

Human African Trypanosomiasis (HAT): *Trypanosoma* spp.

	<i>T. rhodesiense</i>	<i>T. gambiense</i>
Form of disease	Acute	Chronic
Course of disease	Death in months	Death in years
Animal reservoirs	Very significant	Not significant
Vector habitat	Scrub and 2ndary scrub; Riverine species can transmit	Riverine habitats
Geography	SE savannah and southern Africa	Central, western and NW Africa
Note on Geography	Overlap in Uganda, on N. border of L. Victoria	
Mortality	Guaranteed	Guaranteed

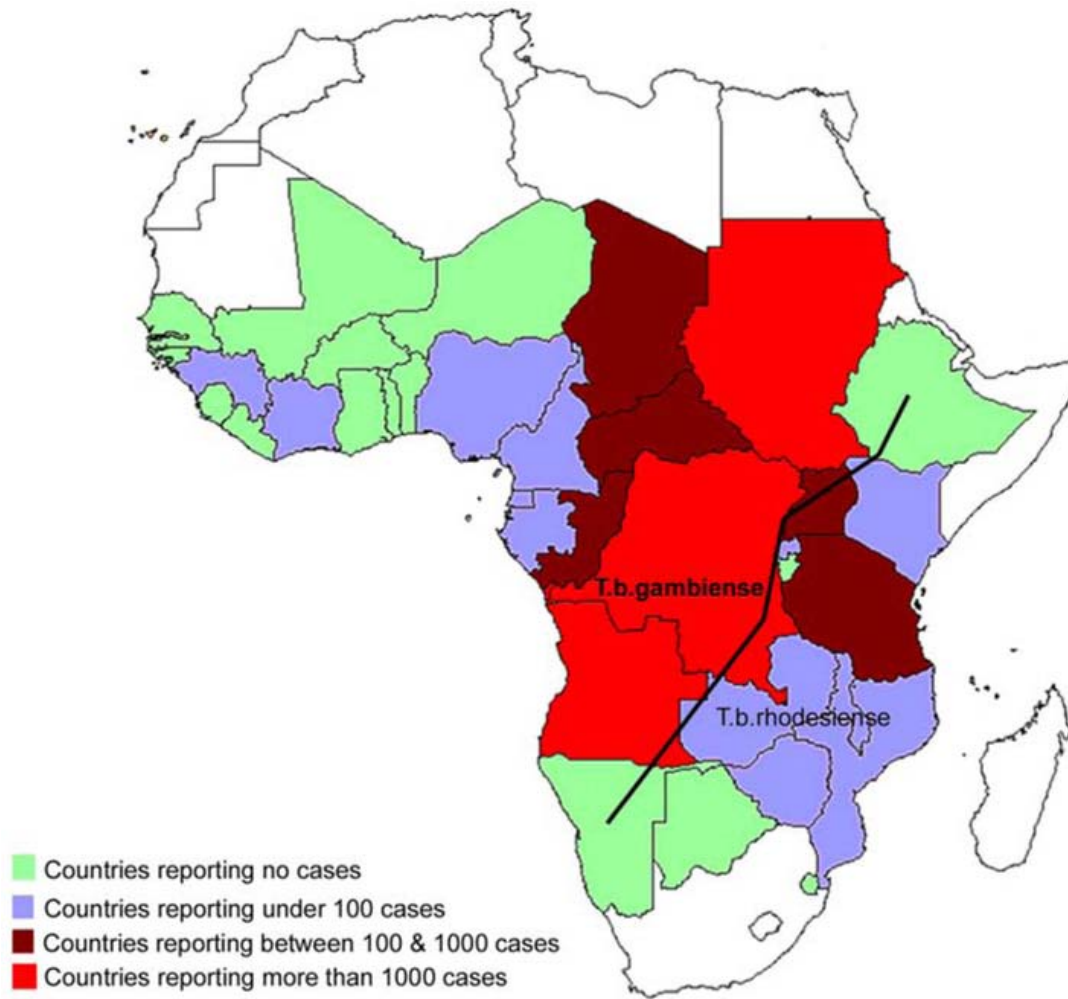


Figure 1. Map of Sleeping Sickness. Image credit: [23].
doi:10.1371/journal.pntd.0000333.g001

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Depopulating epidemics (for example):

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Congo River Basin (1901): 500,000 dead.

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Cause not well understood historically.

Terrifying disease: certain death with no predictability.

