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**Pastoral Livelihoods and the Epidemiology of
Emergent Trypanosomiasis on the Jos Plateau,
Nigeria**

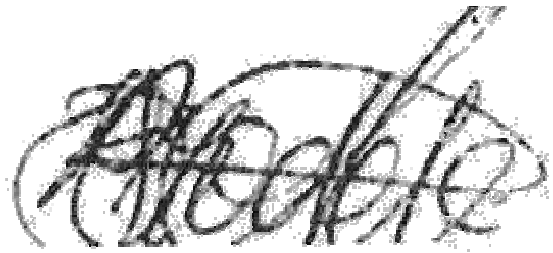
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Submitted in fulfilment of the requirements of the
degree of Doctor of Philosophy

The University of Edinburgh
2011

Declaration

I declare that the research described within this thesis is my own work and that this thesis is my own composition and certify that it has never been submitted for any other degree or professional qualification

A handwritten signature in black ink, appearing to read 'Ayodele Majekodunmi', written in a cursive style.

Ayodele Majekodunmi

Edinburgh, 2011

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Abstract

African trypanosomiasis is a widespread disease of livestock which is a major constraint to livestock production, mixed farming and the rural economy. The Jos Plateau in Nigeria was historically free of tsetse flies and trypanosomiasis and this lack of disease attracted large numbers of cattle keeping pastoralists. The area now plays an important role in the national/regional cattle industry, holding 300,000 pastoralists and over a million cattle, ~ 7% of the national herd. However, over the past twenty years tsetse flies have (re)invaded the Jos plateau and trypanosomiasis is now a significant problem. Little is known about the distribution and overall prevalence of the disease across the Jos plateau or about the habits and customs that could affect the epidemiology of the disease in this area. This knowledge is essential if successful interventions to reduce its impact are to be put in place.

To bridge this gap, a longitudinal two stage cluster survey was carried out in 2008 to determine the prevalence of bovine trypanosomiasis. The study showed that the prevalence of trypanosomiasis across the Jos plateau was 46.8% (39.0 – 54.5%) with no significant seasonal variation. *T. b. brucei* was present at a prevalence of 3.3% (1% – 5.5%); *T. congolense* savannah at a prevalence of 27.7% (21.8% - 33.6%); *T. vivax* at a prevalence of 26.7% (18.2% - 35.3%). Although there was no significant seasonal variation in prevalence across the Jos plateau, seasonal variations were observed at village level to create 3 distinct groups. Group 1 villages (50.0%) which followed the expected pattern of low prevalence in the dry season and high prevalence in the wet season; Group 2 villages (16.7%) where there was no seasonal variation; Group 3 villages (33.3%) where paradoxically the prevalence was higher in the dry season and lower in the wet season. This reversed epidemiological pattern is attributed to the harsh climatic conditions of the dry season which reduce resistance to infection in cattle and increase vector – host contact. Migration was shown to be a significant risk factor for trypanosomiasis infection and the dry season was shown to significantly increase the effect of all risk factors.

Participatory rural assessment was also conducted to investigate socio – economic factors and knowledge, attitudes and practices concerning tsetse and trypanosomiasis. The results of the participatory rural assessment exercise show that trypanosomiasis is well recognised by farmers on the Jos plateau. They are aware of the animal health and production disadvantages associated with it and make considerable efforts to control it, along with other livestock diseases. However, they lack the adequate knowledge to effectively control these diseases themselves and there are gaps in veterinary service provision. Wealth ranking showed that the majority of pastoralists in the study were either in the ‘middle’ or ‘better – off’ groups. Only 6.1% were classed as poor.

Anaemia as an indicator for trypanosomiasis was investigated and FAMACHA charts were evaluated as a potential penside test for anaemia. Results show that anaemia in cattle on the Jos Plateau is not strongly related to trypanosomiasis and that the FAMACHA chart is a poor test for anaemia in cattle.

List of Abbreviations

AAT	African Animal Trypanosomiasis
bp	Base pairs
CBAHW	Community based animal health worker
CATT	Card agglutination trypanosomiasis test
CSF	Cerebrospinal fluid
DNA	Deoxyribonucleic acid
FAO	Food and agriculture organisation
HAT	Human African trypanosomiasis
HCS	Haemoglobin colour scale
GIS	Geographical Information System
LGA	Local government area
PCR	Polymerase chain reaction
PCV	Packed cell volume
SOS	Stamp out sleeping sickness
TBR	<i>T. b. brucei</i>
TCS	<i>T. congolense</i> savannah
TV	<i>T. vivax</i>
T&T	Tsetse & trypanosomiasis
WHO	World Health Organisation

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Chapter 1: General Introduction

1.1 Pastoralism

Pastoralism describes the extensive mobile grazing of livestock on communal rangelands. A pastoral household is defined as one that obtains greater than 50% of its gross income from mobile livestock rearing on unimproved communal pastures (Rass, 2006). Pastoralists have also been defined as livestock keepers residing in areas with less than 400mm of annual rainfall and a growing period of 0 – 75 days where cropping is not practised; and who derive more than 50% of their agricultural income from livestock rearing through opportunistic grazing on communal land (Swift, 1988). Pastoralism is the primary production system practised in arid/semi-arid areas. Characteristic features of this production system include a high dependence on herbivorous livestock as the only practical means of transforming pasture and browse into food and income; and regular herd movements on communal land in response to erratic rainfall patterns. The form and degree of such movements determines further categorisation into nomadic, transhumant or sedentary pastoralists (Rass, 2006).

Nomadic pastoralists are characterised by high mobility and frequent, irregular movements of the entire household, both people and livestock. Movements tend to follow established migration routes but erratic rainfall and dynamic external conditions may necessitate deviations from these routes. Transhumant pastoralists undertake regular movements of their livestock between fixed locations to exploit seasonal availability of pasture. They often have a permanent home where women, children and older male members of the household reside permanently. Sedentary pastoralists are the least mobile group who remain in one location permanently and graze their livestock on communal lands around their homestead (Rass, 2006).

Globally, there are 120 million pastoralists, of which 50 million are found to reside in Sub-Saharan Africa where they comprise 12% of rural populations and 8% of the total population. Sub-Saharan Africa contains a high percentage of the world's pastoralists (42%), but is also home for the majority of the world's poor pastoralists (54%) (Rass, 2006). Despite this, investment in pastoral development has declined steadily over the past few decades and is not proportionate to the potential economic contribution of pastoralists to both local and national economies. This is due to general recognition that there is limited scope for increased production and productivity of the pastoral system to meet growing demand for livestock products (Oygaard et al, 1999; Rushton et a, 1999).

1.2 Agriculture and Trypanosomiasis

Agriculture is critical to the economy of countries in Sub-Saharan Africa and small-scale agriculture for food production is particularly important in rural areas. Agriculture contributes 33% to the GDP of Nigeria where 51% of the population (>77 million people) live in rural areas (World Bank, 2011). Livestock keepers rely on their animals for food, home consumption, transport, draught power and income from the sale of animals and animal products. But livestock production is constrained by livestock disease, which decreases it by 30% in developing countries; twice the effect it has in developed countries (F.A.O., 1990). This effect is mostly due to endemic diseases, in particular trypanosomiasis, tick borne diseases and helminthiases that decrease production and increase mortality.

Supply and value of animal products is compromised in areas of tsetse and African animal trypanosomiasis (AAT) risk. The presence of tsetse and AAT reduces cattle density by 37 – 70%, reduces offtake by 50%, reduces calving rate and increases calf mortality by 20%

(Swallow, 2000). The immunosuppressive effects of AAT also exacerbate the effects of other endemic diseases, further compromising animal health and productivity. Hendrickx *et al.* (2000) showed that cattle density and the level of integration of cattle with crop farming is closely associated with the presence of AAT. The annual production losses due to AAT morbidity and mortality are valued at \$4.5 billion across Africa whilst the indirect annual costs of AAT are estimated to be \$134 million (Budd, 1999; Kristjanson *et al.*, 1999). The disease costs the Nigerian economy \$135 million per annum due to its negative effects on weight gain, growth rate, milk yield, reproduction of cattle and its discouragement of the use of draught animals in arable farming. The national herd could be doubled or tripled in size with associated economic benefits in the absence of AAT (Omotainse *et al.*, 2004).

In the past, control efforts against animal disease, including tsetse and trypanosomiasis were coordinated and subsidised or provided for free by government agencies. The current dispensation of liberalised economies and free markets has led to privatisation of veterinary services and a shift in the focus/priorities of government agencies from endemic diseases to epidemic, emerging and transboundary diseases. Farmers are now largely responsible for the control of endemic diseases in their animals. Current animal disease control is characterised by poor access to professional veterinary services, high disease control costs, lack of animal disease knowledge and training and unregulated access to controlled drugs (Odeyemi, 1999; Rass, 2006). As a result, there is less efficient disease control, a decline in animal health and widespread misuse of drugs.

Trypanocides are the most widely used veterinary drugs in Sub-Saharan Africa, regardless of presenting signs or diagnosis. Farmers need tools for accurate diagnosis, improved access to veterinary services, appropriate access to drugs and vaccines against endemic diseases and the knowledge to wield these tools effectively (Machila, 2004). These tools are not always

available to both farmers and rural animal health workers (Kamara *et al.*, 1995; Kamuanga *et al.*, 1997; Doran and van den Bossche, 1998; Sinyangwe and Machila, 1998; van den Bossche *et al.*, 2000). Unrestricted access to veterinary drugs and poor drug administration practices has led to concerns of both toxicity and drug resistance. Isolated cases of drug resistance have been reported but the scale of the problem remains unknown (Eisler *et al.*, 1997, 2000; Geerts *et al.*, 2001). There are few prospects of new drug development due to the poor market strength and high costs involved and it is imperative that the onset of drug resistance be prevented or at least delayed.

1.3 Rationale

The Jos Plateau is well known as a tsetse free area and is widely represented as such in the scientific literature. Its classification as a tsetse free area is used in predictive mapping to set current limits of tsetse habitats and predict future limits. (Ford & Katondo, 1977; Hendrickx, 2001; Rogers & Randolph, 1991; Rogers, 1993).

In turn, risk maps enable us to do the following:

- Identify possible disease clusters
- Define and monitor epidemics
- Provide baseline data on health patterns
- Target control measures and resources
- Show changes in disease patterns over space and time
- Initial exploration between disease and possible risk factors

However, there is a significant body of evidence demonstrating that tsetse flies and animal African trypanosomiasis have been present on the Jos Plateau since the 1980s (Majekodunmi, 2006). Despite the fact that this evidence had been available in the literature for over a

decade, there seems to be very little awareness of the situation in both the general public and the scientific community.

This lack of awareness is significant as the change in tsetse status has far reaching implications for animal health and welfare, livestock productivity, pastoral incomes and the rural economy. The change in tsetse status also means that we may have to revise accepted ideas about tsetse behaviour and ecology and the limits of tsetse habitats, all of which will lead to new ideas about the epidemiology of tsetse and trypanosomiasis, the effects of animal trypanosomiasis and the risk of human trypanosomiasis.

I became very conscious of this gap in the literature and wanted to investigate the process of tsetse expansion/invasion onto the Jos plateau and ascertain the origin of the tsetse flies and trypanosomes present in the area. I was dissatisfied with accounts of the current T & T situation in the literature: the majority of studies were conducted in isolated areas of plateau, with little consideration of the whole plateau as a distinct ecosystem. I was also curious about the state of disease monitoring and surveillance and animal health care provision in the area because these determine the awareness of the situation on ground and the ability to respond and adapt to it.

During my first few visits to the area it became apparent that humans could not be left out of the study. Humans have a fundamental responsibility to ensure animal welfare but livestock are important because of the people who depend on them to provide food, livestock derived products, income and employment. Therefore, any inputs or improvements in the livestock sector are for the ultimate benefit of humans and any changes for the worse will have negative effects on the human population. So it became necessary to include humans and human activities in the traditional triangle of host, vector and parasite used in traditional

analysis of animal African trypanosomiasis . Humans are often viewed by natural scientists as being ‘outside nature’, only exerting external influences on the ecosystem (Waltner-Toews et al, 2003). As such, their involvement in the process of studying and managing ecosystems is limited to politics and decision making. This view is incomplete and creates a false dichotomy between scientific and social data, such that there is little emphasis on social analysis in ecosystem management. (Endter-Wada et al, 1998). This means that social and political components of ecosystems are often misunderstood or ignored and there is vigorous debate as to whether it is possible to balance social science and ecological aspects to achieve sustainable management of ecosystems. (Grumbine, 1994; Noss & Cooperrider, 1994; Wahner, 1993; Wood, 1994). Despite the variety of opinions, it is clear that social science data and its analyses have a role to play in our understanding of ecosystems. I agree with Endter-Wada et al (1998) who propose a framework for maximising the potential of social sciences in understanding ecosystems in which ecological data must be supplemented with scientific analysis of relevant social factors. The goal of my research is to understand the T&T system on the Jos plateau as a precursor and prerequisite to positive intervention and so I felt it necessary to investigate relevant social factors alongside the ecological aspects of the study.

Based on these factors, the idea for a three part study to cover the whole of the Jos Plateau evolved:

- A longitudinal study of bovine trypanosomiasis to provide ecological data about trypanosomes in their primary host. A concurrent study of the tsetse vectors was planned but had to be abandoned due to financial and logistic constraints.

- A comprehensive investigation of social factors, including knowledge, attitudes and practices concerning trypanosomiasis to ascertain human activities which affect or are a response to T&T; Pastoral livelihood assessment to provide a wider context for how cattle and T&T affect pastoral life and rural development; herd productivity to determine the economic viability of keeping cattle and how this is affected by T&T.
- Evaluation of FAMACHA cards as a penside diagnostic tool as a first step towards bridging the gap in current veterinary service provision.

1.4 Tsetse and Trypanosome Biology

1.4.1 The Parasite

African trypanosomiasis is caused by several protozoa of the genus *Trypanosoma*. The main species and their hosts are listed in table 1.1 below. Those of significant economic importance, especially for cattle, are given in bold.

Trypanosome Species	Host Range
<i>T. brucei brucei</i>	All domestic mammals, camels, antelope, carnivores
<i>T. brucei gambiense</i>	Humans, pigs and sheep
<i>T. brucei rhodesiense</i>	Humans, all domestic mammals, antelope, other game
<i>T. congolense</i>	Bovids, equids, sheep, goats, camels, pigs, dogs and mice
<i>T. vivax</i>	Wild and domestic ungulates
<i>T. evansi</i>	Bovids, equids, sheep, goats, camels, pigs, dogs and mice
<i>T. equiperdum</i>	Equids
<i>T. godfreyi</i>	Suids
<i>T. grayi</i>	Crocodiles
<i>T. lewisi</i>	Rats worldwide
<i>T. simiae</i>	Suids
<i>T. theileri</i>	Domestic and wild ruminants worldwide

Table 1.1: Trypanosome species and their hosts

1.4.2 The Vector

Trypanosomes are transmitted by tsetse flies of the genus *Glossina* which has 3 distinct subgenera:

- *Glossina* sensu stricto: commonly known as the morsitans or savannah group; contains 7 species
- *Austenina*: commonly known as the fusca or forest group; contains 15 species
- *Nemorhina*: commonly known as the palpalis or riverine group; contains 9 species

Table 1.2 lists the most important species and the trypanosomes they transmit

Subgenus	Species	Trypanosomes transmitted
<i>Austenina</i>	<i>G. vanhoofi</i>	<i>T. vivax</i>
	<i>G. brevipalpis</i>	<i>T. congolense</i>
<i>Nemorhina</i>	<i>G. tachinoides</i>	<i>T. vivax, T. b. gambiense, T. congolense, T. b. brucei</i>
	<i>G. fuscipes</i>	<i>T. b. rhodesiense, T. b. gambiense, T. b. brucei</i>
	<i>G. palpalis</i>	<i>T. vivax, T. b. gambiense, T. congolense, T. b. brucei,</i>
<i>Glossina</i>	<i>G. longipalpis</i>	<i>T. vivax, T. congolense</i>
	<i>G. pallidipes</i>	<i>T. vivax, T. b. rhodesiense, T. congolense, T. b. brucei</i>
	<i>G. morsitans</i>	<i>vivax, T. b. rhodesiense, T. b. gambiense, T. congolense, T. b. brucei</i>
	<i>G. swynnertoni</i>	<i>T. vivax, T. b. rhodesiense, T. congolense, T. b. brucei</i>

Table 1.2: Trypanosomes transmitted by important species of *Glossina*

1.5 Animal African trypanosomiasis

Animal African trypanosomiasis (AAT) also known as Nagana is caused by *T. vivax*, *T. congolense* and *T. brucei brucei*. It is of great economic importance in Africa as 50 - 70 million cattle are at risk and 3 million die of this disease every year. It restricts livestock production over 10 million km² and is responsible for economic losses of \$4.75 billion a year (Eisler *et al.*, 2004b). Infection with these trypanosomes causes anorexia, anaemia, diarrhoea, staring coat, excessive lachrymation, emaciation, weakness and eventually death. The hyperacute form causes bleeding from natural orifices and in the heart, pleural cavity, peritoneum and diaphragm, which are visible on post mortem. Sheep and goats infected with *T. brucei* species may also show neurological signs such as staggering and paralysis (Taylor and Authie, 2004).

1.5.1 Diagnosis

The majority of people responsible for the treatment and prevention of AAT have no access to any diagnostic facilities. As such, even though the clinical signs of AAT are non-specific and cannot give a definitive diagnosis, the ability of individuals to recognise and correctly interpret these signs is probably the most important factor in AAT diagnosis today. Parasitological diagnosis is based on light microscopy of different preparations, with varying sensitivity and specificity: wet blood films, thin and thick giemsa stained fix blood films, haematocrit centrifugation technique and buffy coat technique. These are the most widely available diagnostic tests available in rural African settings and the buffy coat and haematocrit methods are the most widely used tests for trypanosomiasis.

Xenodiagnosis demonstrates trypanosomes by transferring infection from the suspected case to a different host, vector or *in vitro* culture system. Despite the opportunity it provides to prepare stabilates of the infected trypanosomes for further investigation, this method is not frequently used. Immunological methods are a useful alternative to demonstration of trypanosomes, which may not always be possible. Methods include indirect fluorescent antibody test (IFAT), card agglutination trypanosomiasis test (CATT), antigen detection enzyme linked immunosorbent assay (ELISA) and antibody detection ELISA. These methods are expensive and complicated are better suited to research than field diagnosis.

There are many molecular techniques for the detection of trypanosome genetic material but it is the polymerase chain reaction (PCR) that is most often used for diagnostic purposes. It is based on the repeated amplification of the target DNA, which is subsequently identified using primers with a complementary base pair sequence. Species specific primers have been developed for 11 species/subspecies of trypanosomes, targeting genetic markers such as the 177 bp repeat or the mini exon (Desquesnes and Davila, 2002). Application of this method to field based studies has highlighted the low sensitivity of microscopy $2.5 \times 10^2 - 5 \times 10^3$ parasites/ml of blood (Picozzi *et al.*, 2002) and low specificity of trypanosome identification by movement pattern in host blood and developmental site in tsetse. In contrast, PCR can detect 1 parasite/10ml of blood (1×10^{-1} parasite genetic material/ml) (MacLeod *et al.*, 1997; Morrison *et al.*, 2007) and specifically designed primers give high species specificity. Despite these advantages, species specific PCRs are not ideal for use in large-scale studies as each sample must be subjected to 8 – 10 separate PCRs which is expensive and time consuming. The internal transcribed spacers of rRNA have a high copy number and interspecies length variation, making them ideal genetic markers. Desquesnes and colleagues (2001) used this target to develop a generic

PCR able to detect multiple trypanosome infections. This was further optimized for use in diagnosing infections in cattle and tsetse by Cox and others (2005) and Adams and others (2006) respectively. Table 1.4 summarises the primers available for PCR diagnosis of trypanosomiasis.

