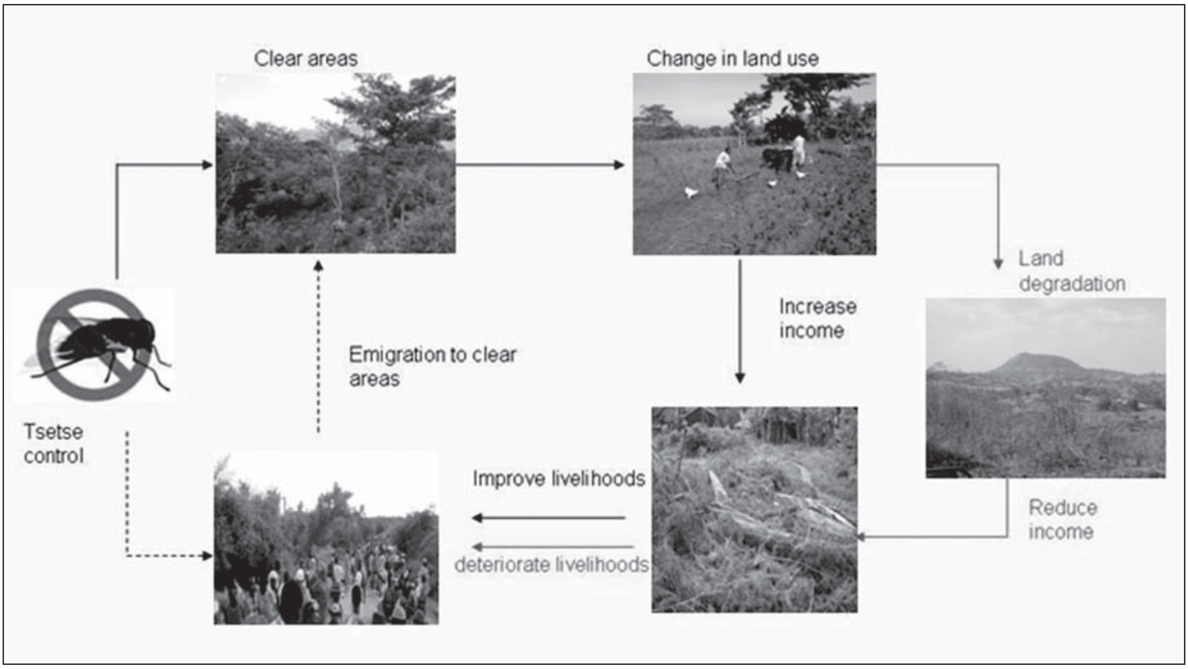

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A conceptual framework for integrated impact assessment of trypanosomiasis interventions

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Executive summary

At the heart of any effort to foster sustainable development, lie scientific analysis and the application of scientific knowledge. Providing scientifically correct and appropriate information that respond to and anticipate the needs of policy makers and other stakeholders is essential when addressing issues from the plight of widespread poverty, global changes and environmental degradation.

Attainment of the Millennium Development Goals (MDG) can not be possible without sufficient technological progress and improved policies to address the global challenges that face the resource poor regions of the world. Coupled with efforts to increase agricultural productivity, natural resources management (NRM) has become one of the cornerstones of research and development within the national, sub-regional and international agricultural research systems. The Consultative Group on International Agricultural Research (CGIAR) has devoted significant resources into this area of research. Development investors, policy makers and researchers alike are keen to assess and evaluate investments in NRM. In the past, progress has been limited by the lack of scientifically valid ways to evaluate the complex environmental outcomes associated with these interventions that need new methods and techniques to enhance their effectiveness.

Understanding of how the interventions affect environmental and socio-economic syatems and pathways is crucial in order to sustain the benefits of these developments and safeguard the destiny of our future generations. Impact analysis must become more problem-focused, and apply an interdisciplinary approach to sustainable development issues in order for science to become more policy relevant.

This document focuses on these felt needs and synthesizes a framework for evaluating the impacts of tsetse and trypanosomiasis interventions. The need to eradicate or eliminate the problem of trypanosomiasis and at the same time promote sustainable utilization of land on which millions of poor families depend, are real concerns for the future of 37 countries of Africa that are faced with this problem. An understanding of how the interventions affect all the other systems that contribute to attainment of the desired goals is now a matter of urgency.

In the past numerous efforts to control Trypanosomiasis, have been made largely focusing on reduction of the abundance and distribution of the vector. However, all gains made through these control efforts have always been short lived due to resurgence of fly populations and disease prevalence in the controlled areas. Based on the experience of past control failures to sustain low tsetse populations, the African Union is now promoting the elimination of the tsetse flies in order to eradicate the disease from the continent through the Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC) with government resources and the support from the African Development Bank and other development agencies

Eradication has costs and benefits that need to be evaluated in order to estimate the viability of the investment and the sustainability of the interventions. All interventions on tsetse control and eradication have expected environmental and socio-economic implications depending on the approach used and the place where the control is undertaken, so the direct and indirect effects of the T&T interventions should be evaluated across the natural, social and economic systems in order to properly estimate the costs and benefits of the eradication campaign.

These natural, economic and social systems are dynamic and complex systems, thus they exhibit non linear behavior and spatial and temporal lags in their response to T&T interventions, making it difficult to estimate their direct impacts on an individual system. In addition environmental, economic and social systems are linked and interdependent. In consequence, interventions on the natural systems can have indirect effects on the economic sector and human societies and in a similar way impact on the economy or society can have indirect effects on the natural environment. Understanding of how the natural, economic and social systems are inter-linked and inter-dependent is necessary in order to identify the direction of the flows and the magnitude of indirect effects of T&T interventions to estimate with higher accuracy the cost and benefit of the eradication campaign, identify areas where further interventions are need to avoid negative feedbacks and design strategies to mitigate adverse effects across systems.

Considering the complex nature of the involved systems, their inter-linkages and feedbacks mechanisms, the impact assessment of T&T interventions could be a difficult task. The challenge is to understand and quantify how the interventions directly affect the environmental, the economic and social systems, and how the indirect effects of an intervention implemented on one system spread through the others affecting their processes and modifying the flow and direction of the linkages between them. Such assessments require first a conceptual framework to help in mapping out the main cause effect relationships and response patterns. Secondly there is a need for guidelines on how to assess the impacts in order to target the right components or groups in the system and apply the right methods and tools to quantify the effects and promote informed decision.

Trypanosomiasis is a vector borne disease which affects humans, livestock and wildlife in Africa; it is an important constraint to the socio-economic development of infested areas. Considering the interdependence between environmental, social and economic systems, their inherent complexity, the multidimensionality of their links and the existence of non-market cost and benefits, the integrated impact assessment of trypanosomiasis interventions represents both conceptual and methodological challenges. These challenges involve the development of a logical structure of the pathways and interactions of the impacts, and the use of different approaches and techniques to obtain valid assessments. This document presents a framework for integrated impact assessment of trypanosomiasis interventions and briefly summarises the methods available for evaluating the effects on the involved systems.

CHAPTER 1
INTRODUCTION

Trypanosomiasis is a vector-borne disease which affects humans, livestock and wildlife in Africa (Welburn et al. 2001). The direct and indirect impacts of the disease are enormous in terms of human lives, livestock losses and agricultural productivity; moreover the disease is an important constraint to the socio-economic development of infested areas (Kristajanson et al. 1999; Swallow 2000).

