

Review

Sleeping sickness in West Africa (1906–2006): changes in spatial repartition and lessons from the past

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Summary

OBJECTIVE To review the geography and history of sleeping sickness (Human African trypanosomiasis; HAT) over the past 100 years in West Africa, to identify priority areas for sleeping sickness surveillance and areas where HAT no longer seems active.

METHOD History and geography of HAT were summarized based on a review of old reports and recent publications and on recent results obtained from medical surveys conducted in West Africa up to 2006.

RESULTS/CONCLUSIONS Active HAT foci seem to have moved from the North to the South. Endemic HAT presently appears to be limited to areas where annual rainfall exceeds 1200 mm, although the reasons for this remain unknown. There has also been a shift towards the south of the isohyets and of the northern distribution limit of tsetse. Currently, the most severely affected countries are Guinea and Ivory Coast, whereas the northern countries seem less affected. However, many parts of West Africa still lack information on HAT and remain to be investigated. Of particular interest are the consequences of the recent political crisis in Ivory Coast and the resulting massive population movements, given the possible consequences on HAT in neighbouring countries.

keywords sleeping sickness, West Africa, northern limit, migration, population movements, rainfall

Introduction

Human African trypanosomiasis (HAT) appeared in cyclical epidemics on the African continent in the 20th century. After an epidemic from 1900 to 1950, HAT was considered under control in the 1960s as a result of a vast campaign based on active screening and treatment of the patients by mobile medical units (Jamot 1935; Richet 1962). In the 1970s, the number of cases gradually increased again and over the last 20 years the situation has again become as alarming as it was 100 years ago.

In 2000, the estimated number of infected individuals was approximately 500 000 (Cattand *et al.* 2001). Over the last 5 years, screening – by mobile units – and treatment have greatly increased in Central Africa, the region most affected by HAT. The results seem promising since in 2004 only 17 600 cases were reported (WHO

2006). Disease elimination may be considered to be underway (Jannin 2005), although this process may take a long time since only 10% of the 60 million people at risk are under surveillance. For instance, in West Africa, no reliable information is available on how widespread HAT is in the historical foci of Guinea, Ivory Coast, Burkina Faso, or Liberia, Sierra Leone and Ghana.

Human African trypanosomiasis typically develops in geographically limited foci, which implies that interactions between vector (tsetse fly), parasite (trypanosome) and host (human as well as animal) are complex and influenced by the biophysical and human environment. Efforts to control this disease – beyond the knowledge on the parasite/vector/host complex – need to take into account more global data considering economic, social and climatic factors.

The history of HAT has already been discussed in a variety of publications, on different scales, for Africa

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(Louis *et al.* 2002), Central Africa (Penchenier *et al.* 1996) and East Africa (Hide 1999). However to our knowledge, these reports do not cover how HAT has evolved geographically in West Africa in the last 100 years, although a great number of epidemiologic data are available thanks to reports of surveys performed by medical teams. This study – in no way exhaustive – of available HAT data, combined with the field experience of the authors of the present article, attempts to trace back how this pathology evolved over time and space in the sub-region and to correlate it with the factors which may play a significant role in how sleeping sickness foci evolved geographically, such as human migrations and climate (annual rainfall). Their impact on the environment and on the distribution of the tsetse seems to play a significant role on the observed spatial changes of sleeping sickness distribution since last century.

Material and methods

This study collected spatialized data on HAT foci, organization of colonial health services, and human (mainly migration) and environmental factors in West Africa, as well as northern tsetse distribution limit, from the beginning of the 20th century to the present time. A number of libraries were consulted: Institut de Médecine tropicale du Service de Santé des Armées (IMTSSA) Marseille, France; Centre d'Archives d'Outre-Mer (CAOM), Aix en Provence, France; Institut de Recherche pour le Développement (IRD), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Paul

Valéry University, Montpellier, France; Organisation Ouest Africaine de la Santé (OOAS), IRD, Centre International de Recherche Développement sur l'Élevage en zone Sub-humide (CIRDES), Bobo-Dioulasso, Burkina Faso; IRD, Ouagadougou, Burkina Faso; IRD, Abidjan, Ivory Coast.

Contemporary data were collected from bibliographies (articles and mission reports) and field surveys that the authors of this article have contributed to in Ivory Coast, Guinea, Mali, Benin and Burkina Faso. These medical surveys were all conducted by national programme teams with the technical support of Institut Pierre Richet (Ivory Coast) and the Institut de Recherche pour le Développement (IRD), with most of the support from World Health Organisation (WHO) and French and Belgian cooperation agencies.

