THE DEVELOPMENT AND USE OF GEOGRAPHIC INFORMATION SYSTEMS TO ASSIST TRYPANOSOMIASIS CONTROL IN UGANDA

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ABSTRACT

The study shows how remotely sensed and environmental data could be combined in a decision support system to help in forming tsetse control programmes. A relationship assessment was used to describe both the links between land cover and radiation recorded by a remotely sensed image and the links between land cover and the disease carried by the tsetse vectors. The study demonstrates the ability of GIS analysis to assess the relationship between tsetse fly distribution and cattle density and determine the strength of the link between tsetse and agricultural production relative to other factors that might influence land-use (human population). The study demonstrated the capacity of geographic information systems to make significant contributions to country-level analyses of factors affecting tsetse distribution, human population density and land-use intensity. Such analyses will play important roles in the process of resource allocation to improved food production in Uganda through more effective disease control.

INTRODUCTION

Nagana in cattle and sleeping sickness, or human African trypanosomiasis, which are vector-borne parasitic diseases prevalent in sub-Saharan Africa is caused by the parasite *Trypanosoma brucei (T. brucei)*, and transmitted by an infected tsetse fly (*Glossina spp.*) (Leak, SGA. 1999). Nagana is a disease condition of livestock and other wild animals. There are two subspecies of *T. brucei* that cause sleeping sickness: *T. b. gambiense* which causes a more chronic form of sleeping sickness and is prevalent predominantly in the west, central Africa and southern Sudan (Leak, SGA. 1999). *T. b. rhodesiense* causes a more acute form of the disease and is predominant in east and southern Africa. Sleeping sickness has continued to be a significant public health burden in Uganda since its identification in 1898 (Leak, 1999; Odiit, 2003). In Uganda, both forms of sleeping sickness are present, with the chronic form, *T. b. gambiense*, currently found in the north-western and west Nile region. The more acute, *T. b. rhodesiense*, is much more prevalent in the east. As such, Uganda forms the African boundary for the two forms of sleeping sickness. Recently, evidence of disease spread to districts considered to be previously uninfected (Fèvre, 2001) has highlighted the need for increased understanding and implementation of disease prevention and control. The spread of disease foci is of particular concern in Uganda, where there is significant risk of the two sleeping sickness subspecies merging in the socially unstable north-central districts. (Welburn, 2002).

In 1998 for example, cases of sleeping sickness began to be recorded in the central district of Soroti. These cases of the disease were associated with transmission of *T. b. rhodesiense* imported from the south-east via cattle movements (Fèvre *et al*, 2001). More recent disease spread includes outbreaks in Kumi Kaberamaido, and Lira Districts in 2004 and 2005 (Rodriguez, 2005; Uganda: Ministry of Health; 2004). This expansion of the disease range exacerbates concern over the potential risk of the two sleeping sickness strains, *T. b. gambiense* (in northeast) and *T. b. rhodesiense* (in the southeast), merging in north-central Uganda. (Welburn, 2002; Hutchinson, 2003) Such a concern is compounded by reports of tsetse presence, cattle movements, rebel activity, internal displacement of large portions of the population, extensive poverty and civil conflict in central districts. Recent research (Picozzi *et al*. 2006) showed that while the *T. b. rhodesiense* and *T. b. gambiense* foci remain discrete, there is now only 150 km between the ranges of the foci. According to them, areas now infected by *T. b. rhodesiense* also now overlap with areas previously infected by *T. b. gambiense* in the 1950's. The continued spread and shifting of the sleeping sickness distribution within Uganda and the potential for sub-species overlap highlight the need for increased understanding of disease dynamics and factors driving transmission.

Previous studies focused on infection of the disease using parametric and non-parametric technique for their analysis. The prominent among these are the studies by Ford (1969); Buyst (1977); Wellde (1989); Khonde (1995); Leak (1999). This study aims, therefore, at using remote sensing and GIS techniques to examine and map the spatio-temporal distribution of tsetse flies and to assess the relationship between tsetse fly occurrence and livestock distribution in Uganda between 1986 and 2001. Remote sensing is primarily used in the context of disease mapping, in which statistical associations are demonstrated between ecological variables and processes that can be observed remotely (e.g., rainfall, temperature, vegetation cover, wetness, etc.). These, in turn, are correlated with vector distributions as well as disease incidence and prevalence (Hay, 1997). The approach, sometimes referred to as landscape epidemiology, follows the following sequence: (1) remotely sensed data of 1986 and 2001 is used to provide information on land cover types and thereby identification of the tsetse habitat; (2) the spatial distribution of a vector-borne disease is related to the habitat of the tsetse flies as the vectors; and (3) data on land cover types, habitat and human population provide information on the spatial distribution of sleeping sickness and nagana in livestock (Curran *et al.* 2000, Landscape Epidemiology and RS/GIS). Knowledge of the likely distribution of vectors and the intersection with human populations and cattle rearing can help make more efficient use of public health resources, (in terms of spraying and eradication efforts, distribution of prophylactics and drugs for treatment, or location of health staff and facilities).