Species specific PCR	Reference	Generic ITS PCR	Reference
<i>T. congolense savannah</i>	Moser <i>et al.</i> , 1989	<i>T. congolense savannah</i>	Desquesnes <i>et al.</i> , 2001
<i>T. congolense Kilifi</i>	Moser <i>et al.</i> , 1989	<i>T. congolense Kilifi</i>	Desquesnes <i>et al.</i> , 2001
<i>T. congolense forest</i>	Moser <i>et al.</i> , 1989	<i>T. congolense forest</i>	Desquesnes <i>et al.</i> , 2001
<i>T. vivax</i>	Masake <i>et al.</i> , 1997	<i>T. vivax</i>	Desquesnes <i>et al.</i> , 2001
<i>T. vivax West Africa</i>	Dickin and Gibson 1989	<i>T. brucei s.l.</i>	Desquesnes <i>et al.</i> , 2001
<i>T. brucei s.l.</i>	Moser <i>et al.</i> , 1989	<i>T. simiae Tsavo</i>	Desquesnes <i>et al.</i> , 2001
<i>T. brucei rhodesiense</i>	Welburn <i>et al.</i> , 2001	<i>T. simiae</i>	Desquesnes <i>et al.</i> , 2001
<i>T. brucei gambiense</i>	Bromidge <i>et al.</i> , 1993	<i>T. godfreyi</i>	Adams <i>et al.</i> , 2006
<i>T. simiae Tsavo</i>	Majiwa <i>et al.</i> , 1993	<i>T. theileri</i>	Desquesnes <i>et al.</i> , 2001
<i>T. simiae</i>	Majiwa and Webster 1987	<i>T. evansi</i>	Desquesnes <i>et al.</i> , 2001
<i>T. godfreyi</i>	Masiga <i>et al.</i> , 1996	<i>T. equiperdum</i>	Desquesnes <i>et al.</i> , 2001
		<i>T. grayi</i>	Adams <i>et al.</i> , 2006

Table 1.3 Primers available for PCR diagnosis of trypanosome infection

1.5.2 Treatment

The variety of drugs available for both treatment and prophylaxis as shown in Table 1.4:

Active Ingredient	Trade Names	Species	<i>Trypanosoma Spp.</i>	Main Action
Diminazene aceturate	Berenil	Cattle	<i>T. vivax, T. congolense,</i>	Curative
	Veridium Many others	Dogs	<i>T. brucei</i> <i>T. evansi, T. congolense,</i> <i>T. brucei</i>	
Homidium bromide	Ethidium	Cattle	<i>T. vivax, T. congolense,</i> <i>T. brucei</i>	Curative
		Equids	<i>T. vivax</i>	
Homidium chloride	Novidium	Cattle	<i>T. vivax, T. congolense,</i> <i>T. brucei</i>	Curative
		Equids	<i>T. vivax</i>	
Isometamidium chloride	Samorin	Cattle	<i>T. vivax, T. congolense,</i> <i>T. brucei</i>	Curative and prophylactic
	Trypamidium			
	Veridium			

Table 1.4: Drugs available for treatment and prophylaxis of AAT

1.6 Human African Trypanosomiasis

Human African trypanosomiasis (HAT) or sleeping sickness is caused by *T. brucei gambiense* and *T. brucei rhodesiense* which are geographically separated by the Great Rift Valley so that *T. b. gambiense* occurs in West and Central Africa and *T. b. rhodesiense* occurs in East and Southern Africa. Sixty million people are at risk and it is estimated that 250,000 – 500,000 are infected with HAT (WHO, 1998). The acute form of HAT caused by *T. b. rhodesiense* parasites is a zoonosis and domestic cattle are the predominant animal

reservoir. The role of animal reservoirs for *T. b. gambiense* HAT remains controversial. Several domestic and wild animals have been identified as susceptible to the parasite (Gibson *et al.*, 1978), however, only the domestic pig has been shown to act as a true reservoir as it is associated with incidence and persistence of *T. b. gambiense* HAT (Magona *et al.*, 1999; Simarro *et al.*, 2001; Nkinin *et al.*, 2002; Onah and Ebenebe, 2003). Both sub species of sleeping sickness parasite have markedly different pathologies although they cause the same signs and symptoms. *T. b. gambiense* causes Gambian sleeping sickness, a chronic disease of insidious onset. It has a long asymptomatic period and may persist for years. *T. b. rhodesiense* causes Rhodesian sleeping sickness, an acute disease of rapid onset which persists for weeks or months. Both are universally fatal if not treated. Fatality is associated with febrile illness and subsequent meningoencephalitis. Table 1.5 lists the symptoms of both early and late stage sleeping sickness.

Stage 1	Stage 2
Chancre at site of inoculation	Persistence and worsening of stage 1 signs
Local oedema	Daytime somnolence and narcolepsy
Skin rash and pruritus	Reduced attention span and mental alertness
Adenopathy	Loss of muscle tone
Deep hyperaesthesia	Psychiatric problems: aggression, delirium, manic episodes, dementia, melancholia
Endocrine dysfunction	Hypertonicity/hypotonicity and tremors
Cardiovascular disturbance	Coma and death

Table 1.5: Pathology of HAT

1.6.1 Diagnosis

Clinical suspicion may offer indirect evidence of trypanosome infection but symptoms are highly variable and non-specific. Clinical diagnosis must be used as a basis for treatment, stage determination and to assess treatment failure. Direct evidence of trypanosome infection is obtained by microscopic examination of lymph, blood or cerebrospinal fluid (CSF). This is mandatory for definitive diagnosis. The various methods used for this are laborious but not very sensitive and are therefore limited to use in clinical/serological suspects. Apart from this low sensitivity, trypanosomes can be difficult to detect if parasitaemia is low. Therefore failure to demonstrate parasites should never be used to exclude infection.

The different techniques available include:

- Wet films of blood/lymph/CSF/chancere aspirate
- Thick films of blood/lymph/CSF/chancere aspirate
- Microhaematocrit centrifugation technique
- Quantitative buffy coat
- Mini anion exchange centrifugation technique

Indirect evidence of trypanosome infection can be obtained by the demonstration of specific antibodies or parasite antigens in serum. These are generally less laborious than the parasitological methods and their development represents a significant breakthrough in the diagnosis of HAT. Reliable antigen detection tests are yet to be developed and positive results in antibody detection tests must be interpreted with care because antibodies can persist for three years after an infection is cured. For antibody detection tests, the type of

antigen chosen determines the sensitivity and specificity of the test. Variant surface glycoproteins (VSGs) are preferred for *T. b. gambiense* while non-variable antigens are preferred for *T. b. rhodesiense*. Techniques available include:

- Immunofluorescence assay
- ELISA
- Immune trypanolysis
- Card agglutination test for trypanosomiasis (CATT) (*T. b. gambiense* only)
- Haemagglutination
- Latex agglutination test (*T. b. gambiense* only)

Only the rapid agglutination tests are useful in the field and the CATT test is widely used. All others are better suited to remote laboratory testing of samples. Method for molecular diagnosis of sleeping sickness parasites are described in section 1.4.1.

1.6.2 Treatment

Treatment depends on the stage of disease diagnosed in the patient. Few drugs are available as shown in table 1.6:

Drug	Date	Spectrum of Activity	Stage	Important Points
Suramin	1922	<i>T. b. rhodesiense</i>	Stage 1	5 day course over 3 weeks; Causes renal damage; 1 in 20,000 patients die
Pentamidine	1937	<i>T. b. gambiense</i>	Stage 1	10 day course; Can be used for mass chemoprophylaxis
Melarsoprol	1949	<i>T. b. gambiense</i> <i>T. b. rhodesiense</i>	Stage 1,2	3x 3 day course; Causes reactive encephalopathy; High mortality, up to 18%
Eflornithine	1981	<i>T. b. gambiense</i>	Stage 1,2	7 day course; Costly & not widely available; Trypanostatic, so requires functioning immune system to cure disease;

Table 1.6 Drugs available for treatment of HAT (Smith *et al.*, 1998; Pepin and Meda, 2001; Stich *et al.*, 2003; Buscher and Lejon, 2004; Stevens and Brisse, 2004)

1.7 History of Tsetse and trypanosomiasis in Nigeria

1.7.1 Tsetse distribution and control

Tsetse flies are found in Nigeria between latitudes 4°N – 12°N with northern extensions along the Hadeija - Jama'ari river valley, flowing into Lake Chad. Eleven species of *Glossina* infest 80% of the country and 4 of these are important in disease transmission: *G. morsitans submorsitans*, *G. palpalis*, *G. tachinoides*, and *G. longipalpis*. The tsetse free 20% of Nigeria consists of the Sahel savannah in the far north and includes Jos, Obudu and Mambilla plateaux (Onyiah, 1983). A further 22.8 % of land was recovered when tsetse flies were eradicated from the North East of Nigeria by ground and aerial spraying of DDT from 1956 – 1978 and by 1980, 35.77% had been reclaimed, bringing the area infested to 44.3% and the area free of tsetses to 55.7% in the 1980s (Onyiah, 1983; Ikede *et al.*, 1987) (see figures 1.1, 1.2 and 1.3.).

Successful tsetse control is feasible in northern Nigeria because it has a generally hot, dry climate with guinea savannah, sudan savannah and sahel vegetation, all of which make it less suitable for tsetse survival than wetter areas with denser vegetation. Hence the successful large scale control programmes carried out in the north east between 1956 and 1980 and plans to carry out new eradication programmes in the north west (Jordan, 1986; Hendrickx, 2001). However, reclaimed areas are at perpetual risk of re-invasion from adjacent infested areas unless preventive measures are implemented and sustained. Unfortunately, measures against re-invasion were not sustained due to economical constraints and much of the areas cleared of tsetse flies have been reinfested. Immediately after the eradication programme, the Jos plateau was only exposed to the threat of re-

invasion from the south-west, whereas now that previously reclaimed areas are re-infested with tsetse flies, it is exposed on all sides. Hargrove (2000) states that areas cleared of tsetse flies are lost at a rate of 100km² a year when exposed to the threat of re-invasion from one direction but that if exposed on all sides, an area of 10,000km² could be lost in 2 years.

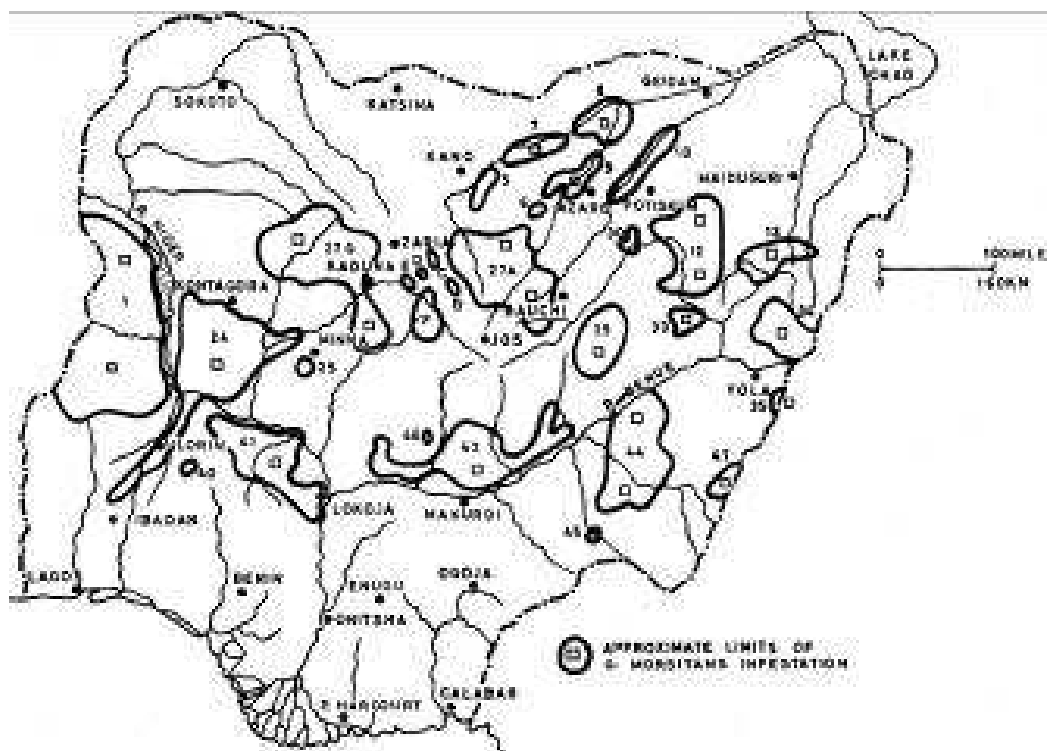


Figure 1.1a: Distribution of *G. m. Submorsitans* (Davies, 1977)

17.2% of the country infested (Onyiah, 1977)

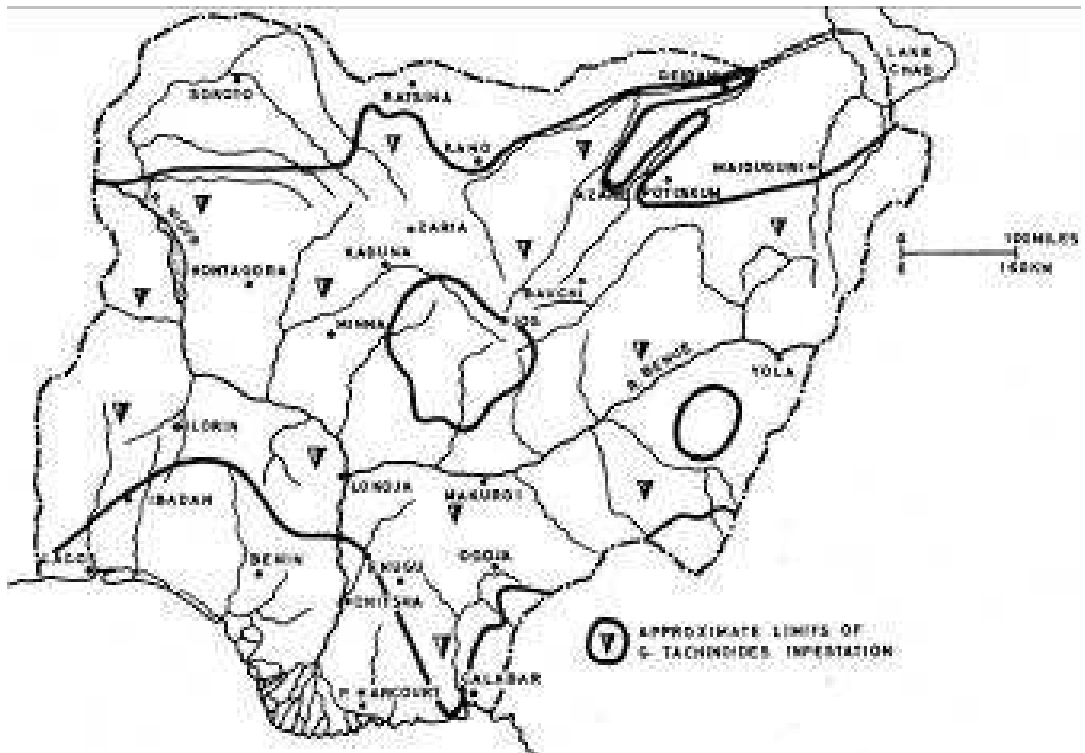


Figure 1.1d Distribution of *G. tachinoides* (Davies, 1977)

67.3% of the country infested (Onyiah, 1977)

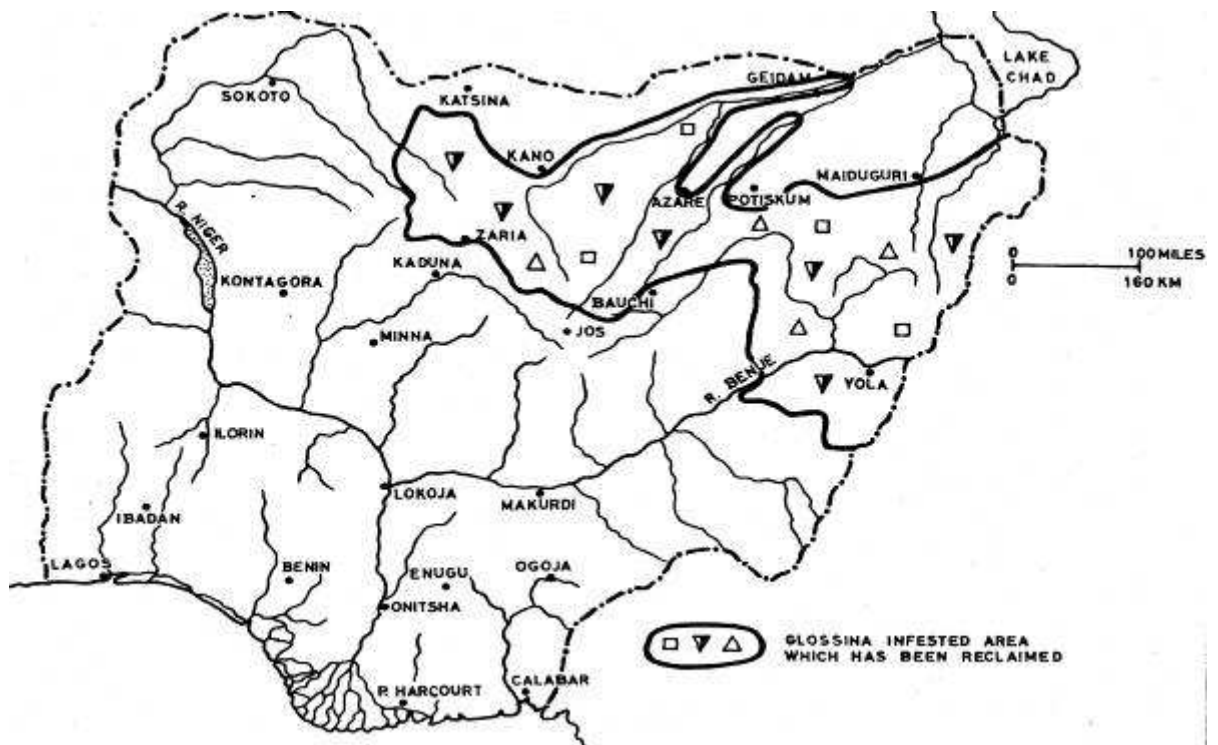


Figure 1.2 Area reclaimed from tsetse flies by 1975 (Davies 1977)

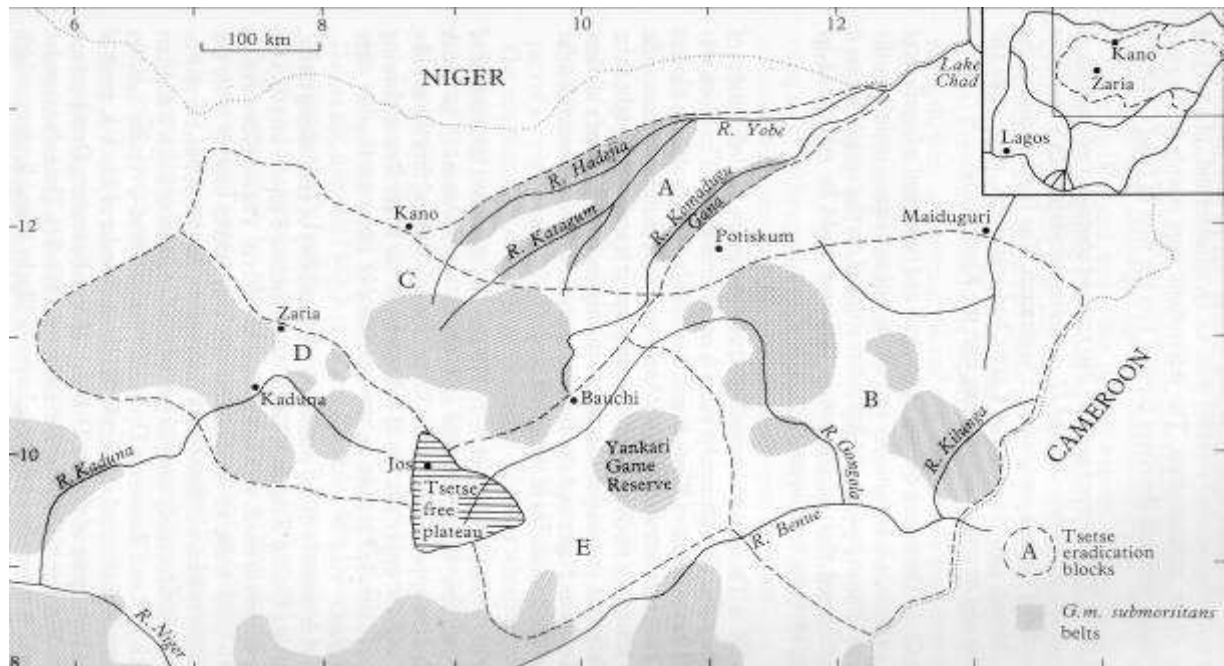


Figure 1.3: Tsetse eradication schemes in Northern Nigeria (Jordan 1986)

1.7.2 Animal African Trypanosomiasis

There is a long history of recognition, avoidance and control of AAT in Nigeria. Fulani herdsman and cavalry have been aware of the disease since pre-colonial times and the position of tsetse belts has played a significant role in determining the routes and limits of their grazing grounds and military operations (Glover, 1965; Bourn *et al.*, 2001). The distribution of AAT corresponds with that of the vectors and the disease is therefore endemic in all tsetse-infested areas of the country. Indeed this is the main reason for the concentration of livestock in the northern half of the country where tsetse levels are lower. The high tsetse and trypanosomiasis risk in the humid south made it very difficult to keep cattle and equines alive and profitable and only small numbers of trypanotolerant taurine cattle were kept. Even today when there are effective control strategies for trypanosomiasis

and other diseases, the number of cattle and equines kept in the humid zone is still much lower than the potential carrying capacity.

