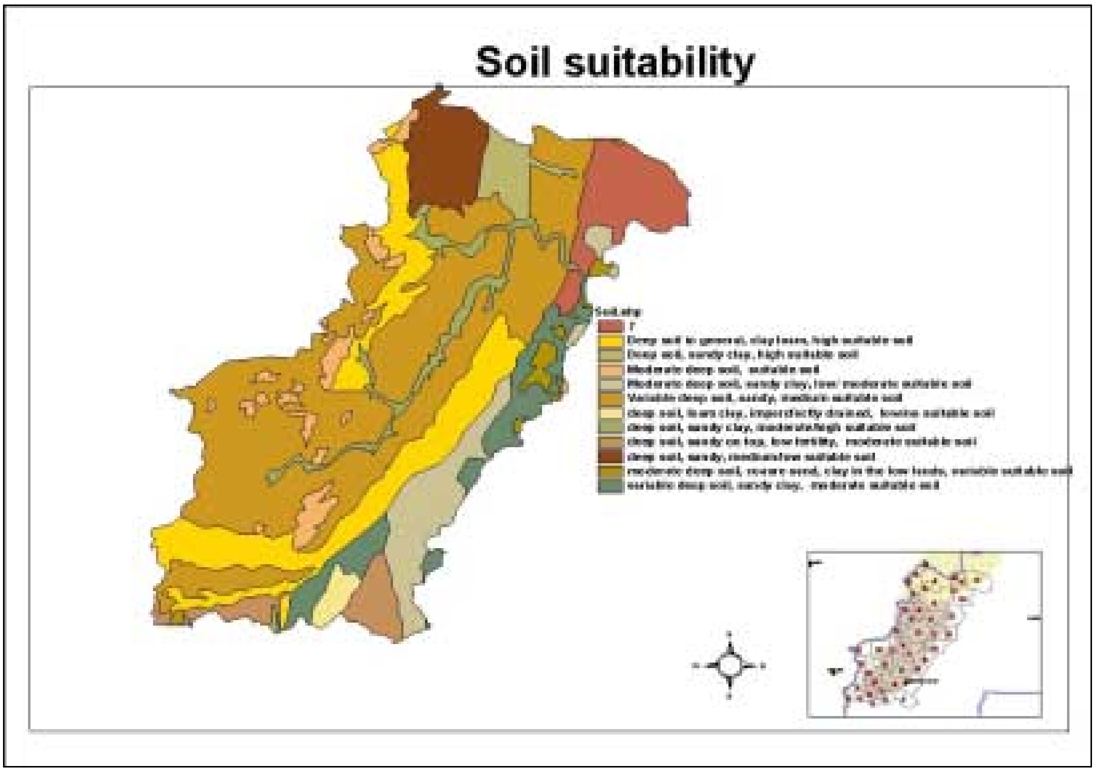


Figure 4 Vegetation in the Study Area

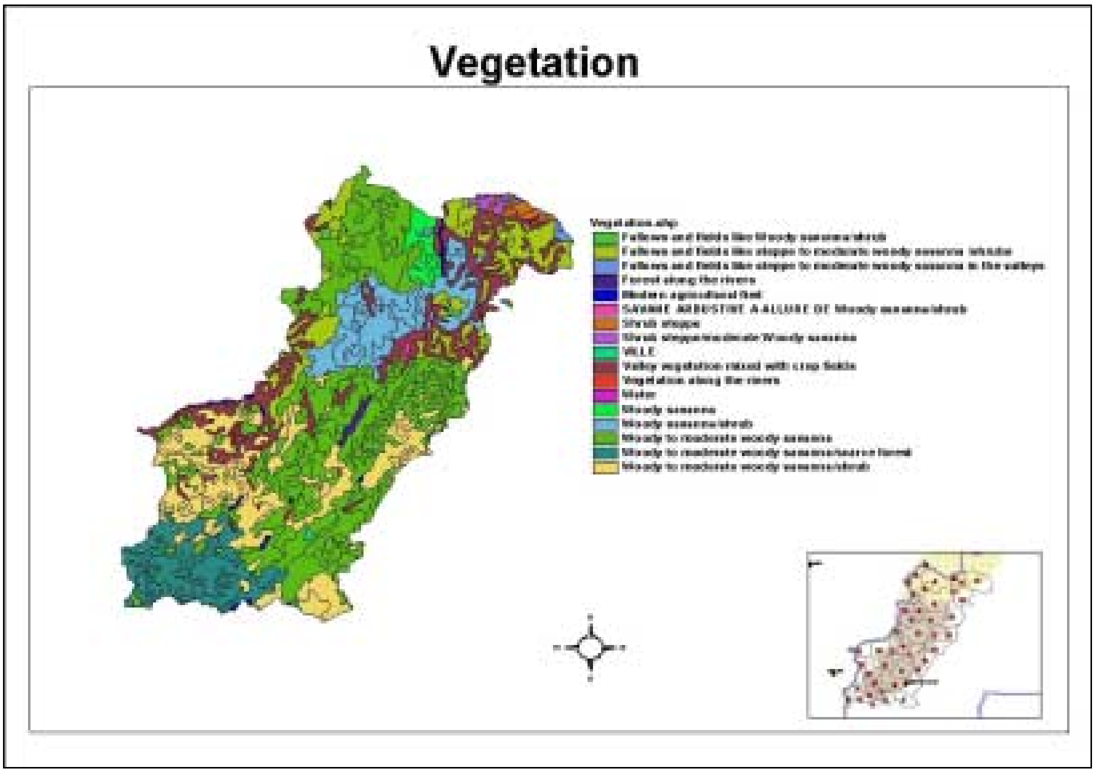


Table 10 Livestock Profile by Departement

Province/ Departement	Ref. No.	Sq km	% in study area	No.Livestock in Study Area ???? Cattle	Sheep	Goats
Houet						
Badema	21	939	100	3403	23202	6497
Bama	22	1325	100	7261	35942	10892
Bobo-Dioulasso	24	2540	60	6899	29476	11289
Fo	25	1174	90	9967	61699	4271
Kourignon	26	559	100	1070	8170	1070
Satiri	28	1169	80	2584	14985	4392
Toussiana	29	557	40	0	1486	3343
Kenedougou						
Djigouera	30	585	100	5839	7263	29623
Koloko	31	1248	50	1907	1192	5005
Kourouma	32	978	80	2848	4339	9492
N'dorola	34	1455	40	8023	4279	14709
Orodara	35	427	100	3848	5498	9163
Samorogouan	38	1132	60	1451	1715	5013
Kossi						
Balave	40	521	100	2866	6195	14794
Dokui	44	782	100	4734	11497	18034
Kouka	47	779	100	7428	14503	46691
Sami	50	686	90	1739	3247	52182
Sanaba	51	917	100	4078	4078	23446
Solenzo	52	1952	100	15032	35791	85183
Tansila	53	1100	90	4129	1032	24775
Mou Houn						
Ouarkoye	57	1073	60	13978	21768	11686
	Total in Study Area			**109084**	**297357**	**391550**

Figure 5 Distribution of Cattle, Goats and Ploughs

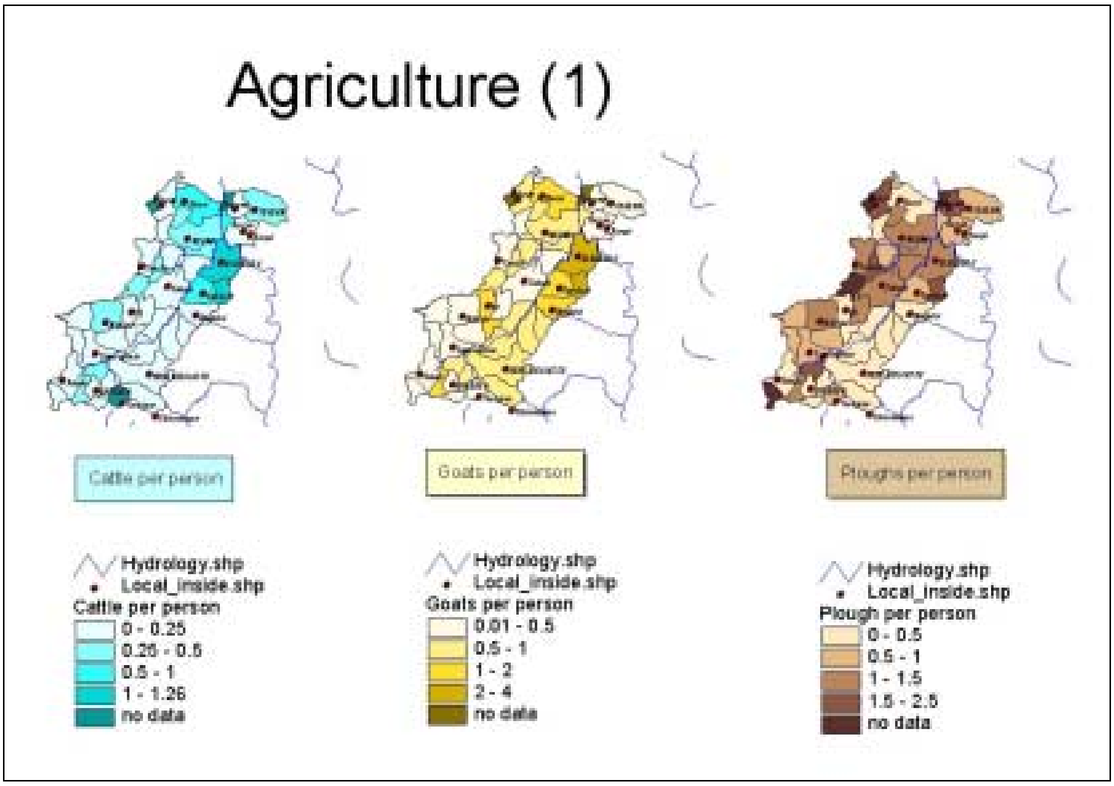


Figure 6 Agro-ecological Zones

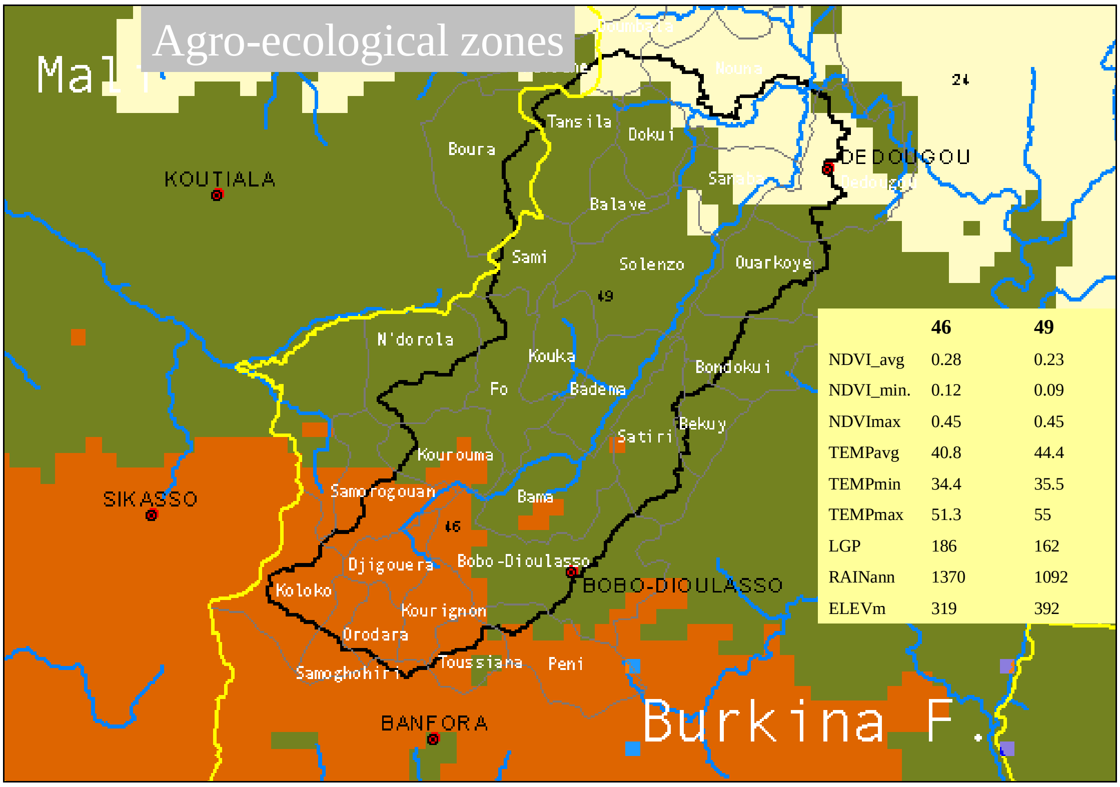


Table 11 Areas of Main Crops Cultivated

Province/ Département	Ref. No.	Total Size Sq km	Millet ha	Sorghum ha	Maize ha	Cash Crops ha	Total Area Cultivated
Houet							
Badema	21	939	670	1169	2399	960	5198
Bama	22	1325	1300	1254	2050	562*	5166
Bobo-Dioulasso	24	2540	715	992	2609	484	4800
Fo	25	1174	1031	1215	2274	953	5473
Kourignon	26	559	1040	1049	1093	1110	4292
Satiri	28	1169	740	1431	2712	1029	5912
Toussiana	29	557	567	466	1217	320	2570
Kenedougou							
Djigouera	30	585	720	772	2852	480	4824
Koloko	31	1248	1000	719	1709	902	4330
Kourouma	32	978	915*	992	2596	460	4963
N'dorola	34	1455	1500	1183	2896	253	5832
Orodara	35	427	260	705	1420	293	2678
Samorogouan	38	1132	849	659	1782	694*	3984
Kossi							
Balave	40	521	1260	1674	1773	549	5256
Dokui	44	782	1245	905	1585	465	4200
Kouka	47	779	720	1317	2399	722	5158
Sami	50	686					
Sanaba	51	917	1018	1300	2259	760	5337
Solenzo	52	1952	952	1385	2523	1070	5930
Tansila	53	1100	603	974	1414	481	3472
Mou Houn							
Ouarkoye	57	1073	691	1120	1533	367*	3711
Areas Cultivated		-	17796	21281	41095	12914	93086
Percentage		4.3%[1]	19%[2]	23%[2]	44%[2]	14%[2]	-

* Estimate [1] Of total Area [2] Of Cropped Area

Table 12 Yields of Main Crops

Province / Departement	**Ref. No.**	**Yield (kg/ha)**			
		Millet	**Sorghum**	**Maize**	**Cash Crops**
Houet					
Badema	21	670	1169	2399	960
Bama	22	1300	1254	2050	*
Bobo-Dioulasso	24	715	992	2609	484
Fo	25	1031	1215	2274	*
Kourignon	26	1040	1049	1093	1110
Satiri	28	740	1431	2712	*
Toussiana	29	567	466	1217	320
Kenedougou					
Djigouera	30	720	772	2852	480
Koloko	31	1000	719	1709	902
Kourouma	32	*	992	2596	460
N'dorola	34	1500	1183	2896	253
Orodara	35	260	705	1420	293
Samoghohiri	37	536	448	2160	340
Kossi					
Balave	40	1260	1674	1773	549
Dokui	44	1245	905	1585	465
Kouka	47	720	1317	2399	722
Sami	50	*	*	*	*
Sanaba	51	1018	1300	2259	760
Solenzo	52	952	1385	2523	1070
Tansila	53	603	974	1414	481
Mou Houn					
Ouarkoye	57	691	1120	1533	*
Average Yield		**882**	**1050**	**2102**	**603**

* No data available

Figure 6 Crop Yields by Departement

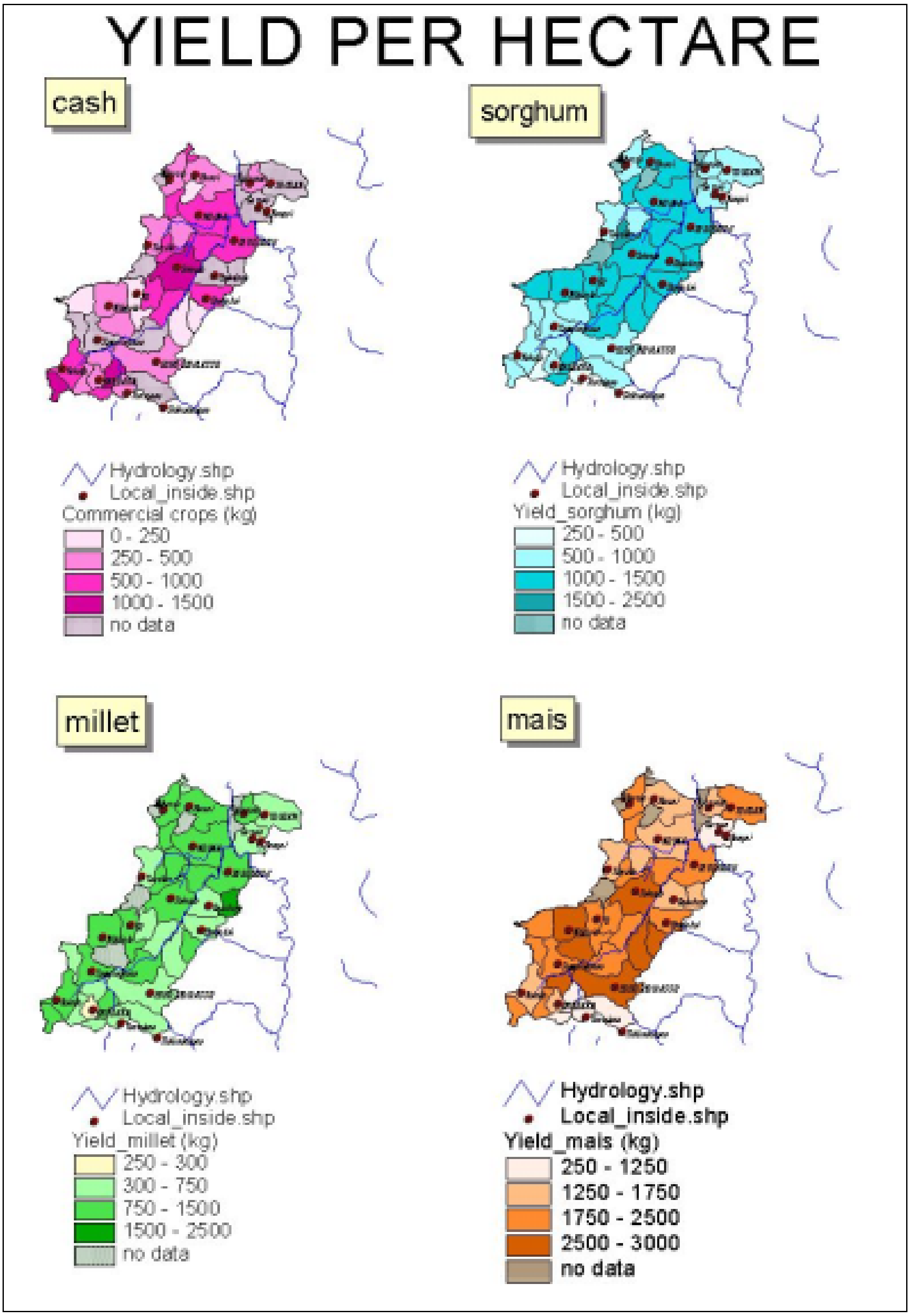


Table 13 Cultivated Area per Person

Province / Departement	Ref. No.	Sq km	Cultivated Area per Person (ha)					
			Sorghum	Millet	Maize	Cash Crops	Other	Total
Houet								
Badema	21	939	0.21	0.09	0.10	0.11	0.02	**0.53**
Bama	22	1325	0.20	0.22	0.10	0.03	0.03	**0.58**
Bobo-Dioulasso	24	2540	0.20	0.21	0.09	0.08	0.02	**0.60**
Fo	25	1174	0.21	0.19	0.11	0.11	0.03	**0.65**
Kourignon	26	559	0.20	0.15	0.02	0.09	0.10	**0.56**
Satiri	28	1169	0.20	0.16	0.11	0.11	0.03	**0.61**
Toussiana	29	557	0.10	0.14	0.04	0.10	0.10	**0.48**
Kenedougou								
Djigouera	30	585	0.11	0.15	0.09	0.20	0.01	**0.56**
Koloko	31	1248	0.10	0.16	0.11	0.10	0.08	**0.55**
Kourouma	32	978	0.11	0.01	0.30	0.20	0.02	**0.64**
N'dorola	34	1455	0.10	0.07	0.30	0.20	0.01	**0.68**
Orodara	35	427	0.11	0.13	0.10	0.11	0.10	**0.55**
Samoghohiri	37	474	0.11	0.16	0.10	0.03	0.11	**0.51**
Samorogouan	38	1132	0.20	0.12	0.30	0.31	0.02	**0.95**
Kossi								
Balave	40	521	0.20	0.24	0.10	0.06	0.03	**0.63**
Dokui	44	782	0.30	0.42	0.05	0.10	0.01	**0.88**
Kouka	47	779	0.30	0.13	0.09	0.04	0.02	**0.58**
Sami	50	686	*	*	*	*	*	
Sanaba	51	917	0.40	0.17	0.10	0.10	0.01	**0.78**
Solenzo	52	1952	0.30	0.11	0.11	0.11	0.02	**0.65**
Tansila	53	1100	0.21	0.15	0.02	0.11	0.01	**0.50**
Mou Houn								
Ouarkoye	57	1073	0.40	0.21	0.07	0.05	0.02	**0.75**

* No data available

Figure 7 Crop Areas Cultivated Per Person

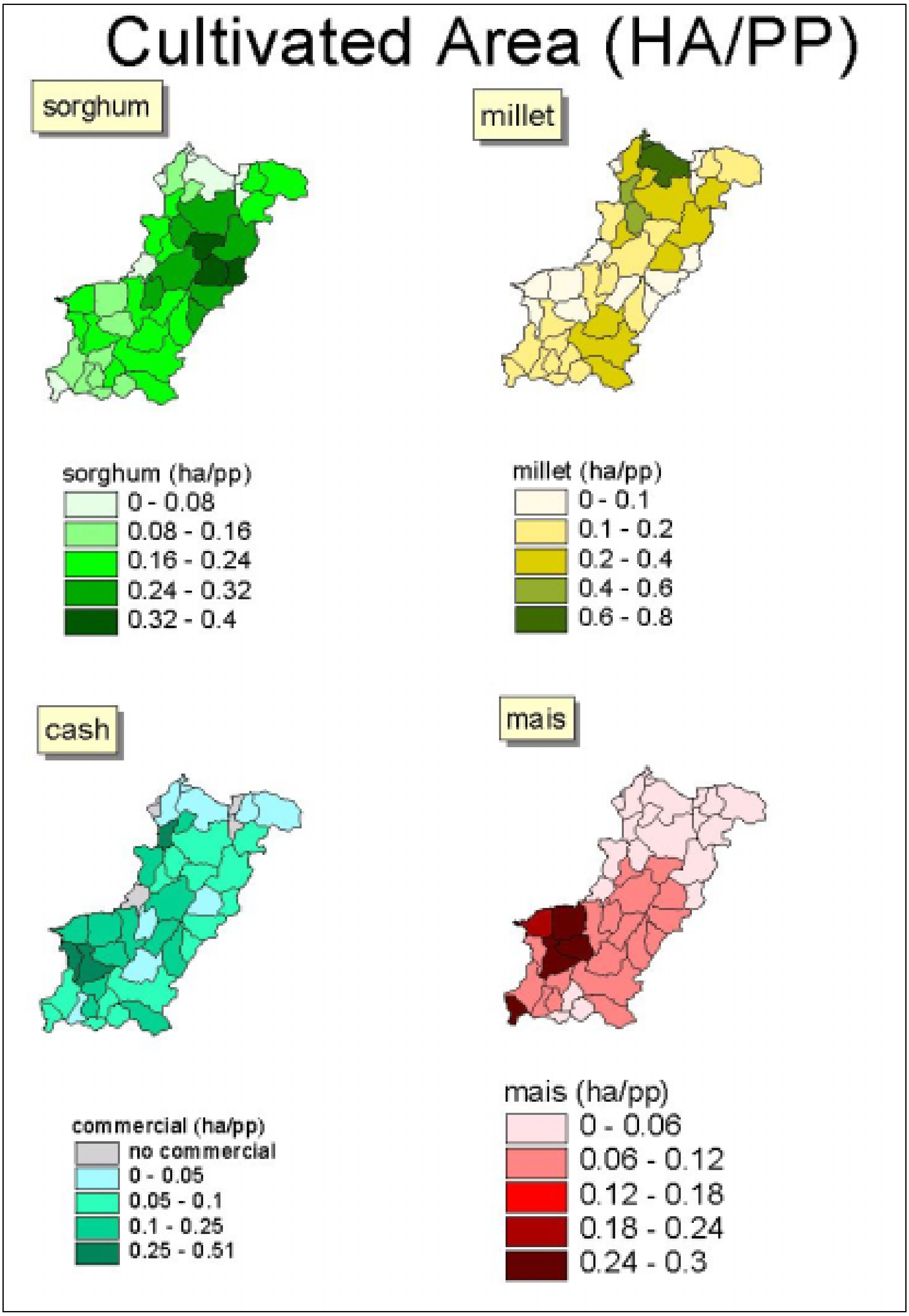
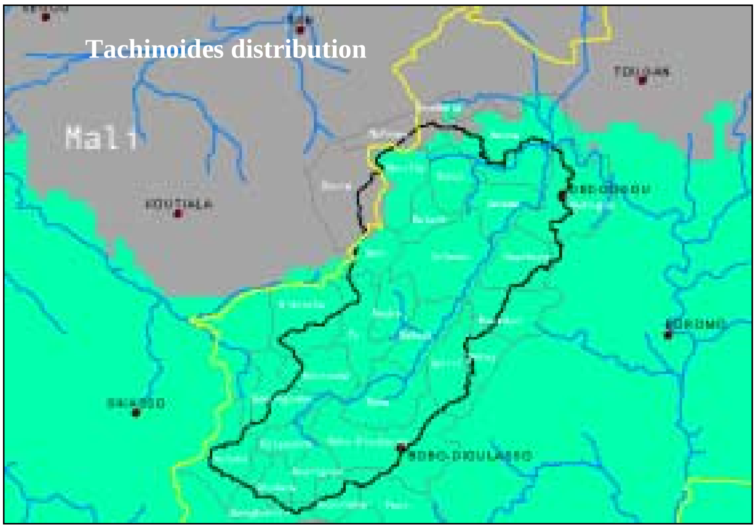
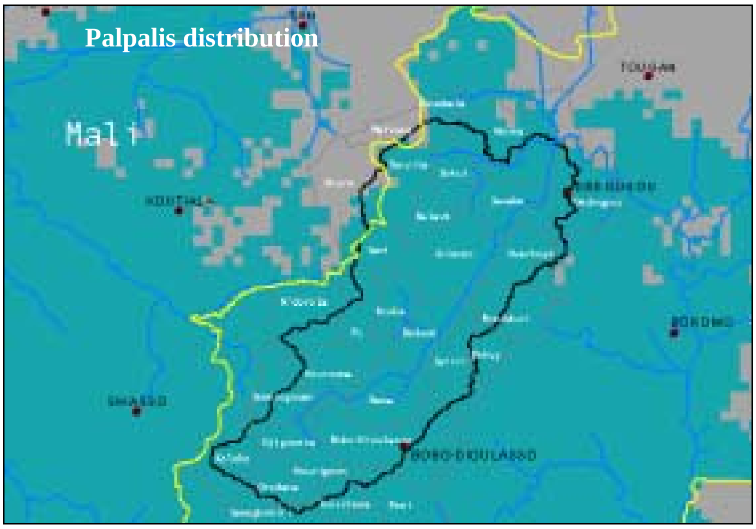
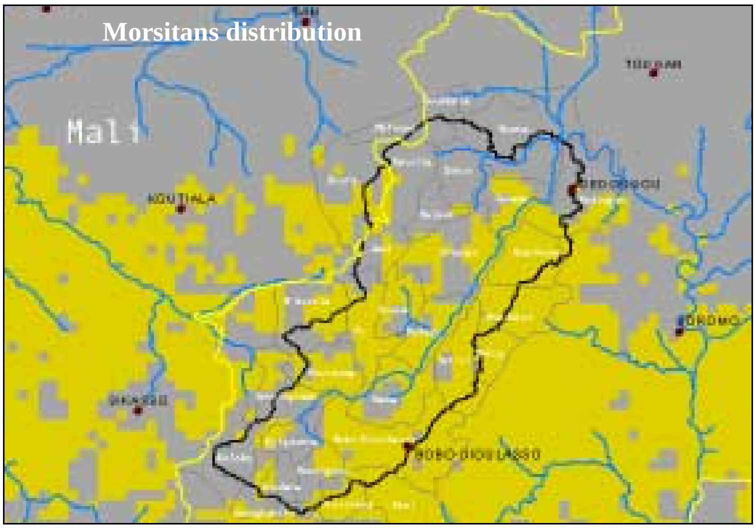


Figure 8 Distribution of Tsetse Species







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AGENCE INTERNATIONALE DE L'ENERGIE ATOMIQUE
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RAPPORT DE CONSULTATION

CONTRIBUTION A L'ANALYSE COÛT /BENEFICE DES SCENARIOS DE LUTTE CONTRE LES MOUCHES TSE-TSE ET LES TRYPANOSOMOSES EN AFRIQUE DE L'OUEST

(DONNEES SUR LA ZONE D'ETUDE AU BENIN)

Par

Dr Victorin CODJIA
Vétérinaire Inspecteur
Spécialiste des Trypanosomoses
Animales

Février, 2001

LISTE DES ABREVIATIONS

AIEA : Agence Internationale de l'Energie Atomique

CARDER : Centre d'Action Régionale pour le Développement Rural

FAO : Organisation des Nations Unies pour l'Alimentation et l'Agriculture

INSAE : Institut National de Statistique et d'Analyse Economique

INSEE : Institut National de Statistique et d'Etude Economique

ITTA : International Institut of Tropical Agriculture

Ha : hectare

Hbts : Habitants

Kg : kilogramme

Kg/ha : kilogramme par hectare

oC : Dégré celsius

OMS : Organisation Mondiale de la Santé

ONASA : Office National de Sécurité Alimentaire

PIB : Produit Intérieur Brut

PLTA : Programme de Lutte contre la Trypanosomose Africaine

PNLTHA : Programme National de Lutte contre la Trypanosomose Humaine(PNLTHA), Ministère de la Santé

SONAPRA : Société Nationale pour la Promotion Agricole

VIH/SIDA : Virus d'Immuno-déficience Humaine/Syndrome d'Immuno-déficience Acquise

SOMMAIRE

PAGES

INTRODUCTION

Les Trypanosomoses animales et la maladie du sommeil constituent une contrainte majeure pour l'Afrique au sud du Sahara. Près d'un siècle de lutte n'a pas suffit à contenir les infestations de glossines ou à réduire l'impact de la Trypanosomose en Afrique. De sorte, que le Développement socio-économique du 1/3 du continent reste gravement compromis par les conséquences de cette maladie débilitante souvent mortelle qui affecte l'homme et les animaux.

