The struggle against tsetse flies and animal trypanosomiasis in Africa[1]

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SUMMARY.— An overview is given of the current techniques to control tsetse flies and animal trypanosomiasis. Currently two main players are involved in the control of African trypanosomiasis: the Programme against African Trypanosomiasis (PAAT) and the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC). The role and the objectives of both programmes are critically analysed. The scientific community is very sceptical about the feasibility of an eradication programme of tsetse flies for the following reasons: 1.biological, geographical and environmental reasons; 2. institutional weaknesses and logistic constraints; 3. the failure of many eradication projects in the past and 4. the fact that there are other priorities in sustainable rural development.
KEY WORDS. — trypanosomiasis, Africa, review, tsetse flies, eradication

SAMENVATTING. — *De strijd tegen de tseetseevlieg en dierlijke trypanosomiase in Afrika.* Een overzicht wordt gegeven van de huidige methoden om tseetseevliegen en trypanosomiase te controleren. Momenteel zijn er twee belangrijke spelers actief op het vlak van de controle van Afrikaanse trypanosomiase: het Programma tegen Afrikaanse Trypanosomiase (PAAT), en de Pan-Afrikaanse Tseetsee en Trypanosomiase Eradicatie Campagne (PATTEC). De rol en de objectieven van beide programma's worden kritisch doorgelicht. De wetenschappelijke wereld staat zeer sceptisch tegenover de haalbaarheid van een eradicatiecampagne van tseetseevliegen omwille van de volgende redenen: 1. biologische, geografische en milieu redenen; 2. institutionele zwakte en logistieke problemen; 3. de mislukking van veel eradicatieprojecten in het verleden en 4. het feit dat er veel andere prioriteiten zijn op het vlak van duurzame plattelandsontwikkeling.
SLEUTELWOORDEN. — trypanosomiase, Africa, review, tseetseevliegen, eradicatie

RESUME. — *La lutte contre la mouche tsétsé et la trypanosomiase animale en Afrique.* Les différentes techniques de lutte contre les glossines et la trypanosomiase sont passées en revue. Actuellement il y a deux acteurs importants qui sont impliqués dans le contrôle de la trypanosomiase : le Programme contre la Trypanosomiase Africaine (PAAT) et la Campagne Pan-Africaine d'Eradication des Mouches Tsétsé et de la Trypanosomiase (PATTEC). Le rôle et les objectifs des deux programmes sont analysés de façon critique. Le monde scientifique reste très sceptique au sujet de la faisabilité d'une campagne d'éradication des glossines pour les raisons suivantes : 1. raisons biologiques, géographiques et environnementales ; 2. faiblesse institutionelle et problèmes logistiques ; 3. l'échec de plusieurs projets d'éradication dans le passé et 4. le fait qu'il y a d'autres priorités dans le domaine du développement rural durable.

MOTS CLES. — trypanosomiase, Afrique, revue, mouches tsétsé, éradication

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Introduction

Trypanosomiasis remains a major constraint to the development of livestock in sub-Saharan Africa. Thirty seven countries are affected covering an area of about 9 million km^2. It is estimated that about 50 million cattle are exposed to the disease and that 35 million doses of trypanocides are used per year (Mattioli et al., 2004). The direct and indirect annual losses are estimated at US$ 4.5 billion (Hursey, 2001). Due to environmental changes (i.a. land use changes due to the increasing population and deforestation) the epidemiology of animal trypanosomiasis is changing (Van den Bossche et al.,2001; 2010). Because of the gradual encroachment of people and cattle, the latter are playing an increasing role as blood source for tsetse flies. This results in a change from a dominant sylvatic to a domestic cycle and it has been nicely shown that bovine trypanosomes in the latter cycle are less virulent and have less impact on production (Masumu et al., 2006; Van den Bossche et al., 2011). However, although the pathogenicity of trypanosomes in certain endemic areas might decrease, this is not everywhere the case and livestock owners very often consider trypanosomiasis as one of the most important disease problems. Human African trypanosomiasis (HAT) will not be dealt with in this review. Contrary to animal trypanosomiasis HAT occurs in certain foci. Most of these foci are well known nowadays and important progress has been made to map them in detail (Simarro et al., 2010). Furthermore, the number of new cases of sleeping sickness has for the first time decreased under 10,000 in 2009 (against about 30,000 in 1999) which gives some hope that the elimination of this disease is in sight (Simarro et al., 2011). Elimination of disease, however, should not be confounded with eradication (Molyneux et al., 2004). Disease elimination means the reduction to zero of the incidence of a specified disease in a defined geographical area as a result of deliberate efforts. It precedes elimination of infection which is the reduction to zero of the incidence of infection caused by a specified agent in a certain area. Eradication is defined as the permanent reduction to zero of the worldwide incidence of infection by a specific agent (Molyneux et al., 2004).