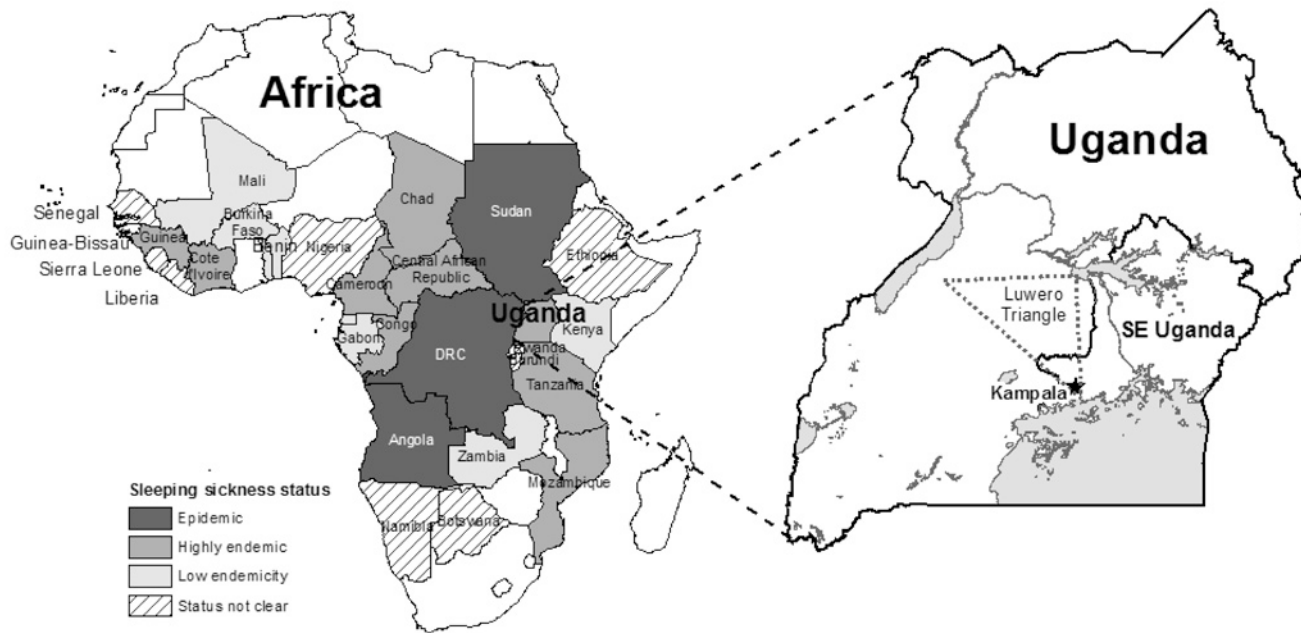
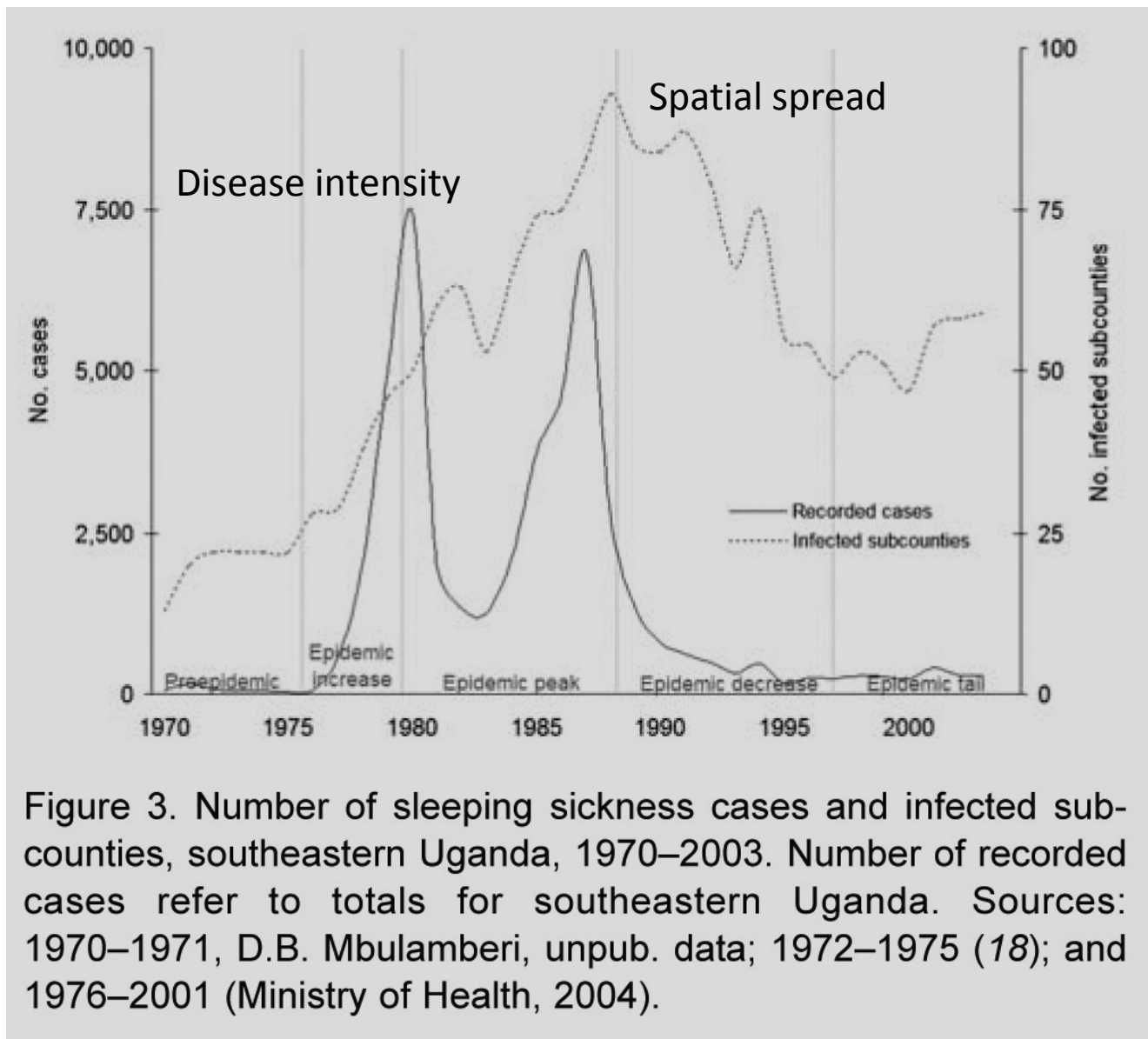