Results**Population movements and HAT at the beginning of the 20th century (1900–1930)**

At the beginning of last century, according to old reports sleeping sickness was highly prevalent in large areas of Guinea and former Upper Volta (now Burkina Faso), going up in latitudes to the Gambia and Casamance, but also to Senegal and Niger rivers up to Saint Louis in Senegal, and Timbuctu in Mali, even though most of the cases of these 'foci' were probably imported from elsewhere due to population movements. The disease was also present in Ivory Coast, Ghana and Benin (Figure 1).

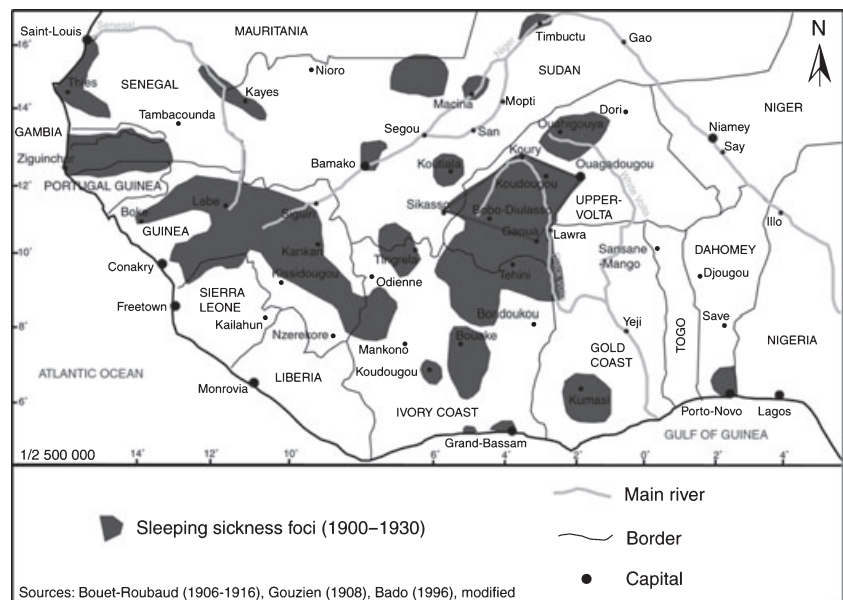


Figure 1 The distribution of West African sleeping sickness foci in the early 20th century.

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Between 1906 and 1908, Paul Gouzien, then head of Upper Senegal and Niger (i.e. currently Mali, Burkina Faso and Niger) Health Service, wrote a report on the disease situation, in which he pointed out that ‘the endemic disease seems to be essentially confined within the limits of a quadrilateral formed by Koury, Ouagadougou, Gaoua (Burkina-Faso) and Sikasso (Mali)’ (Figure 1). Gouzien (1908) thought that ‘the endemic–epidemic first seems to have gone up the Volta river right from its estuary in the gulf of Guinea, spreading afterwards inland through the network of its numerous tributaries’. The commercial relations that the Ashanti kingdom in the Gold Coast (present-day Ghana) had with the Sahelian zone, as well as the advance of the English-occupied hinterland towards the north (M’bokolo 2004) suggested that the disease actually spread from the coast up into the interior of these countries, essentially from Kumasi focus. Samory Touré, who started his riding feats from Kankan (Binger 1982) where HAT was already present (Figure 1) also seem to have played a role in the spread of HAT towards northern Ivory Coast and southern Burkina Faso. For example, in Gaoua, South of Burkina Faso, ‘the inhabitants of Danhalle, Laussera and Diodiona are very positive about that and declare the disease was not known before the Lobi invasion by Samory’ (Gouzien 1908). The descriptions of certain places in this report reveal the impact of the disease on settlement: ‘As for Kaho, a formerly beautiful village of 800–1000 inhabitants, located 400 m from the river, it is now completely wiped out: a palm tree in the middle of tumbling walls, and that is all. The last sick individual died in October 1906 and at the same time the only survivor took refuge at Kosso’.

After the First World War (1914–1918), France experienced a substantial decrease in population and viewed its colonies as a source of raw materials and labour, even though these populations were threatened with increasing morbidity and mortality. The French authorities then decided to control diseases in French West Africa by developing *l’Assistance Médicale Indigène* (Bado 1996). However, behind the will to improve Africans’ health, there was the economic interest of French private and public companies. In reality, there were forced migrations of northern populations towards the various public works in French West Africa – the Thies-Kayes railways and the Ivory Coast railways between Bouake and Bobo-Dioulasso, for example, which may explain why HAT was also found in these regions (Figure 1) – and into the forestry and agricultural companies in Ivory Coast. When Albert Londres came to West Africa, he wrote: ‘So we come to Upper Volta in the Mossi region that is known in Africa under the name of ‘men’s reservoir’: three million negroes. Everybody comes here to get men like water from a well.