Since the end of the 19th century, there have been many efforts to understand the disease, control the vector and to provide treatment for both human and animals (Tilley 2004). These efforts were successful for many years, with diverse perceived economic and environmental impacts. However, as a result of resource limitations, drug resistance and social conflicts, the control measures that were implemented have broken down and there has been a re-infestation of tsetse with resurgence of trypanosomiasis being reported in many areas (e.g. Stich et al. 2003; Abel et al. 2004).

The creation of sustainable tsetse and trypanosomiasis (T&T) free areas in East and West Africa is a joint response of African nations to this disease challenge. To achieve this enormous task a set of different strategies for suppression, control and eradication of disease will be selected, large investments in capacity building will be granted and sustainable land management will be promoted. Impact assessments are needed to facilitate a clear understanding of the extent to which this project will affect the target population and the magnitude of the effects of the intervention on the welfare of the intended beneficiaries. In general terms, impact assessment evaluates the outputs and outcomes of projects, programmes and policy interventions, providing information to donors, policy makers and development managers for planning, setting priorities, demonstrating results and monitoring progress towards an objective (Shiferaw et al. 2005). Comprehensive and integrative impact assessments that include effects on natural, social and economic systems are required. The impact assessment expects to capture the inherent complexity of these systems, the multi-dimensionality of the impacts and the existence of non-market cost and benefits. These requirements represent both conceptual and methodological challenges involving the development of a logical structure of the pathways and interactions of the impacts, as well as the application of different approaches and techniques to obtain valid assessments.

In this paper we develop a framework for assessing the integrated impacts of trypanosomiasis interventions that resembles the structure of the DPSIR conceptual model (see EEA 2000). This framework provides a way to make evident the pressures on the involved systems, define the target groups and levels of analysis, establish cause and effect relationships, organise information about the state of the systems, select appropriate methodologies for impact assessment, identify indicators, scaling up and scaling out the results, promote dynamic learning processes and evidence the potential responses of the society.

The structure of this paper is as follows: We initially introduce the main concepts of impact assessment and present an integrated vision of the interaction between environmental, economic and social systems. Then a set of key questions to be considered in the design of impact assessment studies is reviewed. Later, the basic elements of the impact analysis are shown in a logical sequence to present the conceptual framework for integrated impact assessment of trypanosomiasis interventions. Finally, we briefly summarise the available methodologies for impact assessment on the different systems and provide some conclusions.

CHAPTER 2
TOWARDS A FRAMEWORK FOR IMPACT ASSESSMENT OF TSETSE AND TRYPANOSOMIASIS INTERVENTIONS

2.1 Impact assessments concepts

Impact assessment determines the welfare changes from a given intervention on individuals, households and institutions and whether those changes are attributable to the project, programme or policy intervention (World Bank 2002). These assessments can be made ex ante or ex post. The ex ante assessment evaluates the impact of current and future interventions providing information on the likely environmental, economic, and social impacts and how the flow of costs and benefits is distributed among the affected population. Ex post impact assessment evaluates the impact of past interventions measuring the benefits and costs of the interventions, evaluating the attainment of the objectives and providing information on the pathways through which observed impacts have occurred.

2.2 Integrated vision of the interactions between systems

There is an emerging consensus regarding the need to look for broader approaches to deal with complex systems problems. Natural, social and economic systems are complex in themselves and many of their problems involve the additional complexity of interactions between these systems. Economic and social systems are inextricably embedded in larger natural systems and exchange flows of materials and energy within them; these interchanges of material and energy might also define social structures and processes (Berkes et al. 2003). Considering the relationship between ecological and social systems, it is clear that impacts on the natural systems could affect the societies dependent on the goods and services provided by the ecosystem, thus affecting the welfare of people. Similarly, impacts on the economic or social systems could have positive or negative effects on the environment (e.g. Adger 2000). Hence, impact assessment must consider environmental, socio-political and economic aspects in multiple scale analysis of interventions, and incorporate transdisciplinary and participatory approaches using a broad range of available tools for analysis and communication (Campbell et al. 2001).

The overall objective of tsetse suppression and eradication is to contribute to reducing poverty and improving food security by ensuring the reclaimed areas will be equitably, sustainably and economically exploited. This therefore presents a complicated situation since disease control creates economic incentives for land accumulation by large stakeholders. Furthermore, the relocation of people generates potential changes in social organisation, local institutional arrangements and cultural values, all of which affect the traditional strategies of resource management. This disturbs the dynamics of biophysical processes that determine the sustainability of different land use under distinct ecological conditions.

2.3. Key questions for developing impact analysis of trypanosomiasis interventions

Impact of what: An initial issue is defining in general terms 'what is being analysed'. There are many potential trypanosomiasis interventions in response to a broad set of environmental and socio-economic factors that trigger the need for control and eradication activities. Different interventions might have distinct objectives and scopes, and differ in the methods used. Many of these interventions can go beyond disease related issues and be concerned with issues as diverse as poverty reduction, food security, equity or sustainability (e.g. AFDB 2004).

Impact on what: As was previously mentioned, both economic and social systems are linked and dependent on natural systems. Animal disease can generate a set of direct and indirect impacts on different systems with different magnitudes. Infection with trypanosomiasis negatively affects the number and productivity of animals and their capacity for traction. This may have implications on the agro-ecosystems, by reducing the amount of cultivated land, manure availability and the quality of land preparation. These in turn have a negative effect on crop diversity, crop yields and farmer's income. However, the creation of trypanosomiasis free areas can increase the demand for cropland, generating rapid changes in land use and land cover with potential social impact as a consequence of the high immigration rate into these sites (e.g. Muriuki et al. 2005). Hence it is necessary to define impact based on what is being evaluated. Is the impact on the ecosystems, on the social or economic system or is it an integrative impact assessment considering all of them?

Impact on whom: Trypanosomiasis interventions can have impact on various groups. Depending on the project, affected or beneficiary groups can be defined in terms of livelihood, age, gender, income level, geographic area, ethnicity or other criteria (World Bank 2003). A precision of who are the target groups of the project is useful to define interventions, develop policies and understand potential impacts on other stakeholders. Defining the target groups helps to demarcate the level at which the impacts will be analysed. There are several potential nested hierarchies for both socio-economic and environmental levels of analysis ranging from local to continental scales. Different approaches, methods and indicators can be appropriate and effective for a given level of analysis while others are less so or completely inappropriate (see Kamuanga 2003).

Impact how: Once the adequate environmental, social and economic levels of analysis have been defined and the target of T&T interventions have been identified, the next question is how the impacts of the intervention on the economic, social and natural systems occur. Figure 1 gives a diagrammatic representation on how impacts may result from interventions.

This understanding gives information on where to target assessment of impacts. Researchers must select a set of appropriate methods that will measure changes in the right areas of the system where they occur, taking into account available human and financial capital, prevailing ecological and institutional circumstances and the objectives of the intervention. Choosing a method of analysis often involves a compromise between a method that is sufficiently detailed to capture the impacts on the system(s), and one that produces results that the policy makers will understand and be able to use. In addition, the method of analysis used will determine the data requirements. It is important to know the availability of data for each system and the availability of resources to collect additional data if they are missing or inadequate (see Rushton et al. 1999). Distinct methodologies can be used to answer different questions; different approaches have distinct limitations, provide different information and have distinct data requirements. They also differ in the time needed to complete the study and the required level of skill of the researchers to develop or apply the methodologies (World Bank 2004).