Figure 1
Distribution of sleeping sickness in Africa and map of Uganda showing the case study area. The approximate location of the 'Luwero Triangle' is shown; this is where much of the conflict and violence was concentrated during Uganda's civil war (1979–86). Sleeping sickness status data from WHO (2001).



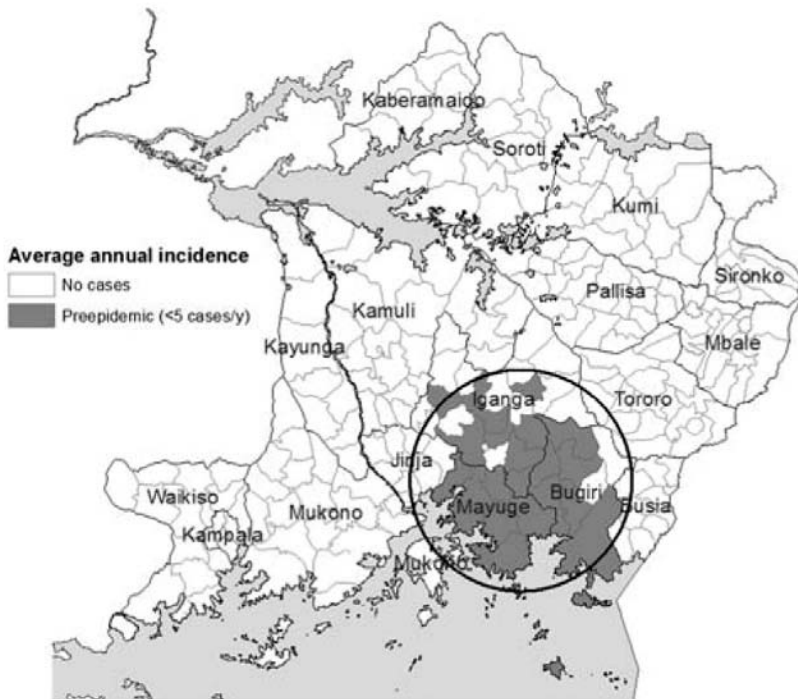


Figure 4. Sleeping sickness incidence, southeastern Uganda, 1970–1975, by subcounty. Circle indicates a significant space-time cluster at the 95% confidence level, as detected by the space-time scan test. See Table for scan test results.