During the building of the Thies-Kayes and Kayes-Niger railroad, the Mossi region was tapped. The foresters came up from the lagoon and tapped the Mossi’ (Londres 1929).

The French colonial policy thus also seems to have contributed to the spread of parasites from North to South, from the Upper Volta (which has now become Burkina Faso) to Ivory Coast and Ghana. First, this resulted from resettlement projects moving large numbers of labourers from Burkina Faso to Ivory Coast (for instance, Ivory Coast colonization villages were given the names of the original Mossi village of Burkina Faso e.g. Koudougou, Figure 1). In these villages, a medical examination every 2 week was compulsory and the trypanosome carriers were sent back to their Burkinabe villages, according to the rules applied at that time (Mandé 1997). Secondly, the policy prompted numerous Voltans to seek refuge in Gold Coast (present-day Ghana), where the English applied a more liberal policy. Thus in Ghana, among the patients screened from 1927 to 1931, nearly 200 had HAT at the Yeji post, in the northern territories, showing the close relation between the Voltan and Ghanaian foci (Vaucel 1962).

From these early observations and field results at the beginning of the 20th century from Pasteur scientists, people were convinced of the importance of the endemic trypanosomiasis, and above all of the epidemic form it took at that time in many regions (Dozon 1985), due in part to the numerous (forced) movements of people, especially between Burkina Faso, Ghana and Ivory Coast.

Colonial doctors, the first disease control programmes and HAT (1930–1950)

Following these observations, General Governor Brévié decided to create the Service de prophylaxie de la maladie du sommeil (the Sleeping Sickness Treatment Service) in 1931. Eugène Jamot travelled across the Upper Volta (Burkina Faso) and many regions of Ivory Coast, Sudan (now Mali), Guinea, Niger, Dahomey (now Benin) and Senegal (Jamot 1935) and, as well as Dr Gaston Muraz a few years later, confirmed that sleeping sickness was at that time the major public health problem of the colonies.

Figure 2 shows that the northern sleeping sickness areas described above already begin to shift to the South, except in Senegal. The Koudougou, Gaoua, Ouagadougou and Dedougou circles of Burkina Faso were still the most severely affected, together with Tougan sub-division of Dedougou, bordering the Black Volta (Mouhoun) river, where 20 years before the Koury post had been decimated by HAT. ‘In the region of Gaoua morbidity and mortality rates caused by trypanosomiasis are impressive. We are not just talking about a few cases treated in Diebougou free

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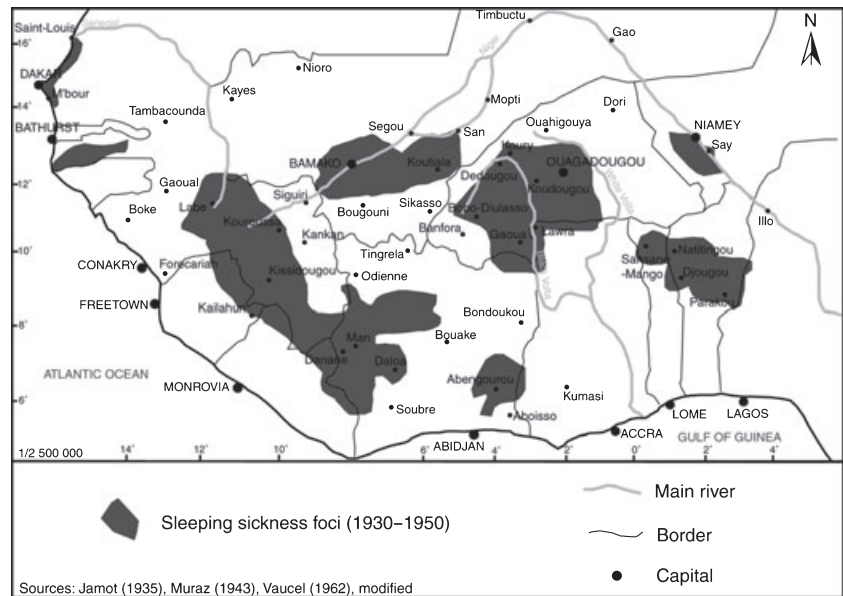


Figure 2 The distribution of West African sleeping sickness foci from 1930 to 1950.