The purpose of this review is 1. to give a brief overview of the current techniques to control tsetse flies and animal trypanosomiasis and 2. to critically analyse the role and the objectives of the two main players involved in the control of African trypanosomiasis: the Programme against African Trypanosomiasis (PAAT) and the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC).

Current methods to control animal trypanosomiasis

The control of trypanosomiasis in livestock can be directed against the parasite, the vector or can also involve the host (table 1).

Table 1. Current techniques to control animal trypanosomiasis

Target	Technique

Vector	• Insecticides
	  ○ Ground or aerial spraying
	  ○ Pour-on
	  ○ Netting
	• Screens and traps
	• SIT (sterile insect technique)

Trypanosome	• Chemotherapy • Chemoprophylaxis
Host	• Management • Trypanotolerant breeds

Methods to control the vector

Tsetse flies are the main vectors of animal trypanosomiasis, but some trypanosomes can also be transmitted mechanically by biting flies such as tabanids and *Stomoxys* spp. Large areas can be cleared from tsetse flies by using ground and/or aerial spraying of insecticides. **Ground spraying** uses residual insecticides (e.g. DDT, dieldrin, endosulfan) which target the tsetse resting sites. Because of the negative effects on the environment these persistent insecticides are more and more replaced by the less toxic synthetic pyrethroids. These products are also used for aerial spraying with fixed wing aircrafts i.e. the **sequential aerosol technique (SAT)**. SAT has been used successfully in several African countries, i.a. Botswana, where the Okavango delta was cleared from tsetse flies without negative impact on the environment (Kgori et al., 2006). Insecticides can also be applied on live animals by spraying or **pour-on**. Nowadays many African farmers use pour-on insecticides because they can be easily and rapidly applied without any sophisticated equipment. Furthermore, the insecticides kill also biting flies and ticks resulting in less nuisance for the animals and higher productivity (Leak et al., 1995). Applications can be restricted to the preferred biting sites of tsetse flies allowing a reduction of up to 90% of the amount of insecticide needed (Torr et al., 2007). Consequently, this kind of treatment reduces the cost to less than 1 US$ per head of cattle per year (Torr et al, 2005). In case of zero grazing animals insecticide impregnated mosquito nets (about 1 meter high) have been used successfully around the stable in order to protect the cattle against tsetse flies (Bauer et al., 2005).

A large variety of **traps and targets** (impregnated with pyrethroid insecticides) has been developed to attract and kill tsetse flies. Especially for the savannah tsetse species the efficacy of these traps/targets can be improved by using odour attractants (such as octenol and phenols) (Green, 1994). At a density of 1 to 4 targets per square km certain tsetse fly populations can be suppressed to low numbers in a short time period. Although this technology is not sophisticated and environment friendly, it is labour intensive and too expensive for most African peasants (Vale & Torr, 2004).

