Foresight

Infectious Diseases: preparing for the future

OFFICE OF SCIENCE AND INNOVATION

T8.8: Cattle trypanosomiasis in Africa to 2030

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Abstract:

Trypanosomiasis diseases are caused by single-cell organisms and affect both humans and cattle. This indicative study modelled the effect of climate change and population growth on the future range of tsetse flies, their main vector, in sub-Saharan Africa. Projected climate change to 2030 has a limited effect on their distribution. Population growth has more significant consequences, mainly caused by the land-use change that accompanies it. It could reduce the area in which tsetse flies are found by 15% by 2030. The main effect would be in drier areas of western, eastern and southern Africa, and in Ethiopia. Humid areas would be less altered. The authors say that other factors such as disease control efforts and changing agricultural practices may also affect the future range of the flies and of the diseases with which they are associated.

1 BACKGROUND

The impacts of climate change, human population growth and expected disease control activities on tsetse distribution and trypanosomiasis risk in sub-Saharan Africa to 2050 were investigated by McDermott et al. (2001). Some of that analysis was repeated here, using new datasets for sub-Saharan Africa that have appeared since then.

Past trends indicate that socioeconomic factors, particularly development, human population growth and distribution, and evolving agricultural and livestock production systems, will increasingly determine the incidence and distribution of cattle trypanosomiasis (Reid et al. 2000). Also, biophysical factors, both influenced by and independent of these socioeconomic factors, will remain important determinants (McDermott et al. 2001). Here, we predict changes in tsetse and trypanosome distribution in sub-Saharan Africa as a result of two global drivers, climate and human population.

Climate and human population directly influence trypanosomiasis risk, and may be correlated with other predictors such as habitat (vegetation, especially tree and bush cover) and livestock numbers. It is important to bear in mind, however, that disease trends can be dramatically changed by unforeseen events. It is also important to stress that the methods outlined below are suited to rapid and broad-brush analyses, so the results presented should be viewed only as indicative.

2 EFFECTS OF CLIMATE CHANGE ON TSETSE DISTRIBUTION

To predict future changes in tsetse distribution and impact, we used the length-of-growing period (LGP) as an indicator of the impact of climate change on key environmental determinants of tsetse distribution and trypanosomiasis risk (such as temperature) and natural resource attributes (particularly tree cover and agricultural activity). A current LGP surface for sub-Saharan Africa was estimated based on long-term, monthly climate normals (rainfall, daily temperature, and daily temperature diurnal range) from the new WorldClim v1.3 climate grids at 1 km^2 resolution (Hijmans et al. 2004). We used the results of the Hadley CM3 Global Circulation Model for two scenarios, A2 and B2 (Special Report on Emissions Scenarios: IPCC 2000), to derive climate data for 2015 and 2030 using the downscaling methodology described in Jones and Thornton (2003). The water balance program, WATBAL, was used to estimate growing season days (Jones 1987). These are taken to be those days when the ratio of actual to potential evapo-transpiration is greater than 0.5 for a soil of average water-holding capacity.

Of the two scenarios used, A2 '… describes a very heterogeneous world, in which the underlying theme is self-reliance and preservation of local identities. Scenario B2 describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability' (IPCC 2000: 5). Because the impacts of scenarios A2 and B2 to 2030 are not very different (they

diverge markedly from 2050 onwards), in the analysis below we used scenario B2 only. The Hadley model predicts substantial reductions in LGP for some areas of west Africa, southern Sudan, Uganda, coastal east Africa, and southern Africa, and some moderate increases in parts of southern Kenya, northern Tanzania, and southern Ethiopia, for example.