Table 1 Number of HAT patients in West Africa

Country	1932–1934	1939	1940–1953	1961	1990–2004
Reference	Jamot 1935; Scott 1960	Muraz 1943; Scott 1960; Vaucel 1962	Masséguin & Taillefer-Grimaldi 1954; Vaucel 1962	Richet 1962; Vaucel 1962; Thomson 1968	WHO 2006
Senegal	54	2734	25 328	104	0
Sudan (Mali)	2580	8296	17 672	1151	78
Niger	369	1053	452	0	0
Haute Côte d’Ivoire Haute-Volta (Burkina Faso)	36 933	89 827	42 175	627	188
Dahomey (Benin)	6351	10 888	8588	86	189
Togo	*	*	*	71	5
Basse Côte d’Ivoire (Côte d’Ivoire)	1491	19 697	53 264	2680	3080
Guinea	4002	19 334	85 659	865	865
Sierra Leone	*	9,127	*	*	0
Liberia	*	*	12 768	*	0
Ghana	2945	4578	*	455	27
Nigeria	*	84 364	*	189	146
Total	49 336	249 898	245 906	6228	4578

*No information available to our knowledge.

clinic but about whole villages in the bush abandoned by their inhabitants in order to flee the disease’ (Jamot 1933).

In Senegal, the disease was still active next to Dakar and around M’Bour (Jamot 1933; Figure 2). In Sudan (Mali), the disease raged between Bamako and Koutiala. In Niger, most of the sedentary villages South to Say were infected. In Dahomey (now Benin), Djougou and Natitingou constituted important border foci in relation with Sansane-Mango in Togo. In Guinea, the disease was present in Labe

and Kissidougou. In Ivory Coast, the disease did not seem very active at that time, possibly because most medical screening was carried out in the northern countries, the main labour force reservoirs. However, the discovery of a large focus in Daloa showed that the disease was indeed present.

In the report of Jamot published in 1935 (Table 1), he concluded ‘So, the number of sleeping sickness patients found in the French West Africa over a 2.5-year period,

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with very limited means, was 45 238 on 1st October and it is of utmost interest to mention that this figure corresponds to the total number of patients who were shown in 1932 in the statistics for French Equatorial Africa (i.e. Central Africa), which is considered the sleeping sickness epicentre and where control measures have been carried out since 1917'.

In English-speaking colonies, the situation was also worrisome. In the border region of northern Liberia an epidemic occurred in 1938 among members of the Kissi tribe. For the members of this tribe living in French Guinea treatment had been available since 1930. From March 1941 to 1943 the first systematic survey was carried out by Veach (Firestone plantations) in the Kissi and Gbandi chiefdoms close to the Guinean border: 12 768 out of 81 915 people examined were sick (15% of the population) – 8000 of them belonged to the Kissi tribe (Vaucl 1962; see Table 1). In Ghana, in 1932 the increasing number of sleeping sickness cases became worrisome. The infection manifested itself above all in the eastern area of the Northern Territories and Mamprussi southern district where, from 1933 to 1936, 250, then 1012, 1683 and 2323 patients were detected; in addition, in the North-West area of the same territories, the Tumu/Lawra region had 2255 cases detected from 1934 to 1936 (Scott 1960).

In spite of Jamot's results, and the echoes of the disease in the neighbouring English-speaking colonies, medical inspector Louis Couvy abolished prophylaxis and trypanosomiasis services in 1935. It was not until 1939 that Gaston Muraz was charged with organizing the Service Général Autonome de la Maladie du Sommeil (SGAMS, Sleeping Sickness General Autonomous Service) in French West Africa. He divided French West Africa into sectors according to disease prevalence (highly affected, moderately affected or unaffected regions). This strategy enabled him to evaluate the situation for the first time, and in 1939, the number of sleeping sickness cases was 151 829 for French West Africa, and 249 898 in all of West Africa (Table 1).

Although three of the most affected sectors (Danane, Man and Daloa) were situated in Ivory Coast (Figure 2), sectors in Burkina Faso (also called Haute Côte d'Ivoire between 1932 and 1947, in contrast with Basse Côte d'Ivoire for Ivory Coast) were given greater importance in contemporary documents (Table 1). This contradiction stems from the fact that the disease had been known for a long time in Upper Volta, endemic areas were very extensive, and it was also a labour force reservoir area and therefore it appeared more urgent to control the disease there. In Ivory Coast, land clearing for wood industry and farming, essentially coffee and cocoa plantations, was made possible thanks to a considerable labour force from Upper Volta, which was

contaminated because the disease was not controlled there (Kaboré 1957). For example, in 1938, the number of labourers under permanent contracts on the plantations was estimated at about 25 000 (Domergue-Cloarec 1986). Contract labourers were required to undergo a medical examination but many evaded it.

In 1944, SGAMS was replaced by the Service Général d'Hygiène Mobile et de Prophylaxie (SGHMP, General Service of Mobil Hygiene and Prophylaxis), a new structure that had to treat endemic pathology (trypanosomiasis, onchocerciasis, malaria, leprosy). Bobo-Dioulasso was still the center of the service, and Le Rouzic became the first director.

