Livestock Diseases and Poverty

A major constraint to improving productivity in Ugandan livestock is the presence of animal diseases and, linked to this, the provision of animal health services. Livestock diseases impose heavy costs on producers and reduce incentives to invest in higher yielding crossbred or exotic animals that tend to be more vulnerable. Important endemic diseases in Uganda include: foot and mouth disease; contagious bovine and caprine pleuropneumonia; peste des petits ruminants; a host of tick-borne diseases (including babesiosis, anaplasmosis, and theileriosis); helminthosis; tsetse-transmitted trypanosomiasis; contagious ecthyma; Newcastle disease; infectious bursal disease; coccidiosis; salmonellosis; African swine fever; tuberculosis; brucellosis; and anthrax.

The government network for controlling disease and providing animal health services in Uganda deteriorated substantially during periods of political unrest. While clinical health services are no longer provided by government institutions and are now regarded as a private good, central government retains responsibility for policy, regulation, surveillance, and control of notifiable epidemic diseases such as contagious bovine pleuropneumonia, and foot and mouth disease (Silkin and Kasirye, 2002). Current concerns relate to preparedness for outbreaks of highly pathogenic avian influenza.

Trypanosomiasis in Uganda (see Box 7 for more detail) is a significant livestock disease in areas where the tsetse vector occurs. A recent study (Thuranira, 2005), conducted across the border in Kenya's Busia district, estimated that farmers' potential income from cattle was reduced by nearly half due to cattle deaths from endemic diseases, principally trypanosomiasis and tick-borne diseases. As a result of the changes in service provision in Uganda, the control of trypanosomiasis in livestock has been left largely in the hands of farmers, who spend considerable sums on trypanocides to cure or protect their livestock.

There are many ways of dealing with trypanosomiasis, ranging from those that focus on the treatment of the parasite in animals ('private goods') to area-wide removal of the vector ('public goods'). At one end of the spectrum is the application of prophylactic and curative trypanocidal drugs, the benefits of which primarily accrue to individual farmers. Applying insecticides to cattle, in contrast, confers further private benefits through the additional control of ticks and nuisance flies and can achieve the public good of effective tsetse control if it is implemented as a coordinated effort. The use of traps and insecticide-treated cattle requires a fully coordinated program over a wide area to be at all effective and to provide benefits to farmers over a broad area. Sequential aerial spraying with non-residual insecticides is another way to achieve area-wide control, as is the release of sterile insects to eliminate residual fly populations once the tsetse population of an area has been suppressed using an insecticidal method.

The comparative costs of different tsetse control techniques in Uganda are discussed in detail in Shaw et al. (2007). Deciding which approach is best suited to a particular situation depends on whether the objective is control or eradication, availability and type of funding, logistical factors such as terrain and infrastructure, the ecology of the vector, the epidemiology of the disease, and finally, the production system context.

Trypanosomiasis is a zoonotic disease (i.e., it can be transferred from animals to people) with the human form being known as sleeping sickness. Uganda is unusual in that sleeping sickness is present in both its chronic *gambiense* form, found in West and Central Africa, and in its more acute *rhodesiense* form, which is found in eastern Africa. The *gambiense* form occurs in the northwest of the country, whereas the *rhodesiense* form, historically confined to the southeastern part of the country, has recently expanded northwest, beyond Lake Kyoga (see Box 7). This poses a risk that the two diseases will overlap (Picozzi et al., 2005). In the areas where the *gambiense* form of the disease is found, control of sleeping sickness relies mainly on finding and treating infected individuals (WHO, 2006). However, in cattle-rearing communities with the *rhodesiense* form of the disease, cattle are often the major disease reservoir and need to be treated as well as people (Hide et al., 1996; Fèvre et al., 2005).

Faced with this situation, a lively debate is ongoing among animal and human health experts as to the best ways to control trypanosomiasis in livestock and people, focusing on issues of scale, sustainability, and cost. All of these have important implications for the choice of technique.

Whichever methodology, or combination of technologies, is ultimately used to intervene, there is a clear need to target interventions appropriately. A spatial targeting approach was adopted in Uganda some years ago by

Box 7 TRYPANOSOMIASIS

Trypanosomiasis is a parasitic disease caused by different species of a one-celled microorganism (i.e., trypanosomes) and affects animals and humans. In Africa, it is transmitted by the tsetse fly, which can acquire its infection from animals or humans harboring the parasites. Only certain tsetse species transmit the disease, each with different habitat preferences, such as wooded savannah or woodlands along rivers and lakes.