The predicted changes in LGP were then used to predict changes in the distribution of the three groups of tsetse flies (*Glossina* spp.): *morsitans* (savanna), *palpalis* (riverine) and *fusca* (forest). Here, we used the simple method of thresholds outlined in McDermott et al. (2001), based on the method of optimal threshold distribution functions (Robinson et al. 1997). While there is a single lower threshold of LGP for the *fusca* and *palpalis* groups of flies (LGP = 185 and 165, respectively) above which habitat should be suitable, for the *morsitans* group there is a lower (LGP = 105) and upper (LGP = 215) threshold between which habitat should be suitable. We used these values to predict the spatial distribution of tsetse based on LGP now and in 2015 and 2030. Figures 1, 2 and 3 show, for each group, the modelled and actual current distribution (modified from Ford and Katondo 1977) and the predicted changes in distribution to 2015 and 2030, indicating areas of continued presence or absence, areas that have become suitable, and areas no longer suitable.
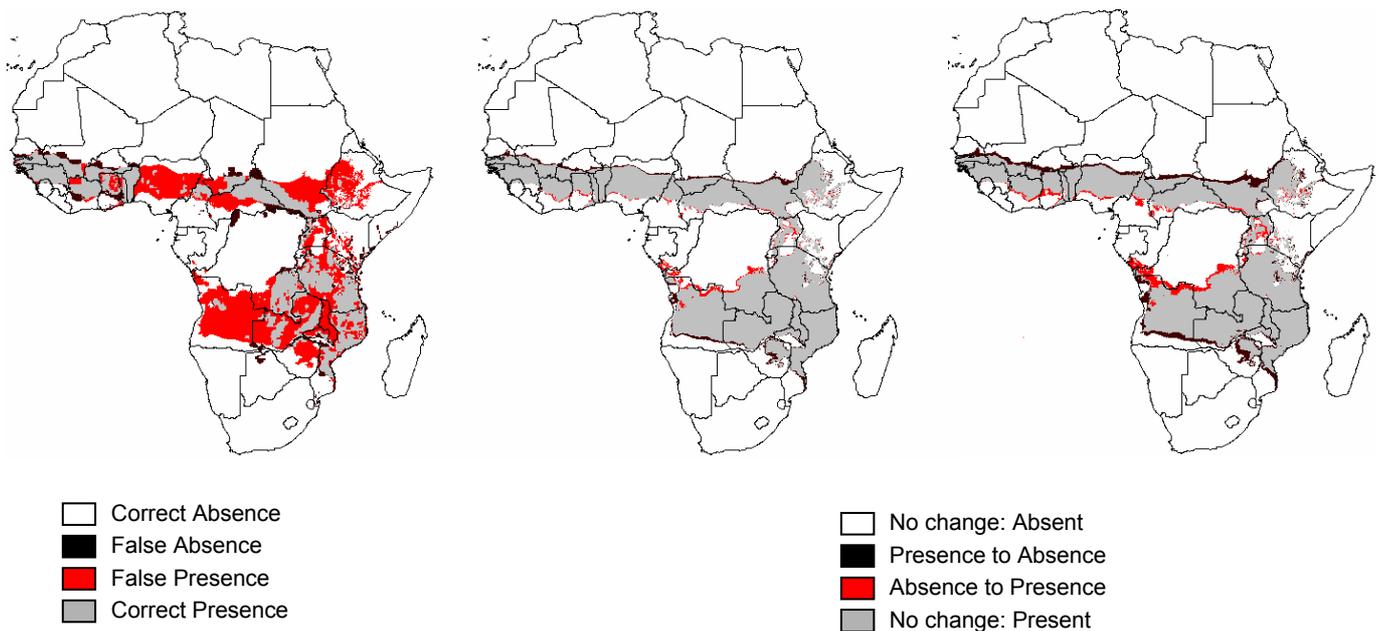

☐ Correct Absence		☐ No change: Absent
■ False Absence		■ Presence to Absence
■ False Presence		■ Absence to Presence
▨ Correct Presence		▨ No change: Present

Figure 1. *Model predictions compared with current distribution of morsitans (left), and predicted change in distribution to 2015 (centre) and 2030 (right) as a result of changes in length of growing period*