The use of remote sensing for the study of disease has grown rapidly in the past decade. The growth is attributable to several factors. Since the late 1980s, there has been growing use of geographic information systems (GIS) and spatial statistics in studies investigating patterns of disease incidence. Remote sensing was discovered to be a useful source of geo-referenced data which, when combined with other data in a GIS, could help researchers identify and understand the environmental correlates of these patterns. GIS and remote sensing also help researchers to answer questions concerning the spatial and temporal aspects of disease outbreaks.

Eastern Uganda is one of such regions that have the highest cases of sleeping sickness recorded from 2000 to 2007 (Ministry of Health Report, 2008 - Uganda). The concerns over re-current foci and continued disease spread highlight the absence of adequate assessment of the differences between current and historical distributions of sleeping sickness. The continued spread and shifting of the sleeping sickness distribution within Uganda and the potential for sub-species overlap highlight the need for increased understanding of disease dynamics and factors driving transmission.

OBJECTIVES

The specific objectives of this study are to:

i. assess the relationship between tsetse fly distribution and cattle density.
ii. determine the strength of the link between tsetse and agricultural production relative to other factors that might influence land-use (i.e., human population).

STUDY AREA

The latitude and longitude denominations of the republic of Uganda positions it on the eastern side of the continent of Africa, on the western side of the African country of Kenya. The latitude and longitude denominations of Uganda are 1 00 N and 32 00 E. The republic of Uganda covers a total area of 236,040 sq km. Uganda latitudes 4^0.0' North and 1^0.30' South of the equator, and longitudes 30^0.0' East and 35^0.0' East of Greenwich. The greater part of Uganda consists of a plateau 800 to 2,000 m (2,600–6,600 ft) in height. Along the western border, in the Rwenzori Mountains, Margherita Peak reaches a height of 5,109 m (16,762 ft), while on the eastern frontier Mount Elgon rises to 4,321 m (14,178 ft) (Advameg, 2007) By contrast, the Western Rift Valley, which runs from north to south through the western half of the country, is below 910 m (3,000 ft). For example, the surface of Lake Edward, Lake George and Lake Albert (L. Mobutu Sese Seko) is about 621 m (2,036 ft). The White Nile has its source in Lake Victoria and as the Victoria Nile, it runs northward through Lake Kyoga and then westward to Lake Albert, from which it emerges as the Albert Nile to resume its northward course to the Sudan. (Advameg, 2007)