Animal Trypanosomiasis

African animal trypanosomiasis occurs in many wild and domestic animals. Trypanosomes can infect all domesticated animals, but in many parts of Africa, cattle are the main species affected because of the feeding preferences of tsetse flies. In cattle, the disease is called Nagana, a Zulu word meaning "to be depressed."

While acute cases of the disease, which are fatal within a week, occur, most cases of trypanosomiasis are chronic, affecting animals over a longer time period. Intermittent fever, anemia, weight loss, decreased milk yield, premature births, and perinatal losses are among the main clinical signs of the disease. Many untreated cases are fatal. Deaths are common among chronically infected animals, particularly when combined with poor nutrition.

The effects of the disease vary with the breed of the animal, as well as the strain and dose of the infecting parasite. Some African livestock breeds are genetically resistant to trypanosomiasis. The roles of different trypanosome species on disease severity in different livestock species and breeds are incompletely understood.

Human Trypanosomiasis

Human African trypanosomiasis, also known as sleeping sickness, is transmitted through the bite of an infected tsetse fly. At first, trypanosomes multiply in the bloodstream (often without any major symptoms) and eventually infect the central nervous system. This process can develop rapidly or take years, depending on the parasite involved. Once the central nervous system is affected, symptoms such as confusion, poor coordination, and sleep disturbance (the latter gives the disease its name) occur. Without treatment, sleeping sickness is fatal. Diagnosis must be made as early as possible to avoid difficult and risky treatment.

In Africa, sleeping sickness occurs only where there are tsetse flies that can transmit the disease, but not all areas with tsetse flies necessarily have cases of sleeping sickness. Rural populations dependent on agriculture, fishing, animal husbandry, or hunting that are the most exposed to tsetse fly bites have the highest risk for the disease. Remote rural areas, weak health care systems, displaced populations, war, and poverty, are all important factors that lead to increased transmission. The disease can develop in small areas, such as a few villages, but also affect a large geographic region. Exhaustive screening of the population at risk is necessary to identify patients at an early stage and reduce transmission; this requires major human and financial resources.

Trypanosomiasis in Uganda

A 2005 study (Picozzi et al., 2005) found that, since the mid-1980s, the area of Uganda affected by the *rhodesiense* parasite and the more acute form of sleeping sickness has increased two and half times (from 13,820 to 34,843 square kilometers), doubling the human population at risk. Before 1985, this form of sleeping sickness was restricted to districts in eastern Uganda clustered around the north shore of Lake Victoria and the source of the Nile. Cattle restocking activities and unsuccessful control efforts contributed to the northwestward spread of the epidemic area, with the disease becoming established in Soroti, Kaberamaido, and Lira Districts. More recent information in 2009 indicates a further spread of sleeping sickness, with the media reporting 120 human cases in Dokolo District, including 11 deaths.

During the same time, civil instability on the Sudanese border resulted in human and livestock movements in northwest Uganda. This contributed to the southeastward expansion of the *gambiense* parasite and the more chronic form of sleeping sickness.

The 2005 study found that the *rhodesiense* and *gambiense* forms of the disease were occurring only about 150 kilometers apart. Without preventive action targeting the parasites within the livestock population, it is expected that the two diseases will converge, requiring a major revision of diagnostic and treatment protocols.

The study recommended real time monitoring of the two diseases (both in livestock and human patients) and treating the animal reservoir for the *rhodesiense* form. In their economic analysis, the authors also indicated that the financial benefits of treating this reservoir (increased livestock income and lower treatment costs for humans) would more than cover the treatment costs and confer large benefits on the poorest and most disenfranchised rural communities with the least access to health care.

Sources: Okino, 2009; CFSPH and IICAB, 2009; WHO, 2006; Picozzi et al., 2005; and Welburn et al. 2001.