Although it having been identified as a major hindrance to the livestock trade (and associated taxes) since the 1920s, sleeping sickness was the priority for tsetse and trypanosomiasis control efforts until the 1950s. At this time, sleeping sickness control measures were established and prevalence was declining, and perhaps more importantly, effective trypanocides became available. A successful treatment programme for pastoral cattle was established by the 1970s (see figure 1.4) and this effectively reduced the AAT problem across much of Northern Nigeria. In the late 1970s the majority of treatments across the savannah and were for prophylactic purposes, given to cattle about to be trekked through tsetse belts on their way to market or during their annual transhumance (Bourn, 1983; Ikede *et al.*, 1987).

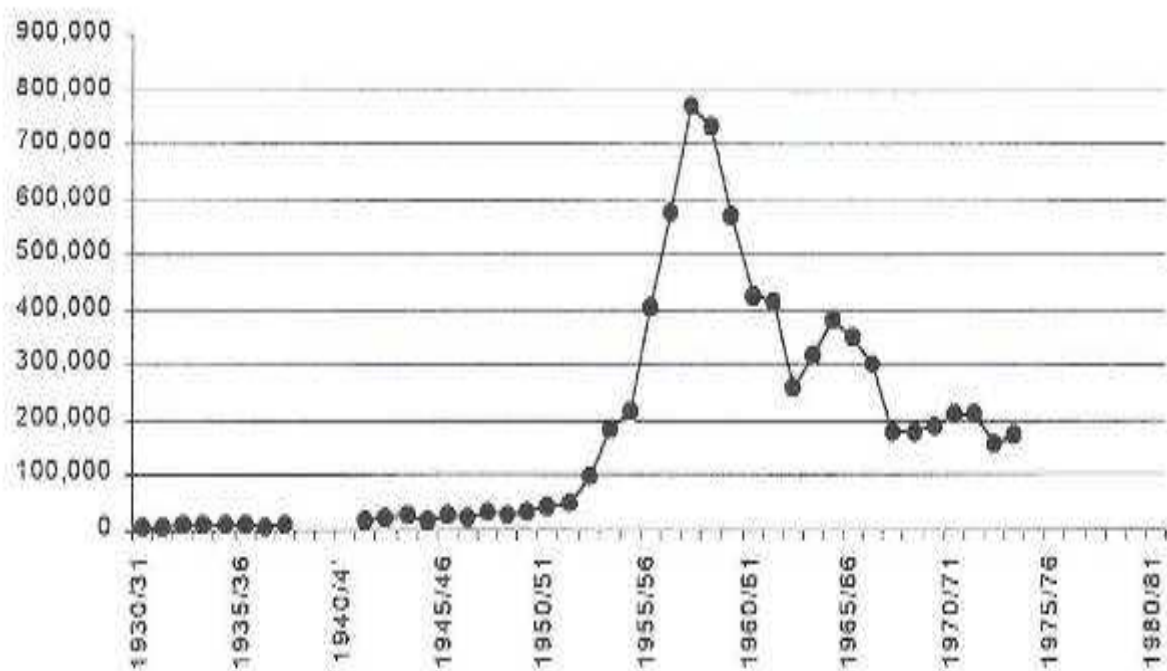


Figure 1.4: Numbers of cattle treated by Veterinary Tsetse and Trypanosomiasis Unit (Glover, 1965)

1.7.3 Human African Trypanosomiasis

Human African trypanosomiasis has existed in West Africa for hundreds of years, as an endemic disease in scattered foci associated with large rivers from Senegal to Angola. During the pre-colonial era in Nigeria, sleeping sickness was reported in association two primordial foci: the Niger-Benue river valley in the North-Central region and the Lake Chad basin in the North-East. There is long standing evidence of sleeping sickness in the Niger-Benue valley up to 100 miles on either side of the confluence of both rivers. All reports point to the disease being confined to the river valley and the people of northern Nigeria associated tsetse flies with livestock disease and not human disease (Duggan, 1962). In the southern part of the country, specifically the south-east, sleeping sickness also has a long history where it is endemic in scattered communities on the eastern banks of the Niger, along its major tributaries and in the Niger Delta area. These include the historical foci of Abraka (Delta state) and Gboko (Benue state) and from the 1980s onwards Ndokwa, Ika, Orhionwon and Ethiope Local Government Areas in Delta state (Olise and Ukah, 1984; Edeghere *et al.*, 1989; Edeghere *et al.*, 1998; Airauhi *et al.*, 2001).

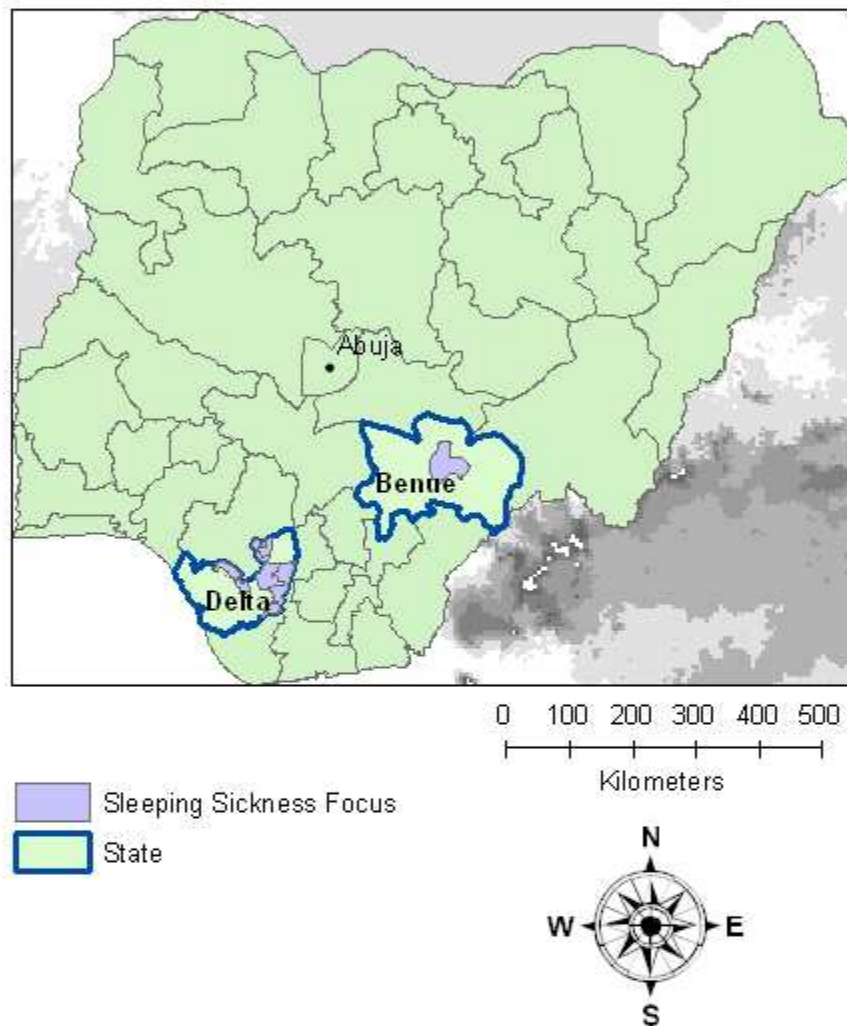


Figure 1.5: Sleeping sickness foci in southern Nigeria(Olise and Ukah, 1984; Edeghere et al., 1989; Edeghere et al., 1998; Airauhi et al., 2001)

In the early years of Lord Lugard’s new colonial government, British troops put an end to inter tribal conflicts and slave raiding (the so called “*pax Britannica*”) and several roads and railways were built to facilitate administration and troop movement. The subsequent peace and ease of movement effectively opened up the interior of northern Nigeria. Areas that had been depopulated or rendered unsafe by former conflicts were resettled leading to the establishment of an agrarian population across the north with good roads and rail access to the Niger-Benue Valley. As a result, many contagious diseases flared into epidemics (e. g.

meningitis, smallpox) and by 1912, sleeping sickness was spreading into northern Nigeria along the communication routes. The introduction of the disease into areas where it was previously unknown led to high morbidity and mortality because communities had little knowledge or experience of the disease. The earliest epidemics died out when the local population was decimated or dispersed, further spreading the disease.

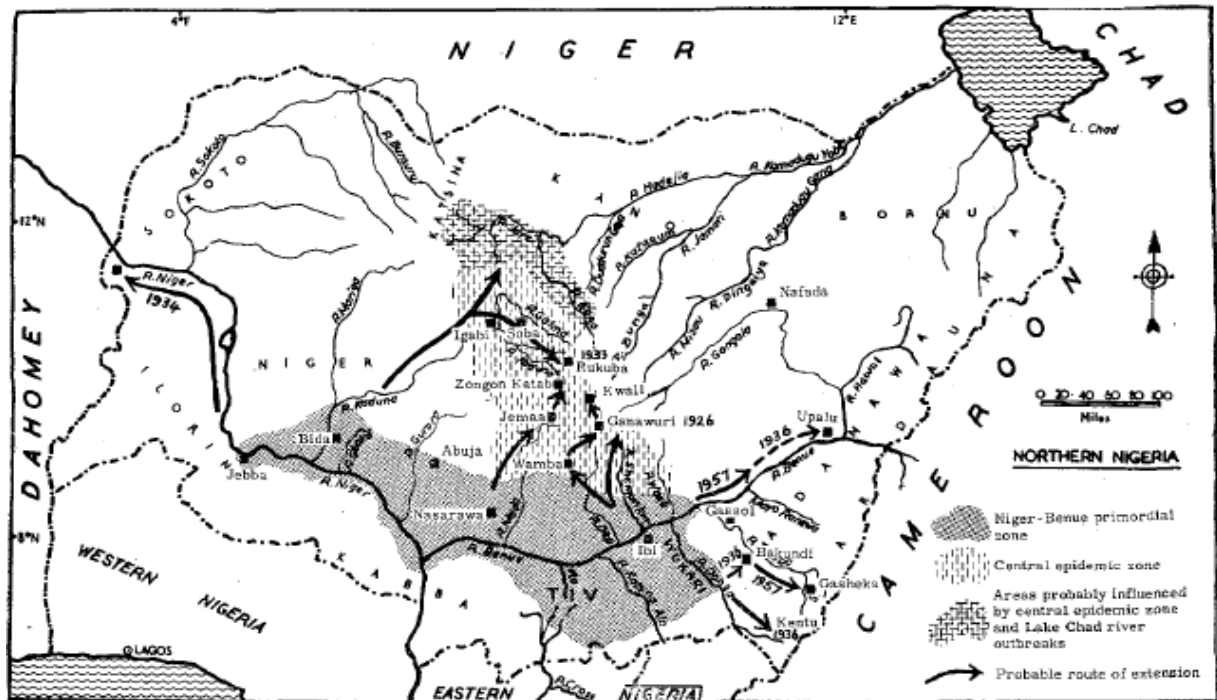


Figure 1.6 Sleeping sickness extensions from the Niger – Benue primordial focus
(Duggan, 1962)

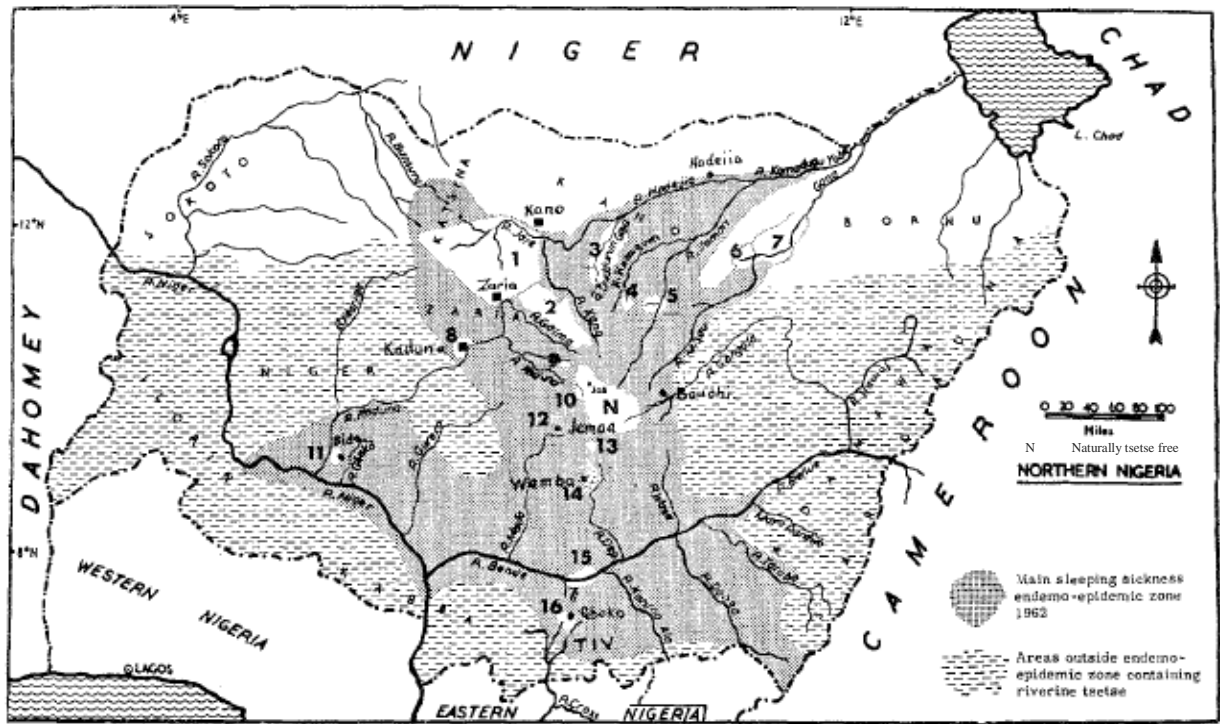


Figure 1.7: Extent of sleeping sickness epidemic and area of potential extension showing sleeping sickness control schemes across Northern Nigeria (Duggan, 1962)

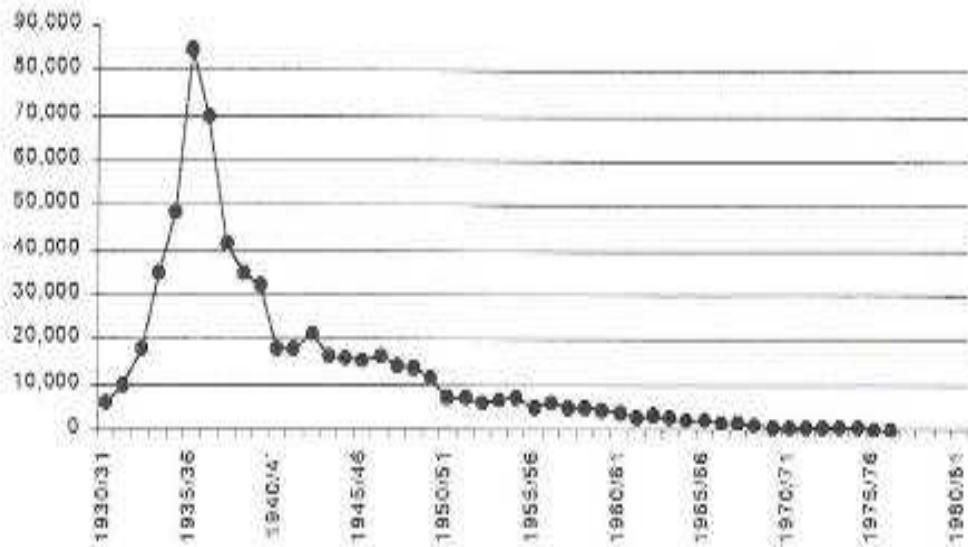


Figure 1.8: Numbers of sleeping sickness cases treated by the Sleeping Sickness Service (Glover, 1965)

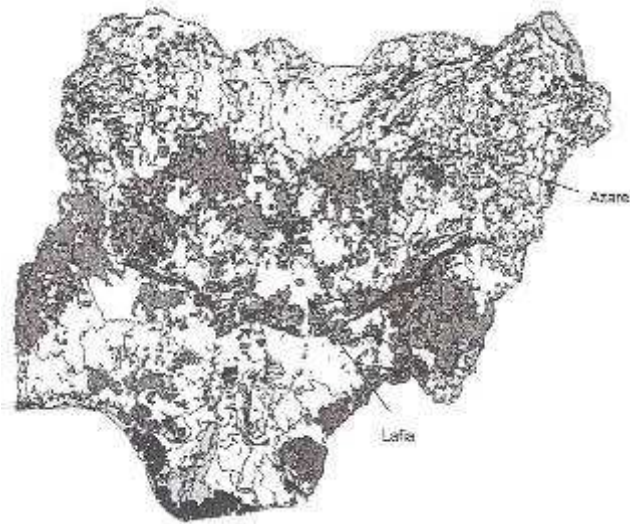
The Lake Chad primordial focus is coincident with the presence of *G. tachinoides* along rivers draining into Lake Chad. Sleeping sickness outbreaks occurred in the area in 1859, 1886 and 1921. Local communities had good knowledge of the disease and were known to practice preventive measures. Outside these epidemic periods, the disease maintained a low endemic status. HAT was present in epidemic proportions in northern Nigeria between the 1930s and 1960s. A successful active surveillance and treatment programme that was established in the early 1930s contributed greatly to the subsidence of the epidemic as shown in figure 1.10 below. The current status in the north is unknown as no surveillance is undertaken but is probably endemic at low levels (Coker *et al.*, 2000).

1.8 Current Tsetse and Trypanosomiasis Situation in Nigeria

There have been several material changes in tsetse distribution in the past 30 years.