Il est pénible de constater que les pays, les plus pauvres du continent qui traversent une période de crise (conflits armés, mouvements de populations) sont les plus gravement affectés par la maladie du sommeil rendant ainsi les interventions des équipes médicales difficiles et périlleux.

Soixante (60) millions d'hommes, de femmes et d'enfants dans 22 des 36 pays en Afrique subsaharienne vivent sous la menace de la maladie du sommeil. Environ un demi million d'hommes sont atteints par la maladie du sommeil. 45.000 nouveaux cas ont été enregistrés selon l'OMS en 1999. Quarante quatre (44) millions de bovins sans compter les autres animaux domestiques se trouvent dans des zones infestées de mouches tsé-tsé.

La maladie provoque une perte de 3 millions de tête de bétail par an, une perte 26% du rendement laitier, une réduction de 50% du nombre de troupeaux dans les zones à haute potentialité agricole (PLTA, 1999).

Le présent rapport a été rédigé pour fournir à l'Agence Internationale de l'Energie Atomique (AIEA) des données diverses sur la zone d'étude au Bénin pour une analyse coût/bénéfice d'un éventuel programme de lutte contre les mouches tsé-tsé et les trypanosomoses dans la zone soudanienne et sahélo soudanienne de l'Afrique de l'Ouest.

La zone d'étude située au Bénin couvre les départements de l'Alibori et du Borgou.

Après avoir présenté des généralités sur le Bénin, ce rapport met l'accent sur :
- l'évolution de la population humaine dans la zone d'étude,
- la situation sanitaire,
- l'effectif et la productiivité du cheptel,
- l'évolution des réalisations des principales cultures,
- les ressources naturelles et la qualité du sol.

En conclusion, il a été indiqué l'impact positif d'un programme régional de lutte contre les mouches tsé-tsé et les trypanosomoses basé sur l'utilisation intégrée des différentes méthodes de lutte non polluantes pour l'environnement (pièges et écrans imprégnés d'insecticides, pulvérisations stratégiques et lâcher de mâles stériles etc.

Etant entendu que le choix des méthodes appropriées sera fonction des réalités sur le terrain.

En annexe, il figure une dizaine de cartes sur la zone d'étude.

1. GENERALITES SUR LE BENIN

1.1- Population

La population du Bénin qui était de 2.069.700 en 1961 est passée de 3.331.200 en 1979 puis à 4.915.555 habitants en 1992. Le taux d'accroissement moyen annuel calculé entre 1979 et 1992 est de 28%. A ce rythme, elle connaîtra un doublement en 2015.

Une caractéristique importante de cette population est sa jeunesse avec une légère dominance féminine : plus de 50% de la population a moins de 16 ans et 52% de la population est féminine selon le deuxième recensement. La population est inégalement répartie sur le territoire où on observe de fortes densités dans le sud.

1.2- Relief

De forme allongée en latitude, le Bénin est limité au nord par le Niger, au Nord-Ouest par le Burkina-faso, à l'Ouest par le Togo, au Sud par l'Océan Atlantique et à l'Est par le Nigeria. Il couvre une superficie de114 763 km² avec un relief peu accidenté. La seule région élevée est située dans le nord-ouest du pays avec la "Chaîne de l'Atacora".

1.3- Climat

L'évolution du climat est marquée par la succession de périodes excédentaires en précipitations, d'inégale durée et apériodique. Cette situation rend difficile toute prévision.

On observe deux grands types de climat au Bénin :

- au sud, un climat subéquatorial qui permet d'enregistrer deux saisons de pluies et deux saisons sèches dans l'année :
- une grande saison des pluies d'avril à juillet
- une petite saison sèche d'août à septembre
- une petite saison pluvieuse d'octobre en novembre
- une grande saison sèche de décembre à mars.
- au Nord, le climat est soudanien. L'année se partage en deux saisons bien tranchées :
- une saison sèche de novembre à début mai ;
- Une saison pluvieuse de mai à octobre.

Dans la chaîne de l'Atacora, l'altitude rend les orages plus fréquents et les températures plus fraîches. Dans l'ensemble, la pluviométrie varie entre 900 mm et 1450 mm d'eau par an, tandis que les températures fluctuent entre 22°C et 37°C sous-abris. Ces perturbations constituent la première des contraintes de la productivité des terres du Bénin.

Le réseau hydrographique du Bénin s'appuie sur le système morphogénétique en place à partir de la ligne de partage des eaux. Aussi distingue-t-on le système Nord ayant comme défluent le fleuve Niger et le système sud dont les eaux convergent vers le Golfe du Bénin dans l'Océan Atlantique. De ces deux ensembles, se dégagent deux systèmes imbriqués de bassins versants auxquels s'ajoute le bassin de la Pendjari (380 km).

Au Nord, le bassin du Niger capte les eaux des affluents suivants d'ouest en Est :

- le Mékrou 410 km
- l'Alibori 338 km
- la Sota 250 km
- le défluent principal, le fleuve Niger qui matérialise la frontière entre la République du Bénin et la République du Niger sur 120 km.

Au Sud, le système du bassin versant de l'Ouémé comprend les affluents permanents de l'Okpara, Zou, Agbado et les autres affluents saisonniers auxquels s'ajoutent les bassins du Couffo et du Mono dans leurs cours inférieurs. Ainsi, on peut recenser :

- l'Ouémé 510 km
- l'Okpara 200 km
- le Zou 150 km
- le Couffo 125 km
- le Mono 100 km

Ce réseau hydrographique est complété par le système lacustre et lagunaire dont les trois principaux plans d'eau couvrent :

- 138 km² pour le lac Nokoué
- 78km² pour le lac Ahémé
- 35km² pour la lagune de Porto-Novo.

Les cours d'eau et plans d'eau du bénin sont poissonneux. Aussi les populations riveraines se livrent-elles à des activités de pêche : pêche dans les lacs et lagunes, et le long de certains cours d'eau (Mono, Ouémé, Zou, Okpara, Pendjari, Niger).

1.4- Végétation

La végétation est échelonnée et se dégrade lorsqu'on passe du sud au nord. Elle est répartie en deux grandes catégories de paysages végétaux :

- la végétation dégradée du Sud-Bénin qui s'étend de la côte jusqu'à la latitude de Setto. Elle est constituée des îlots forestiers, des savanes arborées et arbustives, quelques prairies aquatiques ainsi que des mangroves ;

- la végétation des régions soudanaises qui présente dans le nord une savane arborée dominée par le néré, le karité, le caïlcédrat, le baobab et le kapokier. Le long des cours d'eau se développent des forêts galeries. Il existe par ailleurs des plantations de tecks, d'anacardiers et de manguiers.

1.5- Sol

La plus grande partie du Bénin est composée de sols sesquioxydes, ferrugineux et ferralitiques. Les sols des régions méridionales, dans les départements de l'Ouémé, de l'Atlantique et du Mono sont ferralitiques sur le continental terminal et s'étendent du plateau de Dogbo-Azovè au plateau d'Abomey et à ceux de Pobè-Sakété. Au Nord, dominent les sols à sesquioxydes. Seules, les vallées des cours d'eau présentent des sols hydromorphes et des poches vertisols.

Au total, 70 500 km² de terres arables sont disponibles au Bénin dont seulement 15% environ sont exploitées. Ces taux brut d'exploitation des terres disponibles masque en réalité les disparités régionales entre l'abondance des terres dans le nord du pays et leur rareté dans les régions méridionales.

La faune est très riche et diversifiée. On trouve un grand nombre de gros herbivores (éléphants, buffles, cobs de buffon, bubales), des carnivores (lions, guépards surtout dans les réserves, les parcs nationaux de la Pendjari et du W du Niger), beaucoup de reptiles, de singes, de rongeurs, d'oiseaux et d'insectes.

1.6- Organisation socio-linguistique

Le Bénin est habité par une multitude de communautés qui se répartissent du point de vue linguistique en trois grands groupes, à savoir :

- le Groupe GBE, numériquement le plus important et comprenant les ethnies généralement attribuées à l'aire Adja-Tado (Fon, Aïzo, Goun, Mina, Wèmè, etc) ;
- le Groupe EDE comprenant les Yoruba, Nago et apparentés ;

- le Groupe GUR comprenant la plupart des groupes ethniques de la partie septentrionale du pays (Batonu, Ditamari, Yom, Wama, Naténi, etc).

Ces groupes ont élaboré des formes d'organisation sociale variées allant des systèmes de pouvoir centralisé dont le plus élaboré est celui de l'ancien royaume du Danxomè aux sociétés qui peuvent être qualifiées de segmentaires (nord-ouest de l'Atacora) en passant par des formes de pouvoir décentralisé (royaumes Wassangari du nord-est).

1.7- Migrations

S'agissant du mouvement de la population béninoise, on enregistre deux types de migration : les migrations internes et les migrations externes.

-Les migrations internes se traduisent par :

- les migrations rurales ; de l'Atacora vers le Borgou et le Zou-Nord (où les jeunes sont en quête de nouvelles terres), des campagnes du Mono et de l'Atlantique vers les périmètres d'aménagement ;
- l'exode rural : les jeunes ruraux désertent les villages pour affluer vers les centres urbains (Cotonou, Porto-Novo, Parakou, Abomey), à la recherche d'un emploi salarié et des loisirs. Les villages se vident des jeunes travailleurs et les villes regorgent de ces jeunes ruraux qui ne trouvent pas de travail et deviennent des sans-emploi et des délinquants.
- les migrations interurbaines des petites villes vers les principaux centres économiques régionaux (Cotonou, Porto-Novo, Parakou, Abomey, Djougou). Cette forme de migration concerne surtout les artisans de métier (mécaniciens, tailleurs, cordonniers) et les jeunes ouvriers en quête d'emploi (chauffeurs maçons).

- Les migrations externes se font sous deux formes :

- les migrations saisonnières qui intéressent les jeunes ruraux qui vont vers Ghana (de moins en moins) surtout vers le Nigeria. Ces jeunes migrants vont séjourner dans les plantations de cacao pour les cueillettes surtout d'octobre à mars ; ils sont également manœuvres dans les villes ;
- la deuxième forme assez importante, concerne les ouvriers, les intellectuels et hommes d'affaires qui vont s'installer en Côte d'Ivoire, au Nigeria, au Gabon, au Togo, sans oublier les migrants vers l'Europe (surtout la France)

La démocratisation du régime politique, la stabilité retrouvée et l'accroissement des difficultés économiques des autres pays ont favorisé le retour des béninois aux pays.

1.8- Organisation de l'administration territoriale

Au Bénin, la langue officielle est le français. Dans le commerce et les relations internationales le français et l'anglais sont les langues utilisées. Les lois sur la décentralisation votées par l'Assemblée Nationale en sa 1ère session extraordinaire de l'Année 1998 ont enregistré un début d'application.

En effet, la loi n° 97-028 du 15 janvier 1999 porte le nombre de départements de six (6) à douze (12). Ainsi, le Bénin a été divisé en douze (12) départements administratifs qui sont :

l'Alibori	- l'Atacora	- l'Atlantique
- le Borgou	- les Collines	- le Couffo
- la Donga	- le Littoral	- le Mono
- le Plateau	- l'Ouémé	- le Zou

Le village ou quartier de ville constitue l'unité administrative de base autour de laquelle s'organisent la vie sociale et les activités de production.

1.9- Evolution macro-économique

Le PIB (aux prix de 1985) du Bénin est passé de 469,8 milliards de francs CFA en 1985 à 637 milliards de francs CFA en 1996, soit un accroissement moyen annuel de 2,7%. Après la récession de la fin des années 80, l'économie a amorcé une reprise à partir de 1990. Le taux de croissance moyen annuel entre 1990 et 1997 est de 4,5%. La contribution du secteur primaire qui était de 36,1% en 1990 a connu une baisse significative au profit du secteur tertiaire de 1993 à 1995 avant de remonter pour atteindre 38,4% en 1997 du fait de la dynamique induite par la dévaluation sur la production végétale, notamment de la production des cultures vivrières. Le secteur secondaire demeure le maillon le plus faible de l'économie et représente seulement 13% de 1990 à 1997. Il est dominé par l'industrie alimentaire, l'industrie textile et la production de ciment. Le secteur tertiaire contribue pour plus de 50% au PIB. Il est en plein essor grâce au nouvel environnement de libéralisation politique et économique créé à partir de 1990 et à la proximité du Nigeria. Il est dominé par le commerce et les transports. La dette de la République du Bénin s'élève en 1999 à 902 milliards. La dette extérieure représente 94% (847 milliards de FCFA) de ce montant, le restant étant dû à la dette intérieure.

Tableau N° 1 PROFIL SOCIAL ET INDICATEURS DU DEVELOPPEMENT HUMAIN AU BENIN, juillet 2000

GENERALITES	
Superficie	114 763 km²
Région	Afrique Sub-Saharienne
Climat	Subéquatorial
Population en 1999	6 187 173 habitants
Groupe d'appartenance du pays selon le Revenu (*)	Faible
Groupe d'appartenance du pays selon le niveau I.DH.(*)	Faible

COMPARAISON INTERNATIONALE (Données de 1997)

	Bénin	Pays en Développement	Pays en Moins Avancés	Pays industrialisés	Monde
Espérance de vie à la naissance (années)	53,4	64,4	51,7	77,7	66,7
Espérance de vie à la naissance Femme (années)	55,2	66,1	52,6	80,9	68,9
Espérance de vie à la naissance Homme (années)	51,7	63,0	50,8	74,5	64,7
Taux d'alphabétisation des adultes %	33,9	71,4	50,7	98,7	78,0
Taux d'alphabétisation des adultes Femmes %	20,9	62,9	38,1	98,6	71,1
Taux d'alphabétisation des adultes Hommes %	47,8	80,0	58,8	98,9	84,3
Taux brut de scolarisation tous niveaux confondus %	42	59	37	92	63
Taux brut de scolarisation tous niveaux confondus Femmes %	30	55	32	93	60
Taux brut de scolarisation tous niveaux confondus Hommes %	54	64	43	90	67
PNB par habitant (USD)	380	1314	260	27174	5257
PIB réel par habitant (PPA)	1270	3240	992	23741	6332

	1991	1992	1993	1994	1995	1996	1997
Valeur IDH,(entre 0 et 1)	0,111	0,332	0,327	0,368	0,378	nd	0,421*
Rang du Bénin selon l'I.DH	149	162	156	146	145	nd	155
Valeur IDH (Rapports nationaux sur le développement humain							

(*) Cet indicateur a été calculé suivant une nouvelle formule qui ne permet pas la comparaison directe avec les indicateurs des années précédentes (voir note technique du RMDN 1999)

La consommation et l'emploi dans les capitales des Etats membres de l'UEMOA

(Source Enquête UEMOA 1996)

		Cotonou	Ouaga	Abidjan	Bamako	Niamey	Dakar	Lomé
Population (estimation)		618000	660000	2023000	744000	385000	1551000	528000
Dépense mensuelle par individu en francs CFA								
Dépense totale de consommation		22237	17230	30357	19797	17951	23569	19902
Dépense totale hors consommation		1705	1718	3105	1367	2159	2715	2213
Population en âge de travailler								
Population en âge de travailler (15 ans et plus) PAT		370589	393720	1252425	434946	212971	947769	325820
Population active occupée – PAO		231472	214498	785937	180759	82644	481482	205712
Chômeurs selon les critères du BIT-CHOM		18467	32060	101359	29633	15684	49576	20890
Chômeurs découragés – CD		8095	20020	62495	25262	16999	23327	6202
Autres inactifs – AI		112555	127142	302634	199292	97644	393384	93016
Taux de dépendance – (CHOM + CD + AI)/PAO		60,1	83,6	59,4	140,6	157,7	96,8	58,4
Taux d'activité strict % (PAO + CHOM) /PAT		67,4	62,6	70,8	48,4	46,2	56,0	69,5
Taux d'activité élargi % (PAO + CHOM + CD)/PAT		69,6	67,7	75,8	54,2	54,2	58,5	71,5
Taux de chômage strict % CHOM/(PAO + CHOM)		7,4	13,0	11,4	14,1	16,0	9,3	9,2
Taux de chômage élargi %(Chom+CD)/(PAO+CHOM+CD)		10,3	19,5	17,3	23,3	28,3	13,2	11,6
Taux stricts et Taux élargis d'activité par sexe								
Taux d'activité strict %	Femme	61,5	48,5	62,2	27,4	26,2	42,0	66,9
	Homme	73,4	75,9	79,3	68,6	65,4,	71,6	72,4
Taux d'activité élargi %	Femme	65,3	56,3	70,0	35,4	33,7	44,0	69,3
	Homme	74,0	78,5	81,5	72,3	73,9	74,5	73,8
Taux stricts et Taux élargis de chômage par sexe								
Taux de chômage strict %	Femme	7,2	14,3	13,0	19,6	12,8	7,6	7,0
	Homme	7,6	12,2	10,2	11,9	17,2	10,5	11,4
Taux de chômage élargi %	Femme	12,6	26,1	22,8	37,8	32,1	11,9	10,2
	Homme	8,3	15,1	12,6	16,5	26,7	14,0	13,1

1.10- Santé

La situation sanitaire au Bénin est marquée par une forte prévalence des maladies tropicales transmissibles et parasitaires avec une prédominance des affections endémo-épidémiques. Les principales affections qui minent la population par ordre d'importance sont le paludisme, les diarrhées souvent liées au péril hydro-fécal et les gastro-entérites, les infections respiratoires aiguës et les maladies sexuellement transmissibles.

Le taux de séroprévalence du VIH/SIDA est de l'ordre de 4% au sein de la population générale en 1990 et se situe à près de 60% au niveau des prostituées. Ce tableau sombre est exacerbé par une insuffisance du personnel et des infrastructures. Ainsi, en 1995 on a 1 médecin pour 19.617 habitants (la norme est d'1 médecin pour 10.000 habitants), 1 sage-femme pour 12.504 habitants (la norme est d'1 sage-femme pour 5 000 habitants).

1.11.- Habitat et environnement

L'habitat est caractérisé par un faible taux de latrinisation, une dominance de l'éclairage par le pétrole (97% des cases isolées et 90% des concessions à Cotonou, 51% des ménages sont sans électricité), un système de ramassage des déchets solides et liquides peu fonctionnels. On note de plus en plus une précarité de l'habitat (67,1% des unités d'habitation ont des toits en tôle et 28,4% en paille). En général, les logements sont vétustes, construits sans respect des normes tant au niveau des matériaux que techniques de construction.

L'environment est marqué d'une part, par la pollution par la production des gaz toxiques et production de poussières et d'autre part par la fragilisation des écosystèmes des grandes villes, liée à la croissance rapide des villes et de leurs banlieues.

2 DESCRIPTION DE LA ZONE D'ETUDE

2.1.- Localisation géographique

La zone d'étude est située au Nord-Est de la République du Bénin entre les parallèles 9°54'35" et 11°55'2" de latitude Nord d'une part et le méridien 3°46'44" et 3°33'6" longitude Est d'autre part. La zone d'étude couvre d'une part les Sous-Préfectures de Malanville, Ségbana, Kandi et de Gogounou dans le Département de l'Alibori et les Sous-Préfectures de Bembèrèkè, kalalé et Nikki dans le Département du Borgou.

Voir carte administrative de la zone d'étude en appendix 3.

La superficie totale de la zone d'étude est de 14125 Km² dans la pénéplaine précambrienne qui borde la chaîne de l'Atacora dans le Nord-Ouest et qui se poursuit vers le nord par la couverture sédimentaire qui s'étend jusqu'au fleuve Niger. La zone a une double inclinaison vers le sud et vers le nord de part et d'autre de la ligne de partage des eaux des bassins du fleuve Niger et de l'Ouémé.

2.2- Département de l'Alibori

(Sous-Préfectures de Kandi, Nikki, Ségbana et Bembèrékè)

2.2.1- Climat

Le climat est tropical de type soudano guinéen caractérisé par l'alternance d'une saison sèche (novembre à mars) et d'une saison pluvieuse (juin à septembre)

a)- Température

La température moyenne annuelle est élevée. 27°3 C à Kandi. La température moyenne mensuelle passe de 25°C en décembre (Mois le plus froid) à 32°C en avril (mois le plus chaud). Les variations diverses maxima en décembre – janvier, en saison sèche, lorsque les influences continentales sont prépondérantes et que souffle l'harmattan. Les températures ont une forte amplitude diurne

b)- Les précipitations

La hauteur moyenne des précipitations et leurs répartitions varient peu : le nombre de mois recevant moins 100 mm passe de 5 à 6 au nord.

Kandi : 1055 mm en 80 jours

Ségbana : 1177 mm en 80 jours

Bembèrèkè : 1270 mm en 75 jours (1921-1971)

Kalalé : 1228 mm en 69 jours (1921-1971)

Nikki : 1247 mm en 70 jours (1944-1971)

2.2.2- La végétation

C'est une zone de passage entre la savane arborée apparentée à la forêt claire et la savane arbustive. Le développement de la savane arbustive au détriment de la savane arborée est accéléré par le défrichement et la pratique du feu de brousse.

Au sud de Bembèrèkè, on a les formations suivantes :

- La savane arborée à *Isoberlinia, Uapaca, Afzelia* avec de rare *Kaya* et *Monotes.*

- La savane arborée à *Daniella, Burkea, Pterocarpus, Lophira* sur des sols bien drainés de texture grossière.
- La savane arborée à *Detarium, Combretum, Parinari* sur les sols concrétionnés ou indurés souvent médiocrement drainés.
- La savane arborée à *Gardenia, Terminalia, Macroptera, Pseudocedrela* sur les sols argileux à forte capacité renfermant des minéraux gonflants.
- La savane à *Acacia* dans les zones planes sur des sols dérivant de roche riche en minéraux gonflants ou un horizon argileux très compact est surmonté par un horizon sableux.

On note :

- Quelques forêts galerie le long de l'Alibori et de la Sota et de toutes les rivières bordées de terrasse alluviale de texture limoneuse.

- Quelques savanes à *Mitragyna* avec les larges bas-fonds argileux mal drainés.

A ces formations se surimpose une savane parc anthropique dominé par *Parkia, et Butyrospermun*, avec de nombreux ficus et quelques baobabs qui résistent aux feux de brousse.

2.2.3- Réseau Hydrographique

La Sota est le principal cours d'eau qui traverse cette zone d'étude et qui s'écoule vers le nord. La Sota et ses affluents entaillent une pénéplaine à peine ondulée.

2.2.4- Peuplement

Deux groupes ethniques se partagent la zone : il s'agit des Bariba et des Boussas ou Boko. A ces deux groupes sont associés les Peulhs. La densité de population est élevée au tour des chefs lieux de sous-préfecture. De vastes régions sont vides car infestées de Simulies, de glossines et de Taons.

2.2.5- Agriculture

Les principales cultures pratiquées sont : l'igname,: le maïs, le sorgho et le manioc. Les principales cultures de rente sont : le coton et l'arachide. Les potentialités rizicoles sont sous exploitées. Le système d'élevage est traditionnel.

La faune et la flore sont très variées, la proximité avec le parc de W du Niger et les zones cynégétiques du Djona sont des atouts touristiques non négligeables.