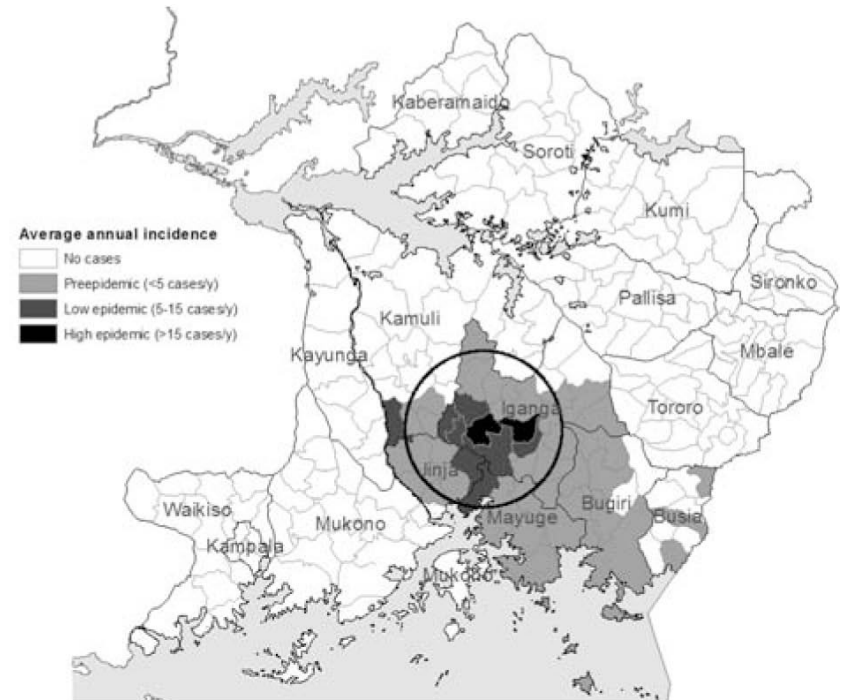


Figure 5. Sleeping sickness incidence, southeastern Uganda: 1976–1979, by subcounty. Circle indicates a significant space-time cluster at the 95% confidence level, as detected by the space-time scan test. See Table for scan test results.

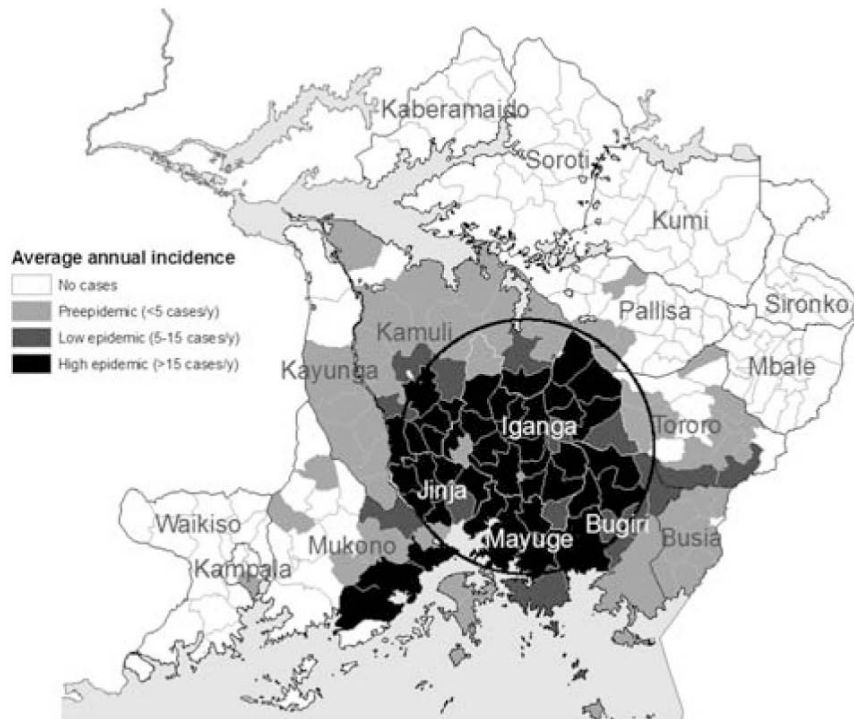


Figure 6. Sleeping sickness incidence, southeastern Uganda, 1980–1988, by subcounty. Circle indicates a significant space-time cluster at the 95% confidence level, as detected by the space-time scan test. See Table for scan test results.