- Decline of *G. morsitans submorsitans* and *G. longipalpis* belts in the North East and Central zones (Onyiah, 1977; Jordan, 1986; Omoogun *et al.*, 1991; Omotainse *et al.*, 2004).
- Expansion of *G. palpalis* and *G. tachinoides* belts onto the Jos plateau with peridomestic activity in Bachit (Kalu, 1996; Dede *et al.*, 1997; Dede *et al.*, 1998).
- Increased density of *G. palpalis* and *G. tachinoides* in nearby Nassarawa, Benue, Niger and Taraba states, with tsetse activity in peridomestic areas (Dede *et al.*, 1998; Ahmed, 2004; Omotainse *et al.*, 2004)
- Re-infestation of the areas previously reclaimed from tsetse flies in the North Eastern states of Adamawa, Taraba, and Bornu (Bature, 1995).

a



b

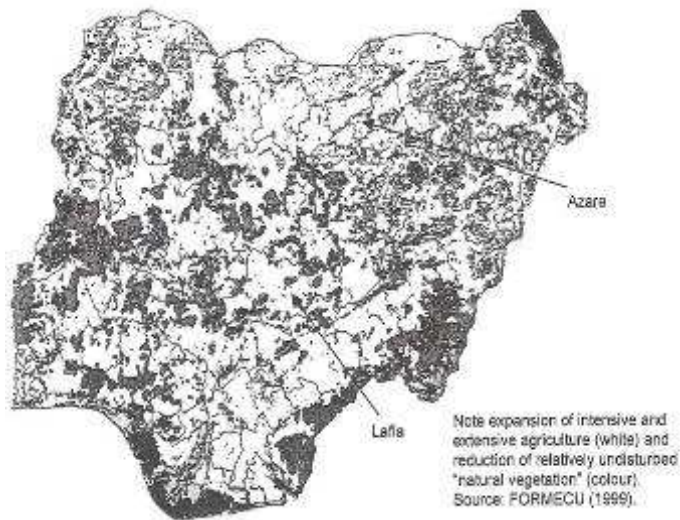


Figure 1.9: Vegetation and land use in Nigeria in 1978 (a) and 1995 (b) (Bourn *et al.*, 2001)

The decline of the morsitans group flies is probably due to the increasing rates of urbanisation, agricultural expansion and population growth seen all over Africa. Nigeria has undergone massive woodland and forest clearance and extensive wetland drainage over the past few decades. Wildlife levels have also declined drastically due to widespread hunting and loss of habitat. Bourn *et al.* (2001) assessed vegetation and land use changes in Nigeria over a 17 year period using satellite imagery. Their results showed that 53,410km² (5.9% of country) went from extensive to intensive agriculture between 1978 and 1995. 65,497km²

(7.2% of country) went from shrub-land, woodland and forest to extensive agriculture, while 53,147km² (5.9% of country) went from shrub-land, woodland and forest to intensive agriculture. There was also a 23,464km² increase in bare surfaces during the same period. Figure 1.9a indicates a fragmented agricultural expansion of the extensive woodland savannahs of the middle belt/subhumid zone by 1978, while figure 1.9b shows the continued fragmentation through the eighties and nineties with few isolated areas of natural woodland savannah left by 1995 (Bourn *et al.*, 2001). These areas corresponded with the *G. morsitans* fly belts shown in figure 1.1 so the habitat degradation and decline in wildlife hosts due to land use changes and agricultural expansion has effectively exterminated previous *G. morsitans* populations.

On the other hand, the increased density and expansion of palpalis group flies may be due to their ability to exploit such factors to their advantage. Reid *et al.* (2000) developed a spatial geographical information system (GIS) model with the first fine resolution GIS coverage of future human populations in Africa; they predict that by the year 2040 the distribution of *fuscus* and *morsitans* tsetse flies will contract in different areas across Africa but will not disappear. Only 75% - 80% of the area currently infested will continue to support these flies. However, Reid *et al.* (2000) do not make predictions about palpalis flies as previous research has shown that they are not always affected by human populations. Nearly 7 million km² (an area larger than Europe) will remain infested with riverine flies in West and Central Africa. Palpalis flies are considered to be highly adaptable to changing conditions, particularly anthropogenic change (Baldry, 1964; Onah, 1995; Dede *et al.*, 1998; de Deken *et al.*, 2005; Courtin *et al.*, 2009; Van den Bossche *et al.*, 2010). In light of this, the assertion by Courtin *et al.* (2005) that they “constitute, in the future, the most dangerous vectors of trypanosomes” has credibility.

1.9 Aims and objectives

The aims of this study are to:

- Characterise the current epidemiology of the disease on the Jos plateau
- Determine the major risk factors for AAT on the Jos plateau
- Determine the knowledge, attitudes and practices of livestock owners on the Jos plateau in relation to animal health and productivity
- Gather information for the planning of interventions against trypanosomiasis

The following specific objectives were carried out to fulfil these aims

- Chapter 2: Background of the study area is presented with emphasis on social issues affecting agriculture. The study design process is also described.
- Chapter 3: A longitudinal survey of bovine trypanosomiasis is presented. Trypanosomiasis prevalence, distribution and seasonal variation are investigated along with analysis for risk factors of trypanosomiasis
- Chapter 4: A study of pastoral livelihoods is presented. Household income, assets, herd productivity and knowledge, attitudes and practices relating to animal husbandry and disease are considered.
- Chapter 5: This chapter considers the association between anaemia and bovine trypanosomiasis and evaluates the FAMACHA card as a penside diagnostic test for trypanosomiasis

Chapter 2: Background

2.1 The Jos Plateau

The Jos plateau is located in the north of Plateau state, north central Nigeria. Plateau state has an excellent road network which provides good access to rural communities and national highways. There are no traditional urban centres on the plateau and Jos, the state capital is its only city. It was established by miners after the discovery of tin on the plateau in 1906 and has since attracted large numbers of skilled and unskilled migrant workers from across the country. It is a highly populated and heavily cultivated area (Freund, 1981; Morrisson, 1976; RIM, 1992).

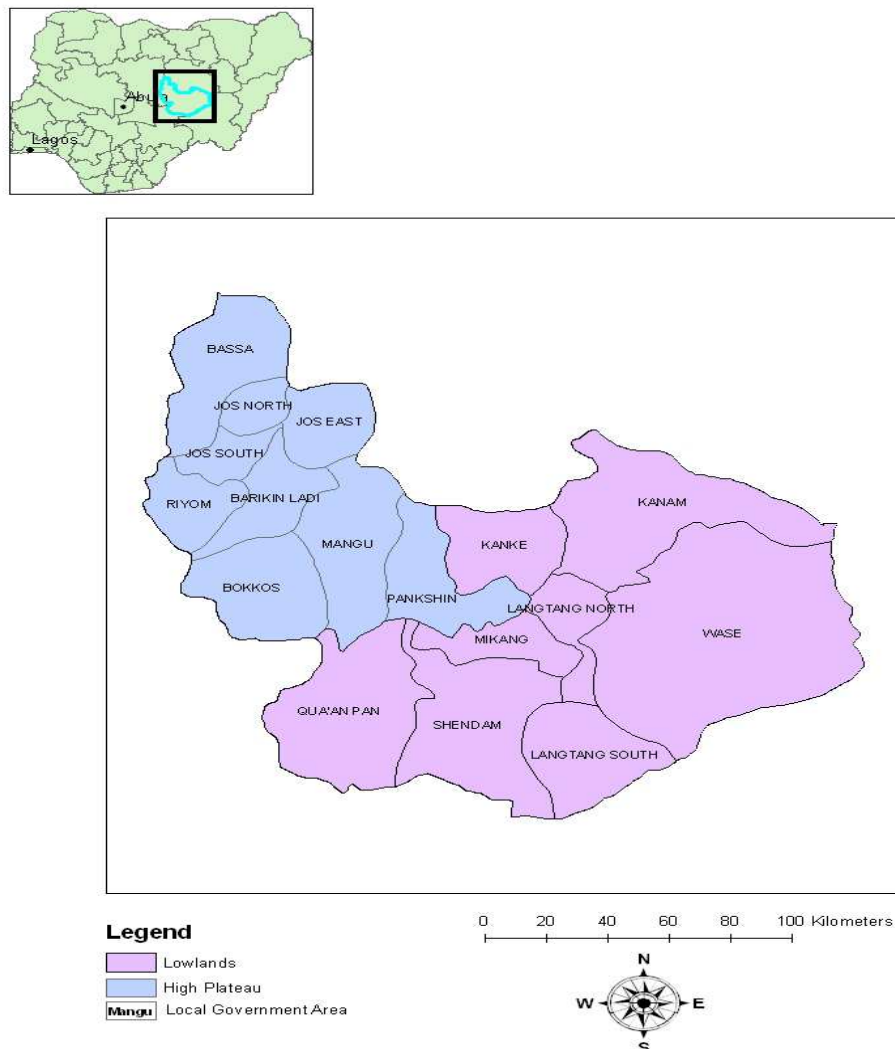


Figure 2.1: Plateau state

2.1.1 Ecology and land use

Plateau State is sharply divided into the Jos plateau in the north and the savannah lowlands that fall gradually to the Benue river valley in the south. The plateau is a granite upthrust of 8000km² rising 900–1700m above the surrounding plains. It is bounded by a steep escarpment in the south and west but falls to the plains in a series of steps in the north and east. It consists of younger granite of volcanic origin and the terrain is characterised by numerous lava flows and flat-topped hills. There are many crater lakes in the extinct volcanic cones and these are often heavily cultivated. The lowland plains of Plateau state are subhumid savannah grassland with fertile soils (Grove, 1952; Blench, 2003; Alfred & Tuley, 1974).

The plateau was formerly open savannah woodland but is now mostly grassland, with the exception of a few reforestation schemes in the central area and on the western escarpment. Destructive traditional farming systems and overgrazing by cattle have taken their toll on the land and much of the plateau is heavily eroded. Past mining operations have also damaged substantial areas of the plateau which are now unusable, adding to the general environmental degradation (Glover, 1965; Kalu, 1996; Blench, 2004). Annual rainfall is 1000 – 1,500mm and the length of the rainy season is 160 – 220 days. However, Plateau is not well supplied with ground water. It is at the centre of four river basins and is supplied by many small streams that originate on the plateau and drain into each of these major river basins (Blench, 2004).

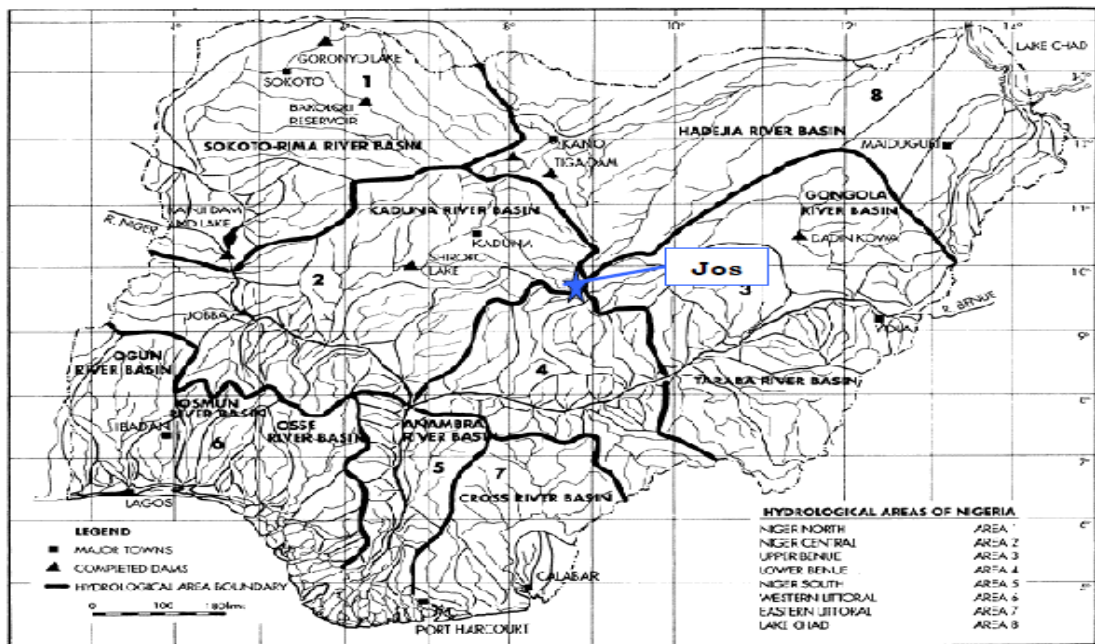


Fig. 2.2: Hydrological Map of Nigeria showing position of Jos plateau

The main farming system was rain-fed cultivation of cereals, particularly acha (fonio) which is uncommon elsewhere in Africa. Davies (1946) reports that 60% of the total land surface was used to cultivate this crop which does well on eroded soils and whose residue is an important feed for livestock. Other crops that are grown include sorghum, millet, yams, cocoyams, sweet potatoes and more recently Irish potatoes, maize and vegetables (Blench, 2004).

2.1.2 People

The Jos plateau shows high ethnolinguistic diversity, without any of the large-scale political units that characterise Yoruba- or Hausa-land. In pre-colonial times, the plateau was populated by a great variety of small ethnic groups living in hamlets with a complex clan organisation and ritual kingship systems. They spoke an assortment of ‘Plateau’ languages and a few Chadic languages related to Hausa. Therefore, no

single language or people were dominant although the largest ethnic groups were (and still are) the Birom, Ngas and Tarok (Gunn, 1953; Blench, 2004). These tribes lived mostly in the natural fortresses provided by the hills and the central plain of the plateau was largely uninhabited. However, after the advent of the British at the turn of the century hill tribes were resettled on the central plain. Soon after, the establishment of the tin mining industry attracted workers and traders from across the country. In the early nineteenth century low human populations, absence of tsetse and mosquitoes and unlimited grassland made the Jos plateau one of the most attractive environments for cattle in northern Nigeria. These favourable conditions drew Fulani pastoralists from the semi-arid regions who established themselves across the plateau. From the 1970s onwards, Fulani also settled on the lowland plains. Currently the Jos plateau is a highly populated cosmopolitan area, with inhabitants from across the country with a significant Muslim/Hausa presence (Blench, 2004; Fricke, 1979; Awogbade, 1983). Rural areas are mostly inhabited by farmers of the original plateau tribes with a significant minority of settled Fulani herders.

2.1.3 Livestock

Cattle on the Jos plateau are either humped zebu (*Bos indicus*) or West African humpless shorthorn (*Bos taurus*). The majority of the zebu are of the Bunaji or White Fulani variety although a few Rahaji (Azawak/ Red Mbororo) and Sokoto Gudali are present. Most zebu are kept by Fulani pastoralists but many indigenous farmers have bought cattle from them which they keep for fattening. Many of these cattle are managed for them by Fulani herders. In some cases, indigenous farmers are 'becoming pastoralists' e.g. the Tarok of the lowland plains whose herds have become

so large that they must be sent on seasonal transhumance. Muturu are the indigenous humpless shorthorn cattle of Nigeria and were common across the humid and subhumid zones in the past. However, their numbers have declined since then due to the rinderpest epidemic in the late nineteenth century (*Bos taurus* are particularly susceptible to rinderpest) and the introduction and widespread uptake of zebu cattle. Zebu cattle are resistant to rinderpest, larger and perceived to be more productive and prestigious than muturu (RIM, 1992; Blench, 2004). Cattle populations on the Jos plateau have been estimated at 400,000 in the wet season and 140,000 in the dry season by (ILCA, 1980) and 1.05 million by (RIM, 1992). This seasonal difference in numbers is due to the practice of seasonal transhumance.

There are few true horses on the plateau but the African pony was commonly kept for transport and ceremonial purposes. However, numbers have declined and few are now left, such as those still being used by few traditional rulers for ceremonial purposes and by the Polo Club in Jos. Donkeys were also commonly kept for transportation but have been displaced by vehicles. They are mainly now treated solely for food and sold for human consumption. Plateau serves a hub market between the major producing areas in the north and the main consumption areas on the lowlands of the state and the south east of Nigeria (RIM, 1992). Plateau is well known for its pig production in small-scale intensive units and traditional production systems. European breeds such as Large Whites and Hampshires although some indigenous black hairy pigs persist. Some of the pork is consumed on the plateau, and is considered a delicacy in certain areas, but most are sold to traders in the south (RIM, 1992). Dogs are also commonly kept as pets and guard dogs and used for hunting and food consumption. Plateau indigenes are considered experts in the

trading and capturing of dogs (also considered a delicacy), and travel across northern Nigeria in the dry season buying unwanted dogs from Muslim communities. Some of these are later sold for food within Plateau but the majority are sold to traders from Cross River in the South East. Sheep, goats and poultry are commonly kept by all groups of people in both urban and rural areas, RIM, 1992).

2.1.4 The Fulani Pastoral Group

The Fulbe trace their origins to the Nile valley in North Africa from which they migrated westwards and settled in the Senegambia. Some Fulbe converted to Islam in this region as early as the eleventh century. Over the years they drifted eastward, first into the Mali and Songhai empires and eventually into Hausa-land in what is now northern Nigeria. Fulbe pastoralists, known in Nigeria as Fulani, began to enter the Hausa lands in the thirteenth century, and were well established across the region by the fifteenth century. At the time, the Hausa lived in seven walled city-states or *birni* scattered across northern Nigeria. The Fulani lived peacefully amongst the Hausa, utilising the grasslands between the walled cities for pasture. Some Fulani clans gave up their nomadic existence and settled in the cities where they intermarried with the Hausa and took on their culture (Croix, 1994; Hopen, 1958; Stenning, 1958).

The Fulani are credited with introducing Islam and the Arabic script to the region and became important figures at court and in the religious and judiciary systems. A turning point in Nigerian history came in 1804 when a Fulani cleric Usman dan Fodio, became dissatisfied with the unorthodox practices of Hausa converts to Islam and began a holy war that resulted in the subjugation of the old Hausa city-states. Having conquered the Hausa, the Fulani adopted their language and merged with their

ruling classes by assuming the highest hereditary positions in the Hausa political system to create a Hausa-Fulani ethnic group under the rule of the Sokoto Caliphate. The Sokoto Caliphate then expanded its territory until it ruled the whole of Northern Nigeria with the exception of the Bornu Empire in the far north-east (Blench, 2003).

The Fulani are traditionally a nomadic pastoral people, herding cattle and small ruminants across the semi-arid Sahel regions of West Africa. Over time they have expanded into the subhumid and humid zones but continue to be a minority population wherever they are present. They have developed a method of livestock management based on seasonal transhumance: the movement of cattle along north/south corridors in pursuit of grazing and water following the climatic pattern of the rainy and dry seasons in West Africa. These herding techniques allow them great flexibility in using seasonally available and localised forage resources (Awogbade, 1983). They live amongst indigenous communities, from whom they lease land on which to build their houses and grow crops on, although some purchase land or occupy unclaimed plots. Livestock are grazed on communal land including uncropped areas, fallow land and harvested fields. Many Fulani have settled and live year round at a permanent site although their cattle may still undertake the dry season migration. Cattle are grazed within 5-6km of the homestead where they are brought back to be tethered at night (Blench, 2003; Blench, 2004).