2.3- Département du Borgou

(Sous-Préfecture de Malanville, Kandi, Ségbana)

2.3.1- Climat

Le climat est tropical de type soudanien à deux saisons très contrastées (saison des pluies de juin à septembre et une saison sèche de novembre à avril). Les mois de décembre, janvier et février sont marqués par une sécheresse absolue. (Harmattan)

a)- Température

La température moyenne annuelle est de : 27°3 C. On note une grande variabilité journalière. On peut enregistrer des températures de 40°C de février à mai et de décembre à janvier le thermomètre s'abaisse à 10°C. Les variations diurnes sont importantes en saison sèche.

b)- Les précipitations

La hauteur moyenne mensuelle des précipitations et les répartitions varient.

Kandi : 1055,1 mm en 80 jours
Malanville : 919,9 mm en 53 jours
Ségbana : 1177,4 en 53 jours.

Il y a un excédent d'eau de juillet à septembre. Le déficit d'eau est sévère.de décembre à avril.

2.3.2- Végétation

Cette zone est une zone de transition entre la savane soudano-guinéenne et la savane soudanienne à affinité sahélienne.

Au sud on a :

- La savane arborée à *Isoberlinia, Afzelia, Anogeissus, Khaya* qui disparaît au profit d'une savane parc à *Parkia, Butyrospermum, Ficus et Vitex*. Dans les zones cultivées cette savane est remplacée par la savane arbustive à *Combretum, Terminalia, Dyospyros, tamarindus, Strychnos, Detarium Hymenocardia* dans les zones indurées ou concrétionnées. Dans les bas-fonds argileux sur les zones riches en minéraux 2/1 se développe une savane arbustive à *Terminalia macroptera.*

Au nord du 12ème parallèle ces formations sont progressivement remplacées par la savane arbustive à *Combretum. L'Afzelia* se maintient tandis que *Isoberlima* disparaît. Les épineux se mêlent aux *combretum* dans les zones concrétionnées. En bordure du Niger sur les zones sableuses à nappe phréatique peu profonde se développent de belles savanes de rôniers.

2.3.3- Réseau d'hydrographique

Cette zone appartient au bassin versant sud du fleuve Niger et drainé par le Mékrou et l'Alibori au centre et la Sota à l'est. On note une absence de relief important.

2.3.4- Peuplement

Dans cette zone les ethnies : Bariba, Boussa ou Boko, Dendi, des Nigériens ou des Burkinabé et des Peulh.

2.3.5- Agriculture

Les principales cultures sont : le Maïs, le Sorgho, le Mil, Manioc, l'igname. Le riz est cultivé dans les bas-fonds aménagés. Les principales cultures de rente sont : le coton et l'arachide. Les cultures maraîchères sont en plein essor (oignon, pomme de terre). De vastes zones restent vides ; il s'agit des parcs, de la forêt de l'Alibori supérieur de la Sota et de la zone cynégétique d'Alphakora.

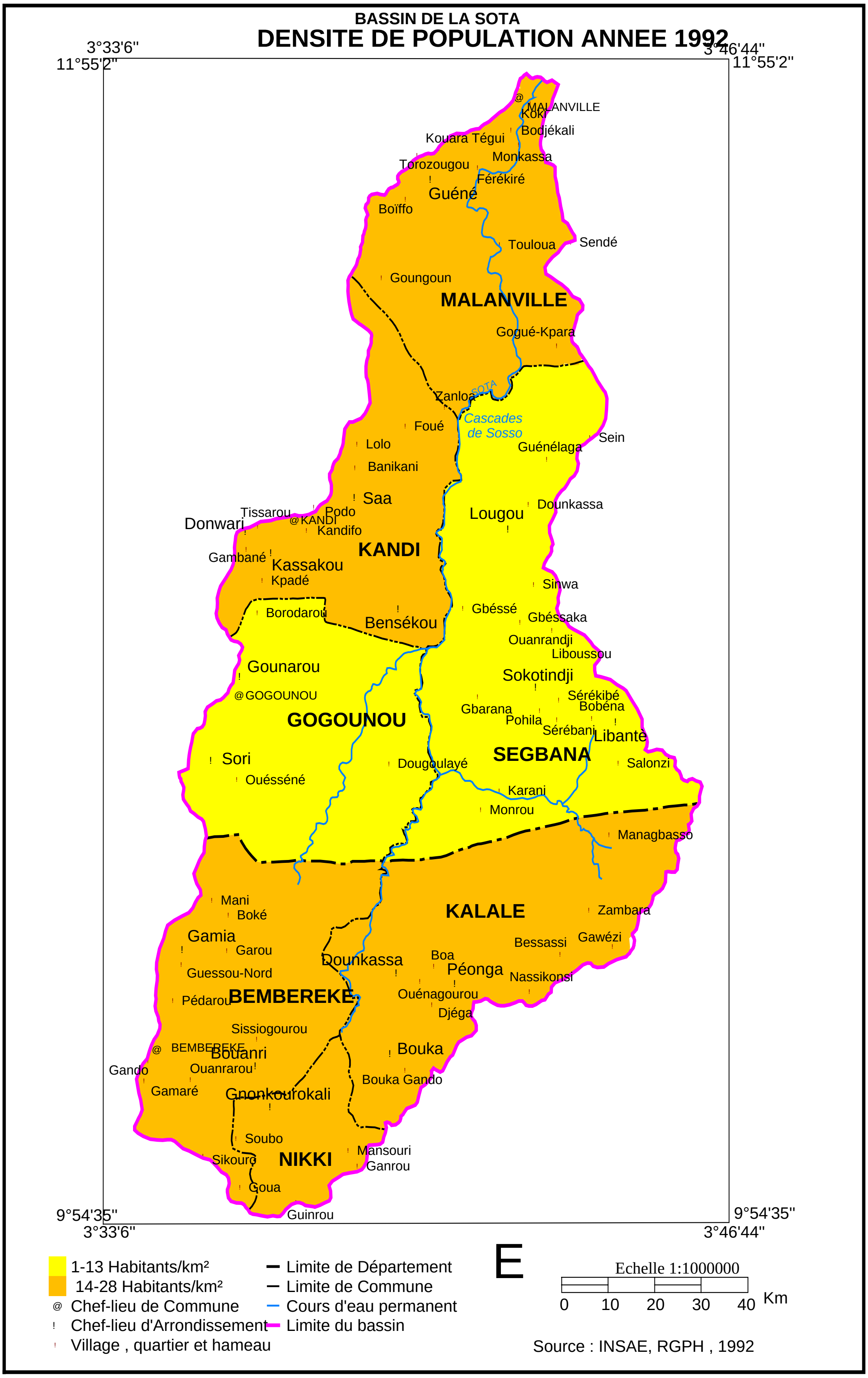
Le tableau N° 2, montre l'évolution de la population dans la zone d'étude.

Tableau N° 2 : Population en 1992 (1979)

Sous-préfectures	Superficie (km²)	Population (millier) 1992	(1979)	Densité (Hbts/km²)	Nombre de Ménages	Taille de ménages
Bembèrèkè	3348	59809	(37,866)	17,9	6540	9,1
Gogounou	4910	50045	(27,830)	10,2	5600	8,9
Kalalè	3586	62805	(38,730)	17,5	6269	10,0
Kandi	3421	73138	(49,102)	21,7	8624	8,5
Malanville	3016	67387	(36,442)	22,3	9592	7,0
Nikki	3171	66164	(34,278)	20,9	7076	9,4
Ségbana	4471	32271	(19,739)	7,2	3666	8,8
Total	25923	410899	243987	15.9	47367	8.7

Source : Deuxième recensement général de la population et de l'habitation, 1992.

Figure 1 Densité de Population dans la Zone d'Etude– 1992



3. SITUATION SANITAIRE DANS LA ZONE D'ETUDE

La situation sanitaire dans la zone d'étude est caractérisée par un état de santé médiocre avec une morbidité et une mortalité élevées. Les maladies parasitaires, les infections, la malnutrition constituent les principaux problèmes de santé. Les Tableaux N° 3, 4 et 5 présentent les incidences des différentes affections. Soulignons que des épidémies limitées de choléra et de méningite assombrissent parfois la situation sanitaire.

Tableau N° 3 Incidence des Affections / année

Départements	1990			
	Paludisme / Malaria (P. 1000)	Maladies, diarrhéiques. (P.1000)	Méningite (P. 10.000)	Tuberculose (P.100.000)
Alibori/Borgou	13,2	34,7	2,27	61

Source : Statistiques Sanitaires Année 1990, République du Bénin, Ministère de la santé

Tableau N° 4 Incidence des Affections / année

Départements	1995				
	Paludisme/ Malaria (P.1000)	Maladies diarrhéiques. (P.1000)	Méningite (10.000)	Tuberculose (P.100.000)	Choléra
Alibori/Borgou	121	44,8	6,2	31	30 cas à Malanville

Source : Statistiques sanitaires, Année, 1995, République du Bénin, Ministère de la Santé

Tableau N° 5 Incidence des Affections / année

Départements	1999				
	Paludisme/ Malaria (P.1000)	Maladies diarrhéiques. (P.1000)	Méningite (10.000)	Tuberculose (P.100.000)	Affections Respiratoires (P.1000)
Alibori/Borgou	32% enfants 10% adultes	2	10,2%	24	3,5

Source : Annuaire des statistiques sanitaires Année, 1999, Ministère de la Santé, République du Bénin,

3.1- Situation de l'onchocercose

La lutte contre l'onchocercose a démarré au Bénin en 1977 et a intéressé les deux (02) départements du Nord. Elle a consisté en l'épandage d'insecticide (larvicide) dans les cours d'eau infestés. Le traitement qui a intéressé tous les bassins fluviaux a été arrêté en 1990 pour être remplacé par le traitement des populations à l'Ivermectine qui continue jusqu'à ce jour.

On peut constater à partir des données épidémiologiques que la plus part des points de surveillance sont à présent hypoendémique (prévalence inférieure à 40 p.100) et donc la maladie n'a plus une expression sociale. Notons, que le bassin de la Mékrou qui intéresse la sous-préfecture de Kérou, une partie de Kouandé, Péhunco et Banikoara est déclaré libérée de l'Onchocercose est actuellement sous surveillance (pas de traitement).

Les tableaux 6 et 7 indiquent l'évolution des données épidémiologiques relatives à l'Onchocercose et les opérations de lutte effectuées.

Tableau N° 6 : Evolution des Donnees Epidemiologiques

SOUS-PREFECTURES	BASSINS	VILLAGES DE SURVEILLANCE	DONNES : PREVALENCE (%) VILLAGE
Malanville	Sota Niger	Koubery	1978 : 73,6 1988 : 44
Kandi	Alibori/Niger Sota/Niger	Alibori	1978 : 68,7 1994 : 20,4
Ségbana	Sota/Niger	Zondji Gbassé	1978 : 68,8 1995 : 6,4
Gogounou	Alibori Sota	Lougou	1978 : 61,0 1994 : 13,1 2000 : 2,7
Kalalé	Tassime/Sota/Niger	Krikoubé	1978 : 59,4 1995 : 24,5
Bembèrèkè	Sota	Wanramou	1978 : 35,6 1992 : 4,6

Source : Programme de Lutte contre l'Onchocercose

Tableau N° 7 : Operation De Lutte Contre L'onchocercose

NOM	LUTTE	ANNEES	1970	1980
Banikoara	X	1977	-	4.383
Bembèrèkè	X	1977	-	3.348
Gogounou	X	1977	-	4.910
Kalalé	X	1977	-	3.586
Kandi	X	1977	-	3.421
Karimama	X	1977	-	6.041
Kérou	X	1977	-	3.745
Kouandé	X	1977	-	3.269
Malanville	X	1977	-	3.016
Péhunco	X	1977	-	2.014
Ségbana	X	1977	-	4.471

Source : Programme de Lutte contre l'Onchocercose

3.2- Situation du ver de guinée

La Draconculose ou ver de guinée existe partout au Bénin mais surtout dans le département du Zou . Le programme national d'éradication du ver de guinée est en cours d'exécution.

3.3- Situation de la maladie du sommeil

Depuis quelques années il a été enregistré le réveil de vieux foyers de la maladie du sommeil dans le Département de l'Atacora. Les enquêtes sont en cours pour l'évaluation de la situation actuelle de la maladie dans le Département du Borgou. Le tableau N° 10 est un récapitulatif de la situation de la maladie du sommeil en 1999/2000.

Tableau N° 8 : Recapitulatif Sur La Situation De La Trypanosomose Humaine Africaine Par Sous-Prefecture

Sous-Prefectures	Populations Recensees	Nombre de Prelevements	Nombre de Positifs				Nombre de Positifs au QBC
			Au Catt Sang	Au Catt Serum			
				Non dilué	Dilué au ¼	Dilué au 1/8	
TANGUIETA	3 043	1 868	31	31	23	15	03
MATERI	12 903	3 480	96	96	65	29	12
COBLY	27 903	7 960	28	28	20	13	0
KEROU	39578	10870	198	197	159	115	64
TOTAL	**83 389**	**24 178**	**353**	**352**	**267**	**172**	**79**

Source : Programme National de Lutte contre la Trypanosomose Humaine(PNLTHA), Ministère de la Santé

4 DONNEES SUR L'ELEVAGE ET LE BETAIL DANS LA ZONE D'ETUDE

4.1-Les races de bovins

Dans la zone d'étude la majorité des bovins appartiennent à la race bovine Borgou. Les Bovins de race Borgou sont issus d'un croisement stabilisé entre taurins à courtes cornes d'Afrique occidentale et le zébu white fulani. La race bovine Borgou est considérée comme possédant une certaine trypanotolérance. Dans presque toutes les sous-préfectures de la zone d'étude, on rencontre aussi des zébu Mbororo, Goudali ou White fulani.

4.2- Mode d'élevage traditionnel

Dans la zone d'étude, l'élevage est pratiqué selon le mode extensif traditionnel avec deux systèmes d'exploitation des pâturages naturels :

- Le système transhumant, caractérisé par une grande mobilité et une faible association avec l'agriculture.

- Le système sédentaire où l'élevage est associé à différentes cultures (de subsistance ou de rente) occupe les zones situées aux alentours des villages.

- Les éleveurs Peuhl détiennent près de 95 p.100 du cheptel. Certains accordent plus d'importance à la production animale tout en pratiquant l'agriculture d'autoconsommation, d'autres peuhl ont diversifié leur production en accordant autant d'importance à l'élevage qu'à l'agriculture (igname, maïs, sorgho, coton).

Les mouvements de transhumance sont déterminés par les besoins hydriques, nutritionnels et sanitaires du bétail et par les besoins socioculturels des éleveurs.

Dans la zone d'étude plus de 50 p. 100 des troupeaux transhumants vont au Nigeria et environ 25 p.100 vont dans une autre région du département et le reste des troupeaux se déplace vers le sud et parcourent entre 25 et 150 km.

Notons que la culture attelée est en plein essor dans la zone d'étude.

Les tableaux N° 9 et 10 indiquent l'évolution du cheptel dans la zone d'étude.

Le tableau N° 11 présente l'évolution de l'effectif des bovins de trait.

Sur le tableau N° 12 figure la structure démographique des troupeaux de bovins Borgou.

Les tableaux N° 13 et 14 indiquent les paramètres de reproduction et les indices de production de la race bovine Borgou dans son environnement.

Tableau 9 Effectifs Estimes du Cheptel

	1975	1981	1990	1993	1996	1999
Bovins	289200	335659	423575	460730	559000	622248
Ovins	254100	315414	167400	163580	185100	166731
Caprins	171800	213341	135160	128110	151500	172207
Equins	1745	1971	188	238	239	0
Asins	0	0	12	314	342	0

Source : Rapports Annuels Direction de l'Elevage 1975,, 1981, 1990, 1993, 1996, 1999

Tableau N° 10 : Effectif des Bovins de Trait

Sous-préfectures	1996	1997	1998	1999	2000
Bembèrèkè	1399	1960	2120	2226	2226
Gogounou	7349	7743	8953	12607	13607
Kalalé	4035	6050	6185	6306	6306
Kandi	1060	1060	2434	2434	2734
Malanville	3168	4082	4431	4780	5129
Nikki	3200	3200	3650	3650	4015
Ségbana	1228	1228	1888	2168	2318
Total	23435	27320	31659	36170	38335

Source : Rapports des activités du CARDER BORGOU (1996 – 2000)

Tableau N° 11: Structure Demographique des Troupeaux Bovins Borgou

Age (Années)	Mode d'élevage					
	Sédentaire n= 217		Transhumant n = 341		Ensemble N = 558	
	Mâles	Femelles	Mâles	Femelles	Mâles	Femelles
	(Pourcentage)					
0-1	18,9	15,2	15,6	17,9	16,7	16,4
1-2	6,9	11,0	3,5	8,9	5,3	9,8
2-3	3,2	7,4	1,7	8,9	2,7	8,2
3-4	1,4	6,9	0,6	6,1	1,2	6,8
4-5	0,4	2,7	0,6	3,2	0,7	2,9
5-6	-	3,7	0,3	3,5	0,3	3,8
6-7	-	1,4	-	1,7	-	1,9
7-8	-	6,4	-	5,5	-	5,9
8-9	-	1,8	-	3,8	-	3,2
9-10	-	5,0	-	5,5	-	3,4
10-11	-	1,8	-	3,8	-	3,4
> 11	-	5,9	-	8,9	-	7,4
Nombre Moyen d'animaux par Troupeau	56		70		64	

Moyenne significativement différente ($p < 0,05$)
Source : Projet de Développement Pastoral Intégré

Tableau N° 12 : Parametres de Reproduction de la Race Bovine Borgou suivant le mode d'elevage et la Region

PRODUCTION	**TRADITIONNEL SEDENTAIRE**	**TRANSHUMANT**	**ENSEMBLE**
Taux de fécondité (%)	64,4	66,9	65,4
Taux de stérilité (%)	-	-	
Taux d'avortement (%)	4 ± 10,6	4 ± 10,6	
Age à la puberté	-	-	
Poids à la puberté (kg)	-	-	
Age au 1^{er} vêlage (mois + jours)	42 + 20 (62)	45 + 17 (62)	43 + 16
Intervalle entre vêlages (mois + jours)	15 + 8 (162)	17 + 18 (162)	16 + 3
Poids à la naissance (Kg)	18,4	18,4	
PRODUCTION Taux de mortalité (%)			
- Global	5,7	9,0	7,5
- 0-1 an	18,7	26,6	23,1
- Adultes	3,2	3,2	3,1
Taux d'exploitation	13,8	10,2	11,8,
Taux de croît	3,2	4,0	3,9

Les chiffres entre parenthèses représentent le nombre d'observation
Moyenne significativement différente ($P < 0,05$)
Source : Projet de Développement Pastoral Intégré dans le Borgou Phase II (FAO)

Tableau N° 13: Indices de Production d'une Vache Borgou en Milieu Traditionnel (Pression glossinaire faible)

PARAMETRES	SEDENTAIRE	TRANSHUMANT	ENSEMBLE
Viabilité des femelles adultes (%)	96,8	96,9	96,9
Taux de vêlage (%)	64,4	66,2	65,4
Viabilité des veaux jusqu'à 1 an (%)	81,3	73,4	76,9
Vaux atteingant 1 an (%)	52,3	48,6	50,2
Poids des veaux de 1 an (kg)	89,5	89,5	89,5
Lait trait par an (kg)	200	200	200
Vaches achevant une lactation ((%)	90,6	86,7	88,4
Equivalent en poids vif de lait trait (kg)	20,1	19,2	19,6
Poids total des veaux de 1 an produit par Vache (kg)	46,8	43,5	44,9
Indice de productivité par vache et par an (kg)	67,9	63,7	65,5
Poids des femelles adultes (kg)	239,5	239,5	239,5
Indice de productivité (kg)	28,3	26,6	27,4

Source : Projet de Développement Pastoral Intégré dans le Borgou Phase II (FAO)

4.3- Production laitière

La production laitière journalière d'une vache Borgou en milieu traditionnel est estimée à 2,5 litres (DEHOUX et *al.*, 1992). La période de lactation dure 250 jours. Ainsi donc la production de lait est estimée à 530 kg. Environ 60 p. 100 de cette production est destinée au veau.

4.4- Rendement du troupeau

Le taux d'exploitation (vente, dons, confiage, abattage et perte) est de :

11,8, ± 6,5 p. 100 pour l'ensemble des troupeaux. Le taux d'exploitation est plus élevé pour les animaux sédentaires (13,8 p. 100) que pour les animaux transhumants (10,2 p. 100). Cette différence s'explique surtout par le taux de mortalité plus élevé des taurillons et des génisses dans les troupeaux transhumants.

Les taureaux, les génisses et les veaux représentent respectivement 8,4 et 3. p100 des animaux exploités.

4.5- Cours du bétail

Les prix de vente varient selon la race, l'état, l'âge, le sexe de l'animal et suivant la saison. En saison sèche les prix sont de 15 p. 100 plus élevés qu'en saison des pluies. Les prix varient également en fonction des départements. Les prix sont plus bas dans les zones rurales que dans les zones urbaines (zones de consommation). Précisons qu'à la vente les animaux ne sont jamais pesés. Au Bénin, entre 1993 et 2000, les cours des bovins ont fortement progressé sur les marchés.

Cette évolution est le résultat de la baisse de l'offre sur les marchés, de la hausse des prix des produits pétroliers qui provoque un renchérissement du coût des transports du bétail et d'une forte demande à l'exportation. Les cours des petits ruminants sont aussi en hausse mais ceux-ci sont moins prononcés. Actuellement, seuls quelques marchés sont suivis au Bénin (Bohicon et Glazoué, Parakou etc). Le tableau N° 14 ci-dessous indique les prix approximatifs pratiqués sur les marchés.

Tableau N° 14 : Les Prix Approximatifs de Betail en 1993 et en 2000

TYPE	ANNEES	
	PRIX (F.CFA) 1993	PRIX (F.CFA) 2000
Taurillon	20.000 – 25.000	60.000 – 70.000
Génisse	30.000 – 40.000	60.000 – 80.000
Taureau	50.000 – 55.000	120.000 – 240.000
Vache	35.000 – 45.000	90.000 – 150.000
Ovin femelle	5.000 – 6.000	10.000 – 11.500
Ovin mâle	7.000 – 8.000	11.000 – 14.000
Caprin	4.500 – 5.000	11.000 – 18.000

Source : Rapports d'activités des abattoirs de Cotonou et de Parakou.

En ce qui concerne le prix du kg de viande, il variait entre 400 et 700 F.CFA en 1993. Mais en 2001 il varie entre 1.000 et 1800 F.CFA

4.6- Données sur les mouches tsé-tsé et les Trypanosomoses Animales dans la zone d'étude

4.6.1- Données sur les mouches tsé-tsé

Dans la zone d'étude les espèces de mouches tsé-tsé suivantes ont été capturées au cours des prospections entomologiques réalisées en 1989 (CODJIA V., 1989) :

- *Glossina tachinoides*
- *G. palpalis gambiensis*
- *G. morsitans submorsitans*

Les années de sécheresse successives, la poussée rapide de l'occupation des terres et la rigueur du climat ont contribué à une grande modification de la végétation. En effet lorsqu'on visite la partie septentrionale du Bénin, on a l'impression que la végétation de cette zone est plus dégarnie que dans le sud du Niger qui est situé au nord du Bénin. Cette observation s'explique par :

- le laxisme en matière d'abattage des arbres et des rôniers au Bénin pour faire des lattes de bois pour les constructions,
- l'occupation anarchique des terres et parfois même des aires protégées pour installer des champs.

Les gîtes à glossines sont surtout les galeries forestières qui bordent les cours d'eau, les barrages, les mares et les zones innondables qui servent de points d'abreuvement pour le bétail. Toutefois précisons que les densités apparentes des mouches sont souvent faibles (Voir tableau N° 15).

Tableau N° 15 : Recapitulatif des Densites Apparentes de Glossines par Especes

ESPECES DE GLOSSINES	DENSITES APPARENTES (Glossines/Piège/jour)
G. tachinoides	0,27 – 20
G. palpalis gambiensis	0,05 – 1,07
G. morsitans submorsitans	0,06 – 0,5

Source : Rapport de prospection (CODJIA V., 1989)

4.6.2- Données sur les Trypanosomoses Animales et autres hémoparasitoses

L'analyse des résultats des enquêtes protozoologiques effectuées dans la zone d'étude indique que les espèces de trypanosomes rencontrées sont :

- *Trypanosoma vivax*
- *T. congolense*
- *T. brucei brucei*

La prévalence moyenne est de 22,50 p. 100. Les taux d'infection par espèces de trypanosomes se présentent comme suit : (Voir tableau N° 16)

Tableau N° 16: Taux d'Infection Trypanosomienne par Espece de Trypanosomes

ESPECES DE TRYPANOSOMES	TAUX D'INFECTION (p.100)
Trypanosoma vivax	6,07 – 23,80
T. congolense	3,07 – 30,95
T. brucei brucei	1,09 – 3,07

Source : Rapport prospection (CODJIA V., 1989)

N.B. : Les veaux et les taureaux sont les plus affectés par les trypansomoses (18,9 p.100 pour les veaux et 35,8 p.100 pour les taureaux)

Dans l'ensemble les infections à *T. vivax* sont prédominantes : 11,29 p.100
Contre 10,12 p.100 pour *T. congolense* et 1,09 p.100 pour *T. brucei brucei*. La fréquence relative des infections mixtes de trypanosomes est de 3,83 p.100.

4.6.3- Opérations de lutte contre les mouches tsé tsé et les trypanosomoses animales

Aucune opération de lutte contre les mouches tsé et les trypanosomoses animales de grandes envergures n'a été effectuée dans les zone d'étude. Les quelques opérations de déploiement de pièges et écrans imprégnés d'insecticides ou de traitements insecticides des bovins ont été très limitées dans le temps et dans l'espace.

4.6.4- <u>Données sur la trypanosomose au niveau des bovins de trait</u>

Les bovins de trait font souvent l'objet d'un suivi vétérinaire régulier (déparasitage contre les parasites gastro-intestinales et traitements trypanocides). Les taux d'infections des bovins de trait sont inférieurs à 10 p.100 dans les échantillons qui ont fait l'objet d'une enquête.

4.6.5- <u>Les traitements trypanocides</u>

En l'absence d'un laboratoire de diagnostic vétérinaire fonctionnel ayant des équipes mobiles, le diagnostic des trypansomoses demeure pathognomonique (les marges d'erreur sont souvent élevées)..On utilise donc abondamment les trypanocides. A cause de la forte demande des produits trypanocides, il s'est développé un réseau important de vente de produits falsifiés dont les prix défient toutes concurences.

Le chlorure de chlorhydrate d'isométamidium (Trypamidium N. D.) est le plus utilisé à cause de son activité prophylactique aux doses indiquées par le fabriquant. Le diminazène figure également dans la liste des trypanocides utilisés. Dans plusieurs campements les éleveurs assurent eux-mêmes les injections de trypanocides avec tous les risques que cette pratique comporte (abcès, sous dosage, mauvaise dilution, manque d'asepsie etc).