Impact if: To make informed decisions, public and private decision makers need accurate information about the economic, social and environmental consequences of the interventions. Based on the complexity of the involved systems, the links between them and the possibly competing objectives, there is a set of potential tradeoffs within and among systems. For example trypanosomiasis interventions that indirectly generate a positive impact on agricultural production, could have a negative impact on environmental quality. Identifying what are the tradeoffs of different interventions between the different systems, and how they can be measured or evaluated is essential when designing programmes and monitoring impacts (Crissman et al. 1998). In this context, the translation of impacts in a common currency (e.g. monetary valuation of environmental impacts vs. the monetary value of the agricultural production) makes the tradeoffs more evident and facilitates the identification of data requirements.

2.4 Elements of the impact analysis

Since different interventions are focused on different problems and generate distinct impacts, the approaches for the impact assessment of trypanosomiasis interventions will therefore be different for the various case studies. However, it is possible to identify a set of key issues to be considered at the design, implementation and monitoring stages of the studies, enhancing the quality of the research. Below, we present these issues in a logical sequence and briefly discuss them in the context of the framework for impact assessment of trypanosomiasis interventions.

Identify the pressures to justify the need for T&T interventions: Based on data from the natural, economic and social systems, it is possible to estimate the relationships between the potential costs and benefits of the interventions per unit of area and the human population density at the research site to detect if the interventions are justified (e.g. Shaw 2003).

Define the specific T& T interventions: Based on the objectives of the interventions, existing scientific knowledge, technical capability, prevailing ecological conditions, availability of resources and political decisions, a specific set of control or eradication methods will be selected for the intervention (see Allsopp 2001).

Define impact on what: Delimit impact on what is being evaluated. Is the impact on the ecosystem, on the social or economic system or is it an integrative impact assessment considering all of them?

Define impact on whom: Trypanosomiasis interventions can have impact on various groups at different levels of analysis.

Define target groups: It is necessary to identify and analyse those who are affected by the trypanosomiasis interventions and those who can potentially affect the success of the interventions. Different groups can have distinct susceptibility to the disease based on labour division and distinct behaviour, and specific economic groups can exhibit distinct willingness to be involved in control activities and promote or encourage the interventions based on their own evaluation of their costs and benefits (e.g. Pepin et al. 2002).

Define the level of analysis: Different impacts can be evident at different spatial and temporal dimensions. The choice of an appropriate scale is very circumstantial and depends on many factors such as the type and size of project or plan, the availability of resources, the social and ecological processes being studied, and how heterogeneous or homogeneous the spatial setting is (see Gibson et al. 2000).

Understanding transmission channels and expected size and direction of the impacts: Considering the complexity of the interactions between environmental and socio-economic systems, the use of models is required to deal with cross-cutting issues and effects. Simple conceptual models describing the pathways through which an intervention is expected to affect the systems and the likely magnitude of the impacts are useful for ex ante assessments to calculate costs and benefits of the interventions and prioritise actions. However, only ex post assessment provides information on the pathways through which observed impacts have occurred, facilitating the understanding of the effects on different systems. These impact pathways should include both direct and indirect impacts. Direct impacts are effects caused by the proposed action, occurring at the same time and place while indirect impacts are effects caused by a given action, occurring later in time or farther removed in distance but which are reasonably foreseeable. Alternative pathways represent distinct impact scenarios and different social groups can develop distinct impact pathways based on their own perceptions and knowledge (de Lacroix et al. 2003)

Impact how: Once a level and target group have been identified, the next question is how to asses the impacts of the intervention on the economic, social and natural systems.

State of the systems: It is necessary to understand the state of the system for the specific level of analysis in terms of the changes in the links and interdependence between the natural, social and economic systems, evaluating the modification of the flows of matter and energy, and the changes in the supply or demand for goods and services. For example the creation of areas free of disease can trigger immigration to these sites, generating an increase in the demand for cropland within the former tsetse belts, increasing the supply of crop products but reducing the forest area and eventually diminishing the capacity of natural systems to provide goods and services of local and global relevance (e.g. Reid et al. 2000)

Gathering data and information: Integrated impact assessment can be extremely data-intensive and specific data requirements will depend on the nature of the analysed impacts. These requirements should involve gathering qualitative and quantitative data both from primary and secondary sources. Primary sources refer to original data that have not been interpreted, discussed or analysed, e.g. first-person accounts of events, surveys, interviews, data obtained through original research while secondary data sources refer to commentaries, explanations, analysis, interpretation, discussions or compilations done by other authors based on primary data. Different data collection instruments, data type and data analysis can exhibit advantages and disadvantages depending on the impact to be assessed (see Baker 2000). When adequate data are not available, several strategies can be used to obtain valid assessments: the first strategy is adapt the analytical approach to data currently available; the second option is to collect additional information; and the third one is to rethink the intervention or postpone it until adequate data can be collected and appropriate analysis be conducted (World Bank 2003).

Analysing impacts: In general, four factors are used to select the method for analysing the impacts of trypanosomiasis interventions: availability of data, monetary constraints, availability of time and human skills. The various methods used to assess economic, social and environmental impact assessment of trypanosomiasis interventions are summarised in Section 3.

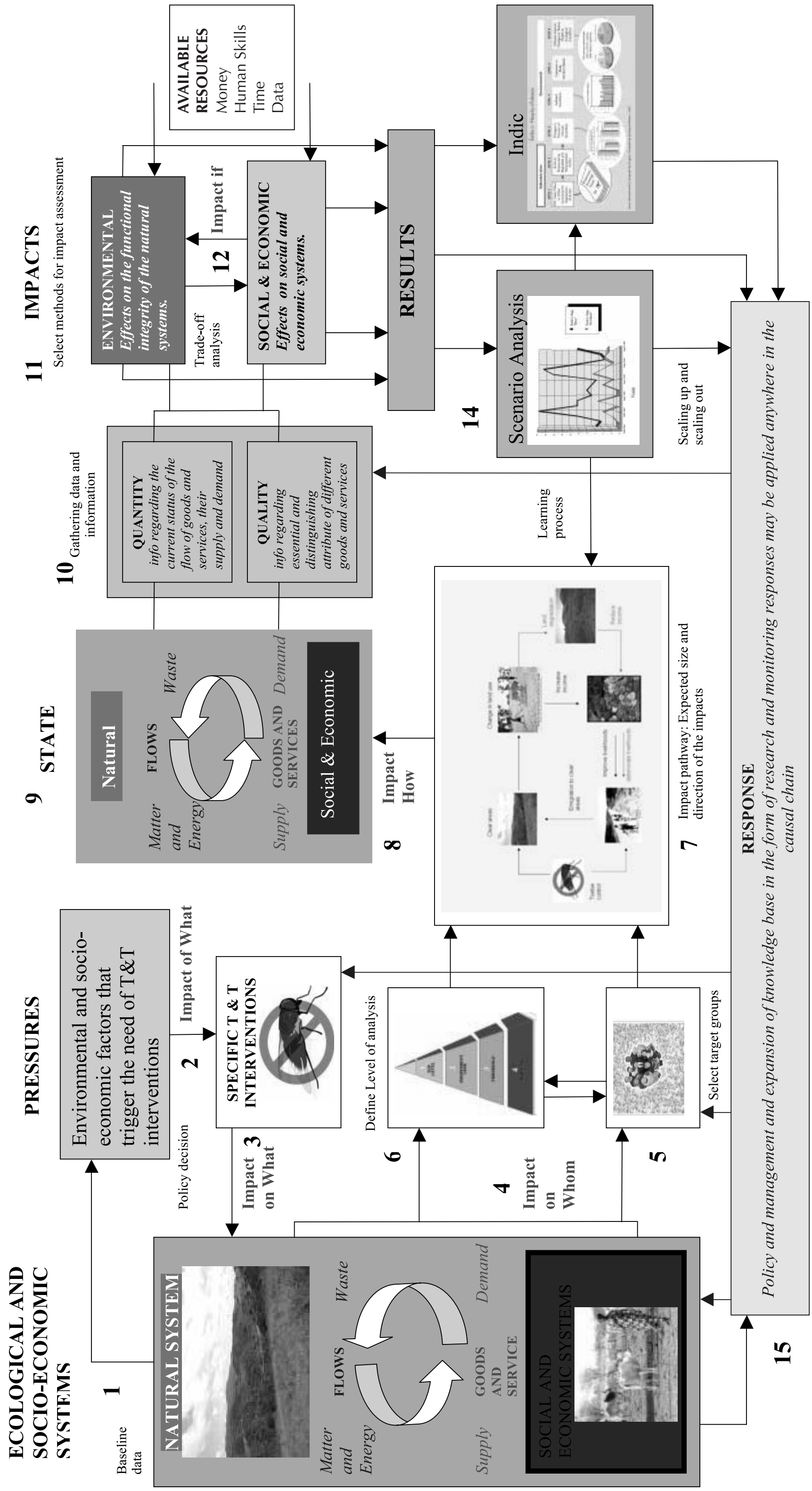
Impact if: Considering the inherent complexity of the environmental, social and economic systems and the links between them and the existence of competing objectives, there is a set of potential tradeoffs within and among systems. Different impacts are evident at different spatial and temporal scales, so it is important to define basic spatial and temporal units to analyse the tradeoffs (see Stoorvogel et al. 2004).