PATTEC—the Pan African Tsetse and Trypanosomiasis Eradication Campaign—to prioritize areas for trypanosomiasis control. The method is described in detail in Gerber et al. (2008) and summarized in Wint and Robinson (2007). In essence, a GIS-based modeling approach (weighted linear combination) was used to combine relevant spatial data to identify priority areas for animal trypanosomiasis control. Five criteria were chosen and weighted in terms of their relative importance for prioritizing areas for trypanosomiasis control by stakeholders in the livestock sector in Uganda. The criteria were: (1) density of rural poor, derived from the 1992 poverty maps (UBOS and ILRI, 2004); (2) probability of presence of tsetse (Wint, 2001); (3) length of growing period as a measure of agricultural potential (Jones and Thornton, 2005); (4) cattle density, to measure current level of livestock investment (Wint and Robinson, 2007); and (5) percentage crop cover, to gauge current levels of cropping (UBOS, 2004). Based on that analysis, areas of high priority were selected as the zone where the initial activities under the PATTEC program would be implemented.

In recent years, new data have become available to evaluate the problem of trypanosomiasis in Uganda. The following sections take the reader through an analysis in which livestock and poverty data—using the latest available poverty maps—are explored in the context of tsetse distributions, and the importance of livestock production systems is acknowledged in assessing the number of cattle and people at risk from animal trypanosomiasis. There is no scope here to include an analysis of human sleeping sickness, other than to emphasize the important additional benefits that would result from effective tsetse and trypanosomiasis control where the *rhodesiense* form occurs, mainly in the southeast of Uganda.

TRYPANOSOMIASIS RISK AND LIVESTOCK

It is estimated that some 70 percent of Uganda is infested with 11 species of tsetse, each of which occupies a different ecological niche. By far the most important species, however, are *Glossina pallidipes*, *G. morsitans submorsitans* and *G. fuscipes fuscipes*, which together stretch across the country in a belt from northwest to southeast, with the populations apparently more fragmented and less dense in the central area around Lake Kyoga. Map 10 shows the aggregate distribution of these three tsetse species, derived from predicted distributions of the three most important species based on multivariate models that combine environmental data with known distributions (Wint, 2001). The methodologies for predicting tsetse and other disease vector distributions are well established and are described, for example, in Robinson et al. (1997); Rogers and Robinson (2004); and Pfeiffer et al. (2008).

When considering trypanosomiasis, as with the majority of livestock diseases, it is important to take a systems perspective. This is because the disease is likely to present itself differently in different production systems based on livestock species and breeds, stocking rates, and management practices. Moreover, the impact of the disease on the livestock, and more importantly on the keepers of those livestock, is likely to be different because the role of livestock in peoples' livelihoods varies among production systems. Furthermore, provision of animal health services is likely to differ across systems and the optimal choice of control approach will vary; for example, using insecticide-treated cattle for tsetse control is highly dependent on cattle numbers and stocking rates (Hargrove et al., 2003).