4.6.6- <u>Autres hémoparasitoses</u>

Outre les trypanosomes, les parasites sanguins rencontrés sont :
- *Babesia bovis*
- *Theileria mutans*
- *Anaplasma marginale*
- *Setaria labiatopillosa* (mocrifilaires)

Tableau N° 17 : Taux d'Infection des autres Hemoparasites

ESPECES D'HEMOPARASITES	TAUX D'INFECTION (p.100)
Babesia bovis	2,98 – 9,49
Theileria mutans	3,79 –6,03
Anaplasma marginale	0,29 – 3,07
Setaria labiatopapillosa	1,66 – 19,10

<u>Source</u> : Rapport prospection (CODJIA, V., 1989)

4.7- <u>Autres vecteurs de maladies</u>

4.7.1- <u>Les tiques</u>

Les infestations à tiques sont importantes au cours des saisons pluvieuses. Dans la zone d'étude les genres de tiques dominants sont :

- *Amblyomma*……………….87,7 p.100
- *Hyalomma*…...……………..7,4 p.100
- *Boophilus*……...……………4,9 p.100

Avec les principales espèces que sont :
- *Amblyomma variegatum*
- *Hyalomma nitidum*

- *Hyalomma truncatum*
- *Hyalomma marginatum rufipes*
- *Boophilus annulatus*
- *Boophilus geigyi*

4.7.2- Les Tabanidés

Les tabanidés capturés dans la zone d'étude sont :

- *Tabanus gratus*
- *Tabanus taeniola*
- *Hippocertrum versicolor*

4.7.3- Les Hippoboscidés

Hippobosca variegata est souvent rencontré dans les sous-préfectures de Ségbana kalalé et Kandi.

4.7.4- Autres diptères

Plusieurs autres diptères muscidés et calliforidés pullulent dans la zone d'étude.

4.8- Autres causes de mortalité

En dehors des Trypanosomoses Animales et les parasitoses gastro-intestinales (LADIKPO, 1984) affectent sérieusement l'état de santé des animaux qui sont parfois en état de sous – nutrition. La brucellose bovine à *Brucella abortus* dont la prévalence sérologique est estimée à 10,7 p. 100 (DEHOUX, 1992). La Streptothricose (*Dermatophilus congolensis)* est fréquente en saison des pluies et provoque la mortalité chez les jeunes animaux.

Le taux d'infection de la tuberculose est de l'ordre de 0,47 p. 100. Des foyers de péripneumonie contagieuse bovine existent dans la zone d'étude et chaque année plusieurs dizaines d'animaux sont abattus. Le charbon symptomatique et bactéridien et la Septicémie hémorragique sont diagnostiqués tous les ans après le retour de la transhumance ou des pluies (SAKA et *al.* 1991). Tous les ans des campagnes de vaccinations contre les maladies majeures du bétail sont organisées par les services vétérinaires.

5. DONNEES SUR LES PRODUCTIONS VEGETALES DANS LA ZONE D'ETUDE

5.1- Les cultures de rente et cultures vivrières

Les productions végétales sont en progression depuis plusieurs années compte tenu de la demande croissante des populations et des besoins d'accroissement des revenus des agro-éleveurs. Les principales cultures de rentes sont : le coton et l'arachide.

Les principales cultures vivrières sont : le manioc, le maïs, le sorgho, le riz, le niébé, l'igname, le piment, le petit mil et la patate douce.

Les tableaux N° 18 et 19 présentent l'évolution des réalisations des principales cultures par sous-préfecture.

Tableau 18 Superficie ha.

	1993/4	1994/5	1995/6	1996/7	1997/8	1998/9
Coton	59000	50112	81653	109981	115066	103458
Arachide	11760	13177	12712	14318	15713	18839
Manioc	3731	3939	4548	5003	4447	5186
Mais	46455	51039	55182	57610	63619	69190
Sorgho	40984	43404	43119	42473	45701	47950
Riz	574	1294	1060	1847	2184	2609
Niebe	7270	8698	9180	9140	9591	9646
Igname	21145	23090	24333	28421	26667	29266
Piment	1894	1830	2075	2174	1968	1808
Petit-Mil	437	396	246	385	530	267
Patate douce	114	199	1043	510	493	526
Total	193364	197178	235151	271862	285979	288745

Source : Annuaire statistique du Ministère du Développement Rural campagne 1998 – 1999

Tableau 19 Rendement kg / ha.

	1993/4	1994/5	1995/6	1996/7	1997/8	1998/9	Average
Coton	1392	1787	1479	1026	1086	875	1274
Arachide	1029	1009	1013	1121	1073	1036	1047
Manioc	6467	7739	6539	6404	6072	6511	6622
Mais	1157	1141	1158	1194	1333	1318	1217
Sorgho	830	831	859	773	827	836	826
Riz	1693	1406	1582	2308	2413	2778	2030
Niebe	563	616	617	621	765	876	676
Igname	9276	9456	9357	8621	8352	9603	9111
Piment	710	950	941	997	1272	1251	1020
Petit-Mil	650	699	699	600	600	599	641
Patate douce	1746	5241	1443	4261	3724	3525	3323

Source : Annuaire statistique du Ministère du Développement Rural campagne 1998 – 1999

5.2- Interventions phytosanitaires

Au cours des cinq dernières années, le recensement des problèmes phytosanitaires au niveau des paysans a révélé les préoccupations majeures suivantes :

- destruction des semis par les insectes terricoles, les rongeurs et les oiseaux granivores ;
- fonte des semis sur tomate ;
- infestation du maïs stocké en spathes ;
- infestation de la culture de niébé ;
- chute des fruits sur manguiers et agrumes ;
- infestation des cultures maraîchères ;
- infestation des cultures de maïs, sorgho et niébé par la Striga ,
- dégâts de sauteriaux et du criquet puant sur les céréales et le manioc ;
- pourriture des fruits sur tomate ;
- pourriture sur pomme de terre au stockage ;
- infestation des cossettes de manioc et d'igname.

L'impact économique de ces problèmes phytosanitaires sur l'économie national est assez préoccupant. Le Service de Protection des Végétaux et Contrôle Phytosanitaire a effectué les interventions suivantes :

En 1999

- La lutte contre les sauteriaux dans le Département du Borgou (sous-préfectures de Malanville, Karimama, Banikoara et Kandi) : 1.781 hectares ont été infestés avec une densité moyenne de population de 12,7 individus par m². 964 hectares seulement ont été traités avec 1.350

kilogrammes de Propoxur PP 4% à la dose de 4 kilogrammes à l'hectare et 694 litres de Fénitrothion 500 EC à la dose de 1 litre à l'hectare.

- La lutte contre les chenilles légionnaires *Spodoptera exempta* dans les départements de l'Atacora et du Borgou : 366 hectares ont été déclarés infester. 307 hectares (84%) ont été traités à l'Orthène 75 SP(Acéphate 750 kg à la dose de 5 kilogrammes dans 30 à 50 litres d'eau à l'hectare et au Fénitrohion 500 EC à la dose de 1 litre à l'hectare. Parmi les cultures infestées, seul le riz a pu reprendre rapidement. Pour les autres (maïs, sorgho et petit mil), les semis ont été remis en place.

- La lutte biologique contre le Grand Capucin du maïs (*Prostephanus truncatus*) au niveau des greniers paysans : l'activité de production en masse des individus de *Teretriosoma nigrescens* en vue de la lutte biologique contre le Grand Capucin du maïs ((*Prostephanus truncatus*) est permanente. 116.800 individus de *Prostephanus truncatus* ont été produits et ont permis d'élever 22.184 individus de *Teretriosoma nigrescens*. 19.500 individus de *Teretriosoma nigrescens* ont été lâchés dans 10 sous-préfectures (Savalou, bantè, Pèrèrè, Sinendé, kandi, Parakou, Ségbana, Tchaourou, Banikoara, Malanville). Le suivi et l'évaluation de l'impact des lâchers de l'ennemi naturel dans les greniers permettront d'apprécier le niveau d'infestation des stocks de maïs par le Grand Capucin du Maïs. L'assistance technique de l'IITA a aidé à soutenir ce programme.

EN 2000

- La lutte contre les sauteriaux dans le Département de l'Alibori (sous-préfectures de Malanville, Karimama, Banikoara et Kandi) 1.415 hectares ont été infestés avec une densité moyenne de 17,5 individus par m². Au total, 1384 ha (97,8%) ont été traités avec 1020 kg de Propoxur PP. 4% à la dose de 4kg/ha 214 litres de Cotaim D à la dose de 1 litre à l'hectare et 1038 litres de Fenitrothion E.C à la dose de 1 litre à l'hectare.

5.3- Prix de cession des intrants aux producteurs de coton

La filière de production du coton bénéficie du soutien de la Société Nationale de Promotion Agricole (SONAPRA). Les tableaux N° 20 et 21 indiquent respectivement :

- les prix de cession des intrants aux producteurs au cours des campagnes de 1996/1997 à 1999/2000
- les prix d'achat du coton graine des campagnes 1992/1993 à 1999/2000.

Tableau N° 20 : Prix de Cession des Intrants aux Producteurs

PRODUITS	PRIX DE CESSION (FCFA)
	99/00
Tout engrais (kg)	
Insecticide UL (L)	2000
Insecticide CE (L)	3450
App. Berthoud (U)	32900
App. ULVA (U)	32900
Cotodon (L)	5200
Cotogard (L)	4975
Fluorone D (L)	5800

Source : Rapports d'activités de la SONAPRA.

Tableau N° 21: Prix d'Achat Coton Graine de 92-93 á 99-00

ANNEES	PRIX D'ACHAT F.CFA/Kg	
	1er choix	2ème choix
1992-1993	100	80
1993-1994	110	90
1994-1995	145	110
1995-1996	165	125
1996-1997	200	150
1997-1998	200	150
1998-1999	225	200
1999-2000	185	135

Source : Rapports d'activités de la SONAPRA.

5.4- Prix de cession des produits vivriers sur les marchés

Les prix de cession des produits vivriers sur les marchés varient en fonction de plusieurs facteurs parmi lesquels on peut citer :

- la période de l'année
- le lieu de vente (différence entre zones urbaines et zones rurales)
- la demande des marchés intérieurs et extérieurs.

Les tableaux N° 22 présentent les relevés des prix des produits vivriers sur les marchés pour les années 2000, 1999 et 1994.

Tableau N° 22 : Releves des Prix de Produits Vivriers sur la Marche de Malanville, **(**Jan 1994-Dec 2000)

FCFA/kg												
	Maïs	Mil/Sorgho		Riz		Igname		Igname Coss.	Gari		Manioc Coss.	Ara-chide graine
		Blan.	Roug	Local	Impo.	Ordi.	Pilé		Ordi	Fin		
Dec 2000	80	80	80	235	300	135	200	265	100	150	ND	520
Dec 1999	75	75	80	235	280	60	100	200	95	155	ND	295
Jan 1999	85	110	110	270	305	95	110	215	120	190	120	305
Dec 1994	60	ND	60	225	235	40	ND	105	85	145	40	205
Jan 1994	50	50	50	130	65	60	60	95	90	120	55	210

5.5- Les ressources naturelles

Dans la zone d'étude, il existe des ressources naturelles importantes à savoir :

- les forêts classées (la forêt classée du Goungoun, la forêt classée de la Sota, la forêt classées des trois rivières).
- une faune variée
- de vastes zones agro-pastorales.

Le tableau N° 23 présente la qualité, les risques de dégradation, et les aptitudes du sol pour les productions vivrières et les productions de rente dans la zone d'étude.

Tableau N° 23 : Les Ressources Naturelles

SOLS **RISQUES**

Qualité

N°	SOUS-PEFECTURES	TYPE DE SOL DOMINANT	TYPE CULTURE DOMINANTE	INDICE APTITUDE CULTURALE	INDICE APTITUDE CULTURALE. 2ème CULTURE	RISQUE DE DEGRADATION	ECHELLE App. DEGRADATION	ECHELLE App. DE L'APTITUDE
1	Malanville	Sol peu évolué hydromorphe sur matériaux alluvial argileux du fleuve Niger	Mil 1ère C Oignon 2è C	10 -	- 5	Moyen	5	10
2	Nikki	Sol ferrugineux tropicaux peu lessivé à concrétions sur embréchite	Coton 1ère C Igname 2è C	5	5	Moyen	5	5
3	Gogounou	Sol ferrugineux tropicaux à concrétions sur embréchite	Coton 1ère C Igname 2è C	1	5	Moyen	5	1
4	Bembèrèkè	Sol ferrugineux tropicaux peu lessivé à concrétions dans altération kaolinique granito gneiss alcaline	Coton 1ère C Igname 2è C	5	5	Moyen	5	5
5	Kalalé	Sol ferrugineux tropicaux peu lessivé sans concrétions sur grès du Crétacé	Coton 1ère C Igname 2è C	5	5	Moyen	5	5
6	Ségbana	Sol ferrugineux tropicaux peu lessivé sans concrétions sur éluvions sablo argileux du crétacé	Coton 1ère C Igname 2è C	1	5	Moyen	5	1
7	Kandi	Sol ferrugineux tropicaux peu lessivé induré sur grès du crétacé	Coton 1ère C Igname 2è C		10	Moyen	5	1

Source : Service d'Agro-pédologie, Ministère du Développement Rural. N.B. : App = Appréciation.

CONCLUSION

Les mouches tsé-tsé et les Trypanosomoses Animales sont reconnues par la plupart des services techniques, comme étant une des contraintes majeures pour le développement socio-économique de la zone d'étude.

En effet le Programme de Lutte contre l'Onchocercose a réussi à enrayer l'impact négatif des simulies. Il reste maintenant à éliminer ou tout au moins à réduire l'impact des mouches tsé-tsé et des Trypanosomoses.

De l'analyse des statistiques disponibles au niveau des différents services chargés du développement, on note clairement un accroissement rapide de la population de même que l'accroissement des superficies mises en valeur.

Il va sans dire que la demande en produits vivriers, cultures de rente (arachide et coton) et produits maraîchers est forte.

La visite de la zone d'étude permet de constacter une forte pression anthropique vers les galeries forestières bordant les principaux cours d'eau (Fleuve Niger et Sota) et leurs affluents. Il est même fréquent de contaster une occupation des aires protégées.

L'un des facteurs limitants majeurs de cette forte pression anthropique est la mouche tsé-tsé et les Trypanosomoses.

Il est plus certain, qu'un programme de lutte anti tsé-tsé permettra d'accroître le nombre de bovins de trait et par conséquent les productions agricoles. On pourrait donc espérer comme résultats immédiats la satisfaction des besoins alimentaires de même que l'accroîssement des revenus agro-éleveurs dans une zone où règne la pauvreté.

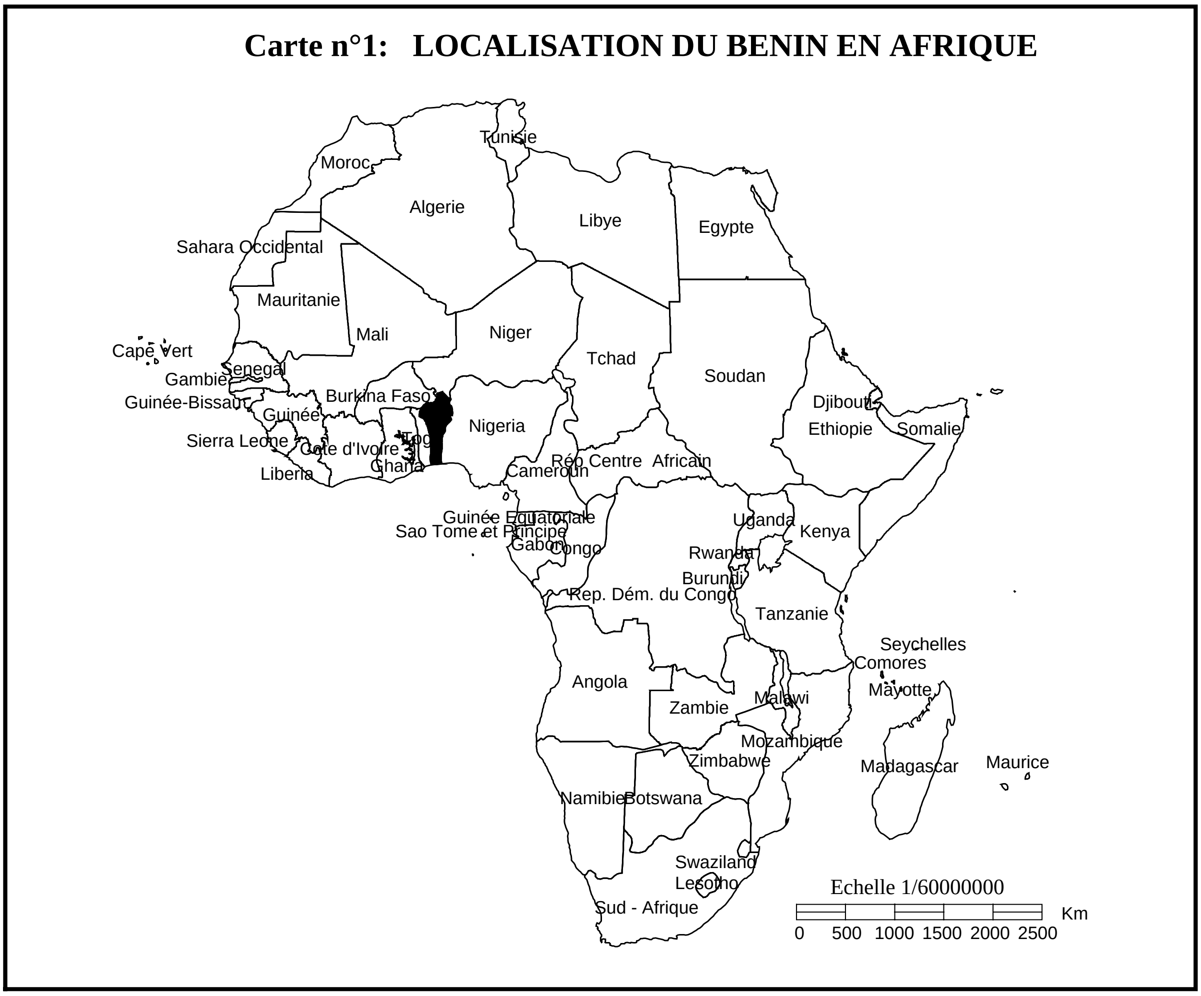
La réussite d'un tel programme dépendra de l'engagement politique des responsables des pays de la sous région et surtout d'un financement coordonné et soutenu dans le temps.

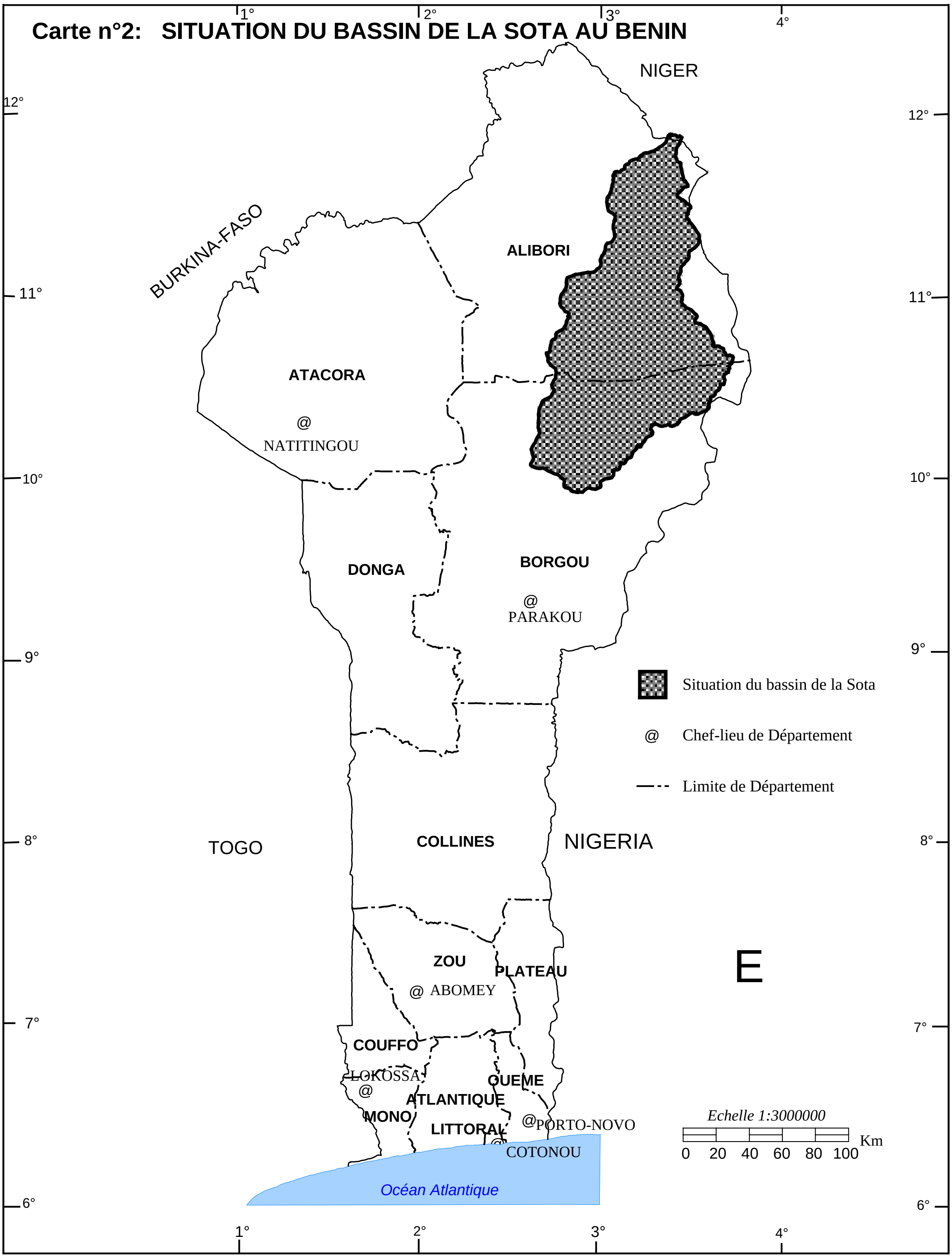
Aucune technique de lutte (pièges et écrans imprégnés d'insecticides, lâcher de mâles stériles, traitements épicutanés des animaux domestiques avec des insecticides, pulvérisations stratégiques) reconnue comme étant efficace ne devra être négligée a priori. On tiendra plutôt compte de la durabilité des résultats visés et des possibilités d'appropriation des différentes méthodes de lutte par les communautés concernées.

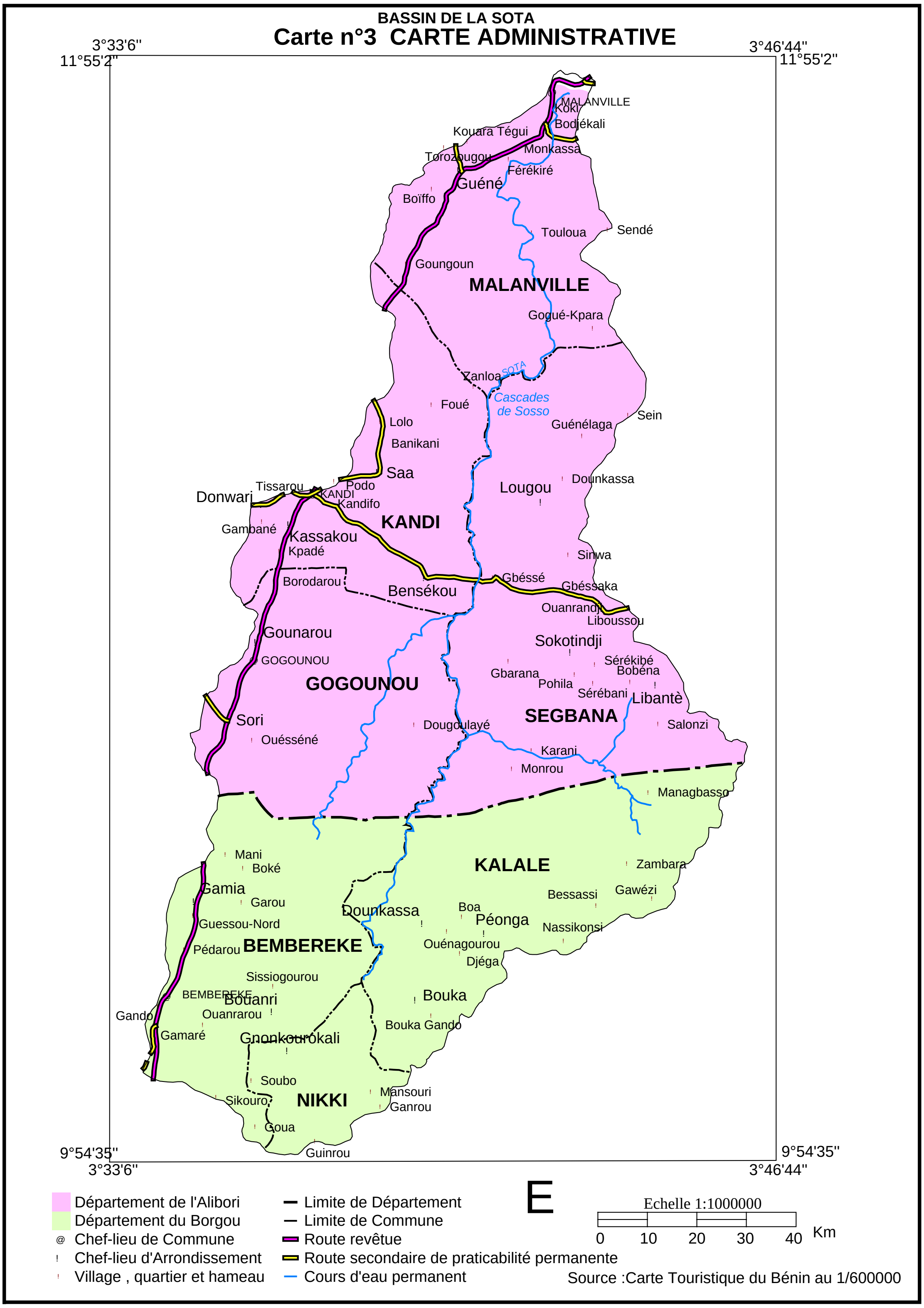
Il s'agira d'opter pour une lutte intégrée en veillant à la spécificité des zones d'intervention.