The **Sterile Insect Technique (SIT)** consists of the release of irradiated sterile male flies at a proportion of at least 10 sterile to one wild male so that they are able to compete with the wild male flies. When a sterile male mates with a virgin female fly, this results in no offspring because female tsetse usually mate only once in their life (Feldman, 2004). SIT is often needed for the final eradication of tsetse flies. It is a very expensive technique because mass-rearing of tsetse flies is necessary to provide huge amounts of sterile males which have to be released (preferably aerially) on a weekly basis for a period of 15 to 18 months. SIT is only effective when the population density of the target flies is very low which implies prior suppression of the flies using other techniques. An example of success of SIT was the eradication of *Glossina austeni* from the island of Unguja, Zanzibar (Vreysen et al., 2000). Unfortunately, with the exception of Zanzibar, there are very few success stories of the use of SIT to eradicate tsetse flies. Although Unguja is a small island infested with only one tsetse species *G. austeni*, it took several years and many millions of dollars to get rid of the flies. Contrarily to the theoretical 10:1 ratio of sterile males to wild males a ratio of more than 100:1 was needed on Unguja. This can be explained by the fact that – contrary to the common belief - some tsetse flies mate more than once (Bonomi et al., 2011; Rogers & Randolph, 2002). This implies that huge tsetse breeding units have to be built in order to produce the required large amounts of sterile flies.

It is generally agreed that SIT makes only sense as part of **area-wide integrated pest management (AW-IPM)** of tsetse. The AW-IPM approach aims at the sustainable removal of an entire tsetse fly population within a delimited geographical area and uses a combination of various techniques including SIT if necessary (Feldman, 2004). The estimated costs of various methods to control tsetse flies are summarised in table 2. They depend heavily on the terrain conditions and on the final objective (control or eradication).

Table 2. Estimated costs of tsetse eradication or control

Technique	Costs (US$) per km^2	Objective and location
Ground spraying	265 – 315	Eradication (Zimbabwe, Zambia)
Targets	220 – 290	Flat terrain
Aerial spraying	345 – 535	Various locations
Cattle treatment	50 – 120	Pour-on, 15 cattle/km2
	60	Pour-on, 44 cattle/km2
Linear km of barrier using targets		Zimbabwe, Zambia
• Barrier establishment	2000	
• Annual barrier maintenance	1600	
Aerial spraying (SAT)	265 – 275	Eradication, Botswana
Sterile Insect Technique (SIT)	800	Eradication, Eastern Africa
	250-400	Eradication, West Africa
Low density monopyramidal traps	26	Annual cost of control, Ivory Coast

Source: Shaw, 2003

Methods to control the parasite

A limited number of drugs is available to treat animal trypanosomiasis. For the treatment of cattle three products are on the market since more than 50 years. Diminazene aceturate has curative properties whereas isometamidium chloride and the homidium salts (ethidium and novidium) have both curative and prophylactic activities. Although ethidium is mutagenic and should be withdrawn from the market, it is still widely used in East Africa (Geerts et al., 2010).

Currently the treatment of affected animals with trypanocidal drugs still remains the most frequently applied measure to control trypanosomiasis. Treatment is mainly carried out by the livestock owners themselves without any supervision by veterinary personnel. It has been observed that underdosing occurs very frequently, which is an important risk factor for the development of drug resistance (Delespaux et al., 2002). Trypanocidal drug resistance is increasingly reported all over Africa and is now present in 21 sub-Saharan countries (Chitanga et al., 2011; Geerts et al., 2010). However, farmers continue to use the drugs because alternative products are not available. Fortunately, it has been observed at several occasions that –even when drug resistance is present at high levels – treatment remains beneficial and allows the animal to survive and to be productive (Chitanga et al., 2011; Delespaux et al., 2010; Geerts & Holmes, 1998).

Host management

Most livestock owners in Africa know very well the sites where tsetse flies are present. They are quite often able to manage their herds and flocks in such a way as to avoid contact with the bites of the flies. However, especially in the dry season when there is a lack of grass, the farmers are forced to bring their herds to wetter places with more grass but often also infested with tsetse flies.