For the *morsitans* group (Figure 1), predictions based solely on LGP are poor. Nevertheless, general predicted trends are a decrease in suitable tsetse habitat along the northern front of the west African fly belt, over a large area in

southern Sudan and in southern Zambia, and an increase in habitat suitability along the southern front of the west African fly belt and in scattered parts of Kenya, Tanzania, Uganda and Ethiopia (the belt of apparent increase in habitat to 2030 running from coastal Angola to southern Congo is associated with a large area of 'false presence' predicted by the LGP model in the left-hand panel of Figure 1).
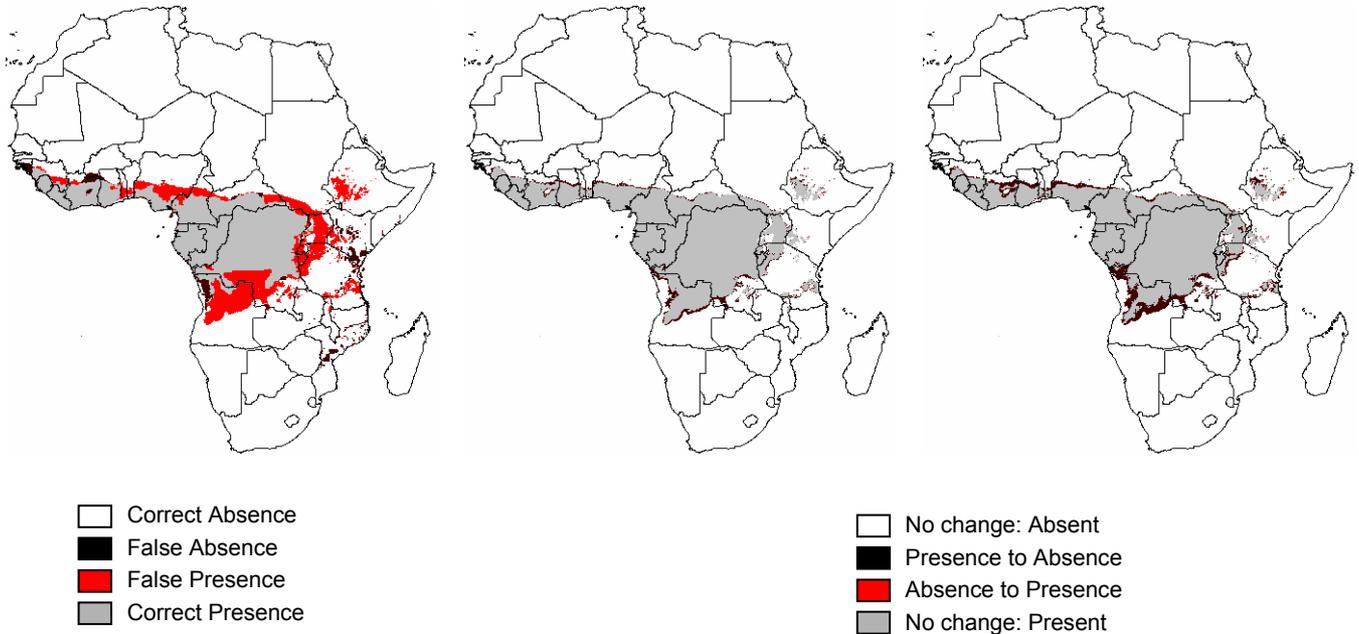

Correct Absence
False Absence
False Presence
Correct Presence

No change: Absent
Presence to Absence
Absence to Presence
No change: Present

Figure 2. *Model predictions compared with current distribution of fusca (left), and predicted change in distribution to 2015 (centre) and 2030 (right) as a result of changes in length of growing period*