2.2 Change in Tsetse & Trypanosomiasis status

Pullan (1980) carried out a study of cattle disease and productivity on the Jos plateau and stated that there were no tsetse flies present and trypanosomiasis was not present

in surveyed herds. Since then there have been many reports of both tsetse and trypanosomiasis on the Jos Plateau as listed in table 2.1

Location	Date	AAT	Tsetse	Reference
Jos	1982	5%		(Joshua, 1982)
Plateau & Kaduna	1989	8.2%	10.1% infection	(Agu <i>et al.</i> , 1989)
Jos plateau	1994	7.5%		(Abegunde and Mafuyai, 1994)
Jos	1995		55 <i>G. tachinoides</i> 10 <i>G. palpalis</i> 25 <i>G. morsitans</i>	(Onah, 1995)
Plateau state	1995	5.6%		(Ajayi <i>et al.</i> , 1995)
Vom	1996	16.4%		(Kalu, 1996a)
Barkin Ladi	1996	11.7%		(Kalu, 1996a)
Bassa LGA	1996	9.1%	9 <i>G. tachinoides</i>	(Kalu, 1996b)
Barkin Ladi LGAs	1996	6.4%	5 <i>G. palpalis</i>	(Kalu, 1996b)
Bassa LGA	1996	38.6%	3.2 flies/trap/day <i>G. tachinoides</i>	(Kalu, 1996c)
Barkin Ladi LGA	1996	37.6%	<i>G. palpalis</i> present	(Kalu and Uzoigwe, 1996)
Miango, Bassa LGA	1999	28.9%		(Omotainse and Kalejaiye, 1999)
Riyom	2000	6.21%		(Kalejaiye and Omotainse, 2000)
Jos North, Jos South, Jos East & Bassa LGAs	2002	7.9%		(Shamaki <i>et al.</i> , 2002)
Bachit	2003	20%		(Anosike <i>et al.</i> , 2003)
Sopp	2003	12%		(Anosike <i>et al.</i> , 2003)
Barkin Ladi	2003	40%		(Anosike <i>et al.</i> , 2003)
Barkin Ladi	2004	20%	97 <i>G. tachinoides</i>	(Yanan <i>et al.</i> , 2004)
Bokkos LGA	2004	17.9% (rains)		(Kalejaiye <i>et al.</i> , 2004)
Bokkos LGA	2004	11.7%		(Kalejaiye <i>et al.</i> , 2004)
Kadunu & Bakin Kogi	2004	27.9% infection	182 <i>G. tachinoides</i>	(Dede <i>et al.</i> , 2004)
Jos East LGA	2005	7.89%		(Dadah <i>et al.</i> , 2005)
Sopp	2006		140 <i>Glossina spp.</i>	(Dede et al, unpublished)

Table 2.1: Reports of tsetse and trypanosomiasis on the Jos plateau

It is clear that the Jos plateau has lost its tsetse and trypanosomiasis free status. To understand why this has happened, it is important to look at the reasons for and against infestation of the plateau.

2.3.1 Factors contributing to the previous tsetse free status of the Jos plateau

High altitude: According to Jordan (1986), tsetse flies cannot survive above 1,800m close to the equator and this upper limit decreases with increasing distance from the equator. The Jos plateau is 1,200 – 1777m above sea level which is close to, but not quite above, the threshold. Therefore it is unlikely, though not impossible, that tsetse flies will survive.

Climate: Temperatures rarely exceed 24°C and often go as low as 13°C. The optimum temperature for tsetse flies is 25°C although they can survive temperatures as low as 10°C if other conditions, particularly, humidity and shade are favourable.

2.3.2 Risk factors for tsetse and trypanosome introduction and establishment on the Jos plateau

Contiguous infested areas: The neighbouring states of Bauchi, Kaduna and Nassarawa and even the lowland areas of Plateau surrounding the high plateau are infested with tsetse flies. Indeed, in past decades when the plateau was still tsetse free, flies from adjacent lowlands could be found advancing onto the escarpment during the rainy season when dispersal of flies occurs (Jordan, personal communication).

Transhumance: In search of adequate water and pasture, the nomadic Fulani move their cattle from the Sahel in the north to the tsetse infested south during the dry season and return to the north as the rains approach. The cattle migration routes in areas that would otherwise be unsuitable (Jordan, 1986). The cattle may already be infected with trypanosomes when they cross the plateau and act as a source of infection for any tsetse flies present. Infected migratory cattle have been implicated in the outbreaks of AAT that occurred on the plateau in 1996 (Kalu, 1996c). Sahelian droughts in the mid 1980s caused many Fulani to take their cattle much further south than usual in search of food and water and even more unusually, many decided to settle in these areas (Humanitarian Policy Group, 2009a; Humanitarian Policy Group, 2009b; Azuwike and Enwerem, 2010). During their stay in these areas, large numbers of cattle would have been infected, ready to pass on trypanosomes any tsetse flies and/or mechanical vectors they encounter on their eventual return to the north.

River links to infested areas: The Plateau is connected via continuous watercourses to non – adjacent infested areas including the Yankari game reserve to the east and the Alawa wildlife reserve to the west. Riverine tsetse flies, particularly *G. palpalis* and *G. tachinoides* are abundant in these areas and are capable of travelling several miles along watercourses (Glover, 1965). Such is the significance of this factor that a feasibility study for eradication of tsetse flies in “Block D” (see figure 1.3) to the east of the plateau deemed it unsuitable for eradication because of these river links with infested areas and the associated risk of re-infestation by palpalis flies (Jordan, 1986).

Mechanical Transmission: Mechanical vectors of AAT like *Stomoxys calcitrans*, *Chrysops* and *Tabanus* species are abundant on the plateau and can transmit trypanosomes from infected migrant cattle to sedentary cattle on the plateau,

establishing a trypanosome reservoir on the plateau. *T. vivax*, which is mechanically transmitted, is reported to be the predominant species on the plateau and there is ample evidence for both mechanical transmission of trypanosomiasis and the presence of the disease outside tsetse belts (Leeflang, 1975; Desquesnes and Dia, 2003a; Desquesnes and Dia, 2003b; Desquesnes and Dia, 2004; Sinshaw *et al.*, 2006).

2.4 Jos: conflict and civil strife

The majority of people in Jos city are Christians of indigenous Plateau tribes whilst Hausa-Fulani Muslim ‘settlers’ comprise a significant minority along with other settlers from across the country (Blench, 2003). It is widely accepted that those who hold political office will favour their own community in the allocation of public resources. There is therefore intense competition between these two groups in Jos and considerable tension when the ‘wrong’ person is appointed or elected to public office. This conflict over political office is often viewed in religious terms as the two opposing groups are also divided by religion. This tension has led to recurring violence in Jos North LGA, since 1994. In August of 2001, a Hausa Muslim was appointed as the poverty eradication coordinator in the area. Tension escalated until September 2001 when it boiled over into riots that engulfed the whole city and was replayed in rural areas. In one week, over a thousand people were killed and tens of thousands of Muslims (including pastoralists) fled, never to return (Bawa & Nwogwu, 2002). These were reported to be religious riots and those fomenting violence on either side were quick to incite their followers on religious grounds (Human Rights Watch, 2001). In November of 2008, this situation repeated itself in disputes over the local government elections in Jos North. There were also outbreaks of violence in November 2009 and in December 2010 –

January 2011 several churches were bombed during midnight mass on Christmas Eve and widespread riots followed.

Outside Jos city, the other major centres of conflict in Plateau State are Langtang and Wase local government areas on the lowland plains some 200km south east of Jos. The Tarok people are the indigenous tribe in this area but there are substantial settlements of Hausa farmers and Fulani pastoralists (Blench, 2004). The Tarok have maintained good relations with these settlers for a long time and are now themselves substantial cattle owners, often as a result of sending their sons to be trained in herding by the Fulani. The Tarok, moreover, have a long tradition of military service, and many of their leaders are ex-generals. Apparently, a fight broke out in Yelwa, at the end of June 2002 between Christian and Muslim residents resulting in the burning of churches. It quickly spread to other communities in the area, and degenerated into protracted guerrilla warfare with each side conducting armed reprisal raids on the other until the end of 2004 (Blench, 2004). Cattle rustling by the Tarok was rife during this period and of the 1.2 million cattle recorded in Wase LGA, an estimated 500,000 were lost to rustlers (Higazi, 2008).

Insecurity has also discouraged farming in many areas and severe food shortages have occurred (Blench, 2004). In May 2009 state security forces stormed five villages in Wase LGA and hundreds of Fulani were forcibly loaded into trucks and driven “back” to Bauchi, Gombe, Katsina, and Jigawa states. Before 2001, the types of violent clashes over natural resources common in other northern states were not characteristic of Plateau and even now rural violence is directly related to the crises in urban areas or the lowlands. These crises exacerbate the growing natural resource conflict in the rural areas, making it more likely that violence will occur.

2.5 Study Design

2.5.1 Cluster sampling surveys

Cluster sampling is a sampling technique used when "natural" groupings are evident in a statistical population. Surveys employing this technique typically identify clusters (geographic, social or census groups) and provide a summary tally of people or households in each. Then using a cumulative list of all clusters, clusters are selected by probability proportionate to size (PPS) sampling where the probability of selecting any cluster varies with the size of the cluster, giving larger clusters a greater probability of selection and smaller clusters, a lower probability. All individuals/households/herds within each cluster are then included in the survey. Cluster sampling reduces data collection costs by taking advantage of the fact that units of the population are often found in close geographic proximity. Because a geographically dispersed population can be expensive to survey, greater economy than simple random sampling can be achieved by treating several respondents within a local area as a cluster but sampling error is higher than in simple random sampling.

Using all the sample elements in all selected clusters may be prohibitively expensive or unnecessary; so multistage cluster sampling, where elements from each cluster are randomly selected for sampling, is used instead. Constructing the clusters is the first stage, deciding what elements within the cluster to use is the second stage. Where PPS has been used for cluster selection, a constant number of elements must be selected within each cluster so that each sampled unit has the same probability of selection. Multistage cluster sampling is used frequently when a complete list of all members of the population does not exist and is inappropriate. In some cases, where the study area or population is very large, several levels of cluster selection may be applied before the

final sample elements are reached. Multistage cluster sampling has the advantages of further reduction in survey costs and increased accuracy over single stage cluster sampling. However, it is still not as accurate as simple random sampling.

The history of cluster surveys is closely tied to that of immunisation campaigns. Rapid surveys to assess the coverage of immunisation programmes were first described by Serfling and Sherman (1965) and modified for use in the smallpox eradication programme in West Africa by Henderson *et al.* (1973). The WHO Expanded Programme of Immunisation (EPI) adopted the method and developed it into the “30 x 7” method where thirty clusters were selected by PPS and seven children per cluster were sampled to assess immunisation coverage. The “30 x 7” cluster survey method was popular and was adopted all over the world although the rationale for the sampling procedure was never fully explained. Lemeshow and Robinson (1985) were commissioned by the WHO to statistically describe the EPI 30 x 7 survey methodology. This was the first published article by a statistician that justified the technique. A more general variance formula based on ratio estimators rather than persons, added the use of portable computers, and developed rapid survey methodology (RSM), an approach allowing community-based surveys to be planned, carried out and reported in less than a month (Frerichs, 1989; Frerichs and Tar Tar, 1989). After this, there was widespread uptake of the method for problems of a more general nature which violated the narrow statistical assumptions of the EPI programme as described by Lemeshow and Robinson (1985) and thus were inappropriate uses of the method. Bennett *et al.* (1991) expanded on the work of Frerichs and Tar Tar and summarized the statistical basis for rapid surveys with ratio estimators (Bennett *et al.*, 1991).

Several software packages are available for designing cluster sample surveys, including EPI-Info, Stata and CSurvey[®] (UCLA, 2007). CSurvey[®] helps select a cluster sample from a list of clusters, calculates the sample size for a cluster survey and creates a random number for selecting random start households or persons within households.

2.5.2 Intracluster Homogeneity

Intracluster homogeneity is a measure of the homogeneity of responses within a cluster. Less information is collected in a less diverse cluster with a large measure of homogeneity than in a more diverse cluster with a small measure. It is important to consider the number of independent observations per cluster to determine the total sample size in multistage cluster surveys (Kish *et al.*, 1976; Sudman, 1976). Kish (1965) defined a measure of intracluster homogeneity called the rate of homogeneity (R.o.H) as

$$\text{R.o.H} = \frac{(D-1)}{(n-1)}$$

Where D = design effect and n = sample cluster size

The design effect is a measure of the variance inflation of an estimator caused by utilizing a cluster design instead of a simple random sampling scheme. In cluster sampling with equal selection probabilities the homogeneity introduced by spatial clustering of respondents reduces the net sample size by a factor known as the design effect which depends on the size of the clusters, on the extent to which respondents of a certain cluster resemble each other (intracluster homogeneity) as well as on the dissimilarity of respondents belonging to different clusters (intercluster homogeneity). It

is calculated as the ratio of the variance of the cluster design under consideration to the variance of a simple random sample of the same total size

$$\text{i.e. } D = \frac{SE_c}{SE_s}$$

An alternative method for estimation of R.o.H. is the proportion variation method, named so because it was derived by realizing that R.o.H. is approximately the proportion of the total variation not accounted for within clusters.

$$\text{R.o.H.} = 1 - \frac{1}{H} \sum_h^H \frac{\sum a_h b_{hi} P_{hi} (1 - P_{hi})}{a_h b_h p_h (1 - P_h)}$$

Where:

H = number of strata

a_h = number of primary sampling units in each stratum

b_h = average cluster size

b_{hi} = number of sample elements in each primary sampling unit

P_h = prevalence in each stratum

P_{hi} = prevalence in each primary sampling unit

The design effect method is widely used but the proportion variation method is better for estimating rates of homogeneity amongst categorical variables. The design effect method is preferable for estimating R.o.H. where sample size is large whereas the proportion variation method may be better for small sample sizes (Clemmer and Kalsbeek, 1984).

2.5.3. Sample size estimation

A stratified two-stage cluster survey method was used to determine sample sizes. PPS sampling at the first stage was used to determine the number of clusters/villages per stratum/river basin to be sampled. A fixed number of cattle, selected by random sampling were sampled in each cluster at the second stage.

R.o.H. was calculated as below:

$$R.o.H. = \frac{(D-1)}{(n-1)} = 0.114 \quad \text{OR} \quad 1-1 \sum_h^H \frac{\sum a_h b_{hi} P_{hi} (1-P_{hi})}{a_h b_{hi} p_h (1-P_h)} = 0.142$$

Sample size for the estimation of the prevalence of an event using two-stage sampling method is determined according to the following equation (Bennett *et al.*, 1991):

$$n = \frac{p \times (1-p) \times z^2 \times [\rho \times (b - 1) + 1]}{e^2 \times b}$$

Where:

n = number of clusters to be selected

p = expected prevalence, based on previous studies

z = value from the normal distribution, based on the desired level of confidence

e = absolute value of the tolerated sampling variance, based on the required precision

b = number of individuals to be selected by cluster, based on operative factors and resources

ρ = rate of homogeneity.

Input Information	
Calculation Purpose	Calculate minimum number of clusters
Estimated proportion with attribute	0.24
One half length of confidence interval	0.05
Desired level of confidence	95%
Homogeneity parameter	Rate of Homogeneity
Rate of Homogeneity ²	0.122
Average number of samples per cluster	50
Results	
Target standard error of proportion	0.0246
Actual standard error of proportion	0.0243
Design effect	8.90
Rate of Homogeneity	0.122
Point estimate of proportion	0.235
Lower confidence limit	0.1856
Upper confidence limit	0.2844
Number of clusters	25
Sample size for proposed cluster survey	1,250
95% confidence interval	0.19 – 0.28

Table 2.2: Csurvey sample size calculation

Information from published reports and pilot surveys of the area was entered into CSurvey (©UCLA, 2007), to determine the minimum number of clusters required.

Average AAT prevalence on Jos Plateau calculated with 95% confidence limits from published reports. Minimum = 10.9% Mean = 17.4% Maximum = 24.0% Maximum used in sample size calculations.

Reported RoH : 0.115 (Otte & Gumm, 1997)

Calculated RoH : 0.128

Average RoH used in sample size calculations: 0.122

2.5.4 Study site selection

The number of selected villages was increased from 25 to 31 to compensate for any attrition during the study. The specific villages to be included in the study were chosen by dividing the area into a grid and choosing one village per cell. Thus, comprehensive spatial coverage of the plateau is achieved and villages with the full range of variables are included in the study.

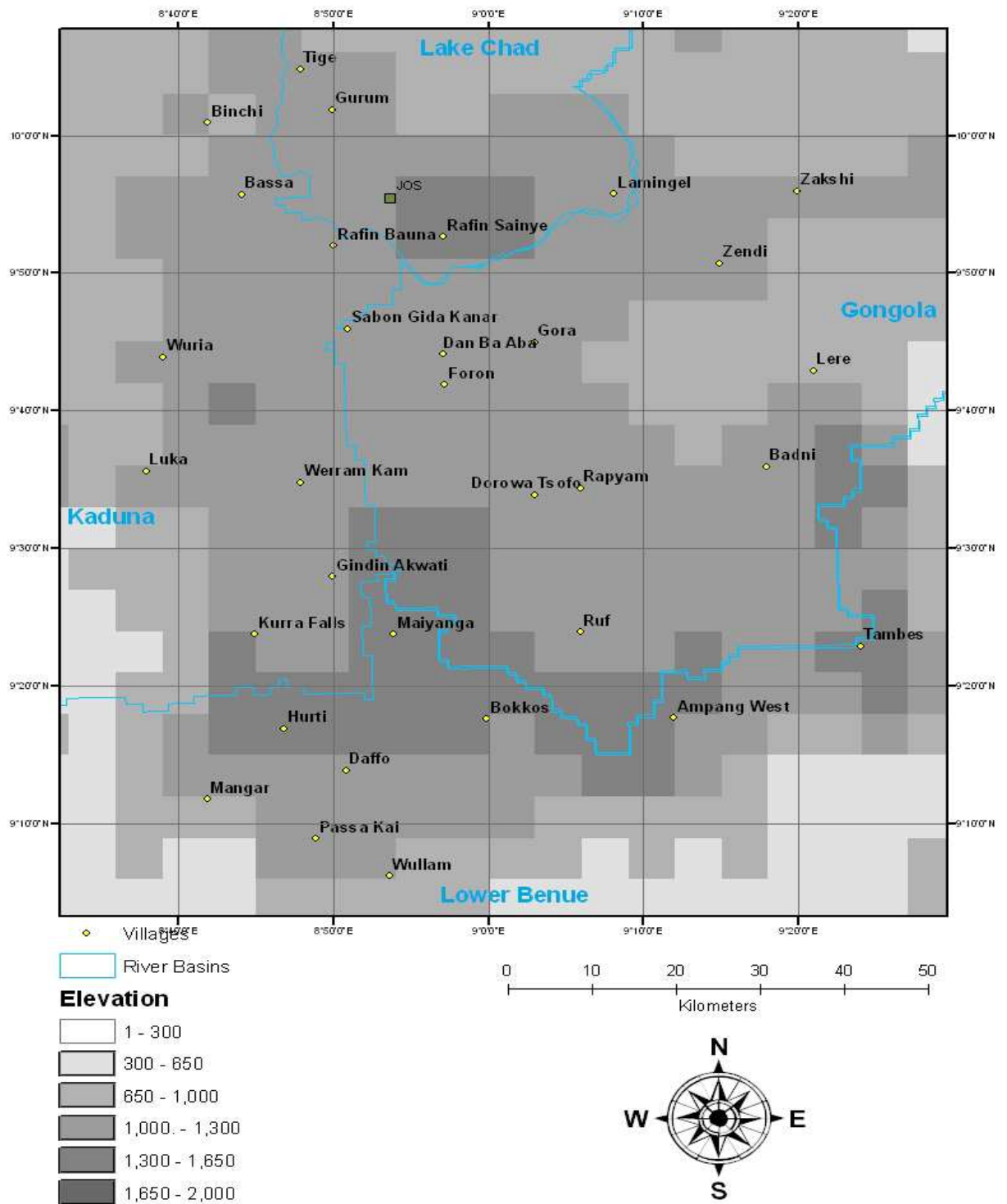


Figure 2.3: Study area showing selected villages

2.6 AAT Prevalence Survey

In each selected village, a sample of the village cattle herd was tested for trypanosomiasis infection. Again, CSurvey[®] (UCLA, 2007) was used to calculate the minimum number of cows per village required to give 95% confidence with confidence intervals of $\pm 5\%$ (50). Therefore, the actual number to be sampled was fixed at 80 to increase confidence.