Trypanotolerance is another host-related characteristic of some livestock breeds allowing them to survive, reproduce and remain productive under trypanosomiasis risk without the aid of trypanocidal drugs (d'Ieteren et al., 1998). The use of trypanotolerant breeds is a highly sustainable approach to control trypanosomiasis in low or medium tsetse infested regions. However, unfortunately only about 6 % of the current cattle population in West and Central Africa consists of Ndama, Baoule and other trypanotolerant breeds. Trypanotolerant Djallonke sheep and West African dwarf goats account for 32 and 47 %, respectively of the sheep and goat population in West and Central Africa (Geerts et al., 2009). In East and Southern Africa there are even much smaller numbers of trypanotolerant livestock breeds.

PAAT and PATTEC: main players in the field of trypanosomiasis

There are two important players in the field of tsetse and trypanosomiasis (T&T): the Programme against African Trypanosomiasis (PAAT) and the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC). PAAT was launched in 1997 and is a joint programme of the FAO, WHO, OIE and the Inter-African Bureau for Agriculture (IBAR) of the African Union (http://www.fao.org/paat). Its objectives are: coordination and optimization of research and control activities, normative and standardization activities, technical and scientific publications, capacity building and the support to trypanosomiasis endemic countries. PAAT has acted as the international forum for all those working on tsetse and trypanosomiasis. Its regular meetings, where issues could be debated freely and solutions found, have underpinned the global effort to deal with this disease, its vector and their role in perpetuating poverty in Africa. PAAT is unique in bringing together three UN agencies as well as the African Union (FAO, 2008). Recently, an external evaluation team made a whole list of recommendations to further improve the functioning of PAAT (Dargie et al., 2010). Inter alia the following three important weaknesses were identified:

1. The emphasis given by PAAT in recent years to “area-wide” approaches to T&T management and to the technologies (primarily SIT and more recently to SAT) considered necessary for undertaking interventions over large areas needs to be balanced by the provision of updated advice and capacity-building on policies, strategies and technologies appropriate for small-scale/community-based interventions. Notwithstanding the importance of “area-wide” principles and of related technologies, the reality on the ground at present is that the depth of knowledge (including e.g. about the vulnerability to reinvasion of areas identified for interventions), and scale of operations and of financial and other resources required to implement these principles and technologies successfully are beyond the means of many affected countries, donors and certainly livestock owners.
2. Although substantial efforts have been made by both the PAAT Secretariat and the PAAT Chairman to reach agreement with the PATTEC Coordination Office on principles for identifying priority areas for intervention and the respective roles and responsibilities of PAAT and PATTEC in assisting countries and the donor community in developing and implementing “bankable projects”, the reality is that this PAAT-PATTEC “harmonization process does not function “in practice”. Urgent action is needed to ensure the active participation of both PATTEC and IBAR in the PAAT Secretariat and activities.
3. Although PAAT has generated extremely valuable and much-needed normative outputs for technical and policy decision-making , it is not sufficiently engaged in assisting countries to generate outcomes at field level. Therefore a FAO-PAAT livestock officer needs to be based in Africa in order to provide technical support to T&T affected countries for planning and implementing integrated field interventions as well as wider animal disease control packages, and for closer and more effective working relationships with PATTEC, AU/IBAR, IAEA, WHO and others (Dargie et al., 2010). In the meantime this officer is in place and is based at the FAO regional office in Accra, Ghana.