For the *fusca* group (Figure 2), LGP is a much better predictor. In general, a decrease in habitat suitability along both the northern and southern fronts of the distribution and an increase in habitat suitability in scattered parts of east Africa are predicted. A belt of apparent decrease in habitat to 2030 running through central Angola is associated with an area of 'false presence' predicted by the LGP model.
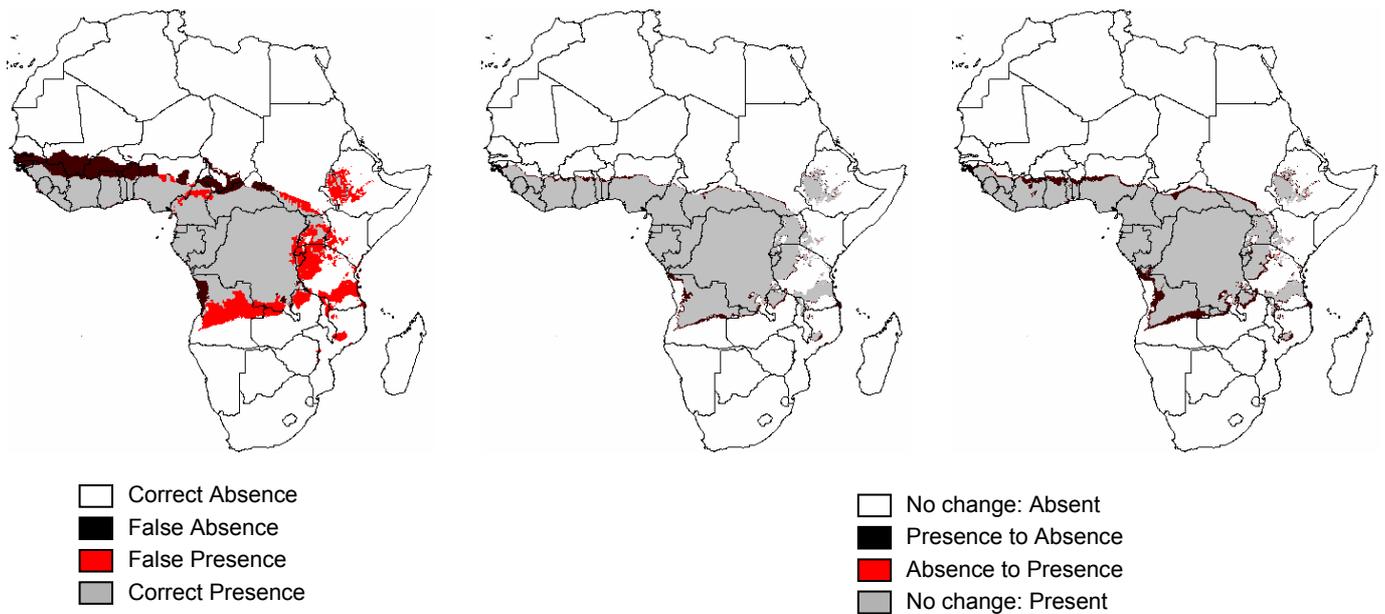
☐ Correct Absence	☐ No change: Absent
■ False Absence	■ Presence to Absence
■ False Presence	■ Absence to Presence
■ Correct Presence	■ No change: Present

Figure 3. *Model predictions compared with current distribution of palpalis (left), and predicted change in distribution to 2015 (centre) and 2030 (right) as a result of changes in length of growing period*

For the *palpalis* group (Figure 3), the quality of the prediction based on LGP is similar to that for the *fusca* group, and with a similar pattern of change expected.

3 EFFECTS OF HUMAN POPULATION GROWTH ON TSETSE DISTRIBUTION

While changes in climate are expected to gradually modify tsetse distribution over the next 30 years and beyond, changes due to increases in human population and associated habitat modification may well be more rapid. As for LGP, here we used the same thresholds as in McDermott et al. (2001), based on the hypothesis that human population density is highly correlated with the area of tsetse habitat cleared for cultivation. We used new human population density maps for Africa from the GRUMP project (GRUMP 2005), which show human population density at a resolution of 30 arc-seconds. We projected human population density for Africa to 2015 and 2030 using the medium variants of the United Nations human population projections at country level available from FAOSTAT (FAO 2005), with densities adjusted *pro rata* based on currently populated areas. Note that the GRUMP dataset incorporates, as closely as possible, the UN estimates of percentages of population in rural and urban areas.

To predict the impacts of human population growth on the distribution of tsetse, the following assumptions were made, from Reid et al. (2000). The impacts of human population on *palpalis* flies were considered minimal, because these flies adapt well to many peri-domestic habitats (Jordan 1986).