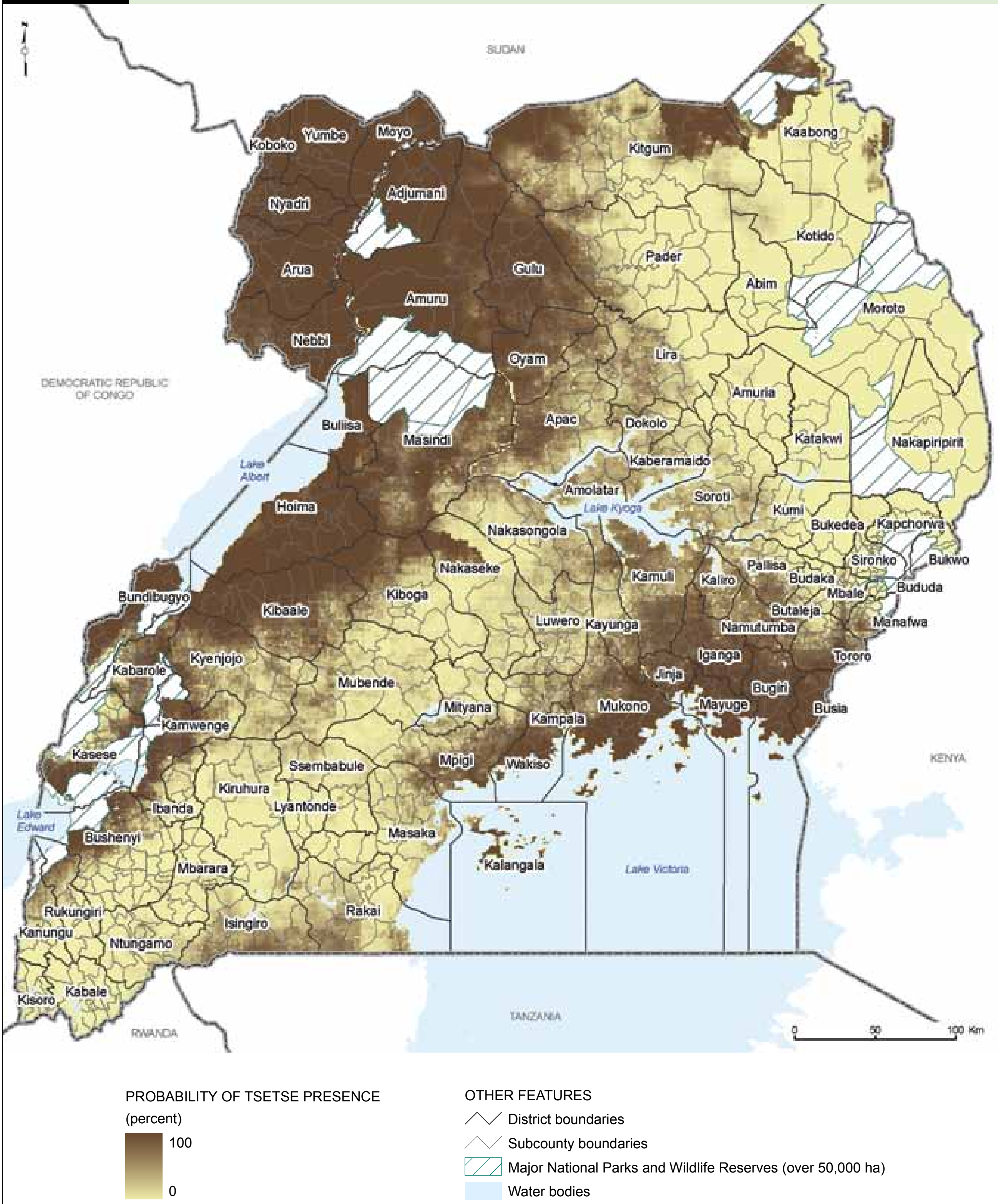
Table 2, derived from combining maps of livestock production systems, livestock density, and tsetse distribution, shows the numbers and densities of cattle in the various livestock production systems of Uganda, inside and outside the areas where tsetse occurs, using modeled 2002 census data (see Box 3 for more detail). Overall, it is estimated that about a third of Uganda's cattle population, about 1.9 million head, were at risk from trypanosomiasis in 2002. By far the largest number of cattle (4.6 million head) is found in mixed rainfed crop-livestock systems. Of these, a higher proportion (36 percent), compared to rangeland-based livestock-only systems (19 percent), is at risk from trypanosomiasis.

Trypanosomiasis is likely to be most prevalent in the humid and sub-humid zones, where length of growing period exceeds 180 days, largely reflecting the habitat preferences of the tsetse fly. It is therefore no surprise that production systems in the humid and sub-humid zone account for the highest share of cattle at risk from trypanosomiasis of Uganda's two major production systems: About 56 percent of the cattle in the mixed rainfed crop-livestock system (1.3 million head) and 59 percent of the cattle in the rangeland-based livestock-only system (93,000 head).

To have the greatest impact on cattle trypanosomiasis, planners targeting these two areas with intervention strategies need to balance absolute and relative livestock numbers, but also take the geographic extent of the target area into consideration (since it is a major cost factor). Examining average stocking rates in different production systems, inside and outside the tsetse areas, can help in prioritizing the most promising locations.