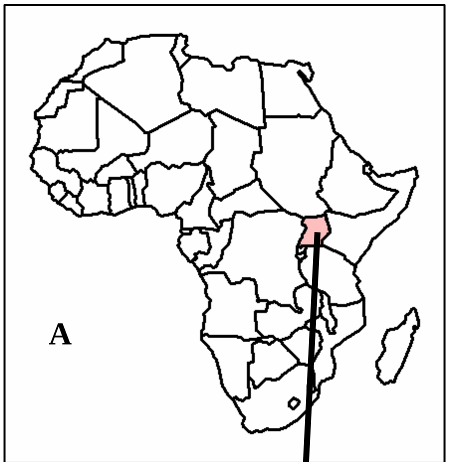

Fig 1A: Map of Africa Showing Uganda

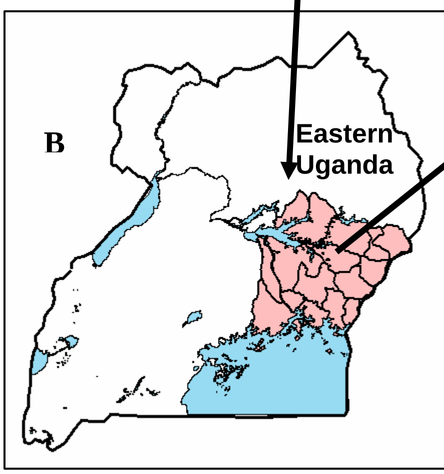

Fig 1B: Map of Uganda Showing Eastern Uganda

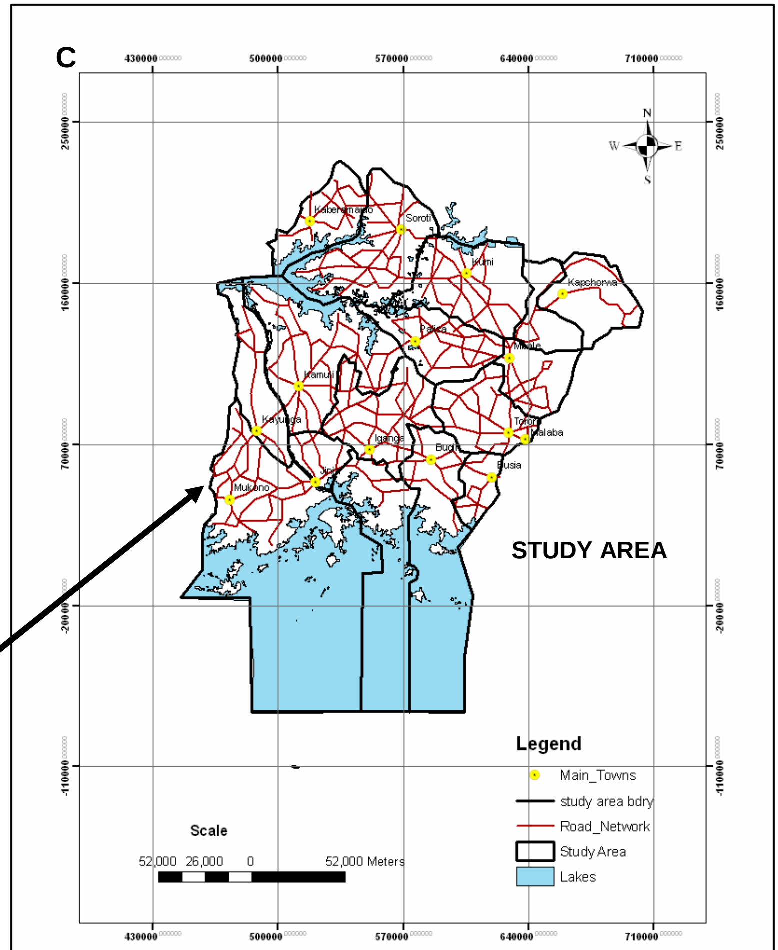

Fig 1C: Map of Eastern Uganda

Uganda has a typically tropical climate with little variation in temperature throughout the year. Distinctive wet and dry seasons characterize the climate of most of the country, except in the semi-arid north east. The dry season is generally from December to February and mid-June to mid-August. The two rainy seasons are from March to May, and September to November. In the south the rainiest month is April. The mountainous areas in western and eastern Uganda can be cold at night (Advameg, 2007).

Uganda's Lake Victoria (26,828 square miles [69,484 square km]), in the southeastern part of the country, is the world's second largest inland freshwater lake by size after Lake Superior in North America, although Lake Baikal in Siberia is larger by volume and depth (Advameg, 2007). Lake Victoria is also one of the sources of the Nile River. Five other major lakes which exist in the country are Edward and George to the southwest; Albert to the west; Kyoga in central Uganda; and Bisina in the east (Advameg, 2007). Together with the lakes, there are eight major rivers. These rivers are the Victoria Nile in central Uganda; the Achwa, Okok, and Pager in the north; the Albert Nile in the northwest; and the Kafu, Katonga, and Mpongo in the west (Advameg, 2007).

DATA ANALYSIS

It has been said that more effective control of tsetse-transmitted trypanosomiasis may open vast areas of Uganda to livestock production, both increasing food production potential and endangering reservoirs of biodiversity on the continent. Removal of the constraint of trypanosomiasis is predicted to allow the expansion of agriculture through increased use of animal traction. If these statement reflects reality, there should be a strong inverse relationship between the distribution of tsetse and the distribution of cultivated land or agricultural land-use in Uganda. The first objective of the GIS analysis in this project was to determine whether such a relationship exists between the distributions of tsetse and agricultural land-use for Uganda. If such a relationship exists, the second objective was to determine the strength of the link between tsetse and agricultural production relative to other factors that might influence land-use (i.e., human population). The tsetse distribution was related to human population density in Uganda. Then agricultural land-use was related to tsetse distribution and human population density in Uganda. The analysis was conducted by overlaying the data layers of interest (tsetse distribution, human population and crop coverage).