Human population scenarios were developed only for the *fusca* and *morsitans* groups. We classified impacts of human population on tsetse distribution into three categories: (1) low human population density having no effect on tsetse populations; (2) moderate human population density causing a decline in tsetse populations; and (3) high human population density eliminating *fusca* and *morsitans* populations. Here we used a 'conservative' scenario of moderate human impact on tsetse. The human population thresholds for no effect and extinction were 30 and 77 people per km^2, respectively.
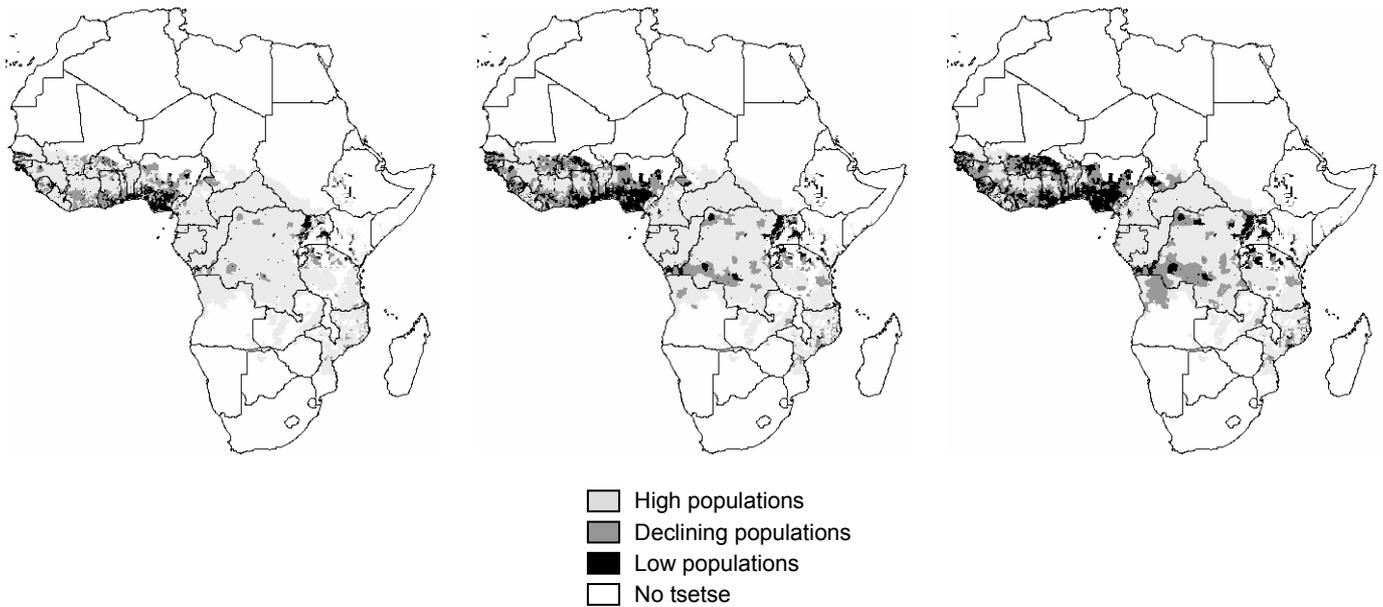

High populations
Declining populations
Low populations
No tsetse

Figure 4. *Current tsetse distribution (left) and conservative scenario for changes in populations of morsitans and fusca to 2015 (centre) and 2030 (right) as a result of human population growth*

Results are shown in Figure 4. It can be seen that human population growth will have important impacts on tsetse distributions between 2000 and 2030. The analysis indicates that tsetse will remain in high numbers over about 60% of their current distribution and in moderate/declining numbers over an additional 24%. The greatest decline in overall tsetse populations will occur in west Africa, with smaller areas of decline in eastern, central and southern Africa (Lake Victoria basin, north-western Uganda, coastal areas of eastern and southern Africa and large areas of central Africa). The *fusca* group is likely to disappear in parts of eastern and southern Africa, coastal west Africa, and several large patches of central Africa. Despite the assumption of little human impact on *palpalis* tsetse distribution, there is likely to be some decline influenced by rising human populations, particularly in drier areas where isolated riparian forests come under threat from human use. This is likely to occur in west Africa.