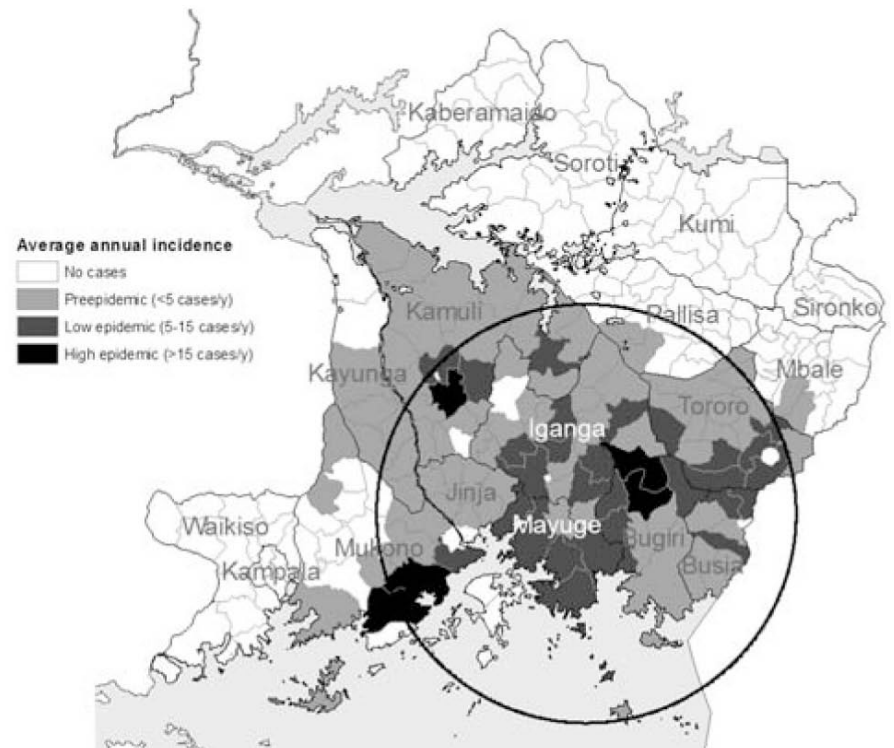


Figure 7. Sleeping sickness incidence in southeastern Uganda, 1989–1997, by subcounty. Circle indicates a significant space-time cluster at the 95% confidence level, as detected by the space-time scan test. See Table for scan test results.

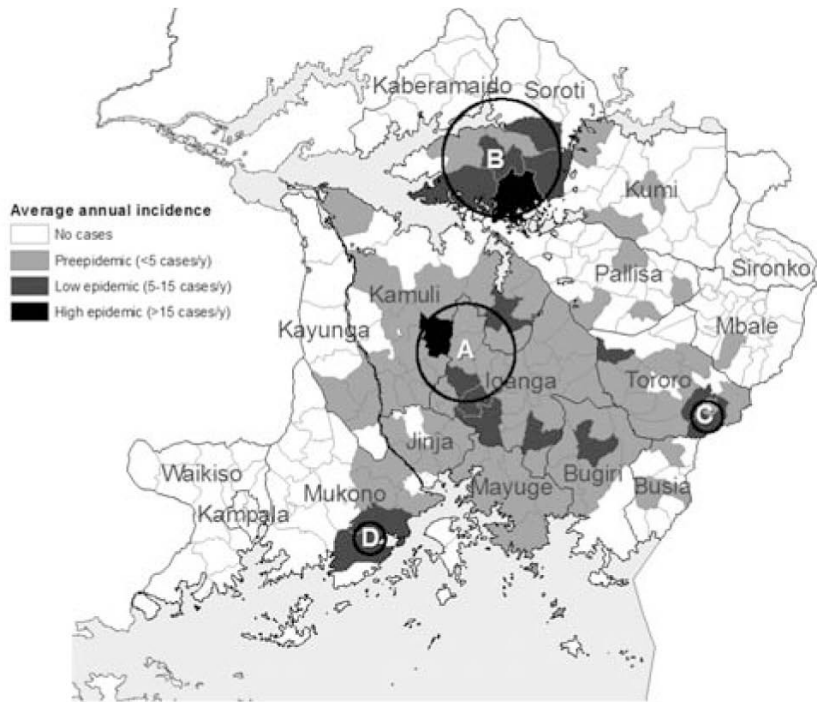


Figure 8. Sleeping sickness incidence in southeastern Uganda, 1998–2003, by subcounty. Circles indicate significant primary (A) and secondary (B, C, and D) space-time clusters at the 95% confidence level, as detected by the space-time scan test. Letters correspond to cluster results in Table. See Table for scan test results.



Figure 9. Velocity vectors (arrows) for the spread of sleeping sickness between subcounties in Uganda. Arrow length is proportional to velocity of spread.

Early colonial history

Rhodesian form primarily a zoonosis.

Humans not preferred diet of tsetse flies.

Hooved animals primary source (Nagana).

Non-native hooved animals highly susceptible.

Horses and cattle, particularly.

Livingstone took oxen.

French/Dutch colonized west Africa; British in east.

Coincides with Gambian/Rhodesian split (see map).

Importance of disease well known.

French:

Focused on human disease, which reduced labor force.

Dutch:

Real @\$%^&^%\$#.

Rubber trees and forced labor in forests.

British:

Suspected zoonosis.

Encouraged massive cattle operations.

Focus on Nagana.