DISCUSSION OF RESULTS

RELATIONSHIPS BETWEEN HUMAN POPULATION DENSITY, CROP COVERAGE, CATTLE DENSITY AND TSETSE DISTRIBUTION

No geo-referenced database existed that adequately shows the distribution of land-use in Uganda prior to this study (Perry, 1994). To solve the problem of lack of data, two alternative approaches were used. First, tsetse distribution was related to human population density in Eastern Uganda, using the latter variable as a surrogate for the land-use data. Secondly, agricultural land-use data was obtained and the data related to tsetse distribution. The analysis was conducted by overlaying the data layers of interest that is tsetse distribution and human population.

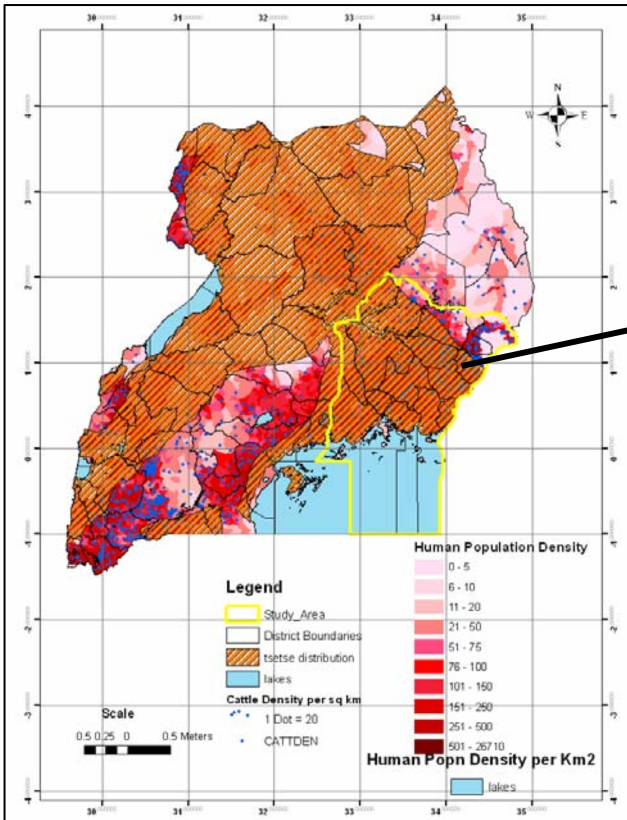

Figure 2A: Map of Uganda showing Overlay of Human Population Density, Tsetse distribution and Cattle Density Per Square Km

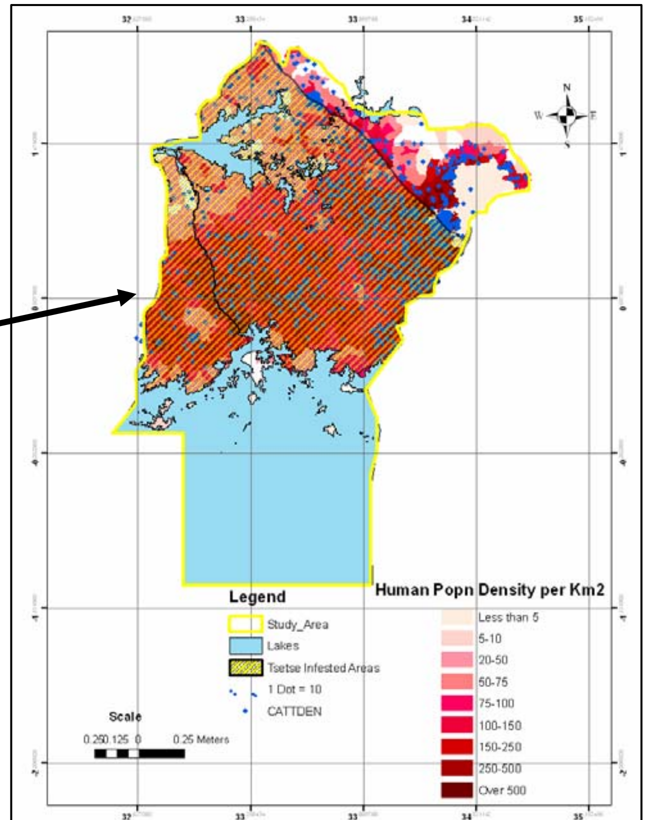

Figure 2B: Map of Eastern Uganda showing Overlay of Human Population Density, Tsetse distribution and Cattle Density Per Square Km