HAT just before and after independence (1950–1970)

The total number of sleeping sickness patients detected in French West Africa had reached 373 012 on 1st January 1954. Indeed, after some rather dispersed attempts, control had become better organized and more efficient after 1939. Just before independence HAT in the northern part of French West Africa seemed under control, except of a few active foci in the Gambia, Mali (San), the Lobi territory of Burkina Faso (Gaoua, Kampti, Tehini) and northern Benin (Figure 3). It still lingered in the forest zone, essentially in Guinea (Boke, Labe, Kissidougou) and Ivory Coast (Man/Danané and around Daloa in the Center West, and Abengourou in the South East), where it receded quite slowly (Masséguin & Taillefer-Grimaldi 1954).

Immediately after independence, HAT seemed under control in West Africa, it was then called residual trypanosomiasis (Richet 1962). At that time, Pierre Richet was in charge of controlling HAT, leprosy and onchocerciasis within the OCCGE (Organisation de Coordination et de Coopération pour la lutte contre les Grandes Endémies/ Organisation of Coordination and Cooperation for the control against Great Endemics).

In Upper Volta, 627 new cases were detected in 1961 but at least half of these cases had been contracted outside Upper Volta and involved seasonal agricultural labourers, most of them coming from Ivory Coast. However, a few Voltan foci remained, including Dedougou and Sindou with 80 new patients in 1961 in the village of Kankalaba. Since Guinea was not included in the OCCGE, data from this country were scarce and unreliable but the situation looked alarming notably because of a high rate of migration between the neighbouring zones of Guinea, Liberia and Sierra Leone (Hutchinson *et al.* 1964).

In Sierra Leone and Liberia, HAT was no longer considered a public health problem, and the Endemic Diseases Control Unit activity was more oriented towards malaria, onchocerciasis, leprosy, yaws and tuberculosis. In

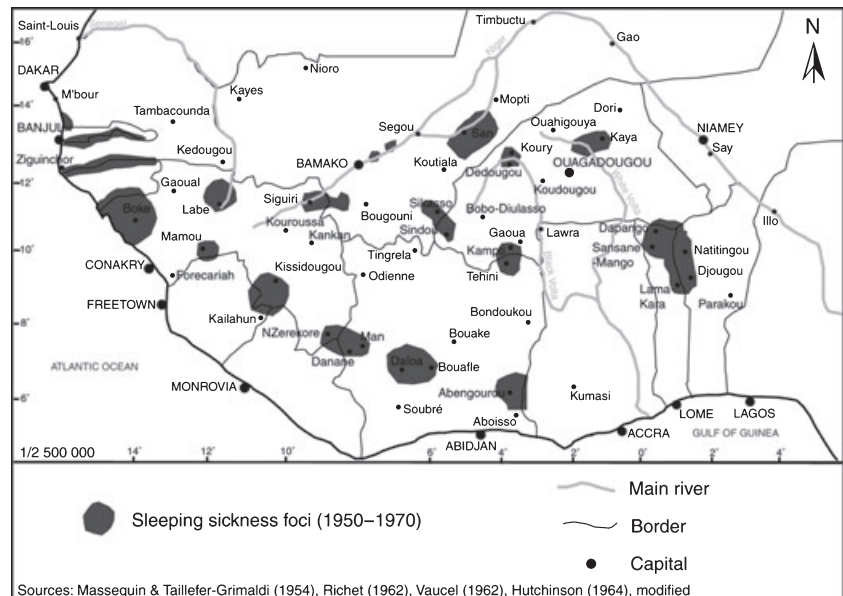


Figure 3 The distribution of West African sleeping sickness foci from 1950 to 1970.

Nigeria, the West African Institute for Trypanosomiasis Research controlled the disease in Benoue province, but the Eastern region still seemed to harbour the disease (80 new HAT patients in 1961) (Thomson 1968).

In the mid-1960s, the situation seemed under control to such an extent that Pierre Richet, in his introductory speech for the first international course on trypanology, said in his conclusion: “You must keep in mind, gentlemen, that HAT is an exceptional disease, that if it is neglected, or forgotten, it can turn into the horrid fire that nearly burnt down your Africa and its tribes during this century, that danger of revivescence will persist as long as there are *Trypanosoma gambiense* and tsetse flies. Those who have not lived recent and yet bygone past have no idea of the danger because it has become very difficult today to show them a classical HAT patient, a beautiful demonstrative ‘sleeping’ case” (Richet 1964).