Based on literature about migration patterns in north Nigeria and on the Jos plateau in particular, a 3 point survey would best serve to clarify the epidemiology of AAT if carried out at the following times:

- January/February: This is the middle of the dry season when migratory cattle have gone and only sedentary cattle remain. A study of the epidemiology of the disease in the absence of migrant cattle will be conducted.
- April/May: This is the beginning of the rainy season when migratory cattle have just returned and allows for the investigation of the infection profile of the returning cows and serves as a follow up study of the sedentary cattle.
- September/October: This is the end of the rainy season when migratory cattle have been back for some time and study of the effect of migrant cattle on the epidemiology of trypanosomiasis on the plateau ensues.

2.7 Participatory Rural Appraisal

Participatory rural appraisal (PRA) uses a range of sample survey methods to gather information by allowing local people to share and analyse their knowledge and experiences and to make plans based on this information (Chambers, 1994). A structured questionnaire, incorporating various PRA techniques was administered to livestock owners who participated in the AAT survey focusing on animal husbandry and its contribution to pastoral livelihoods.

This allowed us to gather data for quantitative analysis of animal productivity and profitability to pastoralists determine which social, economic, ecological and cultural factors influence animal health and disease control by herders and investigate knowledge, attitude and practices of animal husbandry and disease control.

2.8 Evaluation of FAMACHA cards as a pen-side test for Trypanosomiasis

African animal trypanosomiasis is one of the most important livestock diseases in Sub-Saharan Africa, causing 3 – 7 million cattle deaths a year and millions of dollars in lost income (WHO, 1998). This situation is compounded by the lack of accurate diagnosis in the resource poor, rural areas where the disease causes the most damage. Clinical diagnosis is often the only available method for a disease that has no pathognomonic clinical signs (Eisler *et al*, 2004). Thus, inaccurate diagnosis often leads to unnecessary treatment of unaffected animals – wasting resources and promoting drug resistance, or non treatment of affected animals. There is great need for a simple, cheap, reliable penside diagnostic test to combat AAT where it matters most.

Despite the fact that most clinical signs of AAT are non specific, anaemia is one of the most consistent signs of the disease and is often used as a reliable indicator of infection. However, methods for penside evaluation of anaemia are also limited and clinical examination of mucous membranes is the only widely used method (Grace *et al*, 2007). A handheld haemoglobinometer, Hemocue 201, is available, accurate and easy to use. However it uses expensive, disposable microcuvettes and is unreliable at high temperatures (Grace *et al*, 200; Morris *et al*, 2000). In South Africa, an innovative technique for assessment of anaemia in sheep was developed to tackle the problem of

unnecessary treatments for *Haemonchus contortus*. The FAMACHA method consists of a laminated card bearing 5 pictures of sheep conjunctiva which, when compared with the ocular mucous membranes of livestock, allows the identification of anaemic animals. If this method could be successfully applied to trypanosomiasis, it would help to improve diagnosis and reduce the number of unnecessary treatments.

In this study, diagnosis of anaemia will be done using both FAMACHA and Hemocue and results will be compared to assess the sensitivity and specificity of FAMACHA cards. Results will also be compared to trypanosome diagnostic PCR results to assess the use of FAMACHA as a diagnostic tool for trypanosomiasis.

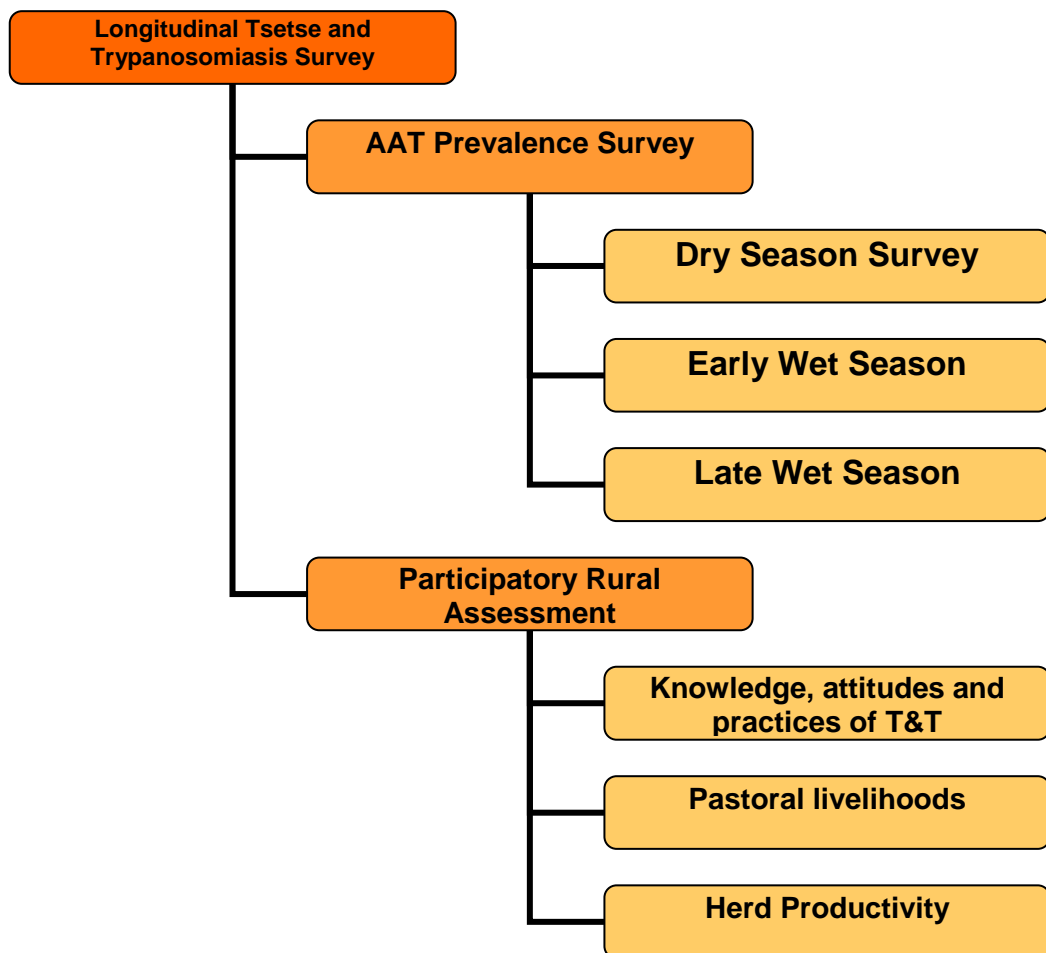


Figure 2.4: Study Design Chart

Chapter 3: Longitudinal Study of Bovine Trypanosomiasis

3.1 Introduction

The Jos plateau in north central Nigeria is an area of 8000km² with an average altitude of 1280m. It has been historically free of tsetse flies and trypanosomiasis. The absence of animal trypanosomiasis and abundant pasture attracted large numbers of cattle-keeping pastoralists. The area now holds over a million cattle and plays an important role in the national and regional cattle industry. However since 1982, there have been increasing reports of tsetse flies and AAT on the plateau. Reports have been based in single villages or LGAs, so little robust epidemiological data was available regarding the distribution and overall prevalence of AAT across the Jos plateau. This knowledge is necessary to design appropriate and effective control strategies for trypanosomiasis, which is vital if this area is to continue to contribute competitively in the livestock sector.

This chapter presents the findings of a longitudinal survey of bovine trypanosomiasis on the Jos plateau, designed to characterise the epidemiology of trypanosomiasis in this area. Epidemiological results and their implications for cattle health and productivity are discussed.

3.2 Aim and Objectives

The Jos plateau has undergone a change in its tsetse and trypanosomiasis status and little information is available on the current state of affairs or the drivers for the epidemiology of trypanosomiasis in this area. This chapter aims to provide a comprehensive summary of the epidemiology of bovine trypanosomiasis on the Jos plateau and identify the factors affecting it by:

- Longitudinal prevalence survey of cattle to capture seasonal variations in prevalence
- Molecular diagnosis of trypanosomiasis infections
- Logistic regression to determine risk factors for trypanosomiasis infection
- Acquisition of baseline data for intervention planning and delivery in the future

3.3 Materials and Methods

3.3.1 Sample Frame

The prevalence of trypanosomiasis in cattle on the Jos plateau was estimated using a longitudinal two stage cluster survey. The study area was stratified by river basin, with villages as primary clusters and a fixed number of cattle to be sampled in each village as described in Chapter 2. Eighty cattle were sampled in each of the 30 selected villages during the dry season, early wet season and late wet season to enable assessment of seasonal variations.

3.3.2 Sample Collection

Eighty cattle were selected for sampling from individual herds within each village. A total of 7143 cattle were sampled, 2230 in the dry season, 2449 cattle in the early wet season and 2367 in the late wet season.

Blood was collected from each by venipuncture and applied directly onto Whatman FTA cards. Cards were air dried at room temperature for at least one hour and then stored in sealed envelopes with dessicant. The sex, age, breed and condition score of each animal was recorded as shown in figure 3.1 below. Condition scoring was done according to

Nicholson and Butterworth (1986) where there are three main categories – fat, medium and lean, with each subdivided into 3 subcategories as outlined in figure 3.1 below. These scores describe the condition of the animal from very lean (L-) to very fat (F+)

<p>Sex Male: M Female: F</p> <p>Age A: 0-6 months B: 6 months – 2 years C: Over 2 years</p> <p>Condition Score Fat: F+ F F- Medium: M+ M M- Lean: L+ L L-</p> <p>Breed Bunaji: B Rahaji: R N'Dama: Nd Keteku: K Friesian: F</p>
--



Figure. 3.1: Sample collection

3.3.3 DNA Extraction

Five 3mm discs were cut out of each sample using a Harris Micropunch. To avoid cross contamination between samples, five discs were punched out of blank filter paper after each sample. Five 3mm discs of blank filter paper were also included as negative controls for the DNA extraction process. The discs were given two fifteen minute washes in 1ml of Whatman FTA purification reagent to remove haemoglobin which inhibits the PCR reaction. Used reagent was discarded after each wash. They were then given two fifteen minute washes in TE buffer (10mM Tris, 0.1 mM EDTA, pH 8.0) to remove the FTA purification reagent and the used buffer discarded after each wash. Discs were dried for 30 minutes in an oven at 37°C. 100µl of 5% chelex suspension was added to dry discs

and incubated at 90°C for 30 minutes to elute the DNA off the FTA discs. Eluted DNA solution was used for the PCR reactions as it was found to be more sensitive than using the dried FTA disc as recommended by the manufacturers (Nicholson and Butterworth, 1986; Wooden *et al.*, 1992; Kain *et al.*, 1993).

3.3.4 *T. brucei* s.l. PCR

This PCR targets the kinetoplast minicircle DNA of *Trypanosoma brucei* and gives a 177 bp PCR product. It can be used for the detection of *Trypanosoma brucei* s.l. infection in humans, animals and tsetse flies (Katakura *et al.*, 1997). The technique demonstrated a high sensitivity by successfully amplifying 0.1pg of *T. brucei* DNA which is equivalent to one parasite per µl of blood (Moser *et al.*, 1989)

Primer sequences:

TBR 1: 5' - CGA ATG AAT AAA CAA TGC GCA GT – 3'

TBR 2: 5' - AGA ACC ATT TAT TAG CTT TGT TGC – 3'

PCR amplifications were carried out in a 25µl reaction mixture as shown in table

3.1below:

<i>Mastermix</i>	25µl
Super Taq 10 x buffer	2.5µl
TBR1 (100pmoles/µl)	0.5µl
TBR2 (100pmoles/µl)	0.5µl
100mM dNTP 0.2µl	0.2 µl
BIOTAQ Red DNA polymerase (1U/µl)	1µl
Distilled water	14.55µl
MgCl	0.75µl
Sample DNA	5µl

Table 3.1: *T. brucei* s.l. PCR Mastermix

Thermal cycling was undertaken using a Dyad Peltier thermal cycler using the following conditions.

Step 1: 94C for 3 minutes

Step 2: 94C for 1 minute

Step 3: 55C for 1 minute

Step 4: 72C for 30 secs

Step 5: Repeat steps 2 – 4 34 times

Step 6: 72C for 5 minutes.

3.3.5 *T. congolense* savannah PCR

This PCR amplifies the satellite DNA monomer of *Trypanosoma congolense* Kilifi to give a 316 bp product as first described by (Masiga *et al.*, 1992). It can be used to detect infections of this parasite in animals and tsetse flies (Masiga *et al.*, 1992); (Katakura *et al.*, 1997). It is sensitive enough to detect a single parasite and does not cross react with other species of trypanosomes, other subspecies of *Trypanosoma congolense* or host DNA (Masiga *et al.*, 1992).

Primer sequences

TCS 1: 5' – CGAGAACGGGCACTTTGCGA – 3'

TCS 2: 5' – G GACAAACAAATCCCGCACA – 3'

PCR amplifications were carried out in a 25µl reaction mixture as shown in table 3.2.

Mastermix	25µl
Mastermix	25
Super Taq 10 x buffer	2.5µl
TCS1 (100pmoles/µl)	1.5µl
TCS2 (100pmoles/µl)	1.5µl
100mM dNTP 0.2µl	0.2 µl
BIOTAQ Red DNA polymerase 1U/µl)	1µl
Distilled water	12.55µl
MgCl	0.75µl
Sample DNA	5µl

Table 3.2: *T. congolense* savannah PCR Mastermix

Thermal cycling was carried out in a Dyad Peltier thermal cycler using the following conditions:

Step 1: 94C for 3 minutes

Step 2: 94C for 1 minute

Step 3: 55C for 2 minute

Step 4: 72C for 2 secs

Step 5: Repeat steps 2 – 4 29 times

Step 6: 72C for 5 minutes.

3.3.6 *T. vivax* PCR

The target of this PCR is a gene encoding a differentially expressed antigen of *Trypanosoma vivax* to give a 400 bp product as first described by Masake and others 1997. It can be used to detect infections of this parasite in animals and tsetse flies (Masake *et al.*, 1997; Clausen *et al.*, 1998).

Primer sequences

ILO 1264: 5' – CAGCTCGCCGAAGGCCACTTGGCTGGG – 3'

ILO 1265: 5' – TCGTACCACAGTCGCAATCGCAATCGTCGTCTGAAGG– 3'

PCR amplifications were carried out in a 25µl reaction mixture as shown in table 3.3

below:

<i>Mastermix</i>	25µl
Super Taq 10 x buffer	2.5µl
TCS1 (100pmoles/µl)	1.5µl
TCS2 (100pmoles/µl)	1.5µl
100mM dNTP 0.2µl	0.2 µl
BIOTAQ Red DNA polymerase 1U/µl)	1µl
Distilled water	12.55µl
MgCl	0.75µl
Sample DNA	5µl

Table 3.3: *T. vivax* PCR Mastermix

Thermal cycling was carried out in a Dyad Peltier thermal cycler using the following conditions.

Step 1: 94C for 3 minutes

Step 2: 94C for 1 minute

Step 3: 55C for 2 minute

Step 4: 72C for 2 secs

Step 5: Repeat steps 2 – 4 35 times

Step 6: 72C for 5 minutes.

3.3.7 Gel electrophoresis

1.5g of agarose was added to 150ml of 1 x Tris Borate EDTA (TBE) buffer (36mM Tris, 30mM NaH₂PO₄, 1mM EDTA, pH 8.0) stained with Ethidium bromide (0.5µg/ml). This was poured into a 30cm x 20cm mould. 15µl of the PCR product from the second round was run on this 1.5% Agarose gel alongside a 100bp graduation marker at 100V for 1hour on a Bio Rad Power Pac 300 machine. The gel was examined on a Gel Doc 2000[®] Bio-Rad using Quantity One[®] Bio-Rad software.

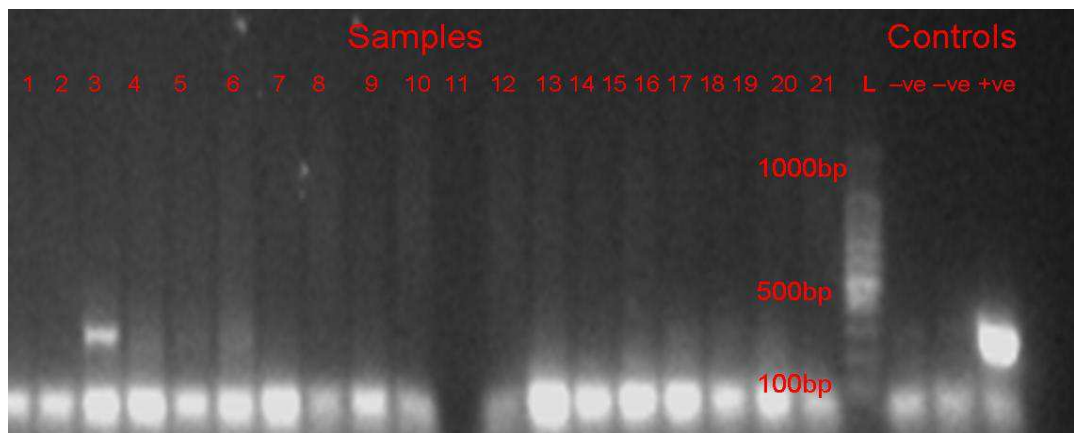


Figure 3.2: Gel electrophoresis image of *T. b. brucei* DNA bands at 177bp

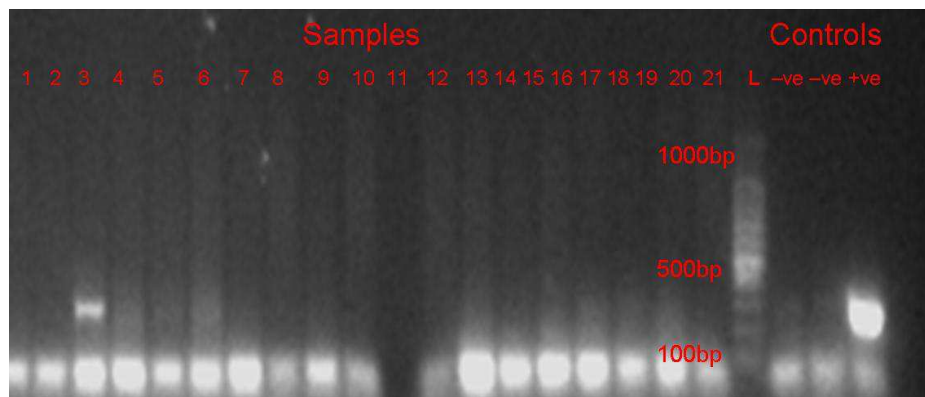


Figure 3.3: Gel electrophoresis image of *T. congolense* DNA bands at 316bp

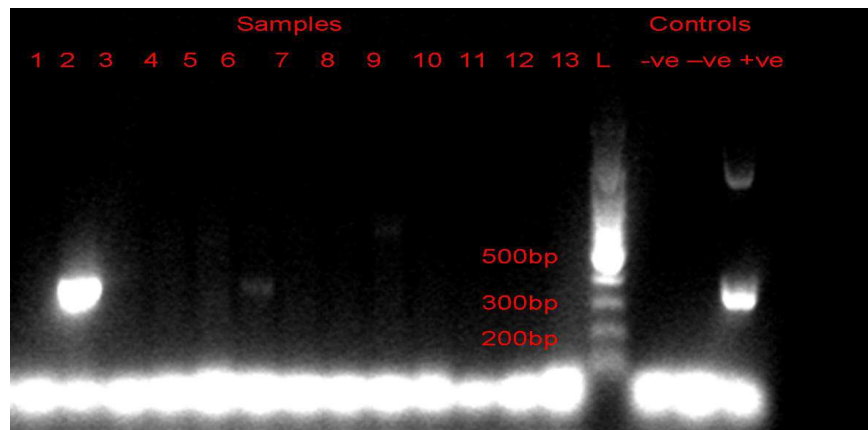


Figure 3.4: Gel electrophoresis image of *T. vivax* DNA bands at 400bp

3.3.8 Statistical analysis

This section provides details of statistical tests used in this study.