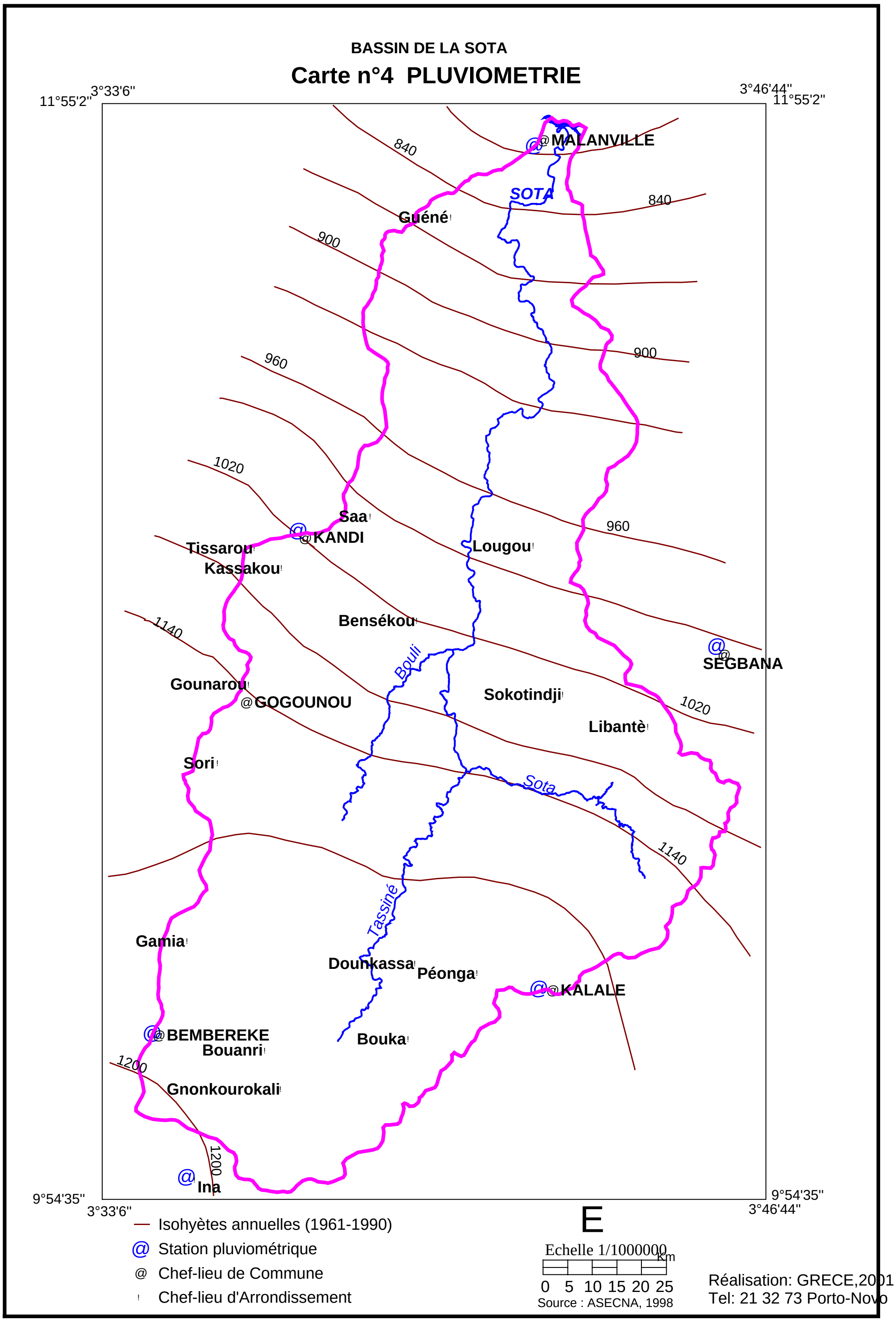
C'est pourquoi, l'initiative de l'AIEA de financer une analyse coût/bénéfice d'un programme régional de lutte contre les mouches tsé-tsé et les trypanosomoses mérite une attention particulière et un soutien de la part des pays concernés. L'objectif ultime étant après tout l'elimination ou du moins la reduction de la pauvreté dans une vaste zone aux potentialités agro-pastorales inouies.

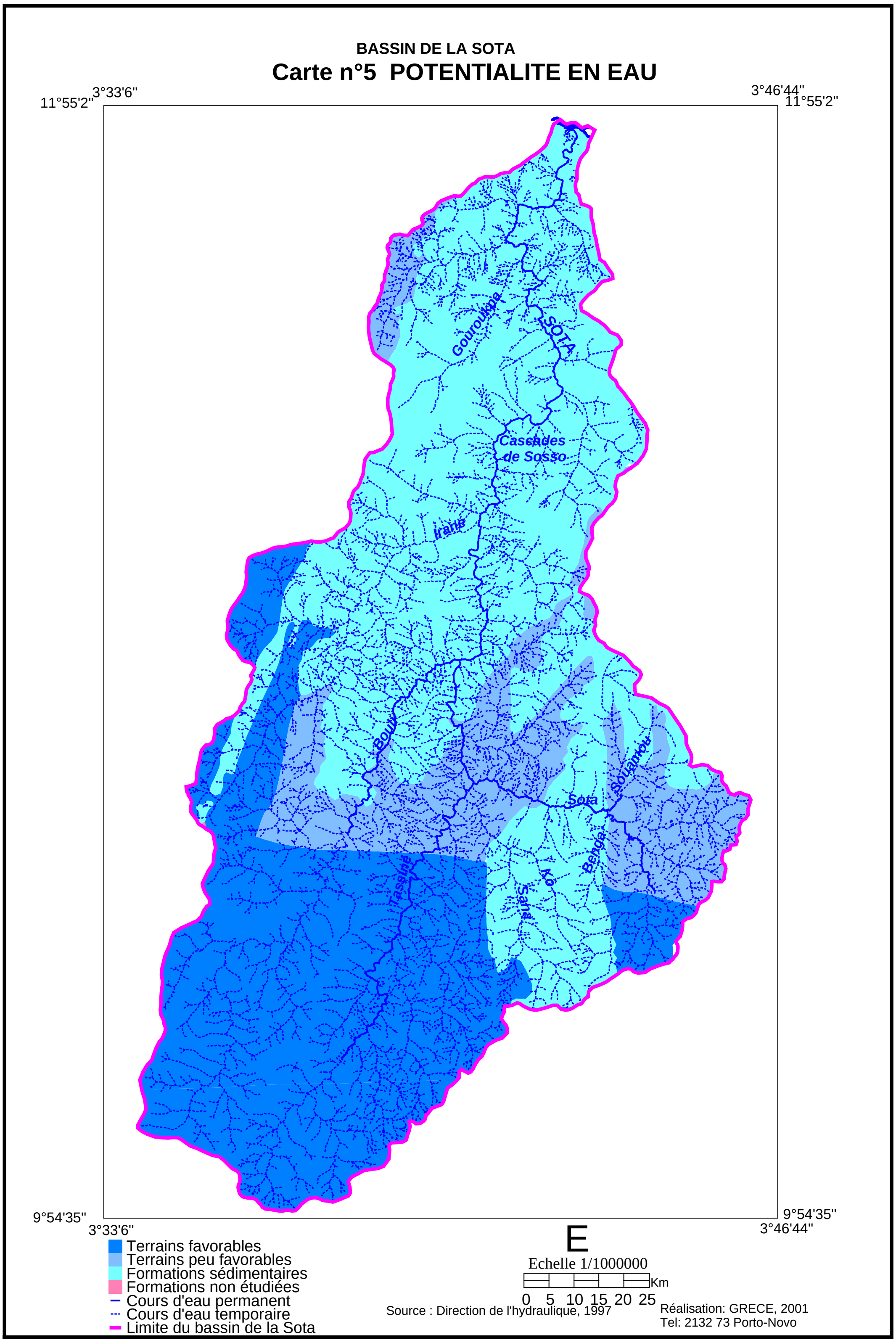
APPENDICES

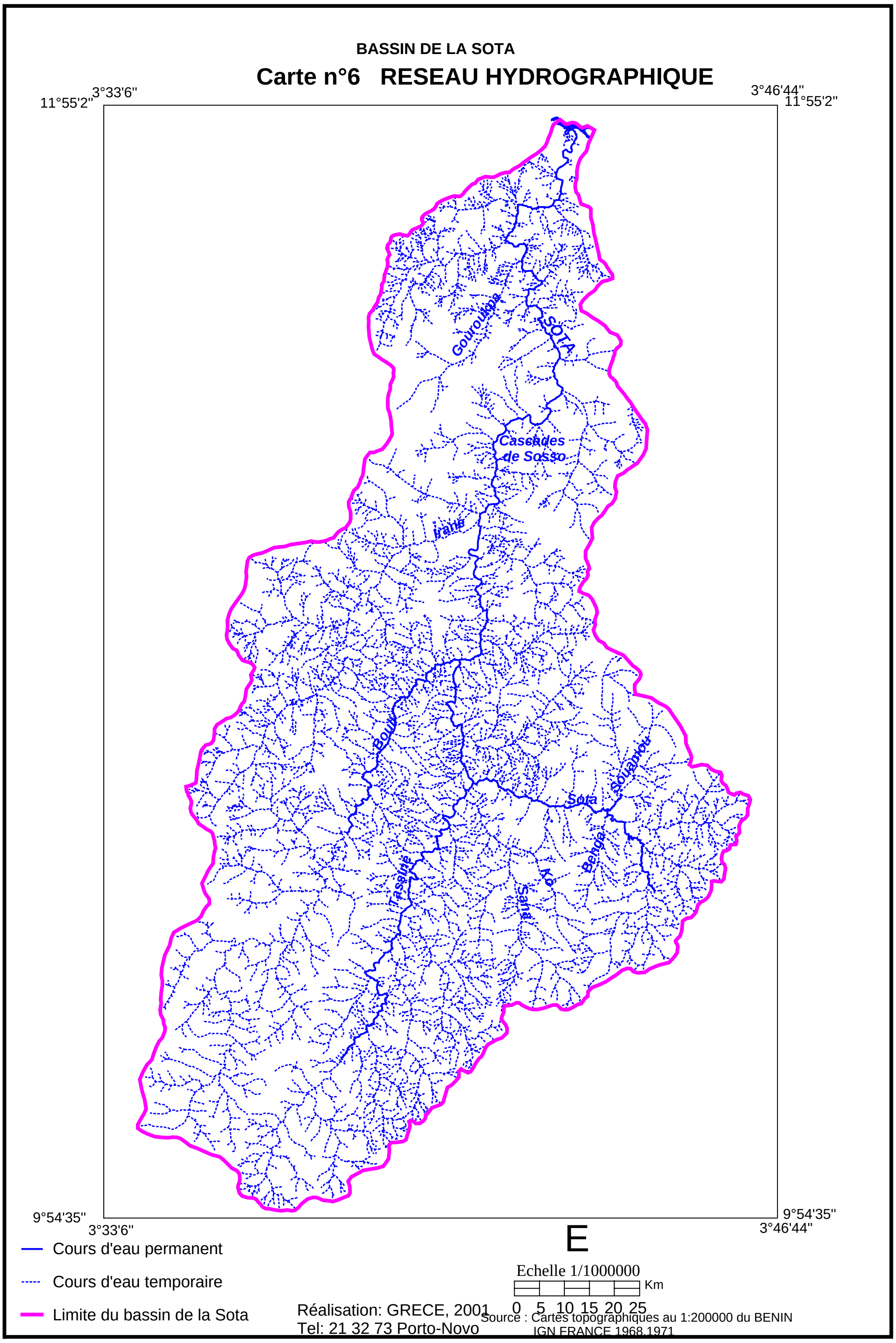

Carte n°1: LOCALISATION DU BENIN EN AFRIQUE
Tunisie
Moroc
Algerie
Libye
Egypte
Sahara Occidental
Mauritanie
Mali
Niger
Cape Vert
Tchad
Senegal
Soudan
Gambie
Burkina Faso
Djibouti
Guinée-Bissau
Guinée
Nigeria
Ethiopie
Somalie
Sierra Leone
Cote d'Ivoire
Ghana
Rép Centre Africain
Liberia
Cameroun
Guinée Equatoriale
Uganda
Sao Tome et Principe
Kenya
Gabon
Congo
Rwanda
Burundi
Rep. Dém. du Congo
Tanzanie
Seychelles
Comores
Angola
Mayotte
Malawi
Zambie
Mozambique
Zimbabwe
Madagascar
Maurice
Namibie
Botswana
Swaziland
Lesotho
Echelle 1/60000000
Sud - Afrique
Km
0 500 1000 1500 2000 2500

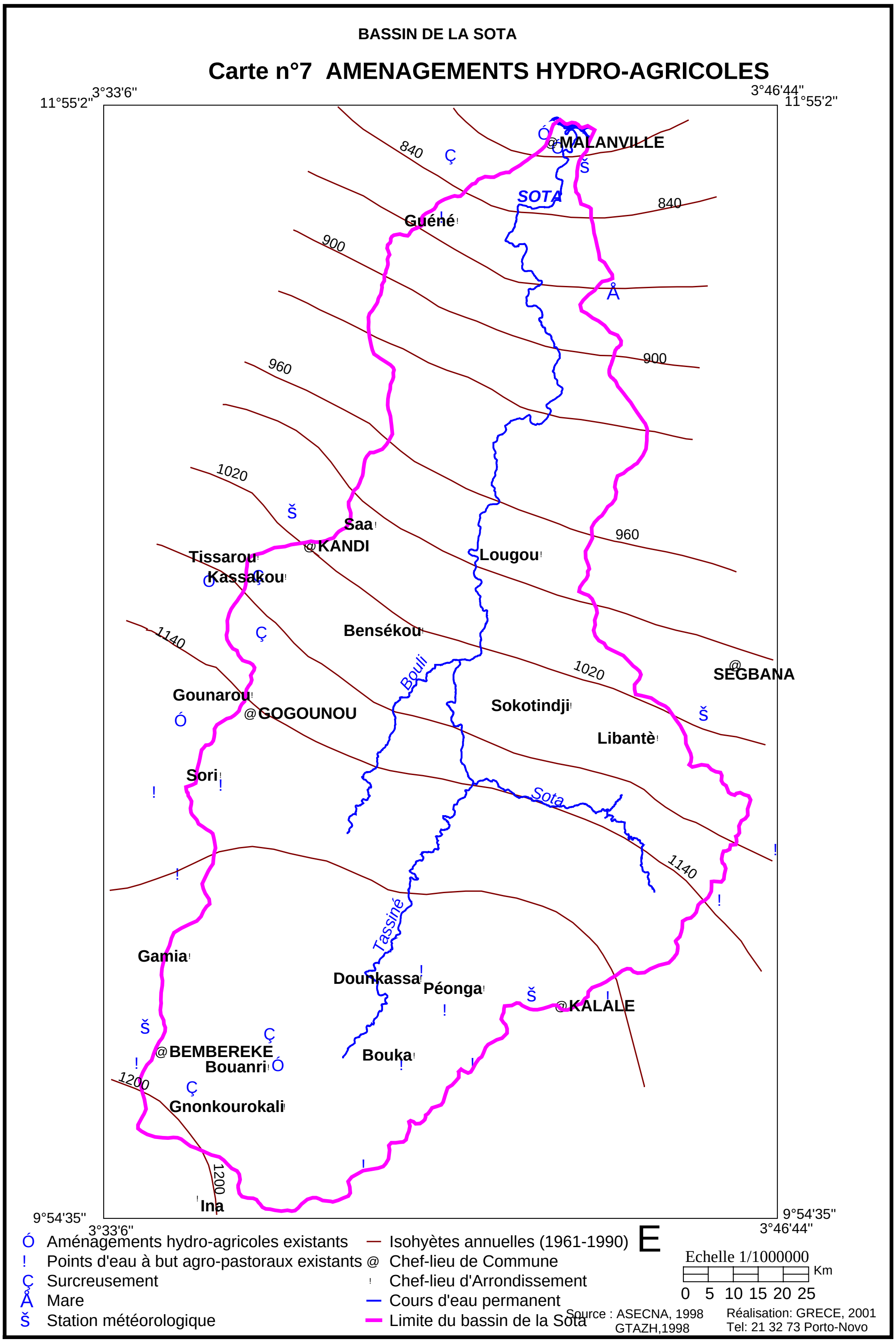

Carte n°2: SITUATION DU BASSIN DE LA SOTA AU BENIN
1°
2°
3°
4°
12°
11°
10°
9°
8°
7°
6°
NIGER
BURKINA-FASO
ALIBORI
ATACORA
@
NATITINGOU
DONGA
BORGOU
@
PARAKOU
Situation du bassin de la Sota
@ Chef-lieu de Département
Limite de Département
TOGO
COLLINES
NIGERIA
ZOU
PLATEAU
@ ABOMEY
E
COUFFO
LOKOSSA
@
OUEME
ATLANTIQUE
MONO
LITTORAL
@PORTO-NOVO
COTONOU
Echelle 1:3000000
Km
0 20 40 60 80 100
Océan Atlantique

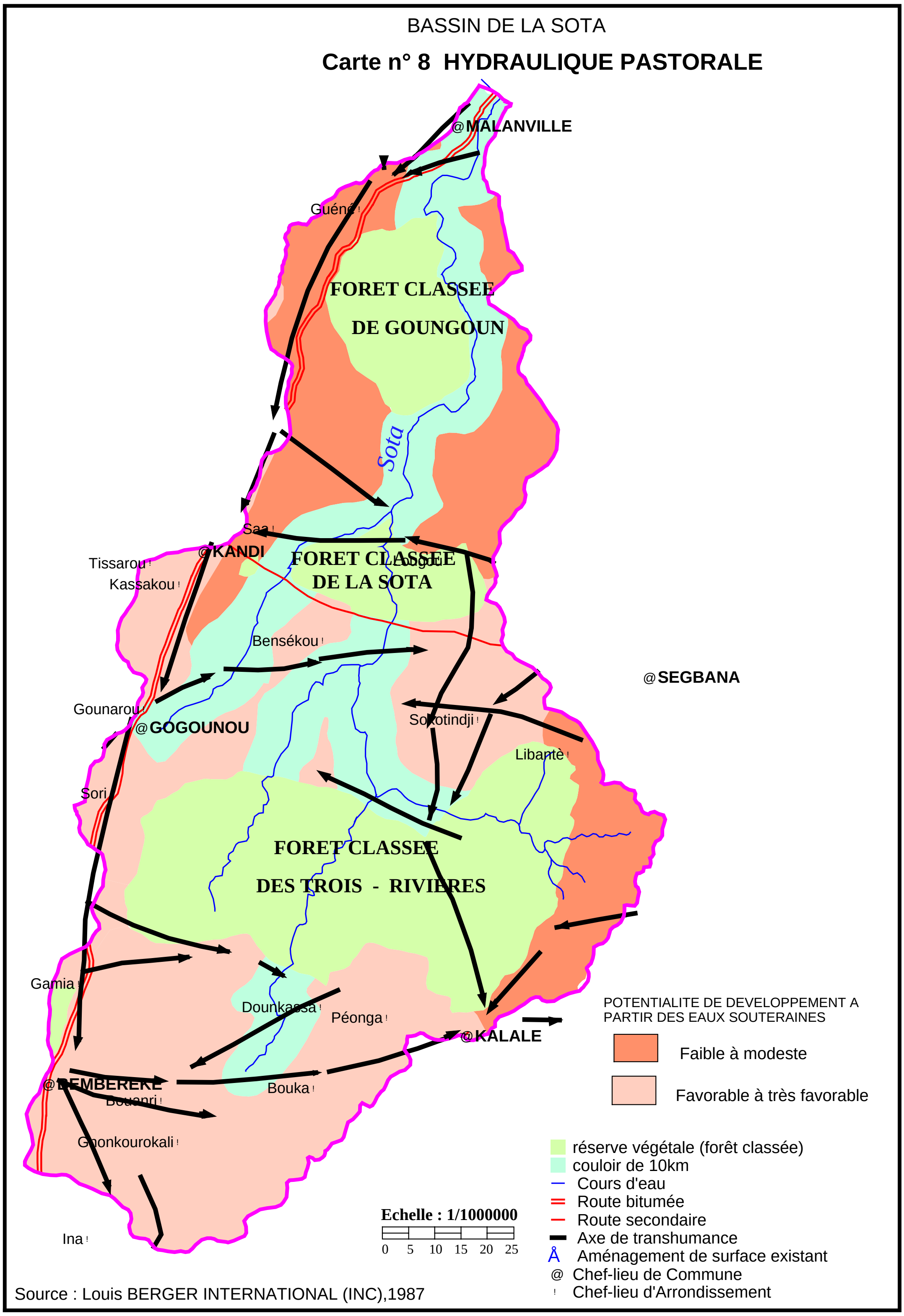

BASSIN DE LA SOTA
Carte n°3 CARTE ADMINISTRATIVE
3°33'6"
11°55'2"
3°46'44"
11°55'2"
MALANVILLE
Koki
Bodjékali
Kouara Tégui
Monkassa
Torozougou
Férékiré
Guéné
Boïffo
Touloua
Sendé
Goungoun
MALANVILLE
Gogué-Kpara
Zanloa
SOTA
Cascades de Sosso
Foué
Lolo
Guénélaga
Sein
Banikani
Saa
Dounkassa
Lougou
Tissarou
Podo
Donwari
KANDI
Kandifo
KANDI
Gambané
Kassakou
Kpadé
Sinwa
Gbéssé
Borodarou
Gbéssaka
Bensékou
Ouanrandji
Liboussou
Gounarou
Sokotindji
GOGOUNOU
Sérékibé
Bobéna
Gbarana
GOGOUNOU
Pohila
Sérébani
Libantè
Sori
SEGBANA
Dougoulayé
Salonzi
Ouésséné
Karani
Monrou
Managbasso
Mani
Boké
KALALE
Zambara
Gamia
Bessassi
Gawézi
Garou
Dounkassa
Boa
Péonga
Guessou-Nord
Nassikonsi
Pédarou
BEMBEREKE
Ouénagourou
Djéga
Sissiogourou
Bouka
BEMBEREKE
Bouanri
Gando
Ouanrarou
Bouka Gando
Gamaré
Gnonkourokali
Soubo
Mansouri
Sikouro
NIKKI
Ganrou
Goua
Guinrou
9°54'35"
3°33'6"
9°54'35"
3°46'44"
Département de l'Alibori
Département du Borgou
Chef-lieu de Commune
Chef-lieu d'Arrondissement
Village , quartier et hameau
Limite de Département
Limite de Commune
Route revêtue
Route secondaire de praticabilité permanente
Cours d'eau permanent
E
Echelle 1:1000000
0
10
20
30
40
Km
Source :Carte Touristique du Bénin au 1/600000

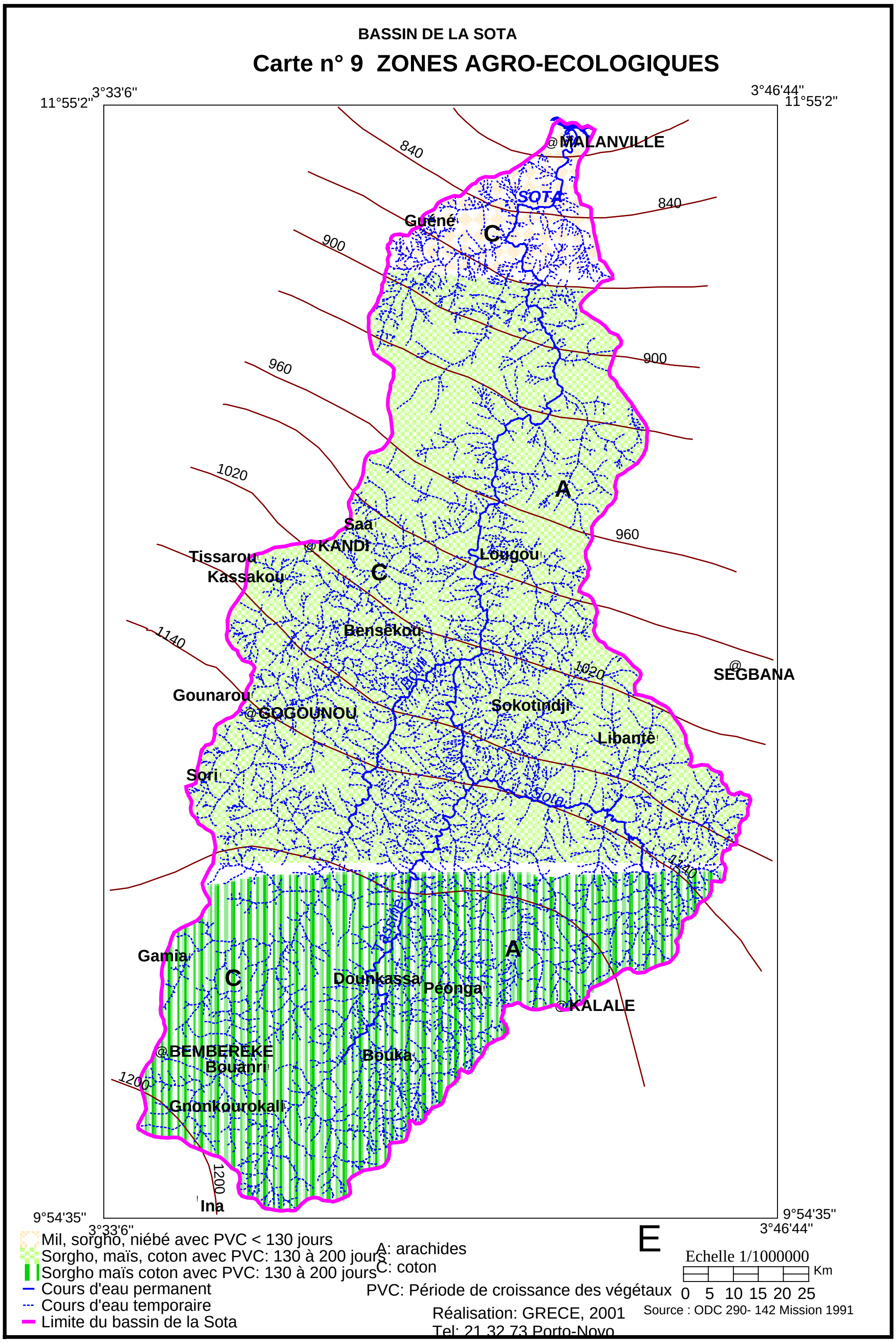

BASSIN DE LA SOTA
Carte n°4 PLUVIOMETRIE
11°55'2"
3°33'6"
3°46'44"
11°55'2"
9°54'35"
3°33'6"
9°54'35"
3°46'44"
MALANVILLE
SOTA
Guéné
Saa
KANDI
Tissarou
Kassakou
Lougou
Bensékou
SEGBANA
Gounarou
GOGOUNOU
Sokotindji
Libantè
Sori
Sota
Bouli
Tassiné
Gamia
Dounkassa
Péonga
KALALE
BEMBEREKE
Bouanri
Bouka
Gnonkourokali
Ina
840
900
960
1020
1140
1200
Isohyètes annuelles (1961-1990)
Station pluviométrique
Chef-lieu de Commune
Chef-lieu d'Arrondissement
E
Echelle 1/1000000
Km
0 5 10 15 20 25
Source : ASECNA, 1998
Réalisation: GRECE,2001
Tel: 21 32 73 Porto-Novo


BASSIN DE LA SOTA
Carte n°5 POTENTIALITE EN EAU
3°33'6''
11°55'2''
3°46'44''
11°55'2''
Gouroubera
SOTA
Cascades de Sosso
Irane
Bouli
Souamou
Sota
Tassiné
Beroua
Kô
Sana
9°54'35''
3°33'6''
9°54'35''
3°46'44''
Terrains favorables
Terrains peu favorables
Formations sédimentaires
Formations non étudiées
Cours d'eau permanent
Cours d'eau temporaire
Limite du bassin de la Sota
E
Echelle 1/1000000
0 5 10 15 20 25 Km
Source : Direction de l'hydraulique, 1997
Réalisation: GRECE, 2001
Tel: 2132 73 Porto-Novo