HAT being neglected and a rapidly changing environment (1970–2006)

The impression that sleeping sickness had been overcome definitively, the disorganization of surveillance structures – stationary or mobile – but probably also changes in and new interactions between epidemiological parameters have enabled HAT to progressively re-emerge in West Africa since the 1970s, to reach back the impressive number of 500 000 cases estimated by WHO in 2001 for the whole Africa (Cattand *et al.* 2001).

In English-speaking West African countries, little information is currently available. According to WHO, in

Ghana 27 cases have been diagnosed since 1990 (Table 1). In Nigeria 196 new cases were diagnosed in 1975 and 126 in 1976, and since the 1980s, some cases have been reported from the Delta State (Edeghere *et al.* 1989). No information on Liberia and Sierra Leone is available to our knowledge. In the French-speaking new independent states of West Africa, the fear for the reactivation of the Ouelesse-bougou focus in Mali in 1973 (Duvallat & Saliou 1976) and the Bouafle focus (Ivory Coast) in 1975 (Carrié *et al.* 1980). In Ivory Coast, the Centre-West region provided the largest number of patients, first with the discovery of the Vavoua focus in 1976 (Duvallat *et al.* 1978). Then came the Daloa and Zoukougbeu foci, the Sinfra focus with more than 4000 HAT patients between 1980 and 2000 (Laveissière *et al.* 2003) and finally today the Bonon focus (Djé *et al.* 2002; Solano *et al.* 2003), to which the Aboisso region near the Ghanaian border must be added (Figure 4).

Since 2000 in West Africa, both Guinea and Ivory Coast are the most seriously affected countries (Figure 4). In Guinea, the coastal region had the best monitoring: there prevalences reach 1–3% in the mangrove foci of Dubreka, Boffa (Camara *et al.* 2005) and probably Forecariah, with sick individuals coming also from Sierra Leone (M. Camara, personal communication).

Looking at the current geographical distribution of HAT foci (Figure 4), the 1200 mm annual rainfall isohyet seems to constitute a northern limit of endemic HAT, with no cases having been found North of this isohyet since several years by active medical surveys, except some cases in Burkina Faso, Mali or Benin, most of which were imported

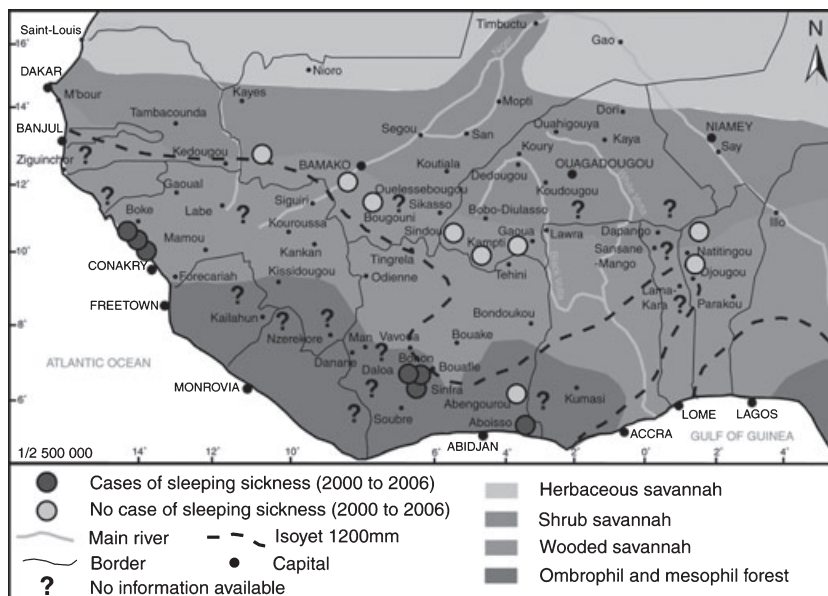
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Figure 4 The current situation of sleeping sickness in West Africa according to medical surveys carried out between 2000 and 2006.

from Côte d'Ivoire (R. Kambire, personal communication for Burkina Faso) or were isolated cases in a non-endemic region. In Mali and Togo, the few recent medical surveys turned up no sick individuals in historical foci. The disease needs to be monitored regularly due to the small number of active medical surveys undertaken.

Looking more closely at climatic variations, it appears that rainfall series between 1951–1969 and 1970–1989 show a shift towards the South of the 500 and 1400 mm isohyets (Mahé & Olivry 1991; see Figure 5). The same shift towards the South is observed with the northern tsetse distribution limit, comparing catches of *Glossina palpalis* and *G. tachinoides* between the beginning of last century and present periods (Figure 5).