3.3.8.2 Chi squared test of independence

The chi squared (χ^2) test for independence tests the association between two categorical variables or nominal data where the basis of comparison is proportions (Plackett, 1983). At the 95% confidence level, a chi-square probability <0.05 indicates association and justifies rejection of the null hypothesis ‘there is no association between the variables studied’. This test was done in EpiInfo™ CDC software.

3.3.8.4 Wilcoxon–Mann–Whitney test

The Wilcoxon – Mann – Whitney test is used to compare two independent groups of ordinal data. The test statistic and associated p value determines whether there is a significant difference between the median value of each group (Wilcoxon, 1945; Mann & Whitney, 1947). This test was done in Minitab® (Minitab Inc.).

3.3.8.5 Exact binomial confidence intervals

The binomial proportion confidence interval is a confidence interval for a proportion in a statistical population that uses the proportion estimated in a statistical sample and allows for sampling error. The confidence interval indicates the range that the true sample proportion would lie within if the test were repeated several times. It assumes that the statistical population has a binomial distribution (Brown et al, 2001). The exact binomial confidence interval, or Clopper-Pearson method, is a more accurate variation of the binomial proportion confidence interval which inverts two single-tailed Binomial tests at the desired level of confidence instead of using a normal approximation (Clopper & Pearson, 1934). Exact binomial confidence intervals were calculated using CIA[©] BMJ software.

3.3.8.6 Logistic regression

Logistic regression was carried out using *Egret for Windows* © Cytel Software (1999). This statistical test is used for prediction of the probability of occurrence of an event by fitting data to a logit function logistic curve. It is a generalized linear model used for binomial regression (Hosmer & Lemeshow, 1989). Like many forms of regression analysis, it makes use of several predictor variables that may be either numerical or categorical. A multivariate, multiplicative/relative risk model was constructed with the fixed effect variables laid out in table 3.4. A village was included as a random effect within the model.

Variable	Type of Variable	Class of Variable
Trypanosomiasis	Outcome variable	Binomial positive = 1, negative = 0
Altitude	Predictor variable	Categorical range 800m – 1350m 50m increase per category
Dry season migration	Predictor variable	Binomial yes = 1, no = 0
Wet season migration	Predictor variable	Binomial yes = 1, no = 0
Alien migratory cows	Predictor variable	Binomial yes = 1, no = 0

Table 3.4: Logistic Regression Variables

3.3.8.8 Moran's I

Given a set of features and an associated attribute, Global Moran's I (Moran, 1950) evaluates whether the pattern expressed is clustered, dispersed, or random. The test calculates a Z score and p-value to indicate whether or not you can reject the null hypothesis. In this case, the null hypothesis states that feature values are randomly distributed across the study area and not clustered. When the Z score indicates statistical significance, a Moran's I value near +1.0 indicates clustering while a value near -1.0 indicates dispersion. At 95% significance level, a p value < 0.05 indicates that clustering is present and the null hypothesis can be rejected.

In this study, the Moran's I test was used to investigate spatial clustering of trypanosomiasis using the spatial autocorrelation tool in ARCGIS[®] ESRI software.

3.3 Results

This section describes the results of the longitudinal prevalence survey carried out and includes data on prevalence, trypanosome species presence and distribution, seasonal variation and risk factors for infection.

3.3.1 Prevalence of trypanosomiasis

A total of 7143 cattle were sampled and 3305 (46.3%) were positive for trypanosomiasis. Of these 3305 infections: 40.4% were *T. congolense* only, 35.8% were *T. vivax* only, 2.09% were *T. b. brucei* only and 21.7% were mixed infections as shown in figure 3.2.

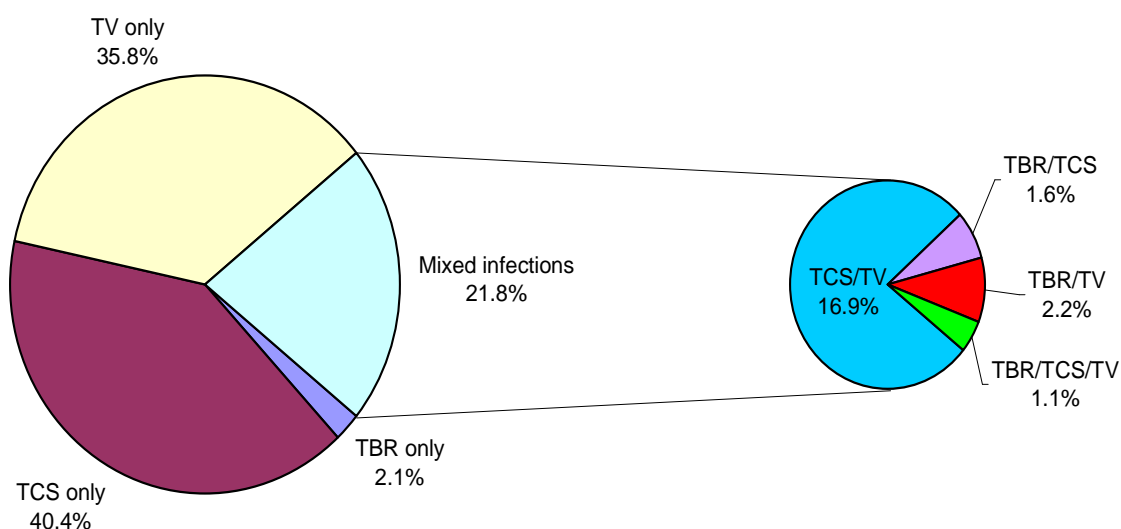


Figure 3.5: Annual trypanosome species distribution

3.3.1.1 Dry season prevalence

2330 cattle were sampled in the dry season and 1079 (48.4%) were positive for trypanosomiasis. Of these 1079 infections: 42.0% were *T. congolense* only, 27.5% were *T. vivax* only, 1.9% were *T. b. brucei* only and 28.6% were mixed infections as shown in figure 3.3.

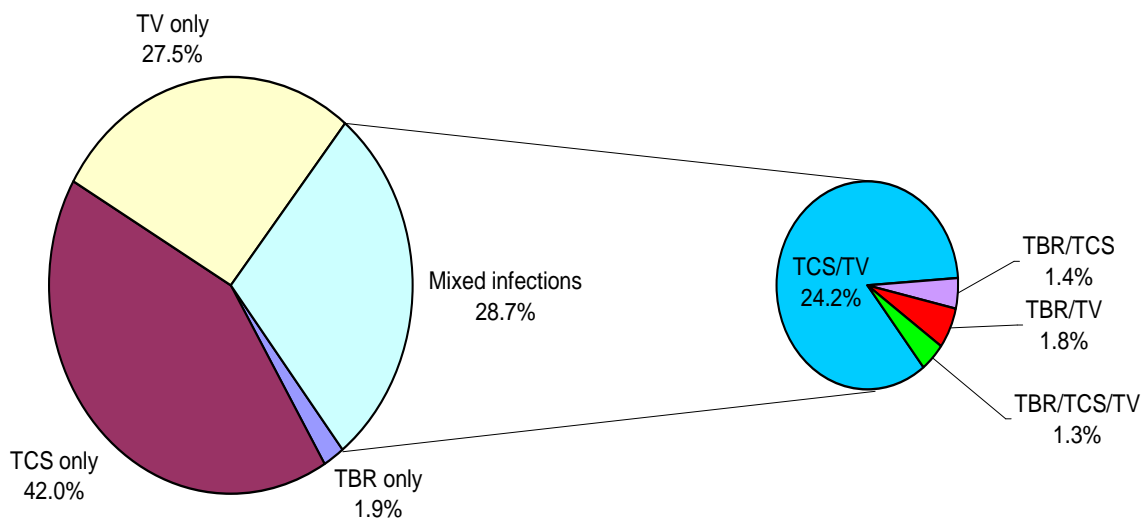


Figure 3.6: Dry season trypanosome species distribution

3.3.1.2 Early wet season prevalence

2449 cattle were sampled in the early wet season and 1087 (44.4%) were positive for trypanosomiasis. Of these 1087 infections: 42.4% were *T. congolense* only, 35.7% *T. vivax* only, 3.8% were *T. b. brucei* only and 18.1% were mixed infections as shown in figure 3.4

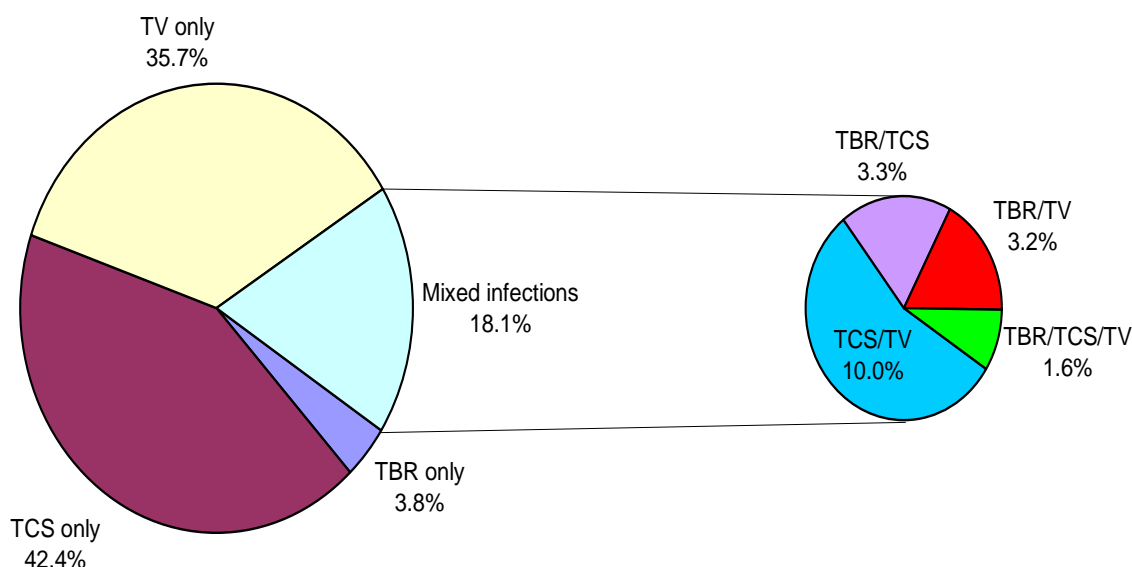


Figure 3.7: Early wet season trypanosome species distribution

3.3.1.3 Late wet season prevalence

2367 cattle were sampled in the late wet season and 1139 (48.1%) were positive for trypanosomiasis. Of these 1139 infections: 37.1% were *T. congolense* only, 43.6% were *T. vivax* only, 0.7% were *T. b. brucei* only and 18.6% were mixed infections as shown in figure 3.5

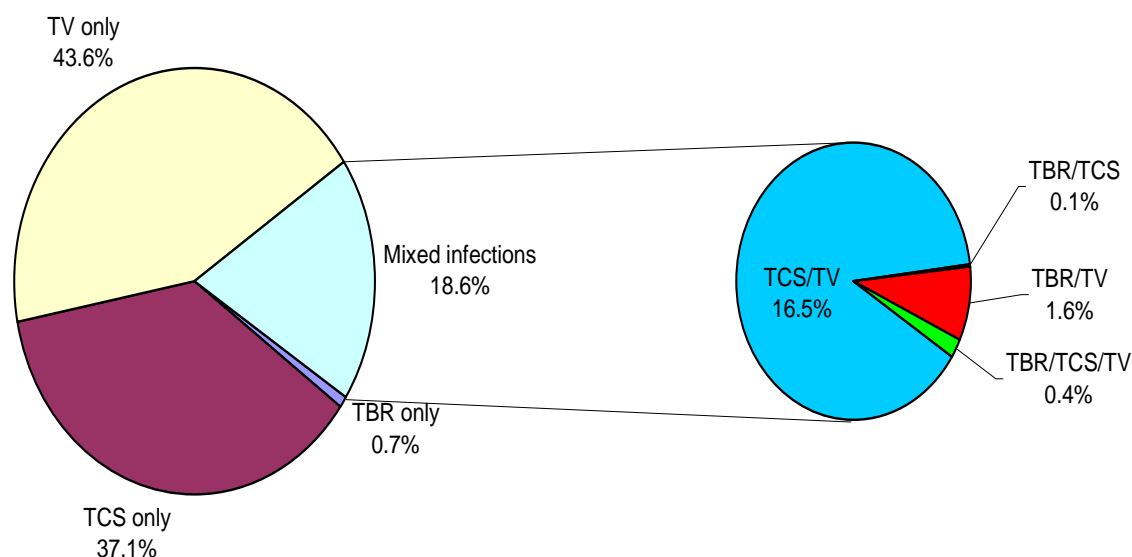


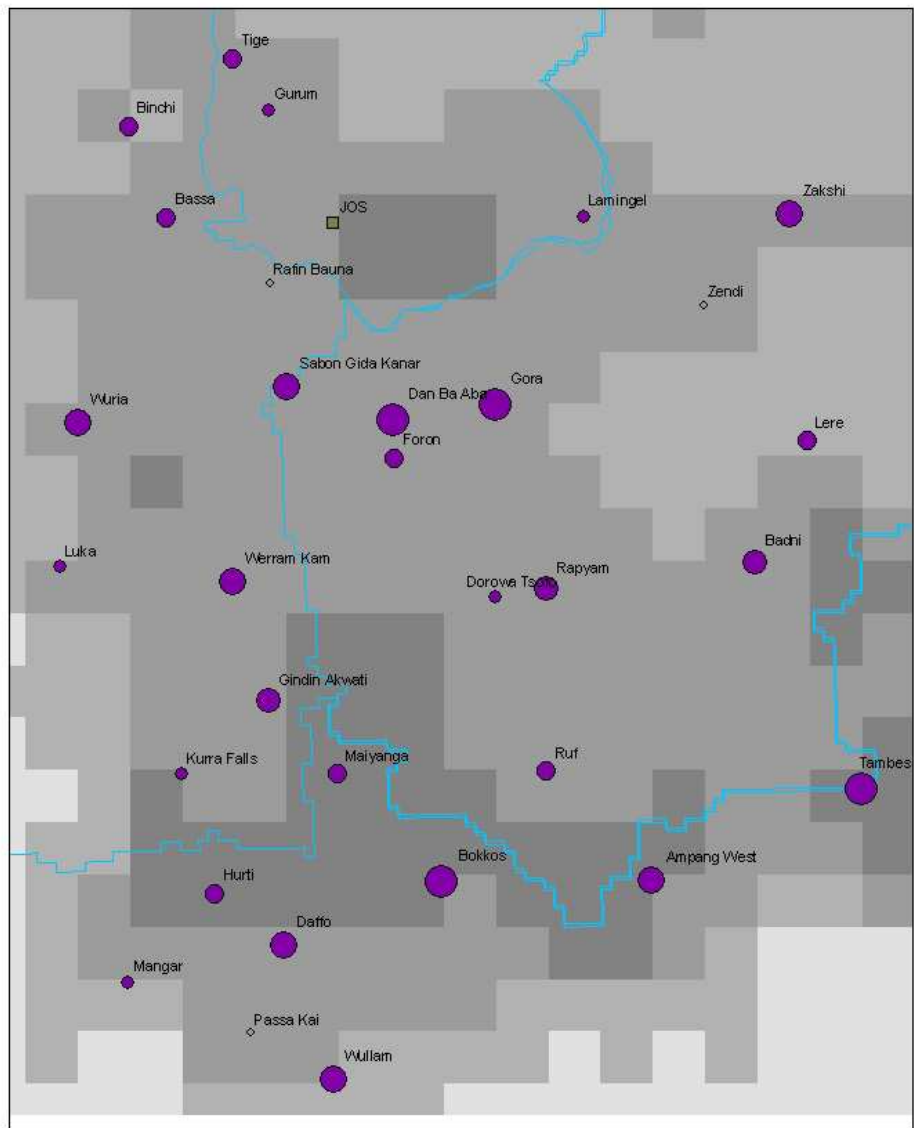
Figure 3.8: Late wet season trypanosome species distribution

Table 3.8 below shows the prevalence of trypanosomiasis across the Jos Plateau. There was significant seasonal difference in prevalence of trypanosomiasis ($\chi^2 = 6.765$, $p = 0.037$).

	Dry Season	Early Wet Season	Late Wet Season	Annual
<i>T. b. brucei</i> *	3.0% (2.4% - 3.9%)	5.3% (4.4% - 6.2%)	1.4% (0.9% - 1.9%)	3.2% (2.8% - 3.6%)
<i>T. congolense</i>	30.7% (22.8% - 38.6%)	25.1% (15.5% - 34.7%)	25.6% (17.0% - 34.1%)	27.7% (21.8% - 33.6%)
<i>T. vivax</i>	24.8% (13.7% - 36.0%)	22.1% (10.8% - 33.5%)	29.9% (17.8% - 42.1%)	26.7% (18.2% - 35.3%)
Trypanosomiasis	44.9% (33.1% - 56.7%)	43.8% (31.7% - 56.0%)	47.9% (37.5% - 58.4%)	46.8% (39.0 - 54.5%)

Table 3.5: Prevalence for trypanosomiasis

*Cluster sample estimation methods assume a minimum of 5% prevalence. Since the observed prevalence of *T. b. brucei* is so low, prevalence was calculated as a simple proportion



Trypanosomiasis

- 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

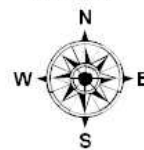
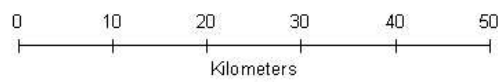
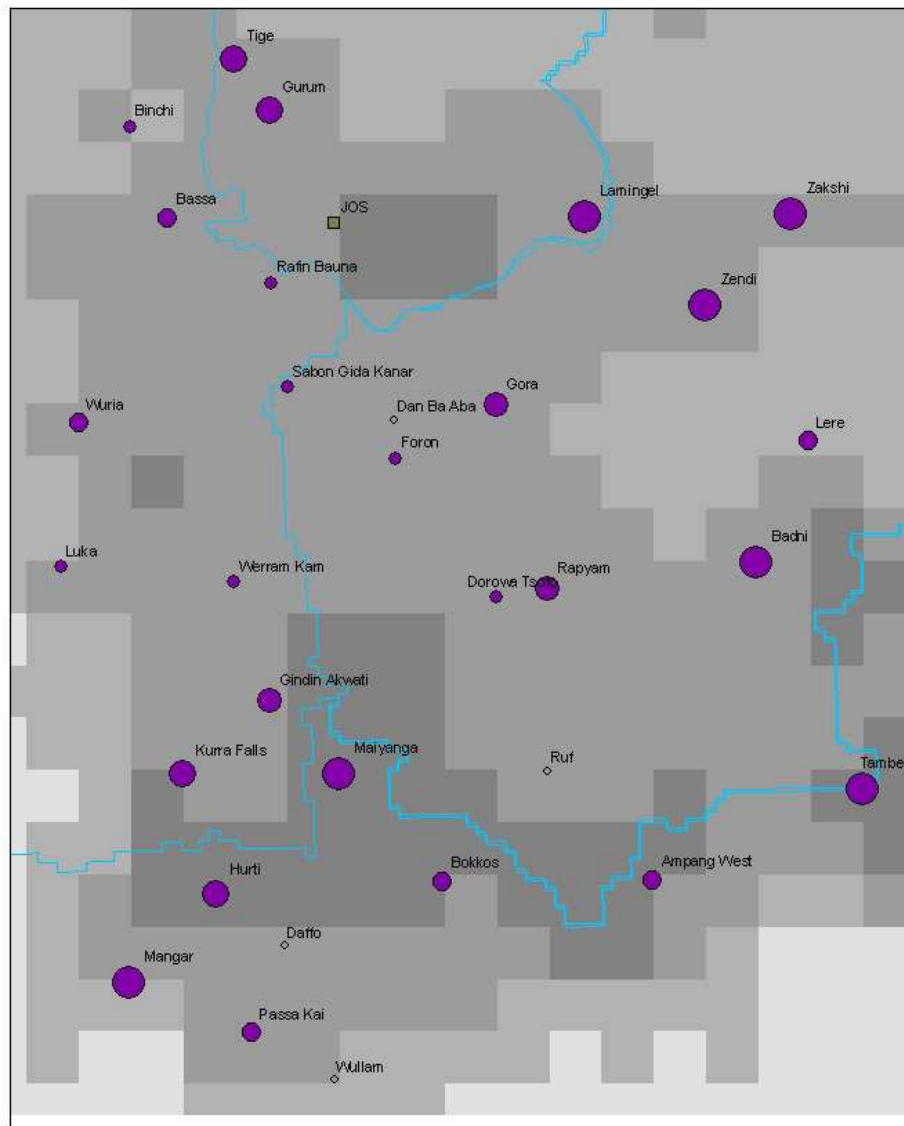