Early differences in colonial powers' response:

1. Reflected economic priorities.
2. Were correlated with biological realities.
3. The Dutch were !@\$%^#\$\$%.

Later colonial history.

Drugs developed in 1920s.

French used them on humans.

Eugene Jamot treated hundreds of thousands in Cameroon.

Introduced mobile treatment teams.

Nominated for Nobel in 1931 by French government.

Eventually, Dutch adopted French approach.

Brits were wary.

Kenyan 'volunteers' proved zoonosis.

Treatment of humans does not reduce incidence.

Focus on keeping cattle alive.

Cause of epidemics.

Gambian form (western form).

Alteration of human-fly interactions.

Flies primarily riverine.

Human habitation along rivers.

Rhodesian form (eastern form).

Lower natural prevalence in humans.

Higher potential for epidemics.

1900-1920 epidemic:

Colonial Disease?

Rinderpest?

Human movements?

1976-2003 epidemic:

Process A: small scale changes in human-tsetse interactions.

Process B: spread via movement of livestock.

Political upheavals in Uganda (1970-1980s).

EPIDEMIC CHART

MODEL AND PARAMETERS

MODEL PREDICTIONS

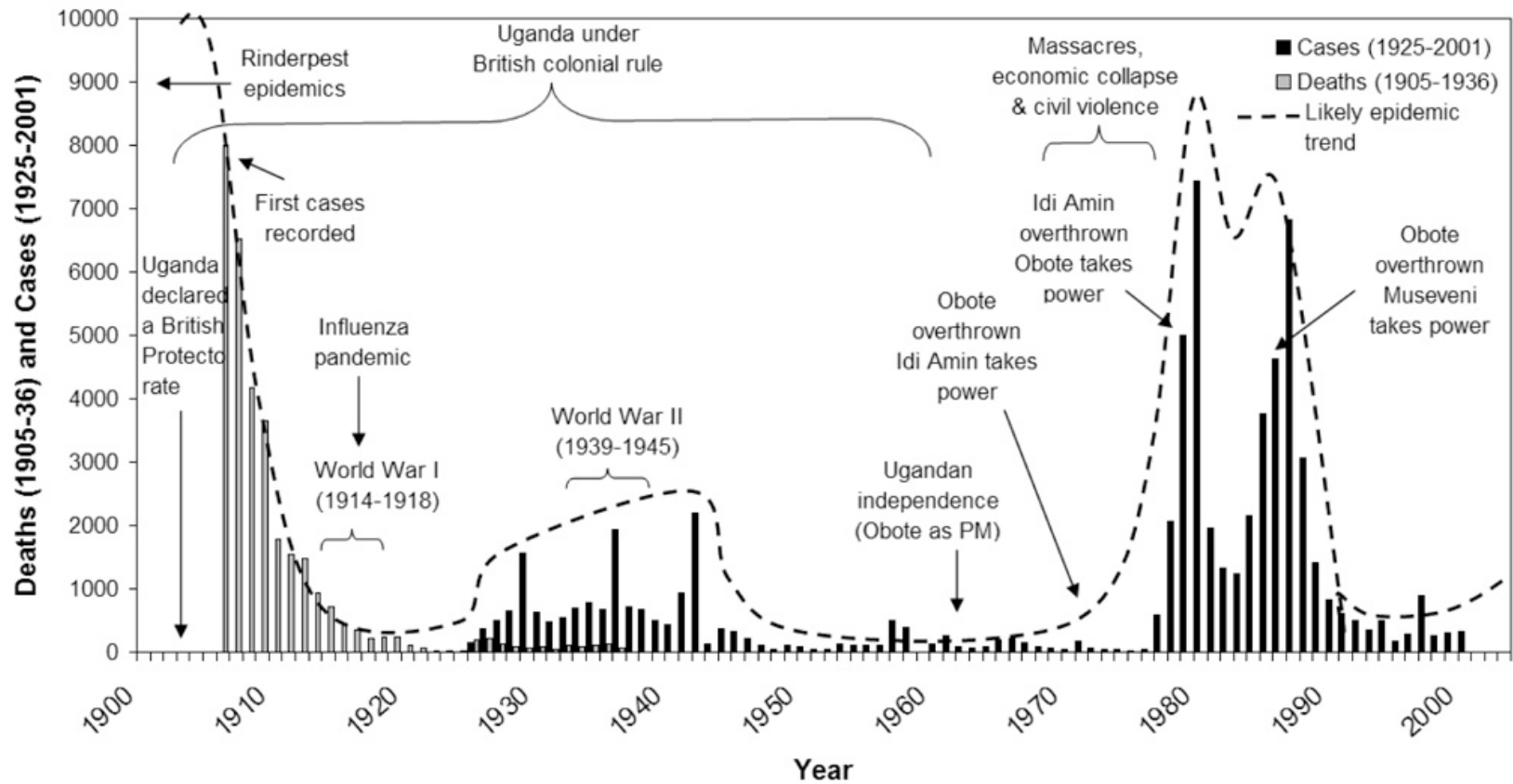


Figure 2
Sleeping sickness epidemics and major political events in Uganda, 1905–2000. Cases from 1936 onwards include south-eastern Uganda only. Sources: Sleeping sickness data 1905–36 deaths [62], 1925–36 cases [62], 1937–58 cases [63], 1960–71 cases (Unpublished report, 1992, Mbulamberi, D. B. The sleeping sickness situation in Uganda: past and present. National Sleeping Sickness Control Program, Jinja, Uganda), 1972–75 cases [54], and 1976–2001 cases (Ministry of Health, Uganda); Political time-series [56, 64, 65].

rhodesiense. The reproductive rate (R_0) can be estimated using the following general equation [44-46]:

$$R_0 = \alpha^2 m b c e^{-uT} / ur \quad (\text{Eq. 1})$$

Where:

R_0 Basic reproductive ratio

α Daily biting rate of flies on humans (or animal reservoirs)

m Ratio of tsetse flies to humans (or animals)

b Probability of a fly becoming infected from an infected person (or animal)

c Probability of a person (or animal) becoming infected from an infected fly

$1/u$ Life expectancy of tsetse flies (days)

T Incubation period in tsetse flies (days)

$1/r$ Duration of infection in a person (or animal) (days)

Table 1: Impacts of social conflict on sleeping sickness in sub-Saharan Africa

Impacts and vulnerabilities associated with conflict	Impact on transmission determinants	Parameter impact
Economic and global effects		
<ul style="list-style-type: none"> • Reliance of governments on external funding for control resources and donor reluctance due to political insecurity 	Reduction in provision of public health services	$\uparrow 1/r$ in people
<ul style="list-style-type: none"> • Reduced reliability of economy for international investment and aid 	Decreased treatment and control of animal infection and transmission	$\uparrow 1/r$ in animal reservoirs