4 CHANGING TSETSE DISTRIBUTIONS AND TRYPANOSOMIASIS RISK

McDermott et al. (2001) and Kristjanson et al. (1999) discuss the possible impacts of changes in tsetse distribution on trypanosomiasis risk in relation to five broad zones in sub-Saharan Africa. These are summarised here. Climate and human population growth are likely to substantially reduce trypanosomiasis risk in the semi-arid and sub-humid zones of west Africa. In the sub-humid zone, the future development of market-orientated systems for cotton and other cash crops are likely to result in farmers improving their control of trypanosomiasis using strategic vector control and chemotherapy (McDermott et al. 2001). Changes in trypanosomiasis risk in the humid zone of west and central Africa are likely to be more gradual, climate change and human population growth decreasing the risk in patchy areas only. The strategy of living with tsetse and trypanosomes will continue, although the current low numbers of cattle and small ruminants in the zone (Kristjanson et al. 1999) will increase with improved selection and management of trypano-tolerant breeds by farmers in response to increasing consumer demand for meat and milk (Delgado et al. 1999).

In Ethiopia, tsetse and trypanosomiasis risk will remain an important constraint to livestock and crop production. The analysis here indicates some reduction in tsetse risk in current risk areas, with declining tsetse numbers in increasingly populated valleys, although climate change may bring about enhanced suitability for tsetse at higher elevations. McDermott et al. (2001) envisage two control approaches here: publicly supported, large-scale vector control, and increased use of insecticides and trypanocides by farmers.

In eastern and southern Africa, in the areas of highest population growth and good market access, population pressure and conventional control by farmers will reduce trypanosomiasis impacts on livestock production. However, it is likely that trypanosomiasis will continue to be a major constraint to livestock production in lowland areas, where the effects of human population growth in some areas will be balanced by more a favourable climate for tsetse in others.

5 CONCLUSIONS

Our indicative, broad-brush results suggest that climate change and human population growth may contract the area infested by tsetse in sub-Saharan Africa by something of the order of 15% to 2030. Most of this contraction appears to be brought about by population growth rather than by climate change. By that date, the number of livestock at risk will represent a much smaller proportion of the total African livestock population than is currently the case. Currently, about 300 million people and 48 million cattle are found in tsetse areas (about 48% and 23% of sub-Saharan Africa totals for people and cattle, respectively; data from Kristjanson et al. (1999) and unpublished International Livestock Research Institute (ILRI) databases). While these changes will tend to contract areas under trypanosomiasis risk continent-wide, the trend will not be uniform. The greatest decrease in the impacts of animal

trypanosomiasis is likely to occur in the semi-arid and sub-humid zones of west Africa where the climate will be drier, human population will increase, and disease control can be expected to have greater impacts (McDermott et al. 2001). The risk of animal trypanosomiasis will also decline in many but not all areas of Ethiopia and eastern and southern Africa. The disease situation in the humid zone of central and western Africa will be less affected.

More sophisticated analysis is possible than was carried out here. In addition to the problem of being unable to specify the levels of uncertainty associated with the results presented, two weaknesses in particular can be highlighted. First, better predictive models of tsetse distribution could be applied, using, for example, the methods of discriminant analysis of Rogers and Robinson (2004). (A better predictive model would address many of the problems of 'false absence' and 'false presence' in Figures 1, 2 and 3.) Second, the use of higher resolution, regional climate models could be expected to increase the robustness of downscaled data associated with the climate change scenarios. Another useful addition to the analysis would be livestock number projections to 2030, in response to population increases, economic development, and changes in demand for livestock products. Spatially disaggregated livestock projections for Africa are currently being worked on at the ILRI, and these will allow the quantification of changes in livestock populations at risk of trypanosomiasis to 2030 and beyond. Taken together, these methods and tools would make it possible to move beyond an indicative, continental-level study of broad trends to much greater levels of detail.

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