Discussion

In this paper, the historical information gathered on the geographical repartition of sleeping sickness foci in West Africa since last century, together with some information on climatic variation and evolution of tsetse distribution limits allows us to see some significant spatial changes that have occurred. The analysis of the historical records of sleeping sickness demonstrates that several human and physical elements play a major role in how the sleeping sickness foci evolve (spread or extinction, endemic or epidemic situation).

One element is the migration of farmers to new areas and their changing of the environment. A perfect example is the correlation over time and space in Ivory Coast between pioneering fronts of coffee/cocoa plantation (Chauveau

1985; Balac 2001) and HAT foci outbreak: HAT foci usually appear a few years after the successive waves of Voltan migrations required to clear the forest and set up and exploit these plantations (Rémy 1982; Laveissière & Hervouët 1988). However, these environmental changes beyond a certain extent of anthropization work against the maintenance of HAT foci, because the biotope favourable to *G. palpalis* HAT vector disappears (Laveissière & Meda 1999; Reid *et al.* 2000). This might explain the disappearance of HAT in zones where human density and pressure on the environment has become too great.

Conflicts entailing population displacements constitute the second element; Samory Touré's historical example being the most illustrative of this situation. Indeed, in the literature, conflicts are reported to encourage the development of disease (Prothero 1994; Kalipeni & Oppong 1998), including HAT (Prothero 1963; Eouzan 1980; Ford 2007), mainly because of health service disorganization and population displacement. The events of September 2002 in Ivory Coast may be a recent example of the impact of population displacements on the geographical changes of HAT (Kaba *et al.* 2006). These events resulted in the forced repatriation of 360 000 nationals from Burkina Faso (CONASUR, UNICEF, PAM 2004): will this situation trigger the re-emergence of HAT in Burkina Faso where tsetse flies are omnipresent in the south of the country? It is difficult to predict, but the question should be raised and answered, as it will probably enable better prediction of priority zones for HAT surveillance.

Element number three is border zone proximity. Examining old and recent reports and papers, it clearly appears

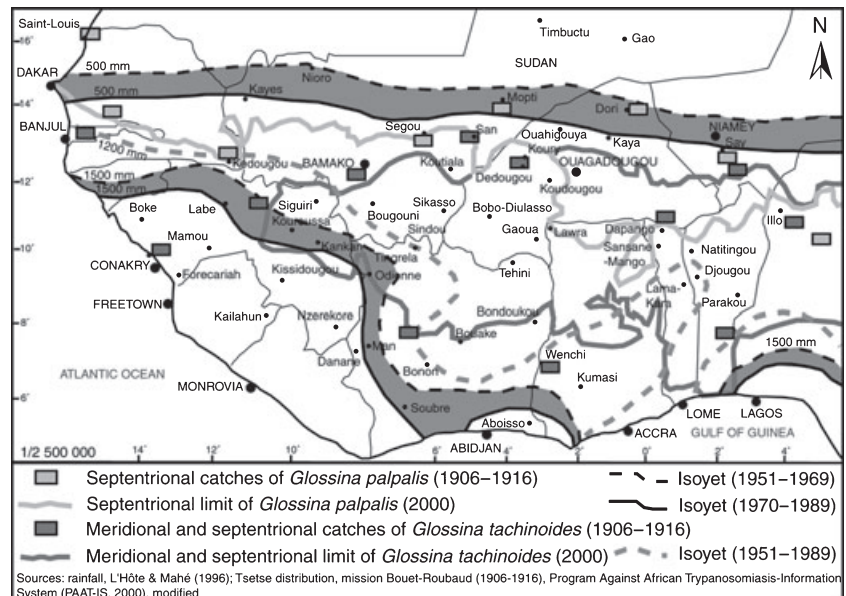


Figure 5 The North–South shift of the 500 and 1400 mm isohyets and of the tsetse northern distribution limit over time.

that border zones favour HAT development. One only needs to read through the list of cross-border HAT foci, be they historical or current ones: Danane-N'Zerekore (Ivory Coast/Guinea), Kampti-Tehini (Burkina Faso/Ivory Coast), Diebougou-Lawra (Burkina Faso/Ghana), Siguiiri-Kangaba (Guinea/Mali), Guekedou-Kailahun (Guinea/Sierra Leone), etc. What is the reason for this? First of all, border territories often constitute sites of high levels of human mobility due to intense commercial activity. Secondly, they are often located far from the capital and therefore far from the main health infrastructures and health services. Finally, during troubles people seek refuge on the other side of the border; consequently at border areas, infected and susceptible people mix easily. Moreover, these border areas often constitute a favourable habitat for tsetse, as borders frequently follow rivers (Leraba, Mouhoun, Cavally, Mano, Senegal, etc.) and often also remain the last refuge for wild fauna (Taï, Bouna, Pendjari, Niokolo-Koba national parks), thus for tsetse which feed readily on these hosts.