Indicators: Based on the results of the impact assessment, a set of key variables or indicators which characterise the state of the system can be developed. The main goal for developing such indicators is to measure, monitor and report progress towards a goal. The use of indicators allows us to better organise, synthesise and use information (von Meyer 2000), thus they represent basic tools to facilitate public choices, support policy implementation and provide a solid basis for decision making at all levels (Capello and Nijkamp 2002). It has been considered that since the ecological, social and economic aspects are interdependent, different indicators might be constructed based on different world views.

Scenario analysis: Based on the results of the impact assessment, it is possible to develop scenario analyses to obtain forward projections which allow us to progress from the current settings to a series of alternative future situations, identify sensitive variables that can be used as indicators, and to scale up and scale out the results. Alternatively, the scenario analysis can provide information on the steps required to progress from a current situation to a desired future one. The results of scenario analysis provide information to enhance the understanding of the different impact pathways in a continuous learning process involving different stakeholders thus encouraging further examination and experimentation (e.g. Purnomo et al. 2004).

Response: The responses refer to actions taken on behalf of the society by decision makers, policy analysts and resource managers. These responses are based on the results of the impact assessment, the changes in the set of defined indicators and the outputs of decision support tools, e.g. scenario analyses, and are subject to a set of different constraints existing in the system (e.g. money, time and human skills). The responses can be as diverse as developing mitigation and monitoring plans for undesired impacts, providing adequate policies, improving management strategies and spreading the results among target groups (e.g. Morrison-Saunders and Bailey 2003).

Figure1. The conceptual framework for integrated impact assessment of trypanosomiasis interventions.



CHAPTER 3
ANALYZING IMPACTS

This section provides an overview of several broad classes of methods for estimating impacts of trypanosomiasis interventions.

3.1 Methods for economic impact assessment

In general, the quantification of the economic impacts of trypanosomiasis interventions was initially biased towards the estimation of the costs of disease. The methods used to estimate the cost of trypanosomiasis have been categorised based on the direct or indirect effects of the disease (Tables 1 and 2). The direct effects involve the changes in productivity and the impact of disease on animal traction, while the indirect effects refer to the additional costs and the revenue foregone as consequence of disease. There are several methods that can be used for the economic impact assessment of trypanosomiasis interventions. We have categorised them considering three different levels of analysis and summarised them considering their different objectives, the data requirements, the outputs of the analysis and the advantages and limitations of each methodology. The methods for economic impact assessment of trypanosomiasis interventions are described at the herd level (Table 3), the farm/household level (Table 4) and the sector, national and international levels (Table 5). Several related tools that can be useful while assessing the economic impact of trypanosomiasis are presented in Table 6.

3.2 Methods for social impact assessment

Social impact assessment evaluates the change in human population, communities and social relationships resulting from a development project or policy change. These assessments are generally focused on modifications of the characteristics of the target population including individual and family changes, the evolution of the community and its institutional structures, and the changes in the available natural, political and social resources. The set of methods that are useful to evaluate the social impact of trypanosomiasis interventions range from methods focused on the impacts on specific target groups (e.g. beneficiary assessment), to more general methods (e.g. social impact analysis), which can be used to evaluate the impact of interventions on larger and more diffuse groups (Table 7).

3.3 Methods for environmental impact assessment

Several methods can be used to assess the impact of trypanosomiasis interventions on the environment. Based on a literature survey we categorised the methods considering three different levels of analysis based on the hierarchical levels of ecological organisation: methods at the individual/population level (Table 8), methods at the community/ecosystem level (Table 9), and methods at the landscape/level (Table 10). All these methods have been summarised considering their different objectives, the data requirements, the outputs of the analysis and the advantages and limitations of each methodology.

3.4 Methods for the economic valuation of the environmental impacts

There are two important stages for the economic valuation of the impact of trypanosomiasis interventions on the environment. The first one is meant to understand and predict the changes in the flow of ecosystem services attributable to the intervention, and the second is to develop acceptable methods for valuing these changes. The economic approaches to the valuation of environmental impacts are based on the contribution of the goods and services provided by the natural systems to human welfare. However, it is not uncommon that a large share of the contribution of environmental goods and services to the well-being of people is not recognised and most cost–benefit analyses do not include these benefits or the external costs result of the interventions. Several methods can be used to value the impacts of trypanosomiasis interventions on the environment (see Table 11).

CHAPTER 4
CONCLUSIONS

Integrated impact assessments serve to provide decision makers with better information on the extent to which different trypanosomiasis interventions affect the target population and the magnitude of the effect of the interventions on the welfare of the intended beneficiaries. It is currently recognised that environmental, economic and social systems interchange flows of material and energy and the links and processes among these systems are evident at different temporal and spatial scales. It is expected, therefore, that the direct or indirect effects of the trypanosomiasis interventions on a given system might affect the quality or quantity of the flows of matter and energy to the other systems, finally having an impact on human well-being.

These impacts can be evaluated following a series of logical stages described in this framework and applying a set of different methodologies which have been summarised in this document. The results of the integrated impact assessment can be used to prioritise actions, justify interventions, evaluate the attainment of the objectives of the programme and provide information of the pathways through which observed impacts have occurred. The results can also be used to develop mitigation and monitoring plans for undesired impacts, provide adequate policies, improve management strategies and spread the results among target groups.