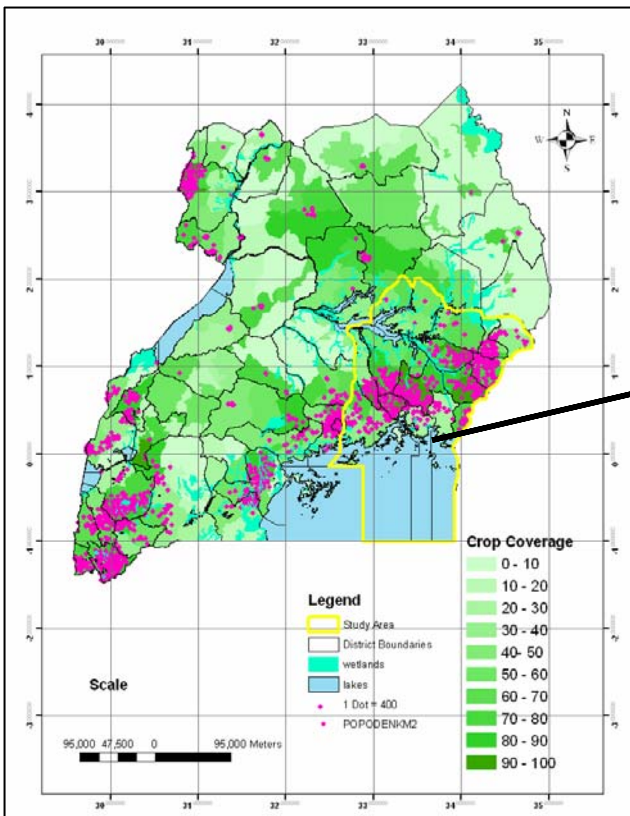

Figure 3A: Map of Uganda Showing Overlay of Crop coverage and Human Population Density per Square Km

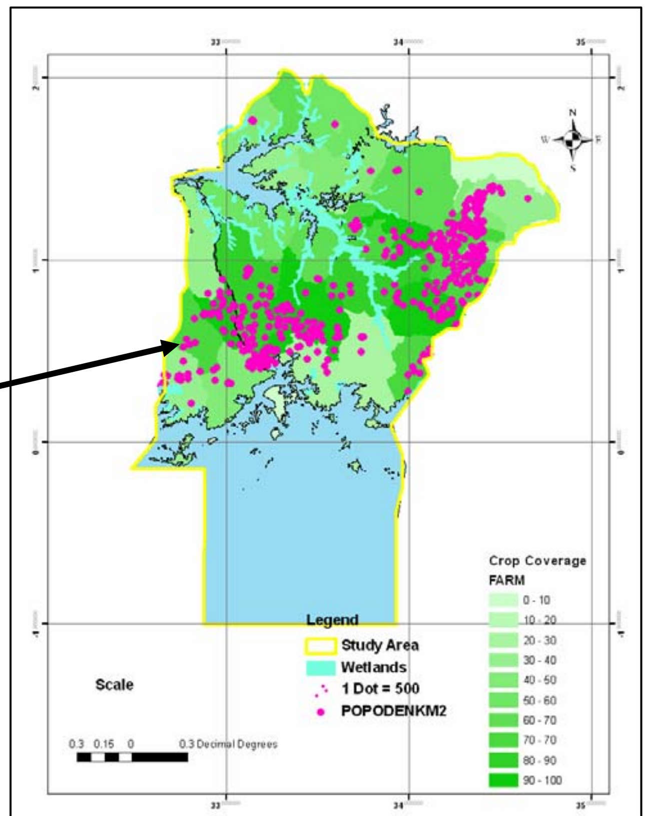

Figure 3B: Map of Eastern Uganda Showing Overlay of Crop coverage and Human Population Density per Square Km