BASSIN DE LA SOTA
Carte n°6 RESEAU HYDROGRAPHIQUE
3°33'6"
11°55'2"
3°46'44"
11°55'2"
9°54'35"
3°33'6"
9°54'35"
3°46'44"
Gouroukpa
SOTA
Cascades de Sosso
Irane
Sota
Souamou
Benga
Ko
Sana
Tassine
Cours d'eau permanent
Cours d'eau temporaire
Limite du bassin de la Sota
E
Echelle 1/1000000
Km
0 5 10 15 20 25
Réalisation: GRECE, 2001
Tel: 21 32 73 Porto-Novo
Source : Cartes topographiques au 1:200000 du BENIN
IGN FRANCE 1968,1971

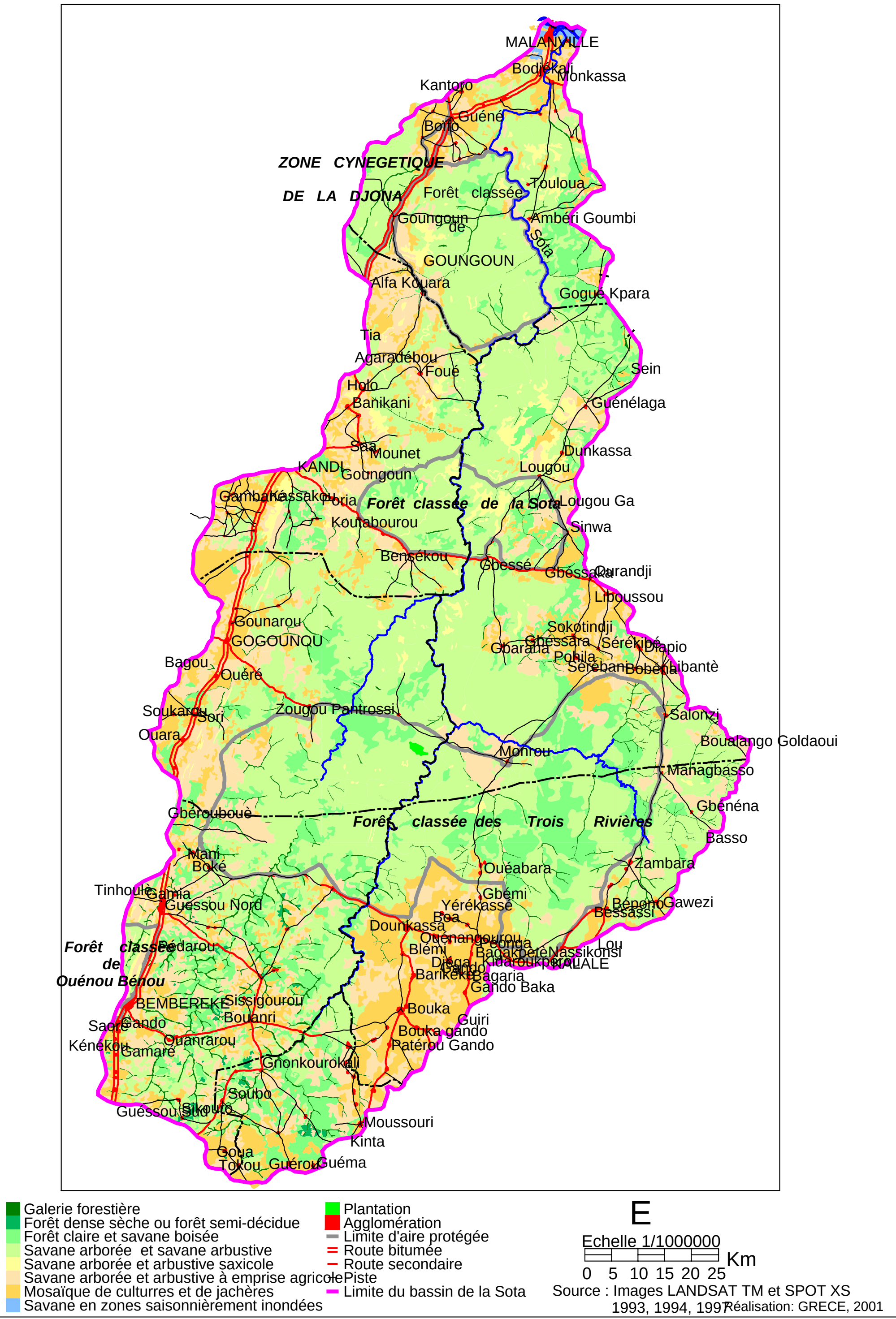

BASSIN DE LA SOTA
Carte n°7 AMENAGEMENTS HYDRO-AGRICOLES
11°55'2"
3°33'6"
3°46'44"
11°55'2"
MALANVILLE
SOTA
840
900
960
1020
1140
1200
Guéné
Saa
KANDI
Tissarou
Kassakou
Lougou
Bensékou
Bouli
SEGBANA
Gounarou
GOGOUNOU
Sokotindji
Libantè
Sori
Sota
Tassiné
Gamia
Dounkassa
Péonga
KALALE
BEMBEREKE
Bouanri
Bouka
Gnonkourokali
Ina
9°54'35"
3°33'6"
9°54'35"
3°46'44"
Ó Aménagements hydro-agricoles existants
! Points d'eau à but agro-pastoraux existants
Ç Surcreusement
Å Mare
Š Station météorologique
Isohyètes annuelles (1961-1990)
@ Chef-lieu de Commune
Chef-lieu d'Arrondissement
Cours d'eau permanent
Limite du bassin de la Sota
E
Echelle 1/1000000
0 5 10 15 20 25 Km
Source : ASECNA, 1998 GTAZH,1998
Réalisation: GRECE, 2001
Tel: 21 32 73 Porto-Novo

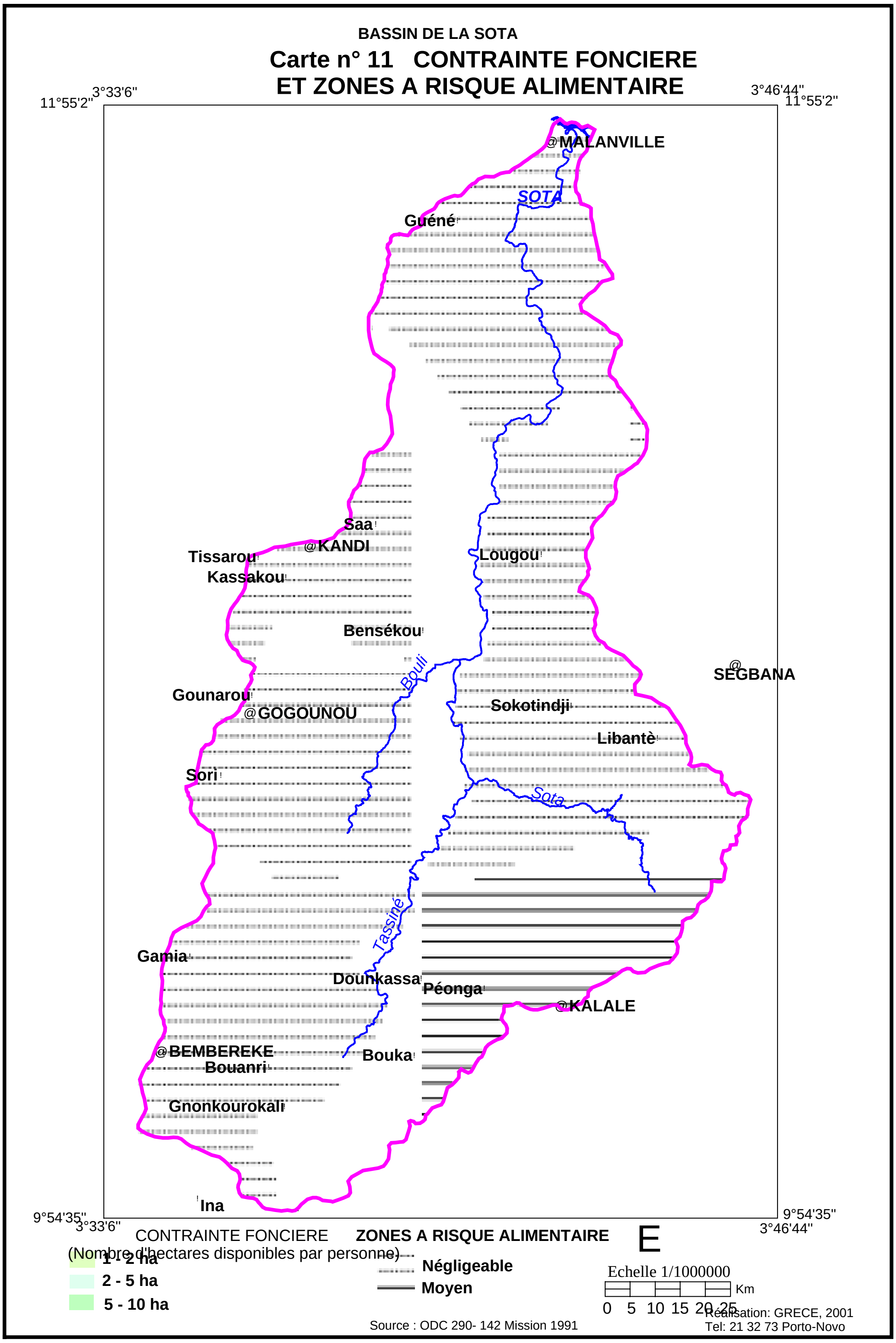

BASSIN DE LA SOTA
Carte n° 8 HYDRAULIQUE PASTORALE
@MALANVILLE
Guéné
FORET CLASSEE
DE GOUNGOUN
Sota
Saa
@KANDI
Tissarou
Kassakou
FORET CLASSEE
DE LA SOTA
Bensékou
@SEGBANA
Gounarou
@GOGOUNOU
Sokotindji
Libantè
Sori
FORET CLASSEE
DES TROIS - RIVIERES
Gamia
Dounkassa
Péonga
@KALALE
@BEMBEREKE
Bouanri
Bouka
Gbonkourokali
Ina
POTENTIALITE DE DEVELOPPEMENT A PARTIR DES EAUX SOUTERAINES
Faible à modeste
Favorable à très favorable
réserve végétale (forêt classée)
couloir de 10km
Cours d'eau
Route bitumée
Route secondaire
Axe de transhumance
Aménagement de surface existant
Chef-lieu de Commune
Chef-lieu d'Arrondissement
Echelle : 1/1000000
0 5 10 15 20 25
Source : Louis BERGER INTERNATIONAL (INC),1987


BASSIN DE LA SOTA
Carte n° 9 ZONES AGRO-ECOLOGIQUES
3°33'6"
11°55'2"
3°46'44"
11°55'2"
MALANVILLE
SOTA
840
Guéné
C
900
960
1020
A
Saa
KANDI
Tissarou
Kassakou
Longou
C
Bensékou
1140
SEGBANA
Gounarou
GOGOUNOU
Sokotindji
Libanté
Sori
Sota
1200
Gamia
C
Dounkassa
Péonga
A
KALALE
BEMBEREKE
Bouanri
Bouka
Gnonkourokali
Ina
9°54'35"
3°33'6"
9°54'35"
3°46'44"
Mil, sorgho, niébé avec PVC < 130 jours
Sorgho, maïs, coton avec PVC: 130 à 200 jours
Sorgho maïs coton avec PVC: 130 à 200 jours
Cours d'eau permanent
Cours d'eau temporaire
Limite du bassin de la Sota
A: arachides
C: coton
PVC: Période de croissance des végétaux
Echelle 1/1000000
0 5 10 15 20 25 Km
Réalisation: GRECE, 2001
Tel: 21 32 73 Porto-Novo
Source : ODC 290- 142 Mission 1991

BASSIN DE LA SOTA

Carte n° 10 OCCUPATION DU SOL




BASSIN DE LA SOTA
Carte n° 11 CONTRAINTE FONCIERE
ET ZONES A RISQUE ALIMENTAIRE
3°33'6"
11°55'2"
3°46'44"
11°55'2"
MALANVILLE
SOTA
Guéné
Saa
KANDI
Tissarou
Kassakou
Lougou
Bensékou
Bouli
SEGBANA
Gounarou
GOGOUNOU
Sokotindji
Libantè
Sori
Sota
Tassiné
Gamia
Dounkassa
Péonga
KALALE
BEMBEREKE
Bouanri
Bouka
Gnonkourokali
Ina
9°54'35"
3°33'6"
9°54'35"
3°46'44"
CONTRAINTE FONCIERE
(Nombre d'hectares disponibles par personne)
1 - 2 ha
2 - 5 ha
5 - 10 ha
ZONES A RISQUE ALIMENTAIRE
Négligeable
Moyen
E
Echelle 1/1000000
Km
0 5 10 15 20 25
Source : ODC 290- 142 Mission 1991
Réalisation: GRECE, 2001
Tel: 21 32 73 Porto-Novo

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Annex 4 Study Area 4 (Ka River, Nigeria) Report

Programme Against African Trypanosomosis

Options For Tsetse Fly Eradication in the

Moist Savannah Zone of West Africa:

Technical and Economic Feasibility Study,

Phase 1 (Ka River, Nigeria)

Professor Albert Ilemobade

March 2001

Annex 4 Study Area 4 (Ka River, Nigeria) Report

1. INTRODUCTION.

As a result of the renewed interest in large-scale tsetse eradication in Africa, the experience of Nigeria's early programme in tsetse reclamation provides a good source on which to build any future large-scale eradication in Nigeria, and of course in West Africa and probably in other parts of Africa. This is more so because of the varieties of ecological zones that exist, the varied agricultural practices and the demographic pressure present in the country to drive the development process following tsetse eradication. Therefore, some of the "Shadow Projects" which were designed to compare the economic benefits of tsetse eradication and ensuing agricultural development, derivable from the level of scales, be it small (20,000 sq. km), medium (200,000 sq. km) or large (600,000 sq. km) were to be tested in Nigeria. As a starting point, however, it was decided to use the small-scale approach and build on that later.

1.1. Geography.

Nigeria lies between longitudes 2 and 15 degrees East and Latitudes 4 to 14 degrees North, occupying a land surface area of some 924,000 sq. kilometers. It covers seven widely varied ecological zones which range from swamp vegetation in the South to the Sahel in the North. The varied ecological conditions are reflected in the different systems of agriculture practised throughout the country, from arable to pastoral. All the ecological zones, except the Sahel and high plateaux of Jos and Mambila, support the existence of tsetse fly (*Glossina sp*.), the vector of animal and human trypanosomosis. Thus, animal trypanosomosis is fairly widespread in the country. Following the large-scale tsetse reclamation programme executed in the 60s and 70s, against particularly the Savannah tsetse, arable farmers have moved in to take advantage of the resulting opportunity. This has led to increased agricultural activities coupled with in-migration to the cleared areas, particularly along river basins when onchocerciasis became less of a threat. Most of the tsetse infestations that still persist, however, are found along river courses especially in the riparian vegetation and these are the riverine species (*G.palpalis palpalis and G.tachinoides).*

1.2. Study Areas

Two Study Areas in Nigeria were selected based on the PAAT-GIS, using the 1991 map of *Glossina* distribution and reclaimed areas, produced by the Federal Department of Livestock and Pest Control Services, and other parameters. Since the map was last updated, however, several developments have taken place including the changing patterns of tsetse distribution and agricultural activities, which are revealed in this study.

The first project area covering a total of 13,161 sq. km is along the River Ka on the Niger River System in the North-Western part of Nigeria and lies mainly in Kebbi State, projecting into Zamfara State. The 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".

The second project area covering a total of 19,858 sq. km is at the foot of the Mambila Plateau in the mid-North-Eastern part of Nigeria located in Taraba State. It was chosen "to represent particular land use and socio-economic aspects of the area". Other factors were the pressure on cattle in transit to the Mambila Plateau and the expansion pressure for cultivation from areas associated with the Benue River System, mainly River Donga which runs throughout the project site.

In the case of Study Area I, it was found that there was no apparent tsetse problem as confirmed by the livestock personnel as well as pastoralists in the area. However, there were some cases of cattle trypanosomosis which were apparently contracted while cattle were in the dry season grazing areas to the south of the study area and showed up on return to their wet season grazing areas. Once treated, the animals appeared free of trypanosomosis until the following season. It would appear therefore, that tsetse have disappeared autonomously from the area following agricultural activities. Spot checks will still need to be done to confirm this assumption. However, because tsetse did not appear to constitute a threat to livestock in this area, it was not considered worthwhile to pursue the study further. The results are given in tables 1 - 7..

Table 1. Demography and Human Diseases, Study Area 4.

Local Govt Authority. (LGA) **	Population		Onchocerciasis	Sleeping Sickness foci
	1991	2000		
Dandi	101,919	132,008	None	None
Suru	116,971	151,503	None	None
Maiyama	113,072	146,453	None	None
Sakaba	197,993	256,445	None	None
Anka*	72,846	93,972	None	None
Total	**604,792**	**782,381**		

*Except Anka, LGA which is in Zamfara State, all others are in Kebbi State
**The LGAs in Kebbi State constitute 29.8% of the land area of the State

Table 2. Land Use and Natural Resources, Study Area 4

Local Govt. Authority. (LGA) **	Land Use	Soil Type	Crop Index	Risk Index
Dandi	Agropastoral	Yellowish sandy loam	7	6**
Suru	Agropastoral	Yellowish sandy loam	7	5
Maiyama	Agropastoral	Yellowish sandy loam	6	6**
Sakaba	Agropastoral	Yellowish sandy loam	7	4
Anka*	Agropastoral	Yellowish sandy loam	6	5

*All LGAs in Kebbi State, except Anka in Zamfara State
**Risk due to seasonal flooding

Table 3. Range of Crops Grown and Productivity, Study Area 4.

Crops	Yield/Ha (Tonne)		Price	Input	% Cultivated	Diseases*	Control
	1992	1998	$/100 kg				
Maize	1.092	1.703	25.2	Chemical fertilizers and herbicides	3.5	Maize streak virus etc.	Pesticides application and cultural practices
Sorghum	0.087	1.236	25.2	-do-	26.2	Smuts etc.	-do-
Groundnut	0.822	1.068	43.2	-do-	5.4	Rosette virus	-do-
Cowpea	0.563	1.159	29.0	-do-	26.4	Pod borer etc.	-do-
Rice	1.224	2.035	50.4	-do-	4.6	Rice blast	-do-
Millet	0.832	1.089	28.8	-do-	34.0	Downing mildew	-do-

*List of complete crop diseases can be given if desired.
US$1 = Naira 112

Table 4. Animal Productivity in Study Area 4

Breed	Herd Size	Calving %	Oxen %	Herd Growth	Offtake		Mortality	Movement
					Milk (l)	Animal Sale		
White Fulani, Sokoto, Gudali	52.5 (25–80)	25	8 -10	25	400	12%	12%	Mostly sedentary

Table 5 Livestock Diseases – Study Area 4

LGA	Trypano-somosis	Prev-alence	Year	Vector	Other diseases	Year	Parks
Dandi	Suspected	-	2000	None detected	Helminthosis, Piroplamosis, CBPP, Dermatophilosis	2000	None
Suru	None	-	-	-	-do-	2000	None
Maiyama	None	-	-	-	-do-	2000	None
Sakaba	Suspected	-	2000	None detected	-do-	2000	None
Anka	None	-	-	-	-do-	2000	None

Table 6. Use of Animal Traction, Study Area 4

LGA	No. of trained oxen	% Household using animal power for cultivation	% Household using animal power for transport
Dandi	172	57	51
Suru	168	54	48
Maiyama	172	56	51
Sakaba	118	28	19
Anka	121	29	17

Table 7 Range of Crops Grown in Study Area 4

CASH CROPS	FOOD CROPS	HORTICULTURAL CROPS
Groundnut	Rice	Onions
Cotton	Millet	Pepper
Wheat	Sorghum	Guava
Sugar cane	Maize	Pawpaw
Tobacco	Potato	Banana
	Cowpea	Cashew
	Cassava	Gum Arabic

Annex 5 Study Area 5 (Eastern Nigeria) Report

Programme Against African Trypanosomosis

Options For Tsetse Fly Eradication in the

Moist Savannah Zone of West Africa:

Technical and Economic Feasibility Study,

Phase 1 (EASTERN NIGERIA)

Professor Albert Ilemobade

March 2001

ANNEX 8 STUDY AREA 5 (EASTERN NIGERIA) REPORT

1 INTRODUCTION

As a result of the renewed interest in large-scale tsetse eradication in Africa, the experience of Nigeria's early programme in tsetse reclamation provides a good source on which to build any future large-scale eradication in Nigeria, and of course in West Africa and probably in other parts of Africa. This is more so because of the varieties of ecological zones that exist, the varied agricultural practices and the demographic pressure present in the country to drive the development process following tsetse eradication. Therefore, some of the "Shadow Projects" which were designed to compare the economic benefits of tsetse eradication and ensuing agricultural development, derivable from the level of scales, be it small (6000 sq. km), medium (60,000 sq. km) or large (600,000 sq. km) were to be tested in Nigeria. As a starting point, however, it was decided to use the small-scale approach and build on that later.

1. GEOGRAPHY

Nigeria lies between longitudes 2 and 15 degrees East and Latitudes 4 to 14 degrees North, occupying a land surface area of some 924,000 sq. kilometers. It covers seven widely varied ecological zones which range from swamp vegetation in the South to the Sahel in the North. The varied ecological conditions are reflected in the different systems of agriculture practised throughout the country, from arable to pastoral. All the ecological zones, except the Sahel and high plateaux of Jos and Mambila, support the existence of tsetse fly (*Glossina sp.*), the vector of animal and human trypanosomosis. Thus, animal trypanosomosis is fairly widespread in the country. Following the large-scale tsetse reclamation programme executed in the 60s and 70s, against particularly the Savannah tsetse, arable farmers have moved in to take advantage of the resulting opportunity. This has led to increased agricultural activities coupled with in-migration to the cleared areas, particularly along river basins when onchocerciasis became less of a threat. Most of the tsetse infestations that still persist, however, are found along river courses especially in the riparian vegetation and these are the riverine species (*G.palpalis palpalis and G.tachinoides).*

Study Areas

Two Study Areas in Nigeria were selected based on the PAAT-GIS, using the 1991 map of *Glossina* distribution and reclaimed areas, produced by the Federal Department of Livestock and Pest Control Services, and other parameters. Since the map was last updated, however, several developments have taken place including the changing patterns of tsetse distribution and agricultural activities, which are revealed in this study.

The first project area covering a total of 13,161 sq. km is along the River Ka on the Niger River System in the North-Western part of Nigeria and lies mainly in Kebbi State, projecting into Zamfara State. The 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".

The second project area covering a total of 19,858 sq. km is at the foot of the Mambila Plateau in the mid-North-Eastern part of Nigeria located in Taraba State. It was chosen "to represent particular land use and socio-economic aspects of the area". Other factors were the pressure on cattle in transit to the Mambila Plateau and the expansion pressure for cultivation from areas associated with the Benue River System, mainly River Donga which runs throughout the project site.

The results for Study Area 5 are given in tables 1 - 7..

Figure 1 Location of Study Area 5

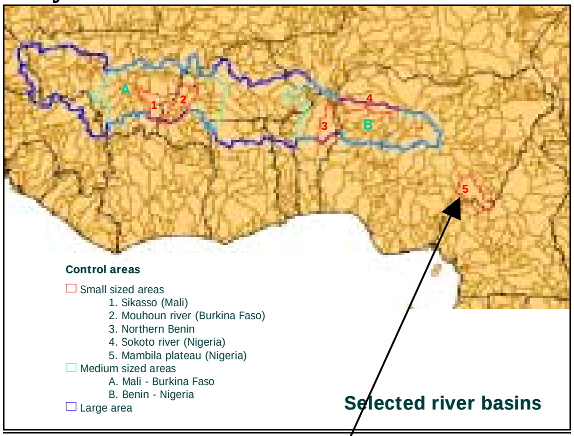
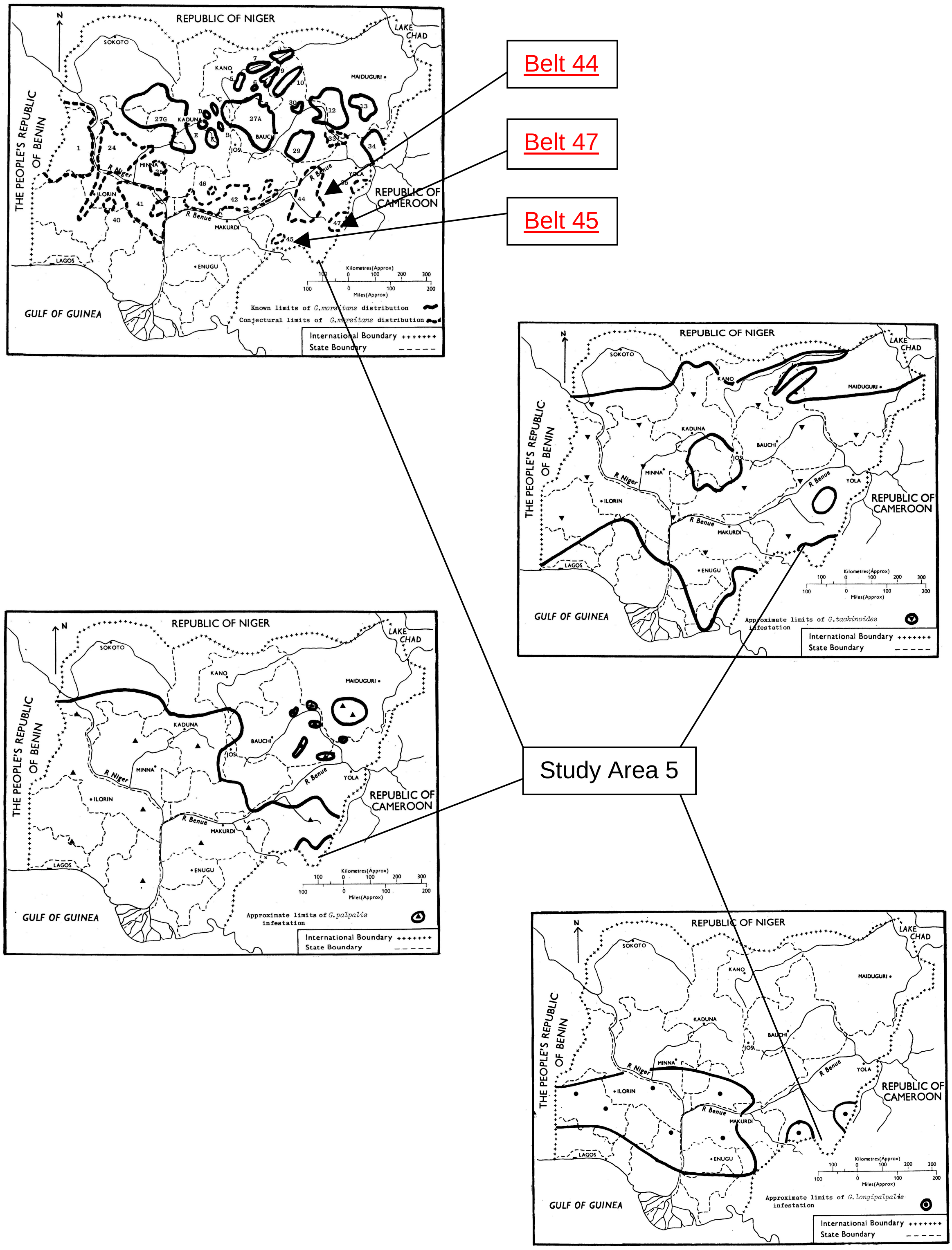


Figure 2 Study Area 5

1.2 Tsetse Distribution

Glossina palpalis palpalis and Glossina tachinoides are present along the fringes of River Donga and its tributaries and are responsible in the main for the high incidence of animal trypanosomosis in this zone. However, reports exist of relic G.morsitans submorsitans in Belt 44, 45 and 47 and its presence has also been recorded in the Gashaka Game Reserve, all these sites are located East of the zone. They may therefore constitute a reservoir of re-invasion for reclaimed land unless demographic pressure and agricultural activities in the area continue to expand. The good news is that expansion of agricultural activities and human migration into the area should occur as soon as tsetse is eliminated, thereby removing its natural habitat and thus hindering its re-establishment in the area. One other notable constraint however, is the presence of tsetse across the Nigerian border with Cameroon, requiring bilateral approach if tsetse is to be totally eradicated from the zone.