In each of the seven livestock production systems shown in Table 2, stocking rates are higher outside the tsetse area and, in some cases, dramatically so. The greatest differentials in stocking rates are in the rangeland-based livestock-only systems. There are nearly six times as many head per square kilometer outside the tsetse distribution in the temperate areas, though these include only relatively small numbers of animals. In the arid and semiarid areas, which do account for large numbers of cattle, there are over five times as many head per square kilometer outside the tsetse distribution. If, as a result of tsetse removal, the stocking rates currently seen outside the tsetse area in each production system could be achieved throughout that system,

Map 10 TSETSE DISTRIBUTIONS: COMBINED MAP OF THE DISTRIBUTIONS OF *GLOSSINA FUSCIPES FUSCIPES, G. PALLIDIPES*, AND *G. MORSITANS SUBMORSITANS*



Sources: International boundaries (NIMA, 1997), district administrative boundaries (UBOS, 2006a), subcounty administrative boundaries (UBOS, 2002a), water bodies (NFA, 1996; NIMA, 1997; Brakenridge et al., 2006), and tsetse distribution (Wint, 2001).

TABLE 2 TRYPANOSOMIASIS RISK IN UGANDA: LAND AND LIVESTOCK PROFILE, 2002

PRODUCTION SYSTEM		PRODUCTION SYSTEM AREA	TRYPANOSOMIASIS AREA	
		Total Area (square kilometer)	Total Area (square kilometer)	Share of Total Area in Production System (percent)
Rangeland-Based Livestock-Only Systems	Arid and Semi-arid	18,913	3,845	20.3
	Humid and Sub-humid	17,355	12,756	73.5
	Temperate and Tropical Highlands	1,208	321	26.6
Total Rangeland-Based Livestock-Only Systems		***37,476***	***16,923***	***45.2***
Mixed Rainfed Crop-Livestock Systems	Arid and Semi-arid	36,428	7,674	21.1
	Humid and Sub-humid	96,615	58,936	61.0
	Temperate and Tropical Highlands	15,941	3,609	22.6
Total Mixed Rainfed Crop-Livestock Systems		***148,984***	***70,219***	***47.1***
Other Livestock Systems		15,588	9,153	58.7
TOTAL		**202,048**	**96,295**	**47.7**

then increases in cattle numbers to the tune of 0.8 million head may result. Such figures can be considered indicative only—there may be other factors that cause the observed differentials in stocking rates—but it is clear that higher stocking rates are achieved outside the tsetse distribution.

TRYPANOSOMIASIS RISK AND POVERTY

Looking at trypanosomiasis risk in terms of numbers of livestock at risk is important, but what decision-makers really need to understand to prioritize their interventions is how the disease affects the owners of those livestock—in terms of livelihoods, welfare, and food security. Table 3 provides a breakdown of demographic and welfare statistics in the context of livestock production systems and the distribution of tsetse in Uganda.

It comes as no surprise that the vast majority of rural Ugandans live in the widespread mixed rainfed crop-livestock system in the humid and sub-humid zone: 12.8 million people are supported by this system, and 40 percent of these—some 5.1 million people—live in areas infested by tsetse. Of these 5.1 million, some 1.9 million live below the poverty line. This system supports by far the greatest number of poor people living under tsetse threat compared to the other systems, though the rangeland-based livestock-only system in the humid and sub-humid zone also has large numbers of poor in the tsetse areas—about 0.2 million—as do the so-called 'other' systems, with some 0.17 million.

It is also interesting to compare poverty rates inside and outside the tsetse areas in the various systems. The greatest numbers of poor live in the three systems within tsetse areas—mixed rainfed crop-livestock system in the humid and sub-humid zone (with 1.9 million poor); rangeland-based livestock-only system in the humid and sub-humid zone (with about 0.2 million poor); and 'other' systems (with about 0.17 million poor). In these three systems greater poverty rates are also seen inside the tsetse area compared with outside: 25 percent versus 15 percent; 45 percent versus 16 percent; and 16 percent versus 12 percent, respectively. The other systems all have higher rates of poverty outside the tsetse area compared to inside. In terms of the density of poor people, it is the humid and sub-humid systems (whether mixed rainfed crop-livestock or rangeland-based livestock-only) that have higher densities of poor people within the tsetse areas compared to outside—for example twice the density of poor people in the mixed rainfed crop-livestock system in the humid and sub-humid zone occurs inside the tsetse areas (32 per square kilometer) compared with outside the tsetse areas (16 per square kilometer).