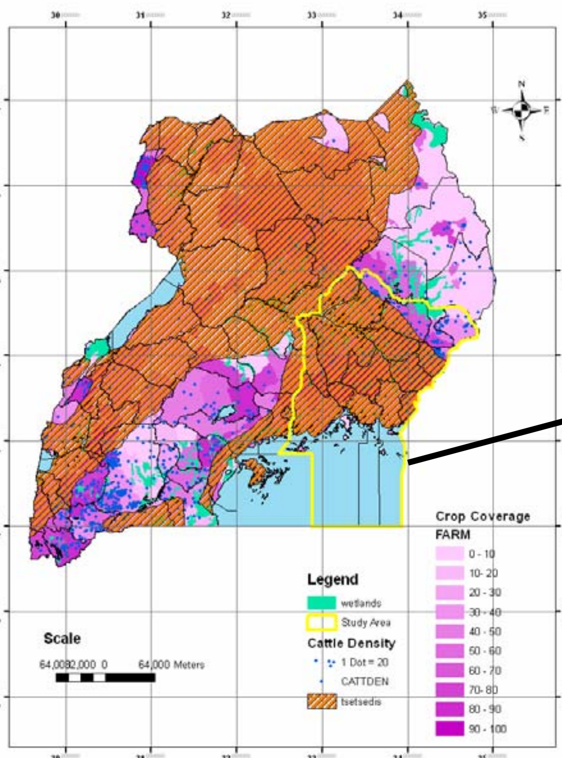

Figure 4A: Map of Uganda Showing Overlay of Crop coverage and Cattle Density per Square Km

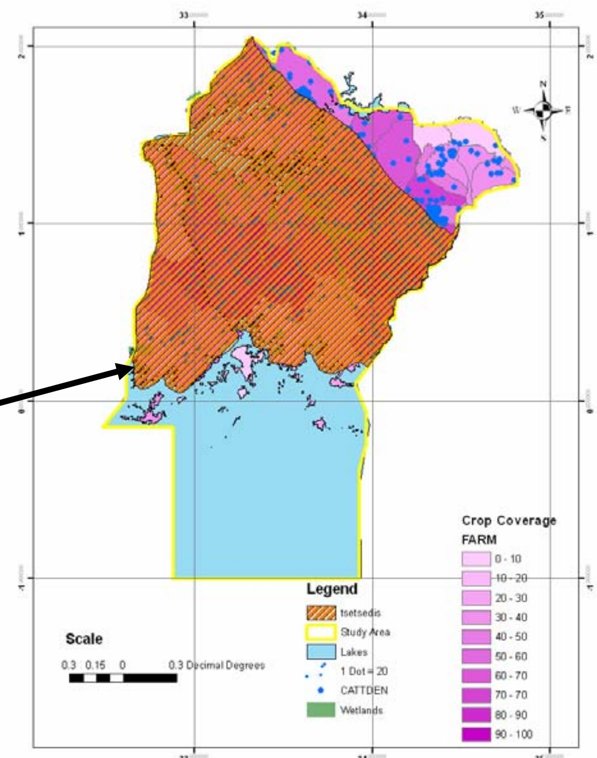

Figure 4B: Map of Eastern Uganda Showing Overlay of Crop coverage and Cattle Density per Square Km

Analysis of the results revealed that for the most part, fewer people live in tsetse-infested than in tsetse-free zones. This however does not demonstrate a cause and effect relationship, but it suggests that tsetse may be an important constraint to human habitation. As shown in Figure 13, there was a strong positive relationship between land-use intensity and human population density for Eastern Uganda and Uganda as a whole. For the country analysis, it was expected that land-use would be low in the presence of tsetse. However, in Uganda case, tsetse presence was associated with both high and low land-use intensity, with farming depending on the climatic zones, soil type and fertility. Areas with high land-use intensity that also have tsetse in Uganda are mostly areas with several water bodies like Lake Victoria, part of Lake kyoga and several rivers. Areas where tsetse and high intensity agricultural land-use overlap were probably zones where the soils were particularly fertile. Conversely,, areas with no tsetse and low intensity agricultural land-use were probably be zones with a semi arid type of climate which are characterized with low rainfall and low soil fertility (Rogers *et al*, 1993).

CONCLUSIONS

The results presented here are of a preliminary nature, but clearly demonstrate the capacity of geographic information systems to make significant contributions to country-level analyses of factors affecting tsetse distribution, human population density and land-use intensity. It is considered that such analyses will play an increasing role in the future in the process of resource allocation to improved food production in the continent through more effective disease control.

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