Figure 3 Distribution of Tsetse species in Nigeria



Source: Putt *et al*, 1980

1.3 Statistical description of Study Area

As no information is available for Wakiri and the Cameroon other LGSs need to be adjusted to estimate the characteristics of the whole study area. This assumption presumes that the whole of the study area is uniform.

Table 1 Area 5 Conversion Factors

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%	-	

Table 2 Demography and Human Diseases, Study Area 5

Local Govt Authority. (LGA) **	**Population**				**Presence of**	
	1991	**2000**	Adjustment Factor (Table 1)		**Onchocerciasis**	**Sleeping Sickness foci**
Bali	318,761	412,297	26%	107192	Present	Present
Dunga	84,626	106,305	130%	138196	Present	Present
Takum	95,478	123,644	52%	64294	Present	Present
Sardauna	226,467	284,941	117%	333381	Present	Present
			Adjusted Total (2000)	643063		

******All in Taraba State

Table 2. Land Use and Natural Resources – Study Area 5

Local Govt Authority. (LGA)	Land Use	Soil Type	Crop Index	Risk Index
Bali	Agropastoral/Semi-nomadic	Yellowish sandy loam	6	5
Dunga	Agropastoral/Semi-nomadic	Yellowish sandy loam	6	5
Takum	Agropastoral/Semi-nomadic	Yellowish sandy loam	6	4
Sardauna*	Agropastoral/Semi-nomadic	Yellow Ferruginous	6**	6**

*Gashaka Park, one of the largest in West Africa, and Filingo Grazing Reserve are located near this LGA.
**Gully erosion due to overgrazing, flooding from River Donga and desert encroachment..

Table 3. Range of Crops Grown and Productivity, Study Area 5.

Crops	Yield/Ha (Tonne) 1992	Yield/Ha (Tonne) 1998	$/100Kg	Input	Diseases*	Control
Maize	2.5	1.06	17.2	Chemical fertilizers and herbicides	Maize streak virus etc.	Pesticides application and cultural practices
Sorghum	1.30	1.10	17.4	-do-	Smuts etc.	-do-
Groundnut	0.56	1.09	49.6	-do-	Rosette virus	-do-
Cowpea	2.50	0.50	42.4	-do-	Pod borer etc.	-do-
Rice	2.18	1.00	45.5	-do-	Rice blast etc.	-do-
Millet	0.88	1.20	16.25	-do-	Downy mildew	-do-
Cassava	7.89	7.20	22.32	-do-	Cassava mosaic virus etc.	-do-

* List of complete crop diseases can be provided if desired
US$1 = Naira 112

Table 4 Animal Productivity in Study Area 5

Breed	Herd Size	Calving %	Oxen %	Herd Growth	Offtake		Mortality	Movement
					Milk (l)	Animal Sale		
White Fulani Rahaji Adamawa Gudali	47.5 (35-60)	19	15 -18	15	520	10%	9%	Mostly sedentary and some semi-trans-humant

Table 5 Livestock Diseases – Study Area 5

LGA	Trypano-somosis	Prevalence	Year	Vector	Other diseases	Year	Parks
Bali	Present	Not determined	-	*G. morsitans sub-morsitans* *G. p. palpalis*	Helminthosis Piroplamosis, FMD, Black quarter	2000	Gashaka Game Reserve (Outside the Core Area)
Donga*	Present	16.1%	1996	*G. p. palpalis*, *G.tachinoides*	-do-	2000	
Takum*	Present	46.6%	1996	*G. p. palpalis*, *G.tachinoides*	-do-	2000	
Sardauna	Present	Not determined	-	*G. p. palpalis*, *G.tachinoides*, *G. morsitans sub-morsitans*	-do-	2000	Gashaka Game Reserve and Fly Belt 44 (Outside the Core Area)

- Prevalence studies carried out by NITR. Tsetse apparent density is 2.05 flies/trap/day in Donga LGA and 0.48/flies/trap/day in Takum LGA.

Table 6 Use of Animal Traction, Study Area 5

LGA	No. of trained oxen	% Household using animal power for cultivation	% Household using animal power for transport
Bali	N/A	40	N/A
Donga	N/A	10	N/A
Takum	N/A	N/A	N/A
Sardauna	N/A	40	N/A

Table 7 Range of Crops Grown in Study Area 5

CASH CROPS	FOOD CROPS	HORTICULTURAL CROPS
Groundnut Tea Coffee Cocoa	Maize Millet Sorghum Cassava Yam Cowpea	Mango Banana Pawpaw Orange

2. PROPOSED STRATEGY FOR ERADICATION

Given the nature of the environment and the ecology of the tsetse species present, the logical first step would be population reduction by trapping and deployment of insecticide-impregnated screens and targets along the river courses where cattle are watered, accompanied by limited ground spraying. These should then be followed by release of sterile males to mop up remnants of tsetse in the zone. This approach was successful in the Feferuwa river systems in the Lafia BICOT project in the 1980s and should, all things being equal, succeed in this area given the similarity in terrain and ecological requirements. In the case of the Belts 44, 45 and 47, sequential aerosol technique (SAT) using non-residual insecticide may be required.

3. PROTECTION AGAINST RE-INVASION OF CLEARED AREAS

Because of lack of natural barriers which can prevent re-invasion, it will be necessary to maintain an artificial barrier until agricultural activities and demographic pressure reach a point where no flies can survive and transmit disease. However, if the cleared area were left unprotected, and given the experience of the cited case of BICOT, it would take between 10 and 15 years before significant re-invasion, requiring intervention, would take place.

4. ERADICATION v CONTROL

Assuming that eradication is not feasible in the area, a strategy based on living with the problem, i.e. control, will have to be adopted. This will consist of a combination of anti-tsetse and anti-trypanosomal measures - the use of traps and insecticide-impregnated screens and live baits and the use of chemotherapy in infected animals.

5. EFFECTS OF TSETSE ELIMINATION

5.1 Short term.

The incidence of animal trypanosomosis will drop dramatically, allowing for improved animal productivity in terms of reduced abortion and calf mortality and, of course, reduced incidence of sleeping sickness. These would be expected to accompany reduced morbidity and treatment costs.

5.2 Medium term.

The economic loss caused by the presence of tsetse is reflected in the loss of potential production that could be realised if such land were tsetse-free. Therefore, removal of tsetse will lead to increased use of draught oxen for ploughing and for moving produce to markets and serve rural transportation generally. This will invariably increase the number of trained oxen, increased use of draught oxen for ploughing and the percentage increase of households using animal power from 20-40% to about 60-65%. It is expected that significant expansion of agriculture, especially crop agriculture, which should lead to improved income and therefore, human welfare will take place. Herd size will increase significantly, just as calving rate, shorter calving intervals, reduced calf and adult mortality and increased milk yield. This improvement is bound to result in increased offtake of both milk and animals, but will require more land for pasture, which will ultimately lead to overgrazing and possible land degradation in the long term.

5.3 Long term.

Removal of tsetse should enhance livestock and crop agriculture, reduce land usage distortion caused by the presence of tsetse and trypanosomosis, encourage population migration to areas hitherto regarded a no-go area because of tsetse and therefore expand agricultural production. Unless there is a regulated land use, clashes can be expected between pastoralists and farmers. Since there is a regular flooding of the plains by the Benue river systems, of which River Donga is one, the flood plains may become veritable sources of liver flukes for cattle that graze on the plains and therefore, a major health hazard. Already, flooding in this area has caused soil erosion and increased livestock without controlled grazing is bound to lead to soil degradation.

Eradication will provide opportunity to deal more effectively with other diseases, e.g. sleeping sickness.

But more importantly is the fact that these developments will lead to generation of employment for the rural community thus reducing rural poverty in the zone.

6. CONSTRAINTS

Some of the major constraints that may not allow farmers to realise the full benefits of the new area cleared of tsetse include:

i) **Lack of timely provision of farm inputs – implements, fertilizers, improved seeds and herbicides.** Successful agricultural practice requires timely provision of appropriate inputs at the particular season of the year when they must be applied, failing which such inputs may not achieve the desired effects.

ii) **Availability and affordability of veterinary drugs.** If maximum benefits are to be derived from tsetse-cleared areas, it is of crucial importance that veterinary drugs be regularly available. It is frequently the case that veterinary drugs are not always available in the quantity needed, and when they are, they may not be affordable.

iii) **Extension Services**. The State Government is expected to provide extension services to the farmers so that their agricultural output can improve. However, apart from what the Agricultural Development Project (ADP) provides, no arm of Government is actively involved in extension work. The Taraba ADP is currently providing extension services to farmers, primarily in crop agriculture. Unless this project extends its activities to animal agriculture, the combined benefits of crop and animal agriculture may not be fully realised.

iv) **Lack of farm credit**. The lack of credit facilities limit the hectareage of land that farmers can reasonably cultivate irrespective of the increased number of work oxen available.

v) **Lack of markets**. Both (iv) and (v) constitute major constraints to maximizing the benefits of cleared land. In many cases, milk can only be sold on market days which means that what is produced during the intervals between market days must be converted to sour milk and cheese which can be avoided were markets easily available to the producers. This also reduces the chances of livestock agriculture becoming serious commercial enterprises in the local area, thus the low percentage of animal offtake and the need for livestock farmers to keep old bulls in their herds longer than they need to.

Most of these constraints can however, be overcome through the setting up of Farmers' Co-operative Schemes. In addition Governments would need to continue to support the ADP in order to provide extension services to farmers and ensure that Banks, especially Agricultural and Co-operative Bank and also Commercial and Community banks, extend soft and timely loans to farmers under the Agricultural Credit Scheme of the Central Bank of Nigeria.

7. LAND TENURE SYSTEM

The land tenure system in the area favours the crop farmers who are sedentary more than the agro-pastoralists/pastoralists. It is for this very reason that bloody clashes have taken place between crop farmers and pastoralists in the past, with the latter coming off worse. Thus, while the eradication of tsetse would benefit both crop farmers and agro-pastoralists/pastoralists, it is the former who would benefit the more because by virtue of their settled nature, they are closer to political power and its influence than the latter. It must be said, however, that since pastoralists started settling down, they seem to have learned the ropes very fast and are becoming used to political manoeuvring .

Annex 6 Practical Application of GIS

Programme Against African Trypanosomosis

Options For Tsetse Fly Eradication in the

Moist Savannah Zone of West Africa:

Technical and Economic Feasibility Study,

Phase 1

Practical application of GIS for the identification and selection of control areas in West Africa.

Dr. Guy Hendrickx, AVIA-GIS

March 2001

ANNEX 6 PRACTICAL APPLICATION OF GIS FOR THE IDENTIFICATION AND SELECTION OF CONTROL AREAS IN WEST AFRICA.

Dr. Guy Hendrickx, AVIA-GIS

Introduction

This paper builds further on the Geneva and Rome-Vienna workshops where past applications of GIS for priority setting were presented and some principles underlying the present paper were adopted.

Decision support framework

Figure 1 details the approach adopted in this paper. It highlights the different steps towards data driven decision support for selecting priority areas for tsetse eradication in West Africa. These differ significantly from previously developed models which aimed at defining priority areas for sustainable trypanosomosis control.

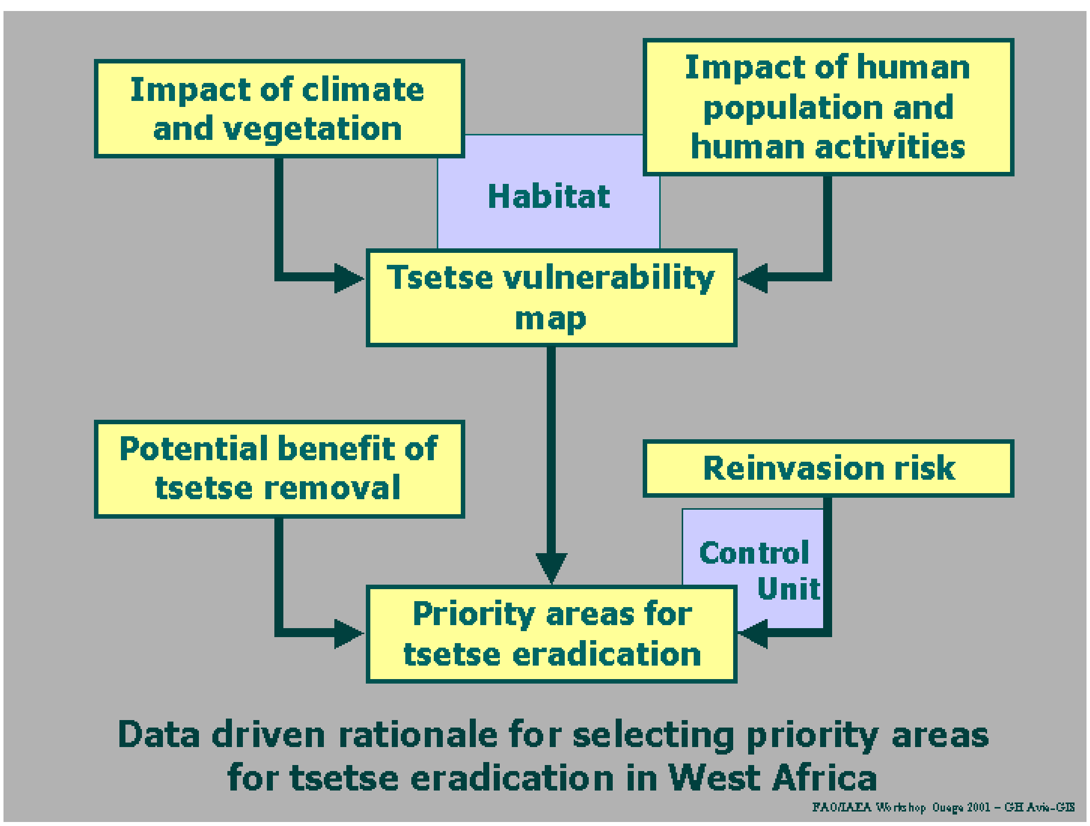


Fig 1 Decision support towards priority setting

Trypanosomosis control aims at sustained suppression of the disease and / or the vector. Therefore decision-making will be mainly anthropocentric, i.e. daily farmers inputs and participation are the key stone of success for any operation (socio-economics of trypanosomosis control).

Decision-making towards selecting priority areas can be carried out at a national or sub-national level where restricted priority areas are selected according to potential costs and benefits. The relative location in the fly belt of selected areas is of lesser importance.

Vector eradication on the other hand is a political decision which aims at permanently removing a major constraint, in this case tsetse as a vector of African Animal Trypanosomosis and Human Sleeping Sickness. Independently of peoples' will to participate, areas have to be selected on a data driven basis. The key stone here is technical feasibility.

Since the success of the actual eradication campaign will highly depend on the technology used, chosen technologies will have to be carried out by professional teams to guarantee quality and speed. Therefore community participation can focus on disease management (basic animal health and production *sensu largo*) and land-use topics.

Here decision-making is highly dependant on concerted action between countries involved. Large scale areas have to be selected according to the feasibility of tsetse eradication, starting from the easiest parts at the distribution limits of the fly and systematically working towards more complex types of habitat.

Climate in West Africa

A typical feature of the climate in West Africa is its band-like pattern. From North to South the climate changes from arid to moist. Subsequent natural land cover layers include : Desert, Grassland, Grassland savannah, Woodland savannah and Evergreen vegetation such as tropical rainforests and mangrove in coastal areas.

This can be visualised with a variety of data layers. Examples include:

1. Rainfall normal: a ground measured variable rainfall,

2. Vegetation index: a remotely sensed variable,

3. Length of growing period: a derived compound variable (Fig.2).

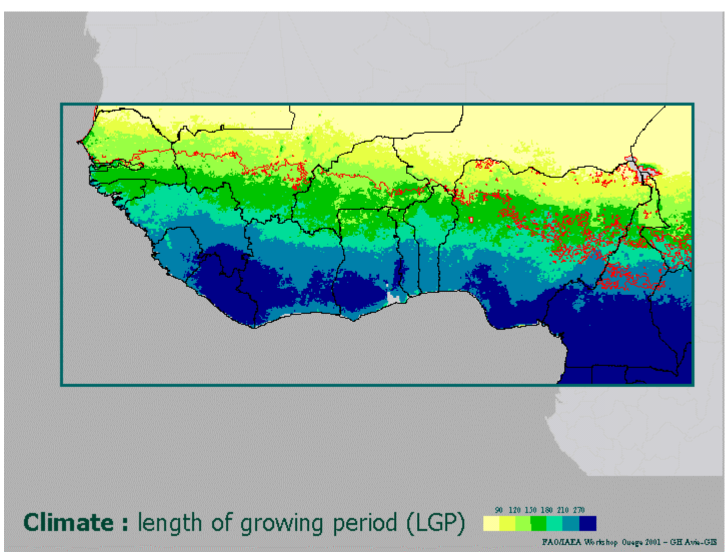


Fig 2 Length of growing period

The length of growing period is the period of vegetation activity in days per year of a specific crop. The layer shown here is a 5km resolution mainly satellite derived spatial prediction of a standard LGP map compiled by FAO (www.fao.org). See PAAT-IS for more details.

Classes limits are (days): <90 / 90-120 / 120-150 / 150-180 / 180-210 / 210-270 / >270

Tsetse distribution in West Africa

In recent years an attempt was made to update ageing tsetse distribution maps. A series of « Potential Range Maps » per tsetse group and per species and, when applicable, per sub-species where produced by the TALA research group Oxford at a 5 km resolution. Predictions are based on data extracted from the Ford and Katondo maps, updated with the most recent field observations where available.

As for any distribution map tsetse are not expected to be uniformly distributed throughout their potential habitat. Due to a combination of circumstances they might even be absent from substantial parts of it.

Maps included in the PAAT-GIS are:

1. Presence/Absence map for all tsetse species combined,

2. *Glossina palpalis sp. (gambiensis* and *palpalis)* and *Glossina tachinoides* : the two most important riverine tsetse species of West Africa,3. *Glossina morsitans submorsitans* : the most important savannah tsetse in West Africa.

Tsetse ecology

Two major factors will affect the viability of tsetse : climate and human activity. The effect of climate (and vegetation) on the ecology of tsetse has been studied since the 1930's and is best illustrated by the work of Nash (1937) and Buxton (1955).

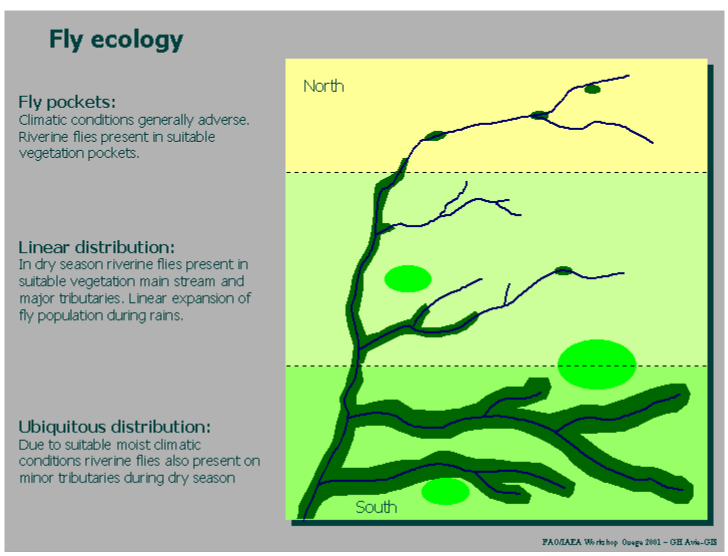


Fig 3 Tsetse ecology bands

Band-like climatic patterns affect fly ecology in West Africa. The identification of such subsequent fly ecology bands is of prime importance to contribute to the development of sustainable area-wide vector management strategies (see also detailed legend in French below[1]).

[1] Légende Figure 3 :

1. Glossines riveraines absentes ou très rares

- In the northern part of the fly belt it is more likely that tsetse could be permanently removed. Populations are expected to be more fragmented. After removal re-invasion is less likely since gaps of adverse conditions prevent fly dispersal.
- In the southern part where tsetse distribution is ubiquitous, high re-invasion pressure is likely to jeopardise permanent fly suppression and/or eradication attempts.
- The separation between « feasible » and « less feasible » is expected to be near the southern border of the linear distribution band (middle band) where the entire river network is not yet populated by tsetse.

From an operational point of view it is important to identify this limit as accurately as possible.

The Burkina Faso data set

During the FAO project, Projet Regional de Lutte contre la Trypanosomose Animale (PLTA), GCP-RAF-347-BEL a series of field surveys were conducted and combined with data from CIRDES. Combined entomological and parasitology field surveys (Fig. 4) allowed the identification of subsequent bands for Western Burkina Faso.

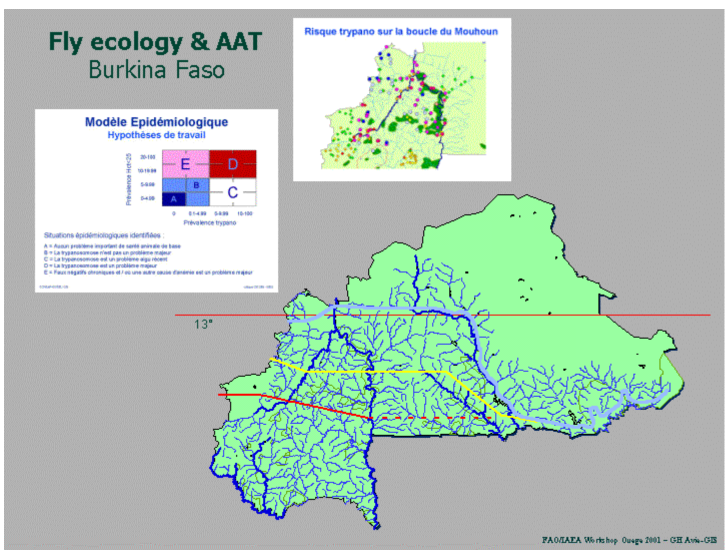


Fig 4 Burkina Faso data set

Fly ecology bands in Western Burkina Faso (legend to figure 4):

1. Light blue line: historical limit *G. tachinoides* (approximately 13° North),

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2. En saison sêche les Glossines riveraines sont présentes uniquement sur les cours principaux aux endroits ou la végétation est particulièrement propice. Elles sont absentes ou très rares sur les cours secondaires. Une fois ces lieux de présence de Glossines identifiés leur élimination peut y être entreprise sans risques majeurs de réinvasion.
3. Glossines présentes sur la totalité des cours principaux en saison sêche. Elles sont aussi présentes de façon saisonnière sur les cours secondaires ou en permanence dans des lieux où la végétation y est particulièrement favorable. La lutte doit y être envisagée sur la totalité des cours principaux de façon concertée en partant des zones à plus densités vers les zones à plus forte densité. Les risques de réinvasion augmentent vers le sud en s'approchant de la zone 4. Leur élimination totale reste envisageable en combinant la lutte avec une politique de gestion des terres adéquate.
4. Les Glossines sont présentes sur la totalité des cours principaux et secondaires tant en saison sêche qu'en saison des pluies. La coordination des activités de contrôle y devient fort complexe. Les risques de réinvasion sont présents sur la totalité du réseau hydrographique. Une action concertée ne peut y être envisagée que lorsque les Glossines ont été éliminées dans les zones précédentes et l'installation de barrières de protection y est incontournable.

2. North of yellow line: tsetse present only on main river,
3. North of red line: tsetse also present on main tributaries,
4. South of red line: tsetse present on all tributaries.

West Africa Northern band

West African climate bands and fly ecology bands identified in Burkina Faso allow us to draw a first tentative northern band, empirically set within the <170 LGP zone, where tsetse habitat is marginal and sustainable tsetse suppression may be more successful than in the Southern areas.

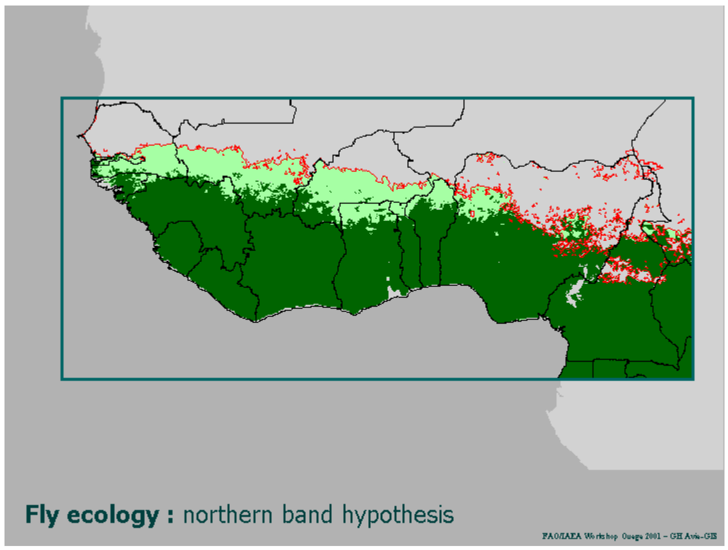

Fig 5 Tentative northern fly ecology band

Legend to Figure 5:

- Red line : northern limit tsetse distribution.
- Light green : area where LGP < 170 days within tsetse limits, marginal habitat likely.
- Dark green : area where LGP > 170 days within tsetse limits.

Tsetse and human population

After climate and vegetation, the second major factor which will influence tsetse ecology is human activity and its impact on the environment. With increasing human populations the number of natural tsetse hosts will drop due to hunting and an increasing part of the land will be cleared through cultivation and due to firewood consumption. As a result tsetse populations will lack both food sources and suitable habitat, and populations will drop.