The other major actor in the field of T&T is the **Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC)** which was launched in 2000 by a declaration of the African Heads of State to render Africa free of tsetse flies (http://www.africa-union.org/Structure_of_the_Commission/depPattec.htm). It is a project of the AU-IBAR. The PATTEC plan of action seeks to apply area-wide principles to eliminate each pocket of tsetse infestation at a time; thus, creating a series of tsetse-free zones that can eventually be linked over a much larger area. The techniques available for use in reducing the tsetse population, including odour-baited traps and insecticide-treated targets, pour-ons and ultra-low volume aerial spraying of insecticide, will be used singly or in combination, and supplemented with SIT to ensure total elimination of the target tsetse population (Kabayo, 2002). The field activities started in 2006 in 6 countries, three in West Africa (Mali, Burkina Faso and Ghana) and three in East Africa (Uganda, Kenya and Ethiopia). A budget of US$ 80 million was foreseen for a period of 6 years (until end 2011). Most of the funding came from the African Development Bank (AfDB; soft loan and grant for 80 and 5 % of the budget, respectively) whereas the governments of the countries involved contributed 15 % of the required budget. Although an independent evaluation of the PATTEC programme has not yet been carried out, it appears that up to now only very slight progress has been made towards the objectives of PATTEC. In most of the 6 countries the baseline data have been collected, but few areas have been cleared from tsetse flies. A lack of regional collaboration was reported among the 3 countries in East Africa and among the 3 countries in West Africa. Furthermore, there was a lack of skilled personnel at all levels in the 6 countries and in Ethiopia serious problems occurred in starting up the tsetse breeding colonies needed for the SIT (PAAT, 2008). The original budget had to be revised because too much funding was foreseen for SIT and insufficient money for tsetse suppression activities. At the end of 2011 it was evident that the performance of the PATTEC programme in the 6 countries was very unequal. In some countries fairly good progress has been realized whereas other countries are far behind schedule. Given the mediocre results of the overall programme there are strong indications that the AfDB will not continue to finance the next phases of the PATTEC. However, because of the good results during the first phase in Ghana the government has decided to continue funding from own resources (Mahama, C., 2012, pers. comm.). It remains to be seen whether other governments will follow the example of Ghana or whether the PATTEC will slowly fade away once the AfDB funds have been completely spent. The aforegoing observations confirm that the scientific community was right when it expressed already 10 years ago its skepticism about the feasibility of the PATTEC programme (Rogers & Randolph, 2002; DFID, 2003).

The eradication of tsetse flies

There are several reasons why the eradication of tsetse flies is not feasible, nor desirable (table 3).

Table 3. Reasons why the eradication of tsetse flies is not feasible, nor desirable (modified from DFID, 2003; Rogers & Randolph, 2002)

• Biological, geographical and environmental reasons • Institutional weaknesses and logistic constraints • Historical reasons • Other priorities in rural development

Biological, geographical and environmental reasons

There are 31 different *Glossina* species in sub-Saharan Africa. Each species has its specific habits and all are very resilient because of the relatively long lifespan of the females, the good pupal survival and the wide variety of hosts for feeding. Nine million km^2 of the African continent are tsetse infested, covering 37 countries among which 28 belong to the least developed countries, which implies that complete eradication is a huge and unrealistic task even in the long term. Furthermore, tsetse eradication does not automatically imply trypanosomiasis eradication. *Trypanosoma evansi* is a parasite which is only transmitted by biting flies. *T. vivax* and *T. congolense* are parasites which are commonly transmitted by tsetse flies, but which can also be transmitted mechanically (Desquesnes et al., 2003a; 2003b). Several reports have been published about the persistence of *T. vivax* in regions without any tsetse flies (Cherenet et al., 2006; Sinshaw et al., 2006). This is not surprising since we know that *T. vivax* in South America was imported from Africa and succeeded in adapting itself to a life cycle without tsetse flies (Jones & Davila, 2001). And finally, a large-scale eradication campaign will have a negative impact on the environment for two reasons: increased pollution (huge amounts of insecticide will be needed to suppress the tsetse populations in vast areas) and loss of biodiversity.

In terms of conservation of biological diversity tsetse flies have the same intrinsic value as other species. Tsetse flies are unique elements of the biological diversity because they have an unusual combination of life history traits (strictly haematophagous, viviparous, low reproduction rate). Countries which have signed the International Convention on Biological Diversity should not accept the eradication of tsetse flies in protected areas (game reserves, national parks). Since South Africa has signed this convention the biodiversity Division of KwaZulu-Natal Wildlife refused to support the control or eradication of tsetse flies inside protected areas in KwaZulu-Natal (Armstrong, 2003). Although several tsetse-infested African countries have ratified this convention (http://www.cbd.int/convention/parties/list/), this has not hindered the African Heads of State to sign the PATTEC declaration.