<ul style="list-style-type: none"> • Collapse of businesses and local economies. Loss of employment, income & provision of products & services 		
<ul style="list-style-type: none"> • Abandonment or appropriation of land; changes in land ownership and land use. Possible increased vector habitat 		
<ul style="list-style-type: none"> • Loss of educated and business elite in cases of emigration, exile, or purging; decreased overall response capacity and economic stability 	Decreased vector control	$\uparrow 1/u, \uparrow m$

Decline of health systems and services

- Absence of public health funding due to economic collapse, corruption, or re-allocation of funds to security or military expenses
- Collapse or decline in training programs for public health, veterinary, and vector control workers; decline in personnel and expertise; limited surge capacity for outbreak response
- Total absence of case surveillance or reporting in some rebel-controlled areas or high-conflict zones; limited screening/treatment
- Demotivation of health care, veterinary and vector control personnel caused by insecurity, inflation, or no pay
- Collapse of vector control and veterinary health programs

Reduction in provision of public health services

↑ I/r in people

Decreased treatment and control of animal infection and transmission

↑ I/r in animal reservoirs

Decreased vector control

↑ I/u , ↑ m

Forced migration and internal displacement of populations

- Increased mortality and morbidity due to conflict violence
- Transport of people and animal hosts, vectors, and parasites into potentially naïve or uninfected populations
- Loss of livelihoods – increased stress, reduced household resources, reduced health & nutritional status
- Decreased access to health facilities; decreased population health
- Separation of household units
- Abandonment of land; vegetation re-growth; increased vector habitat

Increased exposure of people and cattle to tsetse habitat

↑ *a*

Increased vector habitat

↑ *m*

Increased mortality

-

Regional insecurity and restricted access for external humanitarian support

- Treatment facilities prone to looting and insurgent attacks
- Insecurity in affected regions constrains or prevents control and implementation logistics; access of mobile teams limited
- Lack of integration and continuity in primary care where a range of NGOs are the dominant providers of health and intervention services.
- Patients delay seeking medical help due to travel insecurity or unavailable transport; higher proportion of late-stage or unreported and untreated cases.

Reduction in provision of public health services
Increased mortality

↑ $1/r$ in people
-

Take-home lesson

Socio-political & economic changes can be parameterized, i.e., reduced to empirical estimates / observations that can be used in predictive equations and models.

Summary of Effects of Social/Political Conflict

Direct Effects

- Displacement of people.

 - Reduced monitoring of disease.

 - Increased longevity in humans.

 - Increased contact with tsetse.

 - Increased biting rate.