Since last century endemic sleeping sickness has shifted from North to South. Most of the northern foci which produced the largest numbers of HAT cases during the last century are no longer active, i.e. Senegal, the Niger basin in Mali, the Volta foci in Burkina Faso, Niger. Now Guinea and Ivory Coast are the most affected countries, and even on the national level, the affected areas are coastal (littoral Guinea), or within the forest or forest–savannah transition zones (Centre-West Ivorian foci). Since the medical surveys conducted between 2000 and 2006 never found a

confirmed HAT case in the historical foci situated above the 1200 mm isohyete, endemic foci in West Africa seem to be confined now to the zone below this isohyete. This observation does not mean that cases can not be found at these latitudes, but that endemicity seems now restricted to this limit, although we are not yet able to explain it.

Comparing the spatial changes that have occurred since last century elicits several questions: Why does the HAT decline seem to occur in Northern sub-Saharan Africa countries, such as Senegal, Mali, Burkina Faso and Niger, which provided tens of thousands of cases in the first half of the 20th century? Why do we have the impression that today HAT is limited to West African coastal and forested zones? Does the spatial distribution of the current foci, showing an absence of endemic HAT in regions with <1200 mm rain per year, fit in with the facts, or does it merely mirror the zone where medical teams monitor the disease effectively?

There is no doubt that human activities play a role in the appearance or disappearance of HAT foci (see above), but climatic changes – following the example of other pathologies (Amat-Roze 1998) – might play a part as well, although this may be difficult to separate from the role played by human populations. The steady decrease in rainfall between years 1950–1969 and 1970–1989 illustrated in Figure 5 has been said to be worsening these last few years (L'Hôte & Mahé 1996; Patrel *et al.* 1998). Indeed, the decrease in rainfall alters the biophysical – hygrometry, physiognomy – characteristics (Mahé & Olivry 1991) of forests and gallery forests, the main tsetse fly

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biotopes. The decrease in cereal yields (corn, sorghum, rice, etc.) consequent to this phenomenon, coupled with a rapid population growth, gives cause to more land cultivated and a simultaneous loss of tsetse habitat.

Linked to this shift towards the South of isohyets, the tsetse (*G. palpalis* and *G. tachinoides*) northern distribution limit has also shifted towards the South since the beginning of last century (PAAT-IS 2000; see also Figure 5). This has been clearly illustrated at local scales, e.g. in Togo for *G. palpalis* (Hendrickx *et al.* 1999). Therefore, the extinction of some historical foci, such as Saint-Louis in Senegal and Mopti in Mali, can be attributed to the local disappearance of the vector. However, many other factors than tsetse presence are required to explain the current geographical distribution of active foci. For instance, understanding why there is no more endemicity in Burkina Faso, although this country was the most seriously affected, and considering that tsetse are still present in the historical foci, may bring interesting elements for risk prediction and management.

Also, by looking back at Figures 1–4, one can see that there have been changes in the way of representing foci, from big, widespread spots at the beginning of last century, to small circles these last years. Does this signify a real decrease in sleeping sickness prevalence, or only a different way of considering a sleeping sickness focus?

However, the current pictures only reflect the few medical surveys that have been conducted, and much remains to be studied: what is the situation in South Burkina Faso taking into account the thousands of returnees who were living in endemic areas of Ivory Coast? Does the same apply to the Ivory Coast/Liberia/Sierra Leone/Guinea borders with the recent crises? What about Ghana? Sierra Leone? Liberia? the forest area of Guinea? etc. It already seems justified to prioritize surveillance in the most affected areas under the 1200 mm rainfall limit, but HAT surveillance must also continue in the humid savannah areas of Burkina Faso, Mali, and Benin, where information remains incomplete.

Conclusion

The analysis of the changes in HAT over space and time in West Africa enabled us to observe that nowadays, endemic HAT does not seem to occur any more in regions where annual rainfall is <1200 mm/year, which was not so at the beginning of 20th century. The decrease in rainfall, associated to increasing human densities, have an impact on land saturation, which has also changed tsetse distribution. These factors explain in part HAT geographical evolution (disappearance of northern historical foci which are nowadays situated North of tsetse presence).

Understanding how these factors interact with others, such as the link between HAT and population movements due to political crises, the decrease in numbers of wild animals, changes in vector competence or human–vector contact, will explain the geography of HAT foci and deserve further research. We remain convinced that to be sustainable, the elimination process recently launched by WHO has to be linked with substantial research focussed on the study of the conditions of emergence/re-emergence and extinction of the disease. An in-depth study of the spatial arrangement of these factors on the scale of West Africa will enable the prediction of intervention priority zones and will optimize control against HAT.

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