DISCUSSION AND FUTURE ANALYSIS

Much can be learned from overlaying maps showing livestock disease risk on top of maps of livestock distribution, livestock production systems, population, and poverty. The analysis above highlights that, in Uganda, the benefits of trypanosomiasis control are likely to be greatest

CATTLE NUMBERS			CATTLE DENSITY		
Total Cattle Population in Production System (number)	Within Trypanosomiasis Area		Average Cattle Density (number of cattle per square kilometer)		
	Total Cattle Population (number)	Share of Total Cattle Population in Production System (percent)	Within Production System	Within Trypanosomiasis Area	Outside Trypanosomiasis Area
412,821	18,934	4.6	21.9	5.0	26.2
157,479	93,139	59.1	9.1	7.3	14.0
38,076	2,248	5.9	31.7	7.1	40.6
608,376	***114,321***	***18.8***	***16.3***	***6.8***	***24.1***
1,505,110	181,143	12.0	41.4	23.8	46.1
2,405,160	1,344,260	55.9	24.9	22.8	28.2
722,366	145,113	20.1	45.4	40.4	46.9
4,632,636	***1,670,516***	***36.1***	***31.1***	***23.8***	***37.6***
281,514	117,891	41.9	18.1	12.9	25.5
5,522,526	**1,902,728**	**34.5**	**27.4**	**19.8**	**34.3**

Source: Authors' calculation. The data are derived from combining the tsetse distribution (Map 10), taking a threshold for the probability of presence of greater than 30 percent to indicate presence of tsetse and therefore trypanosomiasis, with maps of cattle densities (Map 3a) and livestock production systems (Map 1), using GIS overlay functions.

in the mixed humid and sub-humid systems: these areas have the largest absolute numbers of cattle, the greatest numbers of poor people, and the greatest densities of poor people. Moreover, control of cattle trypanosomiasis in mixed rainfed crop-livestock areas will have additional benefits from the associated crops, for example increases in manure, the potential for draft power, and better use of crop residues. But these systems cover large areas of Uganda—about half of the total land area. More focused targeting can be achieved in some other farming systems where the absolute numbers may not be quite so dramatic, but where the impact of trypanosomiasis may be even greater, albeit over smaller areas. The rangeland-based livestock-only systems in the humid and sub-humid zone, in particular, have the highest proportion of cattle in tsetse areas, have stocking rates inside the tsetse area of only half those outside, and have large differentials in poverty rates and densities inside and outside the tsetse areas.

Without systematic survey data it is not possible to say to what extent poor people in tsetse-infested areas depend on cattle for their livelihoods. To answer that would require survey data, representative at the level of the production system, that explicitly links: (1) household welfare (e.g., income, food security); (2) the role of cattle (e.g., ownership, income); and (3) the importance of trypanosomiasis in those cattle (e.g., mortality, morbidity).

Some indication of cattle ownership can be taken from Ellis and Bahiigwa (2003) who report on surveys conducted in three districts of Uganda in 2001: In Mbale District, which is mostly mixed humid and sub-humid, with some mixed temperate and tropical highlands (on the slopes of Mount Elgon) and a small area under 'other' systems, 37 percent of households own cattle. In Kamuli District, which is entirely mixed humid and sub-humid, 24 percent of households own cattle. In Mubende District, which is mostly mixed humid and sub-humid, with some mixed arid and semi-arid areas, 22 percent of surveyed households held cattle. On average they found about 30 percent of households to be engaged in cattle rearing.

Data from the new National Livestock Census (MAAIF and UBOS, to be published) reveal similar shares of cattle-owning households for Mbale, Kamuli, and Mubende Districts (31, 35, and 21 percent, respectively) for 2008 (see Map 2b). In fact, analysts working with the Ministry of Agriculture, Animal Industry and Fisheries and with national and local planning efforts can use these recent livestock data to establish more accurate estimates of cattle ownership by production system and, in turn, use these estimates to model the economic costs and benefits of different intervention strategies.