Based on an extensive literature study R. Reid and colleagues (Reid *et al.*) postulated two scenario's describing the potential impact of human populations on tsetse distribution. Results shown here depict the expected impact of increased human population numbers (year 2040) on present fly distribution limits according to a liberal scenario (lower population densities have an higher impact on tsetse populations) and a conservative scenario (population levels need to be higher prior to impact tsetse distributions significantly).

It is to be noted that this model applies to savannah flies. The authors expect impact of human activity on riverine flies to be less important.

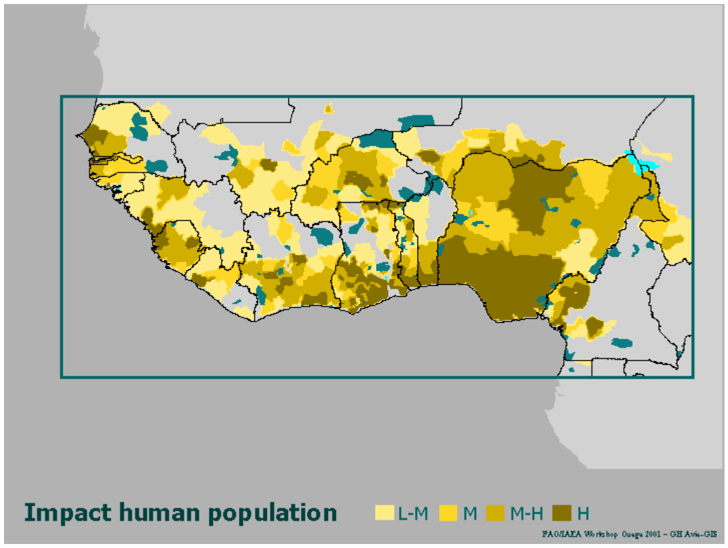

Fig 6 Human population impact classes

In figure 6 both scenarios are combined and new class limits are:

1. < 15 people / km² : Little impact (of human population) on tsetse,
2. 15 – 30 / km² : Low to medium impact,
3. 30 - 40 / km² : Medium impact,
4. 40 – 77 / km² : Medium to high impact,
5. > 77 / km² : High impact.

Population data source : PAAT-IS

Tsetse and agriculture

The impact of human population densities on tsetse habitat is mainly caused through agricultural activities.

Detailed data layers (5 km resolution) of predicted crop agriculture and cattle distributions (see PAAT-IS for more information) are used here to further contribute to highlight areas of major impact of human activity on tsetse populations. Both data layers are reclassed as “high – medium – low” and outputs are overlayed to depict the different mixed farming classes.

Selected class limits for predicted agriculture intensity (% of land in the cultivation cycle) are:

1. < 10 % of land into the cultivation cycle (Low)
2. 10-30 % of land into the cultivation cycle (Medium)
3. >30 % of land into the cultivation cycle (High)

Selected class limits for predicted cattle density (number of cattle per km²) are:

1. < 4 cattle / km² (Low)
2. 4-16 cattle / km² (Medium)
3. > 16 cattle / km² (High)

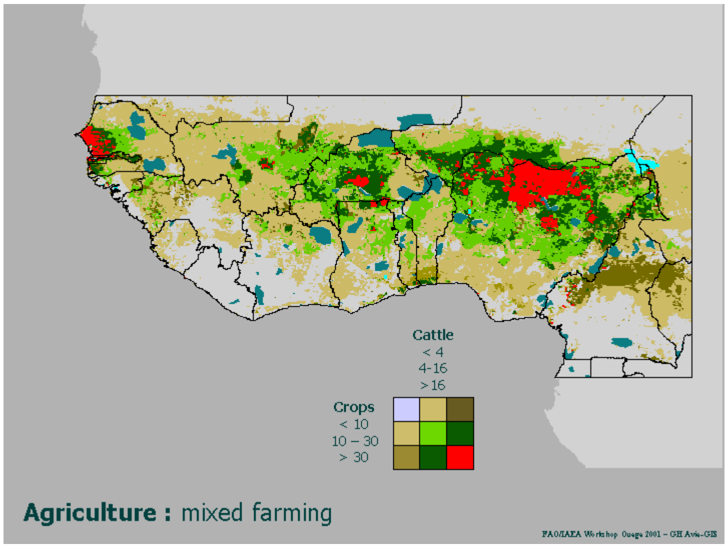

Fig 7 Mixed cattle - crops classes

Figure 7 shows the obtained overlay output. Areas where both cattle and crop agriculture are medium or high (green, red) are of particular relevance since here the impact of agriculture on tsetse populations is likely to be highest.

Tsetse vulnerability

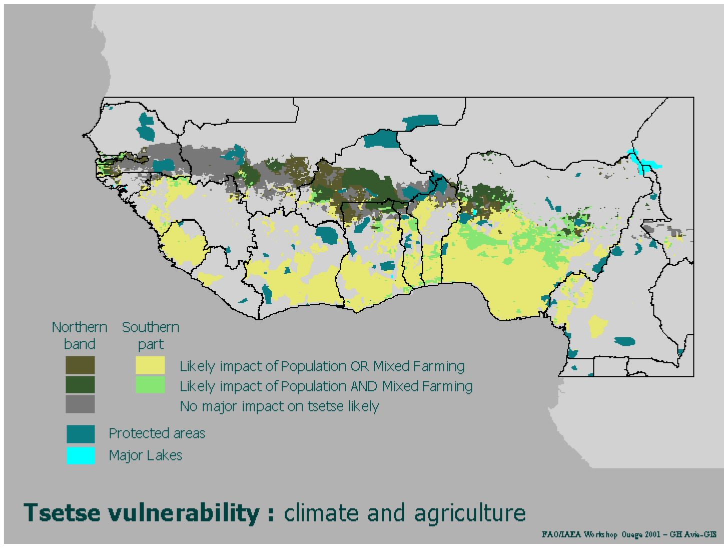

Fig 8 Tsetse vulnerabilty : people - mixed farming

Finally the combined potential effect of climate, human population and human activity on tsetse habitat is modelled by overlaying map outputs depicted in figure 6 and 7.

From a fly suppression (and/or eradication) point of view this impact offers both a direct and indirect advantage:

- Direct advantage: high land pressure will reduce fly populations. Savannah flies are expected to be more affected than riverine flies. Fly distribution is fragmented and once identified fly pockets are more easily dealt with.

- Indirect advantage: the existing high land use pressure will contribute to prevent fly re-invasion following eradication. This affects both riverine and savannah flies.

Figure 8 highlights areas where tsetse populations are most vulnerable to control measures (see legend). The result of this analysis shows two major impact areas.

In Nigeria both mixed farming and human population are likely to influence tsetse, not only in the LGP<170 zone but also in more humid southern parts whilst in Mali-Burkina levels of human population densities and mixed farming are less extreme. There impact appears to be restricted to the LGP<170 zone.

It is also important to mention here that agricultural practices might create new habitat types, especially for riverine tsetse. Nevertheless such habitats should be by definition isolated and therefore vulnerable once identified.

Impact of tsetse removal

Besides external factors affecting fly distribution patterns and increasing vulnerability of tsetse towards control measures, potential benefits have also to be taken into consideration when selecting priority areas for sound vector management.

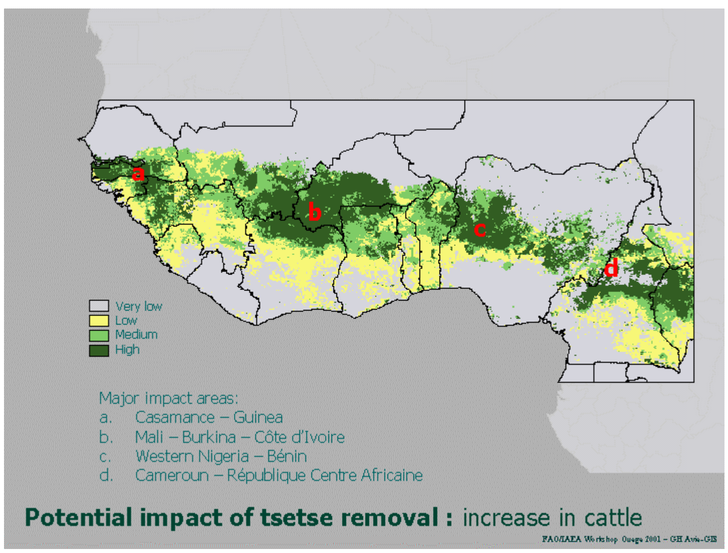

Fig 9 Predicted cattle increase after tsetse removal

Legend to figure 9 :

1. increase of 0-0.1 cattle / km² : Very low
2. 0.1 – 5 / km² : Low
3. 5 – 10 / km² : Medium
4. > 10 / km² : High

Figure 9 shows the predicted increase in cattle densities after removal of tsetse (See PAAT-IS for more details) and currently depicts the best approximation towards mapping the relative potential benefits of tsetse eradication at a 5 km resolution. Four major potential benefit areas are highlighted.

The re-invasion issue

A vital aspect of tsetse eradication is fly re-invasion. Ideally flies should be removed from a completely isolated area with zero re-invasion pressure (e. g. the Island Zanzibar in East Africa). This rarely is the case. On the other hand no example is known of the successful maintenance of a permanent artificial barrier against tsetse after tsetse removal (see also short annotated bibliography on the subject of re-invasion in annex).

Nevertheless in the previous part of this paper it was seen that in the northern band of the fly belt low re-invasion pressure is likely due to :

- Isolated fly pockets in marginal habitat with « near to zero » re-invasion risk,
- Interrupted linear distribution patterns due to high land pressure,
- Reduction of re-invasion pressure due to high land pressure.

In such circumstances, it may be possible to conduct a concerted area-wide eradication campaign. Historically similar conditions have occurred in North-Eastern Nigeria where flies have been removed from vast areas without barriers and with no significant re-invasion to date.

Nigeria case study

Figure 10 depicts the historical distribution limits of G. tachinoides in Nigeria. The red overlay shows the area cleared of tsetse from 1954/55 to 1977/78. No barriers were installed and to date no significant re-invasion occurred in this area.

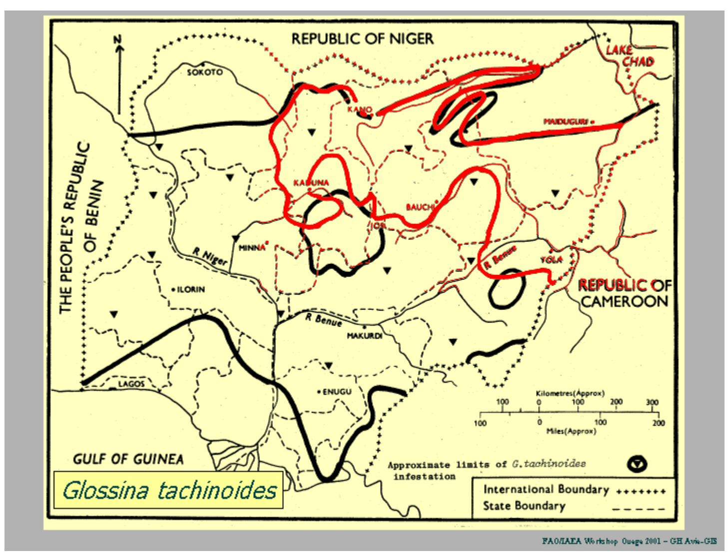

Fig 10 ***Glossina tachinoides*** **in Nigeria**

In order to contribute to the characterisation of those cleared areas, within area frequency distribution histograms of the three climatic variables depicted earlier are given together with mean values, standard deviation and mean plus one or two standard deviations. The latter values allow us to define a "minimum threshold set" below which re-invasion is unlikely : i.e. areas where the average NDVI is below 0.3 AND the LGP below 178 days AND rainfall below 1121 mm.

For the same purpose frequency distribution histograms are depicted for human population, cattle densities and cropping intensity. Here a "maximum threshold set" can be identified above which re-invasion may be unlikely : i.e. human population pressures of more than 29 people / km² AND cattle densities of more than nine head / km² AND cropping intensities of more than six percent of the area cultivated.

Both threshold sets are combined in figure 11.

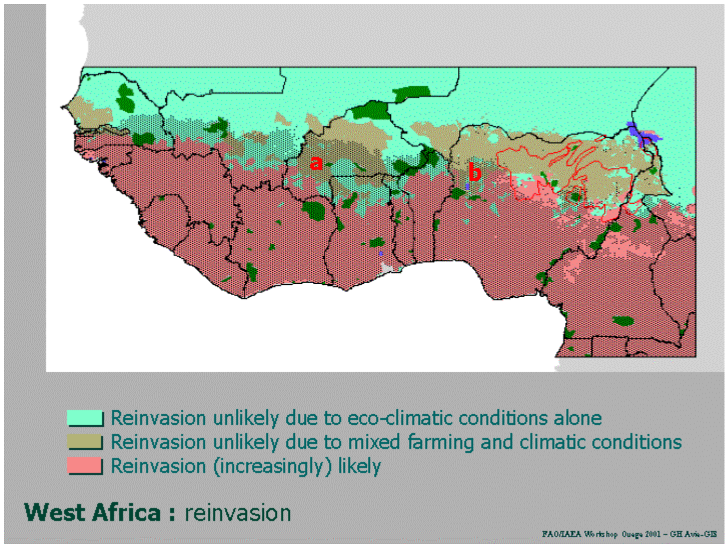

Fig 11 Derived re-invasion risk in West Africa

In areas where climatic conditions alone currently contribute to reduce re-invasion, concerted land use management during and post eradication may be a major tool towards sustained results without the need for costly barriers.

Selection of priority areas

A next step towards selecting priority areas includes the identification of "control units or entities". From a fly ecology point of view, the most suitable unit is the river basin.

River basins can be derived from digital elevation models (DEM), i.e. raster files of altitude measures at a 1 km resolution. Such resolution is detailed enough for the purpose of this study and should also allow planning at the national level. More detailed data may be needed at the local level for proper operational planning.

A processed DEM derived river basin data set for Africa is freely downloadable from the following internet site : http://edcdaac.usgs.gov/gtopo30/hydro/africa.html.

It is important to note here that the principle of fly-ecology layers also applies at the river basins level. Where tsetse distribution is restricted to main rivers and major tributaries and the vegetation along other tributaries is unsuitable, tsetse populations may be relatively isolated with no contacts between adjacent river basins (except where tributaries enter the main river), reducing re-invasion risks.

Figure 12 shows level 4 river basins.

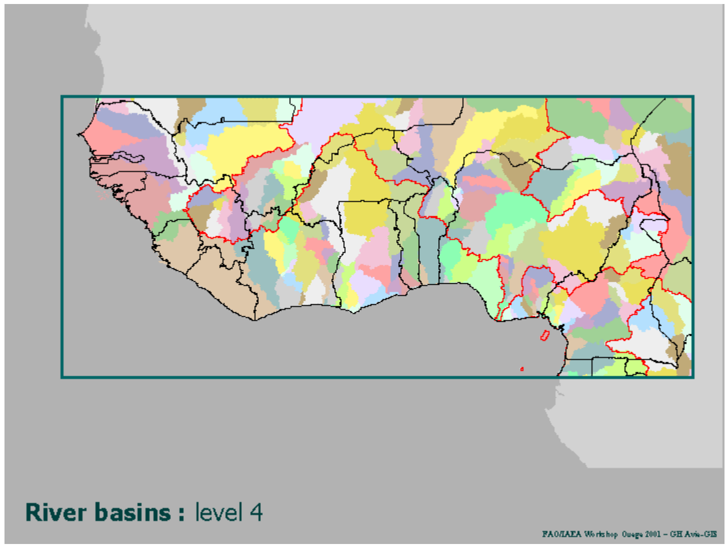

Fig 12 Level four river basins

This layer was used to select priority areas, i.e. river basin clusters, taking into consideration the informa tion gathered above on :

- Vulnerability of tsetse habitat (impact climate / vegetation AND human activities)
- Potential benefits
- Re-invasion risks

The selected river basins are shown in figure 13.

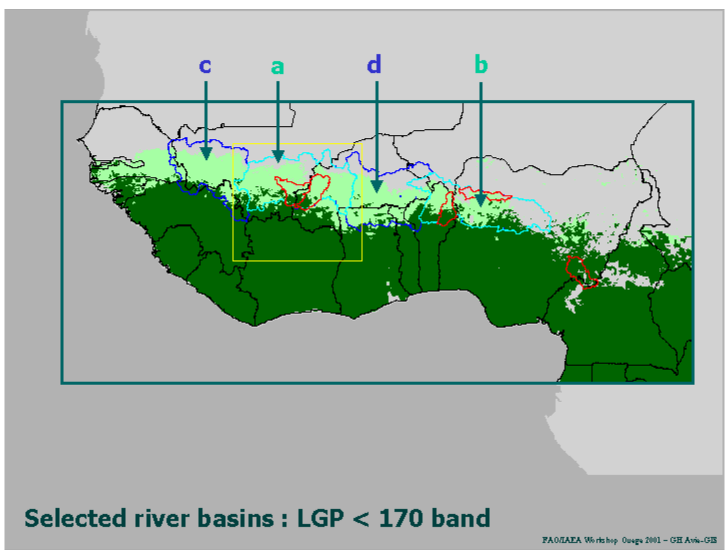

Fig 13 Selected priority areas

Legend figure 13:

1. Area a: Mali-Burkina Faso priority area.
2. Area b: Benin-Nigeria priority area.
3. Area c: Western extension (second level priority area if aim is to clear entire Northern fly band).

4. Area d: Central extension (second level priority area if aim is to clear entire Northern fly band).
5. Red areas: selected river basins for small sized shadow projects discussed in the main report.

The yellow rectangle depicts the area covered in the last part of this report.

Case study: Mali – Burkina Faso priority area (a).

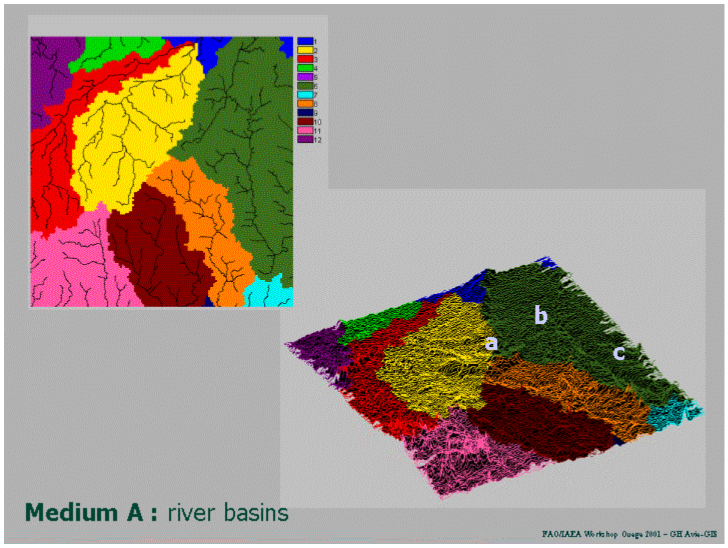

Fig 14 Priority area (a): basins and DEM

In the last part of this study an attempt is made to more precisely identify fly ecology bands in priority area (a), Mali – Burkina Faso (Fig. 14), as described previously in the Mali/Burkina Faso priority area. In summary the following procedure has been followed:

1. Allocate "ecological band value" to respective river basins based on field survey results:
   - Burkina Faso: FAO Project GCP-RAF-347-BEL and CIRDES data.
   - Mali: published results (Djiteye *et al.*) updated by Dr. Djiteye.
2. Create training set to train spatial prediction model (Fig. 15). River basin data were extracted using a 2.5 km buffer along main rivers and tributaries. A distance of 2.5 km on each side of the rivers was chosen since the resolution of the satellite data used in the next step was 5X5 km.
3. Run spatial prediction model, i.e. discriminant analysis model (UNISTAT™), using a set of 5 km resolution NOAA derived meteorological satellite data (satellite data were provided by Prof. D.J. Rogers, TALA research group, Zoology Department, Oxford, UK). The rationale underlying discriminant analysis is to determine whether known gridcells (e.g. 2.5 km buffer training set) belonging to predifined classes (e.g. ecological bands) differ with regard to the mean of a set of variables (e.g. satellite data), and then to use that knowledge to predict class membership of new cases (pixels not covered by training set).
4. Display output.

This approach was first applied using only training data for Burkina Faso and at a second stage using both training data sets from Burkina Faso and Mali.

Figure 14 shows the different river basins together with a three-dimensional 5 km resolution digital elevation model (DEM).

River basins of particular interest for this study include:

- Red, yellow and blue: Niger river basin in Niger
- Green: Mouhoun river basin in Burkina Faso, part of the Volta river system

The 5 km DEM clearly highlights the ridge (a) between Niger and Volta river basins and the Mouhoun "curve" (b) or boucle du Mouhoun and Mouhoun valley flowing southwards (c).

Main rivers and tributaries are derived from the same 1km DEM.

The river buffer training set used to predict fly ecology bands is given in figure 15.

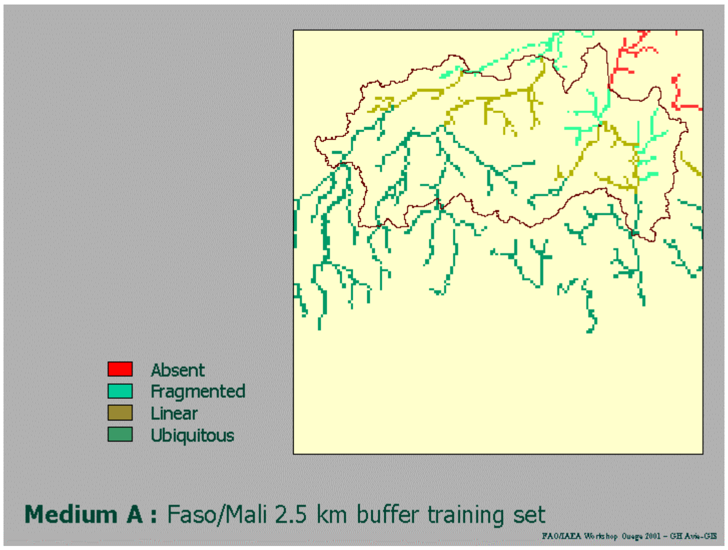

Fig 15 River buffer training set (2.5 km)

Discriminant analysis output 1 (top left map fig.16) :

Based on the Burkina training set the model allocates an "ecological band value" to each pixel.

After comparison with known literature sources for Niger it appeared that the limit between class 2 (fragmented) and 3 (linear) may be more to the North. Therefore Dr. Djiteye (LCV, Bamako) was asked to independently allocate class values to Niger river basins according to his current knowledge of tsetse distribution and ecology in Niger.

In a next step the model was further refined by including these training data for Niger.

Discriminant analysis output 2 (main map fig.16) :

Predicted fly ecology bands using the complete training set are shown in figure 15. The table includes respective surface areas per band for both outputs. These areas are important to study the feasibility of fly eradication and for ex-ante cost-benefit analysis studies.

Both outputs show major differences for Niger. This can be due to two factors:

1. Even when two areas are adjacent a similar set of eco-climatical conditions may affect tsetse ecology in a different way. In this case this may be highlighted by the DEM model given above where it is clearly seen

that basins in Niger and Burkina belong to different watersheds. Field data confirm this: vegetation patterns along the Niger river are different from patterns observed along the Mouhoun river.

2. Class division into a set of "ecological bands" is subjective, and limits between classes will vary from author to author. This can be illustrated with the Bamako example : close to Bamako large parts of the Niger river vegetation are infested with tsetse. Further north a gap of approximately 50 km exists before the next fly concentration is found. Should this be classified as "linear distribution" (argument: vegetation absent in gap, therefore no flies) or "fly pockets"?

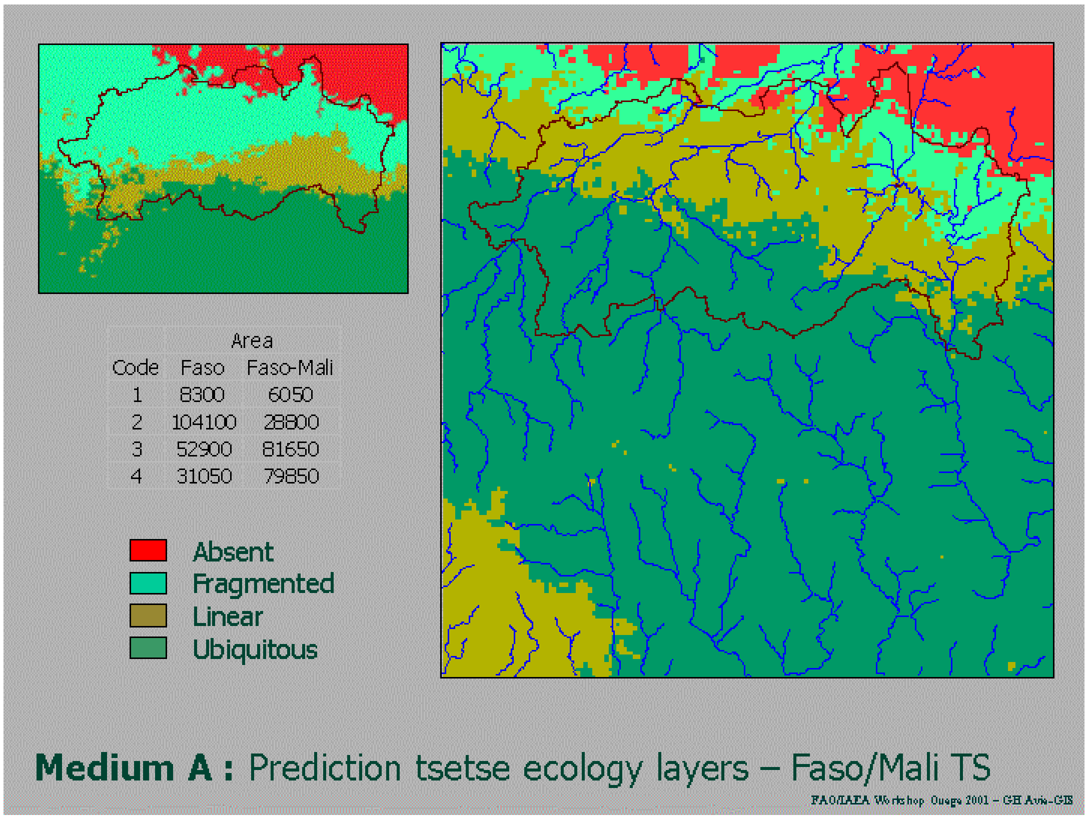

Fig 16 Priority area (a): predicted fly ecology bands

Conclusion

Produced results are a significant step towards data driven selection of priority areas for large-scale vector management. Whilst previously such approaches aimed at selecting areas for trypanosomosis control, the focus here is on concerted vector eradication. Taking the selected Mali - Burkina Faso priority area as an example, a series of subsequent fly ecology bands, of particular interest with regard to vector eradication feasibility, were identified.

Follow up studies should now focus on:

- Further refining obtained results by the use of higher resolution satellite data to identify and predict more accurately different vegetation patterns and river basin settings.
- Ground truthing obtained results.

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