- Loss of funding/coordination of control efforts.

 - Increased abundance of tsetse.

 - Increased habitat for tsetse.

Indirect Effects

- Increased longevity in humans.

 - Loss/reduction of outside and local health care.

 - Travel insecurity (not seeking health care).

 - Insecurity prevents mobility of health care.

Difficulty of control.

Gambian: mass chemotherapy still effective.

Resistance developed.

Treatment difficult and unpleasant.

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Rhodesian: mass chemotherapy not effective due to reservoirs of infection.

Focus on tsetse.

spraying.

short-term and costly (e.g., Okavango).

traps.

effective.

require constant maintenance.

Focus on wildlife.

mass culling.

costly.

ineffective.

morally reprehensible to many.

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Focus on cattle.

Trypano-tolerant cattle.

Cattle as bait.

Costly.

Modification makes cheap.

Importance of HAT.

At-risk population very large.

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Disease is 100% deadly.

Moral argument.

Very high burden of disease (SEE TABLE).

Table 1. Selected DALYs Lost by Cause, 2000.

Cause	DALYs Lost
HIV/AIDS	64,970,667
Malaria	39,568,398
Lymphatic filariasis	4,576,994
Trachoma	2,559,951
Leishmaniasis	1,752,384
Schistosomiasis	1,485,408
Ascariasis	1,405,795
HAT (trypanosomiasis)	1,335,075
Trichuriasis	803,111
Japanese encephalitis	604,002
Chagas disease	574,644
Dengue	542,954
Onchocerciasis	427,440
Leprosy	188,542
Hookworm disease	64,048

Data from [97].
doi:10.1371/journal.pntd.0000333.t001

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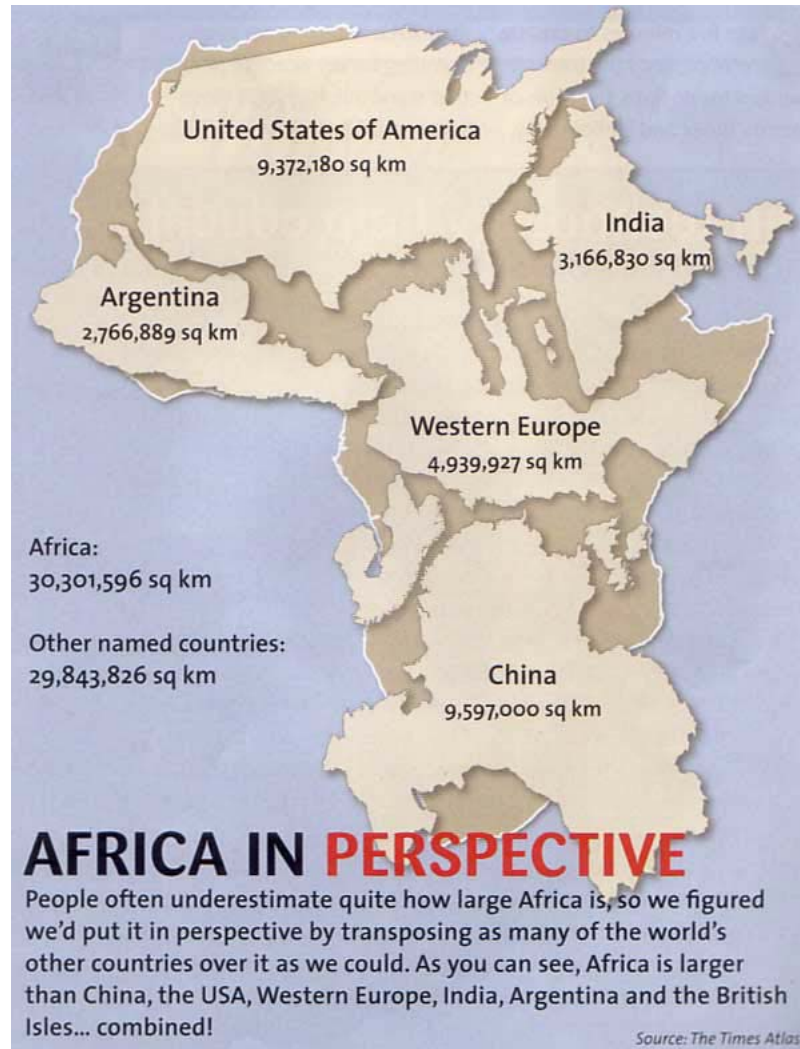
Historical effect.

U.S.-sized area perfect for ranching.

No beasts of burden.

No productive cattle.

Thought experiment.



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Imperceptible Prince

Shadowy Czar

Undetected Dictator

Disguised Despot

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