Such an economic model to estimate the benefits that would accrue from controlling the tsetse fly has been constructed for a regional priority setting study in the Horn of Africa, building on an approach developed for West Africa (Shaw et al., 2006). In a collaborative effort between the Intergovernmental Authority on Development's Livestock Policy Initiative and the Programme Against African Trypanosomiasis, livestock production systems have been

TABLE 3 UGANDA TRYPANOSOMIASIS RISK IN UGANDA: PEOPLE AND POVERTY PROFILE, 2005

Production System		HUMAN POPULATION			NUMBER OF POOR		
		Total Human Population in All Rural Subcounties in Production System (number)	Within Trypanosomiasis Area: Total Human Population (number)	Within Trypanosomiasis Area: Share of Total Human Population in Production System (percent)	Total Number of Poor in All Rural Subcounties in Production System (number)	Within Trypanosomiasis Area: Total Number of Poor (number)	Within Trypanosomiasis Area: Share of Total Number of Poor in Production System (percent)
Rangeland-Based Livestock-Only Systems	Arid and Semi-arid	652,986	25,071	3.8	476,304	12,350	2.6
	Humid and Sub-humid	726,849	371,140	51.1	411,765	203,520	49.4
	Temperate and Tropical Highlands	75,497	3,611	4.8	42,671	2,410	5.6
Total Rangeland-Based Livestock-Only Systems		***1,455,331***	***399,822***	***27.5***	***929,401***	***155,689***	***16.8***
Mixed Rainfed Crop-Livestock Systems	Arid and Semi-arid	2,822,061	152,645	5.4	1,093,965	49,136	4.5
	Humid and Sub-humid	12,759,447	5,128,704	40.2	4,651,206	1,869,793	40.1
	Temperate and Tropical Highlands	3,489,997	143,684	4.1	836,089	35,069	4.2
Total Mixed Rainfed Crop-Livestock Systems		***19,071,504***	***5,425,034***	***28.4***	***6,577,530***	***1,627,595***	***24.7***
Other Livestock Systems		2,554,436	666,428	26.1	687,760	168,533	24.5
TOTAL		**23,081,272**	**6,491,284**	**28.1**	**8,191,229**	**1,946,222**	**23.8**

defined and mapped according to the ratio of livestock- to crop-derived income, using information collected for livelihood analysis. This map has formed the basis for economic herd models analyzing the impact of trypanosomiasis in pastoralist, agropastoralist, and mixed farming systems.

Based on cattle population data, expert opinion, livelihoods surveys, and documented information, the mixed farming systems have been further subdivided into those with high and low use of draft animals and those dominated by dairy production. In essence, the herd model is parameterized separately to account for each of the production systems identified. Within each system, different parameters are also established for areas with and without tsetse fly and trypanosomiasis (e.g., different mortality rates, birth rates, yields). The herd models will then be run for a 20-year period, and outputs—milk, livestock sales, manure, draft power—will be monetarized. In this way, the financial benefits that would accrue over a 20-year period through removal of the tsetse vector will be modeled and mapped. It is expected that the results from this regional analysis will reinforce what is shown in the analysis above: that it will tend to be the systems where cattle and crop production are closely intertwined, often on the fringes of the tsetse distribution, which will see the highest potential benefits from controlling trypanosomiasis in livestock.

POVERTY RATE (percent)			POVERTY DENSITY (number of poor per square kilometer)		
Average Poverty Rate for All Rural Subcounties in Production System	Average Poverty Rate: Within Trypanosomiasis Area	Average Poverty Rate: Outside Trypanosomiasis Area	Average Poverty Density for All Rural Subcounties in Production System	Average Poverty Density: Within Trypanosomiasis Area	Average Poverty Density: Outside Trypanosomiasis Area
75.8	13.4	62.4	25.2	3.2	22.0
60.9	45.2	15.8	23.7	16.0	7.8
78.4	22.0	56.3	35.3	7.5	27.8
69.0	***28.3***	***40.7***	***24.8***	***9.2***	***15.6***
50.5	8.8	41.7	30.0	6.4	23.6
40.1	24.8	15.3	48.1	31.7	16.4
28.4	6.2	22.2	52.4	9.7	42.7
41.4	***18.7***	***22.3***	***44.1***	***23.2***	***21.0***
28.4	16.5	11.8	44.1	18.4	25.7
45.6	**20.4**	**25.1**	**40.5**	**20.2**	**20.3**

Source: Authors' calculation. The data are derived from combining the tsetse distribution (Map 10), taking a threshold for the probability of presence of greater than 30 percent to indicate presence of tsetse and therefore trypanosomiasis, with maps of poverty density (Map 5), population density, and livestock production systems (Map 1), using GIS overlay functions.