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APPENDIX
TABLES ON SYNTHESIS OF METHODS USED TO ASSESS IMPACTS OF T&T INTERVENTIONS

Table 1. Methods to estimate the costs of trypanosomiasis: Direct effects of the disease

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Impacts on animal productivity					
Longitudinal monitoring	A technique to evaluate the impact of trypanosomiasis on animal productivity. Ex post analysis of interventions when data from different years are available for the same location.	● Birth rate and mortality by age/sex ● Weight gain ● Milk offtake ● Abortion rate ● Market prices	Productivity parameters are compared for animals detected parasitaemic a different number of times. The results of the analysis are the productivity losses because of disease, which can be monetarised using market values.	● Accuracy ● Seasonal and inter-annual variations of animal productivity are considered	High cost, large number of animals must be monitored every month for a number of years. The results might ignore considerations of what components of the losses can be realistically reduced. External costs are not considered
Case-control approach	An *ex post* analysis technique to evaluate the impact of trypanosomiasis on animal productivity when cross-sectional data for different locations are available.	● Birth rate and mortality of young animals ● Weight gain ● Milk offtake ● Abortion rate ● Market prices	The results of the analysis are the productivity losses because of disease, which can be monetarised using market values.	Productivity indicators are measured for entire herds rather than for individual animals, diminishing the impact of outlayers	Difference in management and local conditions may affect the evaluation of the disease effects. The results might ignore considerations of what components of the losses can be realistically reduced. External costs are not considered.
Before and after approach	An *ex post* analysis technique to evaluate the impact of trypanosomiasis on animal productivity when data for the same herd within the same location are available.	● Birth rate and mortality of young animals ● Weight gain ● Milk offtake ● Abortion rate ● Market prices	Monitor the health and productivity of particular cattle herds within the same site. The results of the analysis are the productivity losses because of disease, which can be monetarised using market values.	Since the analysis is done for the same location, low environmental bias is expected.	Management changes as part or after the treatment, can affect the evaluation of the disease effect. The method only captures the value of the remaining disease not yet controlled, while missing the value of the disease that has already been successfully avoided.
Impacts on animal traction					
Slopes comparison	A technique to evaluate the impact of trypanosomiasis on animal traction in areas with different trypanosomiasis incidence.	● Area of cultivated land ● Oxen numbers ● Ownership of ploughs ● Renting and exchange of oxen and ploughs	Average area cultivated is plotted against the number of oxen owned for group of households within and outside trypanosomiasis control areas. Comparison of the two slopes provides a measure of the relative inefficiency of oxen in the two areas.	● Easy data sampling ● Average cultivated area is measured for the existing oxen rather than for individual animals	Differences in household management, total available land and terrain characteristics could bias the results. The method assumes that households can share oxen with the neighbours.

Table 2. Methods to estimate the costs of trypanosomiasis: Indirect effects of the disease

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Additional costs					
Control expenditure	A technique to evaluate the impact of trypanosomiasis in the enterprise output because of changes in the variable costs of the exploitation.	● Enterprise outputs ● Cost of the treatment (curative and prophylactic) ● A clear cost structure of the farm ● Any other variable able to influence the farmers' use of drugs	This approach provides a broad measure of the avoided costs, the money saved by farmers if trypanosomiasis is controlled.	● Direct monetary values ● The method can be used to larger geographic areas	A clear cost structure is needed to avoid bias. When extrapolated to larger areas, other variables should be important to consider before aggregating the data
Revenue foregone					
Lost potential	Evaluate the economic consequences of production and management constraints, because of the level of infection prevalence and disease incidence in a region. Make explicit the effect of disease in the farmer's production possibilities and the changes in the production possibilities frontier because of disease interventions	● Adoption level ● Commodity prices ● Commodity offtake ● Cost of new production factors	The analysis quantifies the economic differences between the farmer's outputs in the current situation with disease, where low productivity trypanotolerant cattle are preferred, and a new situation with lower disease risk where a different set of production factors such as cattle genotypes developed for higher productivity traits such as milk and meat will be efficient.	The approach makes evident that after disease interventions is not likely that the production systems remain unchanged	● The estimation of lost potential lacks accuracy The levels of adoption of new production factors are uncertain ● The approach considers changes in the supply of the commodity but under the assumption that the prices are unchanged ● Local environmental conditions and management practices can influence the outputs of high productivity cattle breeds ● The approach focuses on financial returns and does not consider the societal benefits of conserving indigenous genetic resources

Table 3. Methods for economic impact assessment of trypanosomiasis interventions at herd level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Gross marginal analysis and enterprise budget	Evaluate the economic viability of an enterprise when quantitative enterprise data are available and farmers are primarily motivated by profit maximisation.	• Animal sales • Milk sales • Changes in herd value • Total outputs • Variables costs (feed, vaccine and medicines) • Forage costs • Fixed costs (labour and capital)	The result from a gross marginal analysis is commonly expressed in monetary terms or as output per standard unit to enable comparison between different alternatives.	• Fixed costs are avoided • Gross margins can be generated from on-farm records or from standard reference books	• Limited applicability for smallholder farming systems, since financial return is not the only criterion for enterprise selection • Full understanding of both the farming systems for which the gross margins have been derived
Break-even analysis	Evaluate the economic viability of an enterprise as in the gross marginal analysis but under conditions when there is some doubt about the variation in the price of an output or input.	• Animal sales • Milk sales • Changes in herd value • Total outputs • Variables costs (feed, vaccine and medicines) • Forage costs • Fixed costs (labour and capital)	• Identification of important inputs and outputs that affect profitability • Determination of break-even points for prices • Quantities of farm inputs and outputs	The methods allow establishment of analysis under conditions of uncertainty in input and output prices.	Limited applicability for smallholder farming systems, since for them financial return is not the only criterion for enterprise selection.
Partial budgets	Establish the economic impact of the disease. The results do not show the profits or losses of the farm as a whole but the net increase or decrease in net farm income resulting from proposed changes.	• New costs • Revenue foregone • Costs saved • New revenues	The result of a partial budget analysis is expressed as change in income.	Simplicity: It is an easy form of budgeting analysis.	• The analysis only assesses the areas of enterprise that are affected by the change being considered, and thus can only be used to consider changes that can be isolated from the rest of the enterprise • Do not incorporate risk or uncertainty • The time value of money is assumed to be zero
Decision analysis	It is a method used to evaluate issues where the probability of particular outcomes is used to weight the economic consequences should that outcome occur.	• The events over which the decision maker has control (alternatives) • The probability of occurrence of chance events • The value of various outcomes (normally expressed in monetary terms)	• Identification of the available courses of action • Assessment of the value and probability of possible outcomes • Estimation of the value of each possible course of action • Pay-off tables or decision trees	The expected results are not necessarily expressed in monetary units, which can be an advantage in smallholder farming systems. Decision analysis combined with investment appraisal is useful where the frequencies of disease outbreak are unknown.	The general technique ignores the time value of the money.