Institutional weaknesses and logistic constraints

Livestock and veterinary departments including tsetse control services in many African countries are often marginalized and have limited resources. Since tsetse infested areas are often remote and quite inaccessible this implies that a well maintained car park is necessary to reach these localities, which is often not the case. Furthermore, area-wide approaches as proposed by PATTEC are large-scale operations, which pose logistic constraints that surpass their capacity. Moreover, the biggest problem may be the lack of reliable tsetse distribution maps. The currently available tsetse prediction maps at the continental level are to a large extent based on the data collected in the 1970s by Ford and Katondo (1977). There is an urgent need to collect more recent and accurate data (Cecchi et al., 2011).

Historical reasons

Although there are a few examples of successful tsetse elimination projects (i.a. Unguju island, Vreysen et al., 2000; Okavango delta, Kgori et al., 2006), most large-scale eradication projects have failed. Despite the injection of enormous amounts of money by the Cameroonian Government and several international organizations between 1976 and 1994 to clear tsetse flies from the Adamaoua plateau in Cameroon, the project was not successful (Mamoudou et al., 2009). Similarly, the Regional Tsetse and Trypanosomiasis Control Project (RTTCP, 1986-2000) mainly funded by the European Union whose original objective was to eradicate tsetse flies from Zambia, Zimbabwe, Malawi and Mozambique was quite rapidly forced to adapt its goal to control instead of eradication. Reinvasion of cleared areas was a recurrent problem in all large-scale eradication projects. In 3 of the 4 projects in which SIT has been tried out in Africa (Tanzania, Nigeria and Burkina Faso) tsetse populations are on their way back to former levels (DFID, 2003). It is believed that barriers using traps and targets to protect cleared areas against tsetse re-invasion are not very effective (mainly because of lack of adequate maintenance). Many government-run vector suppression schemes were successful in the short term, but failed because budgets for insecticide were cut, or because traps and targets disappeared or disintegrated through poor maintenance (Rogers & Randolph, 2002).

Other priorities in rural development

It is estimated that the eradication of *Glossina* spp. from the African continent will cost US$ 20 billion (DFID, 2003). With limited resources available for poverty reduction and rural development it can be questioned whether this money could be better spent on meeting basic needs such as the provision of drinking water, primary health care, primary education and improved animal health and production. The provision of clean drinking water in the villages will help reducing the incidence of sleeping sickness because women do not have to go any longer to the riverside, which are often tsetse-infested. In the field of animal health there are other important livestock diseases besides trypanosomiasis such as contagious bovine pleuropneumonia, goat plague (PPR) and many others.

Conclusion

Instead of aiming at the eradication of T&T it makes much more sense to focus on enhanced and extended control at farm level for the following reasons:

- Due to the gradual encroachment of people and cattle there is a shift from the dominant sylvatic cycle to the domestic cycle of animal trypanosomiasis. In the latter cycle trypanosomes are less virulent. Consequently cattle are able to live with the tsetse flies and the livestock owners can live with the disease without too heavy reliance on drugs (Van den Bossche et al., 2010).
- Control of T&T at farm level is a bottom-up, demand-led approach in which the farmer and not the government do the work and bear the costs (DFID, 2003).
- Simulation models show that the human population growth will cause a decline of savannah and forest tsetse flies and that by 2040 some species in these groups may even approach extinction in eastern and Southern Africa (Reid et al., 2000).
- Failure of eradication is much more serious than failure of control because failure to eradicate has no fallback position. Whereas 50% of success in a control scheme might still be cost-beneficial, 50% success of an eradication scheme is meaningless (Rogers & Randolph, 2002).

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