Table 3. (continued) Methods for economic impact assessment of trypanosomiasis interventions at herd level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Investment appraisal	It is a technique to examine the impact of a change in disease over a number of years with a flow of cost and benefits at the herd level.	● Identify all benefits and the time the benefits occur ● Identify all costs and the time the costs occur	Investment appraisal uses three decision-making criteria: net present value, internal rate of return and the benefit–cost ratio.	The technique takes account of the time involved for a system to reach a steady state and of the time value of the money.	● It is a deterministic approach ● The method lacks a component to consider the probability of occurrence of a disease outbreak or the success of a treatment or control strategy
Dynamic herd models	Estimate changes in animal productivity along the time when data to calibrate the model is available and analyse the effect of alternative strategies is desired	The variables are model dependent, basically consider: ● Initial herd size, ● Birth rate, ● Mortality rate, ● Herd structure data with specific mortalities and offtake	The common outputs of a herd simulation model are the changes in herd size and structure as well as herd productivity along a defined period.	● Development of scenarios and evaluation of benefits and costs of different interventions ● Flexibility: herd simulation models can be linked with other tools	● The results are dependent on the model assumptions ● Complex models require larger amounts of data for calibration

Table 4. Methods for economic impact assessment of trypanosomiasis interventions at the farm/household levels

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Optimisation approaches	Provide the solution to a problem within a farming system which is optimal with respect to a set of objective and constraints functions.	The optimisation model requires the specification of an objective function and constraints which in turn require specific data collection and analysis to produce a valid objective function.	Information regarding the optimal allocation of finite resources to obtain the highest output for the objective function which represents the priorities of the manager of the farming system.	The approach can be expanded for multiple objectives or multiple criteria decision analysis.	• Low flexibility • Results are dependent on the specification of the objective function • The use of the optimisation model as a predictive tool requires the assumption that the objective function will remain unchanged over time
Simulation techniques	Resemble the behaviour of the farming system and perform scenario analysis.	• Case dependent • Detailed understanding of the system under study	Prediction of the behaviour of the system based on available input data.	• High flexibility • Useful in systems that cannot be solved or investigated by optimisation methods or that involve highly dynamic relationships over many time periods	• Very expensive and time consuming • Data shortages and model assumptions can have serious consequences on model outputs

Table 5. Methods for economic impact assessment of trypanosomiasis interventions at the sector, national and international levels

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Cost–benefit analysis	Compare programmes and interventions in terms of societal welfare effects.	● Productivity impacts ● Costs and prices ● Elasticities ● Adoption data ● Discount rate ● Environmental valuation of impacts	● Net present value ● Internal rate of return ● Benefit–cost ratio	A framework that can combine rigour with comprenhensiveness	● Data requirements ● Analytical skills required are substantial
Economic surplus	Quantify the impacts of a shift in the supply curve and the resultant economic surplus; partition this between consumers and producers.	● Productivity impacts ● Costs and prices ● Elasticities ● Adoption data ● Discount rate	● Economic surplus ● Net present value ● Internal rate of return ● Benefit–cost ratio	A framework that can be extended with considerable flexibility to attain realistic results at the national and international levels.	● Data requirements ● The method lacks intuitive appeal ● Analytical skills required are substantial
Mathematical programming	Maximise an objective function, subject to resource and other constraints.	● Input–output coefficients ● Attitudes and objectives of stakeholders ● Cost-price data	● Activity mixes ● Shadow prices ● Other outputs can be obtained, depending of the objective function	A flexible framework for well-behaved and well-formulated problems.	● Data requirements ● Analytical skills required are substantial ● Need a very clear understanding of the objectives of stakeholders
Simulation models and systems analysis	Use a systems model to perform 'what if' scenario analysis.	Detailed understanding of the system under study.	System's response to particular input conditions.	● Flexible framework ● Ability to incorporate risk, uncertainty, component interactions	● Analytical skills required are enormous ● Problem definition can be somewhat unclear

Table 6. Tools for economic impact assessment of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Spreadsheet models	Analytical tools based on software programs which organise numerical data into columns and rows. Using defined formulas and functions, they allow for calculations to take place. They are useful to make calculations of both ex ante and ex post analysis of disease interventions. Spreadsheets are commonly used in diverse types of cost–benefit analysis, policy analysis matrices and herd models, incorporating a set of specific formulas and functions for each method.	The spreadsheets are tools for calculations. The variables to measure will depend on the specific analysis to be developed.	Since spreadsheets are tools for calculation, the requirements and results of a spreadsheet model are based on the type of analysis developed. The results could be non-monetary, e.g. changes in livestock population, monetary, e.g. farm income, or quantitative indicators such as investment criteria or policy matrix coefficients.	• Spreadsheets make it easy to define one value's dependencies on other values • When an ordinary spreadsheet is fully assembled, its inputs are easy to change • You can carry out 'what if' investigations	• All of the calculation details are exposed in the spreadsheet and can potentially be corrupted. • Comparison of results from multiple modelling runs requires complex multi-spreadsheet links. • Spreadsheets are not designed for circular or iterative calculations. The user must design the calculations so that recycle streams are checked each time the spreadsheets calculate to ensure that a valid solution is reached.
Geographic information systems (GIS)	Geographic information systems are computer based information systems that enable the user to capture, manage, manipulate, analyse and present geographically referenced data. GIS tools are useful for both ex ante and ex post analysis of disease interventions. GIS capabilities can be used to identify and prioritise areas for tsetse and trypanosomiasis control. GIS provides information to evaluate the economic impact of potential control and eradication projects.	The variables to measure will depend of the specific research questions. Previous studies have needed the following data: • Tsetse distribution data layer • Cattle density data layer • Maps of agro-ecological zones • Geo-referenced data: rainfall, temperature, vapour pressure, deficit, vegetation cover, elevation, potential evapotranspiration, length of growing period, human population and number of tsetse species present • For predictive analysis, historical data are needed • For economic analysis, geo-referenced economic data are also needed, following the requirement of the specific method to use	• Current and future number and density of cattle raised under trypanosomiasis risk by agro-ecological zone and tsetse status • Potential changes in animal disease and tsetse abundance as a consequence of environmental changes	• Manipulation of spatial data and linking geographically referenced data to tabulated data • Easy visualisation of information • Create models and scenarios	• Expensive system set up • Training of manpower is expensive • Collection of data

Table 6. (continued) Tools for economic impact assessment of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Animal disease surveillance	These tools are used to detect either the appearance of a disease or an unusual increase in an endemic disease based on time series data. The health surveillance systems are applicable at the herd and potentially the regional or national levels.	The criteria necessary to develop an optimal surveillance system are disease specific. It is necessary to consider both costs of the disease and its control, probabilities of an epidemic occurring and its expected magnitude, before selecting the number of temporally clustered cases needed to activate the early warning.	Statistical significance of an unusual occurrence of disease, test the significance of the appearance of several cases or outbreaks in a single or limited series of time periods. Alternatively, they can examine the time series of data and test the significance of typically infrequent observations in a time period(s)	• Early warning, • Once cause-specific epidemic is identified, immediate and completely effective controls could be implemented reducing the epidemic costs	• High cost of surveillance • Surveillance does not attempt to quantify the costs associated with correctly or incorrectly identifying the early stages of an epidemic

Table 7. Methods for social impact assessment of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Participatory appraisal	Provide a quick, systematic and cost-effective picture of livestock conditions and veterinary problems in agro-pastoral communities.	• Background information Production information • Seasonal information	Several types of diagrams are widely used to summarise and present the data collected	Uncomplicated, reliable and cost-effective method for collecting information on which to base tsetse intervention decisions.	Outsiders and representatives of powerful groups can influence people's behaviour and influence the opinion of minority groups.
Stakeholder analysis	Determine the interests and influence of the different groups involved in a project.	• Information on constraints to project implementation • Identification of stakeholders from diverse groups • Qualitative data about stakeholders' interests	• Information on the potential social and political effects of the interventions • Perceptions and roles of different groups	• Simple method • Low cost	• Stakeholder analysis relies on qualitative data • The absence of statistical sampling procedures obligates a careful selection of respondents and interpretation of data
Beneficiary assessment	Evaluate and monitor human and animal health projects based on participatory assessment and direct consultation of those affected by and influencing the interventions.	Background information on stakeholders, on cultural, ethnic or socio-economic variations, and on the variables determining whether specific groups would be affected (such as type of access).	Information on the beneficiaries' perception of the problem, their reception to the project and the positive and negative effects of the implementation of trypanosomiasis interventions.	• Less resource intensive than other tools to evaluate social impact • Some quantitative analysis could be developed with the beneficiary feedback	The method provides low contextual and historical background information.
Social capital assessment	Evaluate the role of institutions, networks and norms in the promotion of collective action.	Quantitative and qualitative information at household, community and institutional levels regarding the role of organisations and their membership in aspects such as solidarity, trust, cooperation and conflict resolution in the context of the disease interventions.	Information about the effect of the disease in the community, the institutions and organisations that are more affected and the interest of different social groups in participate in tsetse interventions.	The social capital assessment tool is able to capture their bonding, bridging, structural and cognitive aspects.	• To be operative, some proxies for social capital relevant to the study should be defined • If some indexes are defined, this could be a problem of subjectivity in the weight of the involved variables
Social impact analysis	Iterative framework based on detailed social information to identify and analyse the impacts of and responses to animal health intervention by people and institutions.	• Data from relevant issues to the tsetse interventions • How different groups will be affected • The extent of influence of these groups on the success of the intervention	Contextual information on the social and political systems in the area of the project. The analysis identifies the different affected groups along the project development, their preferences and priorities, and their capabilities to develop coping mechanisms to mitigate negative impacts.	Uses different methods to obtain both quantitative and qualitative data from a sample representative of a particular region or population groups relevant to a particular project. The method can be used even when national household data do not exist or do not contain the specific information needed to assess reform impacts.	• High level of knowledge of local customs and culture are required for structuring and interpreting qualitative and quantitative data • The method has limitations when the transmission channels and groups affected are not well known

Table 8. Methods for environmental impact assessment of Trypanosomiasis interventions at the individual/population level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Randomised block sampling designs	To assess changes in species composition under various ecological and experimental regimes.	• Number of plant and animal species • Frequency • Baseline data	• Spread vegetation types indicating degradation and changes in productivity and intensity of grazing • Information on succession stages	Robust in identifying small-scale variations in a population	• Case specific • May have limited application to some areas
Quadrant sampling: Vegetation cover assessment	To evaluate changes in an abundance of species in various vegetation or land cover categories and estimate proportions of cover for species including bare ground.	• Per cent canopy and ground cover of various plant species • Count of individual plants of a particular species per quadrat • Soil samples	• Changes in composition of species • Information on changes in soil fertility, soil erosion and pollution • Grazing intensity • Wood harvesting by humans	• Reliable • Simple • Requires no complicated field equipment	• Need for field identification of plants • Estimation of relative percentage cover could lead to bias
Insect capture methods	To evaluate diversity and abundance of insects and determine their dispersal ranges.	• Number and type of insect species • Diversity and richness in different ecosystems • Chemical analysis	• Direct and indirect impacts on non-target organisms • Accumulation of toxins in insects	• Easy to use • Prompt results • Applicable to many insect groups	Timing of the sampling needs to be right for the target insect group.
Chemical toxicity tests	• To determine the effects of chemical use on the ecosystem • To assess rates of biodegradation of compounds and level of toxicity to species	• Data on chemical analyses of samples from different organisms • Field and ecological surveys of biota • Information on chemical pathways in an ecosystem	• Levels of bioaccumulation of chemicals in different organisms and different environments • Temporal variation in element cycling	• Guides to protect the environment, • Determines maximum permissible levels for chemicals,	May be costly depending on chemical in use.

Table 9. Methods for environmental impact assessment of trypanosomiasis interventions at the community/ecosystem level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Habitat change assessment	• To evaluate changes in habitat structure and function • To assess effects of ecosystem fragmentation and disturbance to ecosystem integrity	Measurable parameters of habitat quality and condition, e.g. changes in vegetation composition, stratification, cattle and wildlife density, grazing intensity, soil characteristics etc.	Changes in habitat conditions and composition.	Easy to use.	Requires good knowledge and uniform descriptions of habitat characterisation as a baseline.
Grazing intensity assessments	To estimate grazing pressure on a habitat.	• Vegetation height • Bare ground cover • Evidence of trampling and compaction • Browsing • Faecal density • Trails etc.	Changes in vegetation (structure, species composition, growth form and cover) due to grazing	Easy and quick method of assessment.	• Need a good knowledge of plant species names and their importance to grazing • Seasonal abundance data are required
Land use change analysis	• To determine the trends in land use changes over time at a landscape level • To evaluate changes in spatial patterns	• Historical information • Satellite imagery at different time intervals	• Information on trends of land use change and cropping systems • Relative proportions of land cover	Outputs are easy to understand and visualisze	Requires GIS skills and good computing capability.
Characterisation of ecological parameters	• To delineate ecological ranges, ecosystem function units or systems • To determine critical ecological processes that are important to the interventions	• Ecological zoning underlying different ecological parameters • Thresholds of ecological processes	• Natural resources distribution maps • Potential impacts on the distribution and resilience of species to interventions	Prior information on impacts of interventions before implementation.	• Requires data from different sources, e.g. soils, climate water • Difficult to account for external influences

Table 9. (continued) Methods for environmental impact assessment of trypanosomiasis interventions at the community/ecosystem level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Transect sampling (line/belt): Vegetation	● To evaluate vegetation types and species composition ● To assess variation in species composition over space	Species types, phenological characteristics and life forms.	Similar to those obtained by quadrat methods except that the outputs here will show more about spatial distribution of species	Good for monitoring changes in areas of ecological gradients.	Intensive sampling and massive data to handle.
Species census: total and sample counts; sighting and voice recognition	To estimate population size of different wildlife species.	● Requires sample or actual counts of species of interest in the focal area ● For impact assessment, abundance of indicator species is preferably measured	● Can provide important baseline data for impact assessment of tsetse interventions ● May provide important reference point in monitoring wildlife trends in areas of intervention	● Total counts are easy to calculate (= sum of observed individuals) and does not require particular statistical treatment ● Easily understood by wildlife officers and managers, eliminating doubts and prolonged debates by experts ● Sample counts are less expensive and achieve high accuracy and precision	● Total counts are very expensive and require very high logistics ● Sample counts are often not easy to compare when done by different teams during different periods and can raise doubts between census experts, the wildlife authorities and managers
Timed species count	● To evaluate birds species richness and composition ● To determine migration patterns of birds	Counts of bird species at different times of day and season and in different habitats	● Composition of bird species ● Proxy information on ecosystem pollution	● Quick results ● Inexpensive	Requires good skills in identification of birds and voice recognition

Table 10. Methods for environmental impact assessment of trypanosomiasis interventions at the landscape level

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Time series aerial imagery analysis	To estimate trends in the distribution in space and time of ecosystems in a given area.	• Time series aerial photographs of the same area, taken during the same season • Field surveys to ground truth the images • Historical data on changes	Provides information on the changes in land use and land cover by integrating relevant factors to evaluate the contribution of interventions to the landscape changes.	Integrates and captures the social dimension that contributes to land use change.	Aerial photography is expensive if not available from government survey departments.
Remote sensing and GIS	To analyse temporal and spatial patterns of natural resources, trends of change in composition and distribution.	Satellite images taken in different years.	• Spatial distribution maps • Variability in distribution over time	Are accurate and can cover large areas and regions.	• Satellite images may be expensive • Need technical training on image interpretations
Regional population models	To compute and extrapolate inter-census growth rates.	• Population census data over time • Settlement patterns and environmental changes	• Rates of annual changes • Relates stages of environmental changes to population growth patterns, includes social dimensions	Employs historical population growth patterns in analysis of environmental changes.	• Not sensitive to external factors over the period of estimation • Data requirements and cost of monitoring are high

Table 11. Methods for the economic valuation of the environmental impacts of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Market price method	Assess the impact of disease interventions on the society, valuing the changes in quantity or quality of several ecosystem goods or services that are bought and sold in commercial markets based on the quantity people purchase at different prices, and the quantity supplied at different prices.	• Data on the quantity demanded at different prices, plus data on other factors that might affect demand, such as income or other demographic information • Data on variable costs of production and revenues received from the goods	• Consumer surplus • Producer surplus • The method provides the value of the economic losses due to the intervention as the sum of lost consumer surplus and lost producer surplus	• Uses standard, accepted economic techniques • People's values are likely to be well-defined • Price, quantity and cost data are relatively easy to obtain for established markets • The method uses observed data of actual consumer preferences	• Market may not reflect the value of all productive uses of a resource • The method has limitations to assess changes that affect the supply of or demand for a good or service • Market imperfections and/or policy failures may affect the estimations
Productivity method	Estimate the direct and indirect impact on society of disease interventions that generate changes in the quantity or quality of ecosystem goods and services that are factors of production for commercially marketed goods.	• Data regarding how changes in the quantity or quality of ecosystem goods or services generate changes in consumer surplus and/or producer surplus • Data for costs of production of the final good, supply and demand for the final good and supply and demand for other factors of production	Considering that changes in quality or prices of the final good will affect consumer surplus and changes in productivity or production cost will affect producer surplus, then changes in the economic surplus will provide an estimate of the economic value of environmental impacts.	• The method is easy to understand and intuitive • Data requirements are limited • The relevant data may be readily available, or obtained from simulation models, so the method can be relatively inexpensive to apply	• The method does not measure the value of non-marketed environmental goods and services • Scientific understanding of the relationships between the changes and productive outcomes are needed • Some lags in temporal and spatial effects can occur since changes in productivity associated with the environmental effects may take a long time to be seen by farmers
Hedonic pricing	To estimate the direct impact on society of disease interventions that generate changes in the quantity or quality of an ecosystem good or service, under the premise that market prices reflect environmental and non-environmental attributes and the consumer behaviour can be revealed through surrogate markets.	Generally, cross-section and/or time-series data on real estate property values and property and household characteristics for a defined market area that includes different levels of environmental quality are needed.	Hedonic functions that can be can be used to determine the implicit price associated with some environmental characteristics, holding all other factors constant.	The method is based in current choices and flexible enough to be adapted to many different situations, since data of real estate prices are commonly reliable, available from many sources and property markets are relatively efficient and competitive	• The surrogate markets capture only the direct impacts under the assumption that users can perceive the differences in environmental quality and given their income, they can select the combination of features that prefer • The method is sensible to market distortions and model specification

Table 11. (continued) Methods for the economic valuation of the environmental impacts of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Travel cost	Estimate the impact on society of disease interventions that generate changes in the quantity or quality of ecosystems or sites that are used for recreation.	● Data regarding the origin of the visitors, distance travelled, the number of visits in a defined period of time, the number of days involved in the trip, the reasons for the travel, the time spent at the site and other destinations ● Travel expenses, income and some socio-economic characteristics of the visitor ● Data regarding potential substitute destinations and perceptions of environmental quality at the selected site	A demand curve from data on actual travel costs, under the premise that the time and travel cost expenses that people incur to visit a site represent the 'price' of access to the site. The area below this demand curve gives the average consumer surplus, which is multiplied by the total relevant population to estimate the total consumer surplus for the site.	● The method is relatively inexpensive to use ● The methodology is based on users' current decisions rather than stated preferences and the results are relatively easy to interpret and explain because the method uses commonly used techniques to estimate economic values based on market prices	The method cannot be used to measure non-use values or off-site values provided by the natural system, and is only suitable for goods and services recognised by the users,
Damage cost, avoided cost, replacement cost and substitute cost methods	To provide estimates of the economic impact of animal disease interventions on the environment, by quantifying the value of ecosystem goods or services based on the costs of avoiding damages, purchasing substitutes or replacing the altered functions provided by natural systems.	● Information on the ecosystem service in terms of how it is provided, who the users are and how its level of provision is affected ● Estimation of the potential damages for a defined period of time ● Identification of the least costly alternative means to provide the service ● Calculate the cost of the substitute or replacement service	The monetary value of the costs incurred by people to avoid damage, replace or provide substitutes for ecosystem goods or services should represent a rough estimate of the value of those services.	The advantage of these methods is that they can provide at least a rough measure of the value of ecosystem goods or services which may be difficult to value by other means when data or resource limitations make it impossible to estimate peoples' willingness to pay for them.	● The methods do not consider social preferences for ecosystem services or individual's behaviour in the absence of those services ● These methods can underestimate or overestimate the benefits, since simplistic applications do not consider the degrees of substitution between the alternative and the natural good or service, nor their non-use values

Table 11. (continued) Methods for the economic valuation of the environmental impacts of trypanosomiasis interventions

Methods	Objective	Data requirements	Outputs	Advantages	Limitations
Contingent valuation	To estimate economic values of all kinds of ecosystem goods and services. It can be used to estimate both use and non-use values and it is the most widely used method for estimating non-use values.	The specific variables to include in the questionnaire will necessarily be case dependent. It is recommended to involve respondents familiar with the issues to evaluate, present the scenarios without uncertainty, avoid asking for the willingness to accept, provide realistic payment vehicles, prefer dichotomous choice formats, include theoretical validation tests	The method estimates the Hickisian consumer surplus—either the compensating variation or the equivalent variation—due to changes in the provision of public goods.	This is a flexible tool, able to estimate use and non-use values and ex ante and ex post assessments. Thisis the most widely accepted method for estimating total economic value, including all types of non-use, or 'passive use', values. CV can estimate use values, existence values, option values and bequest values.	The major criticism of results of CV is a series of biases which can be focused on two different aspects: validity (accuracy) and reliability (reproducibility). Several other sources of error are consequences of embedding, sequencing, information and elicitation effects, as well as hypothetical and strategic bias
Contingent choice	To estimate both use and non-use values not directly asking people to state their values in monetary terms. Rather, values are inferred from the hypothetical choices or tradeoffs that people make.		● State a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost ● The results may also be used to rank options, without focusing on monetary values	● The method can be used to value the outcomes of an action as a whole, as well as the various attributes or effects of the action ● The method allows respondents to think in terms of tradeoffs between alternatives which may be easier than directly expressing monetary values thus increasing consistency of responses because they do not present choices between environmental quality and money	● Lack of familiarity of respondents with some tradeoffs constrain the evaluation ● Some biases can appear because of the complexity of choices or their high number ● Translating the choices to monetary values is not a simple process ● The validity and reliability of the method for valuing non-market commodities is largely untested

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