Figure 3.9a: Trypanosomiasis Distribution and prevalence - Dry season



Trypanosomiasis

- 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

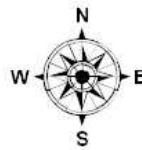
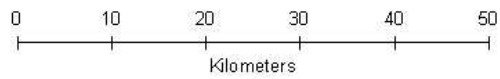
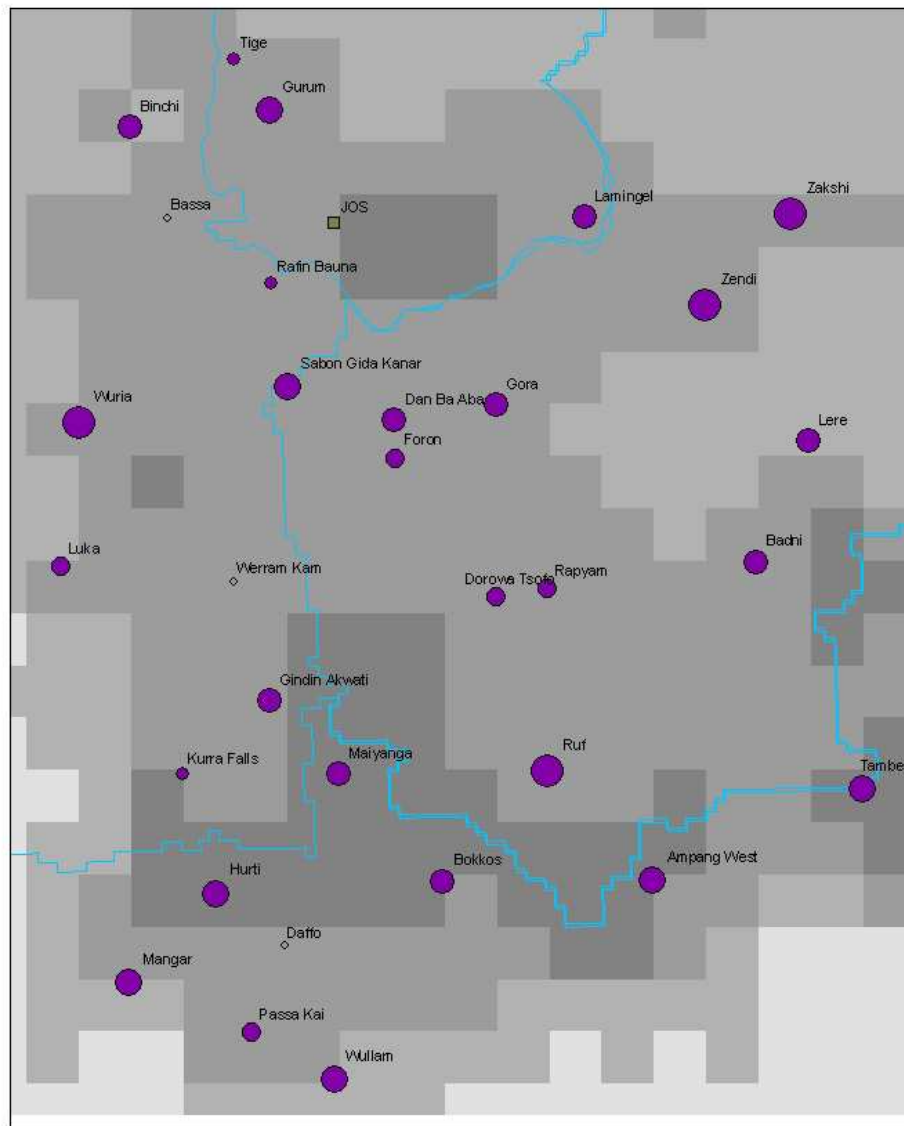


Figure 3.9b: Trypanosomiasis Distribution and prevalence - Early wet season



Trypanosomiasis

- 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

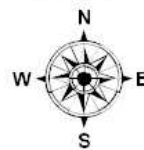
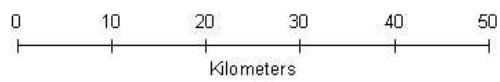
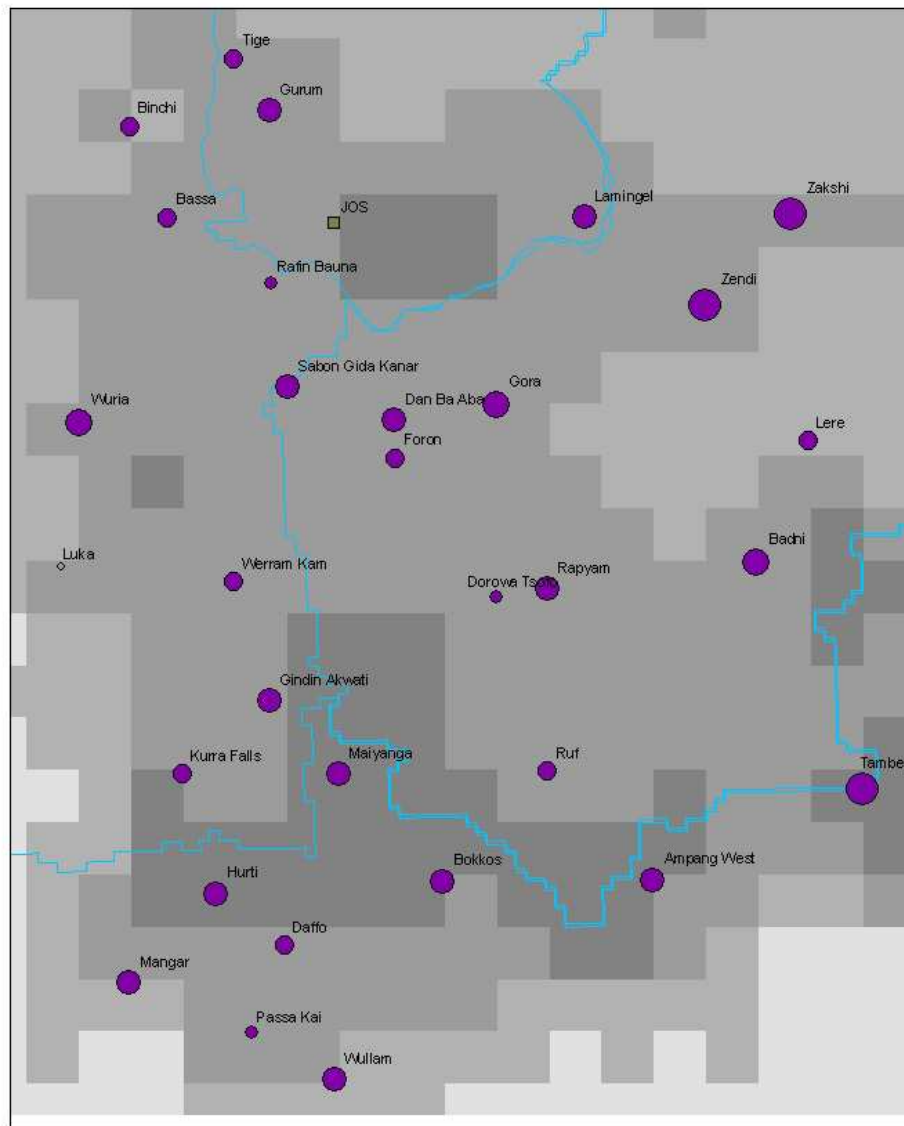


Figure 39c: Trypanosomiasis Distribution and prevalence - Late wet season



Trypanosomiasis

- 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

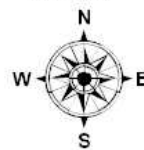
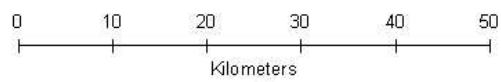


Figure 3.9d: Trypanosomiasis Distribution and prevalence - Annual

There was no clustering of trypanosomiasis (Moran's $I = 0.01$, $p = 0.902$)

3.3.2 Risk factors for trypanosomiasis

Risk factors for trypanosomiasis infection were dry season migration and wet season migration as shown in table 3.6. Altitude and the presence of alien migratory cattle reduced the risk of infection with trypanosomiasis. There was a significant interaction between wet season migration and the presence of alien migratory cattle which increased the risk of trypanosomiasis.

Variable	β	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.0918	< 0.001	0.9123	0.8964	0.9284
Dry season migration	0.1998	< 0.001	1.2212	1.0867	1.3722
Wet season migration	0.2051	0.0253	1.2276	1.0257	1.4693
Alien migratory cows	-0.3675	< 0.001	0.6925	0.6193	0.7743
Wet season migration* Alien migratory cows	0.4198	< 0.001	1.5216	1.2105	1.9127

Table 3.6: Risk factors for trypanosomiasis

Risk factors for trypanosomiasis infection in the dry season were migration in the preceding wet season and altitude as shown in table 3.7. The presence of alien migratory cattle reduced the risk of infection during the dry season.

Variable	Coefficient	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	0.0625	< 0.001	1.0645	1.0306	1.0995
Dry season migration	0.2326	0.0204	1.2619	1.0366	1.5361
Wet season migration	0.9367	< 0.001	2.5514	2.0642	3.1537

Table 3.7: Risk factors for trypanosomiasis in the dry season

The only significant risk factor for trypanosomiasis in the early wet season was migration during the preceding dry season while altitude reduced the risk of infection as shown in table 3.8.

Variable	Coefficient	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.1967	< 0.001	0.8214	0.7961	0.8476
Dry season migration	0.4075	< 0.001	1.5031	1.2229	1.8476

Table 3.8: Risk factors for trypanosomiasis in the early wet season

The only significant risk factor for trypanosomiasis in the late wet season was migration in the early wet season as shown in table 3.9. Both altitude and the presence of alien migratory cattle (odds ratio = 0.689, $p = <0.001$) reduced the risk of infection.

Variables	Coefficient	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.1152	< 0.001	0.8912	0.8647	0.9184
Wet season migration	0.4230	< 0.001	1.5265	1.2287	1.8964
Alien migratory cows	-0.5033	< 0.001	0.6045	0.5101	0.7164

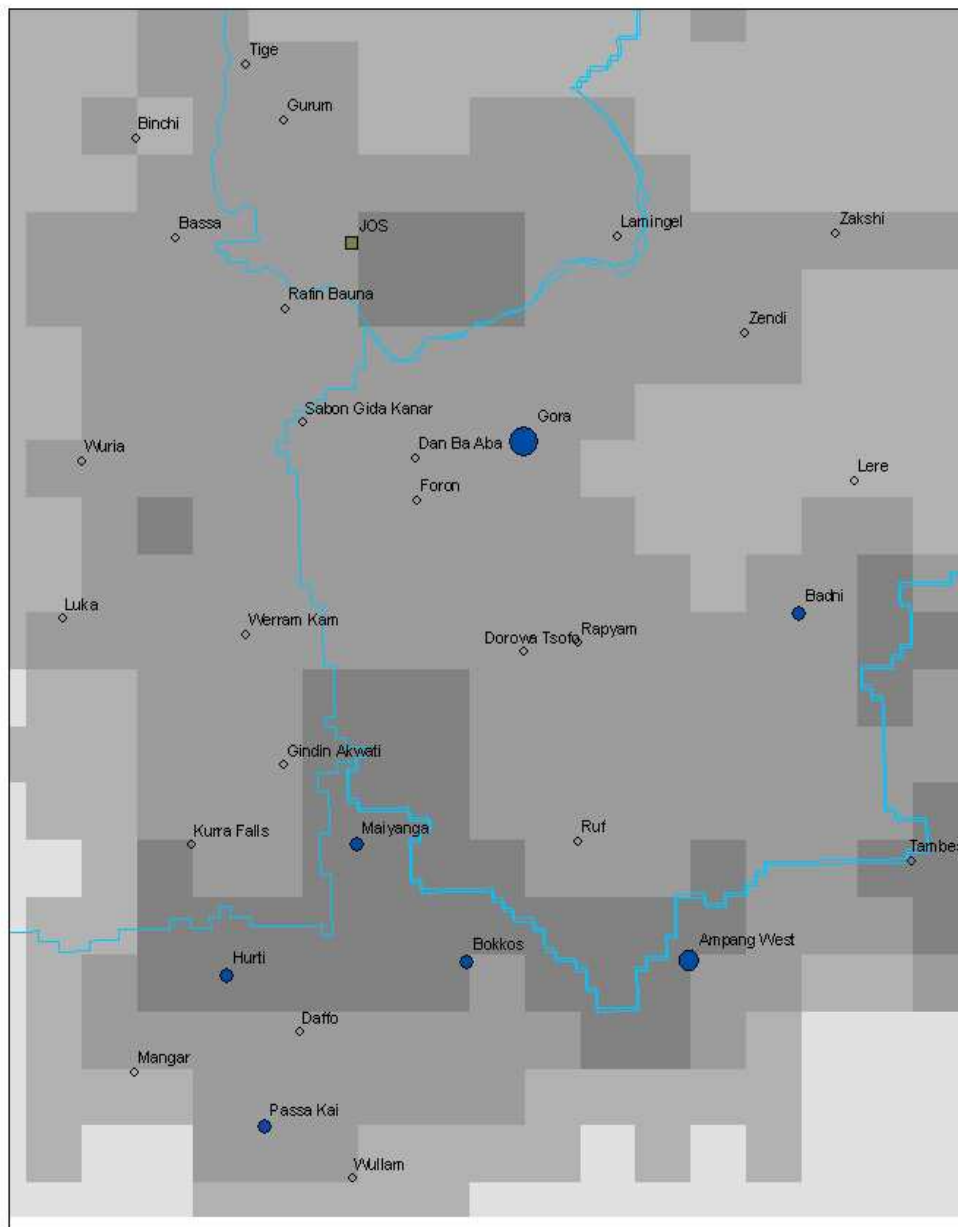
Table 3.9: Risk factors for trypanosomiasis in the late wet season

3.3.3 *T. b. brucei* prevalence and risk factors

T. b. brucei prevalence was 3.0% (2.4% - 3.9%) in the dry season 5.3% (4.4% - 6.2%) in the early wet season and 1.4% (0.9% - 1.9%) in the late wet season. Total annual prevalence was 3.2% (2.8% - 3.6%). Table 3.10 below shows the prevalence of *T. b. brucei* across the Jos Plateau. Cluster sample estimation methods assume a minimum of 5% prevalence. Since the observed prevalence of *T. b. brucei* is so low, prevalence was calculated as a simple proportion. There was a significant seasonal difference in prevalence ($\chi^2 = 56.1$, $p = >0.001$).

	Dry season	Early wet season	Late wet season	Annual
<i>T. b. brucei</i>	3.0% (2.4% - 3.9%)	5.3% (4.4% - 6.2%)	1.4% (0.9% - 1.9%)	3.2% (2.8% - 3.6%)

Table 3.10: Prevalence of *T. b. brucei*



TBR

- ◊ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

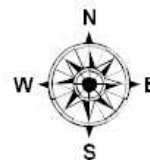
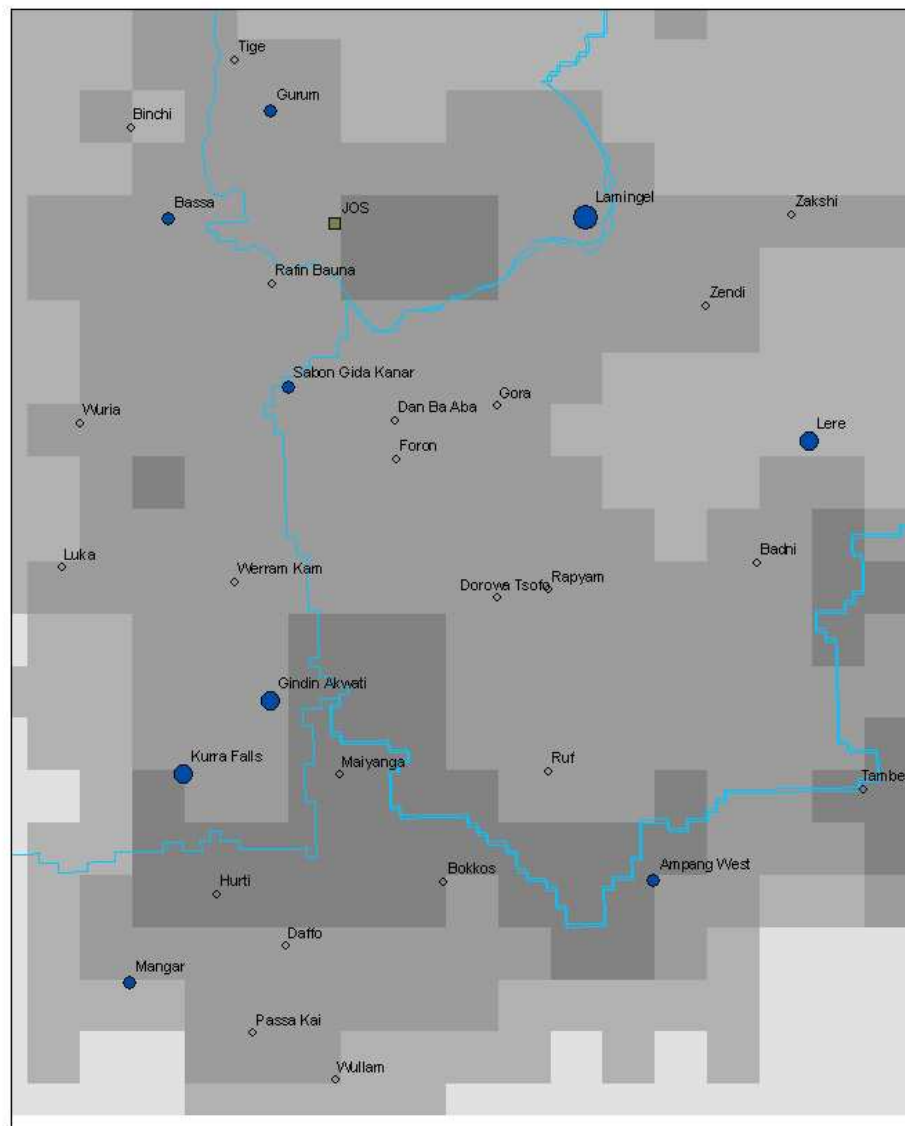


Figure 3.10a: *T. b. brucei* Distribution and prevalence - Dry season



TBR

- ◊ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

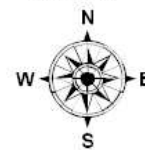
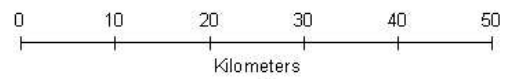
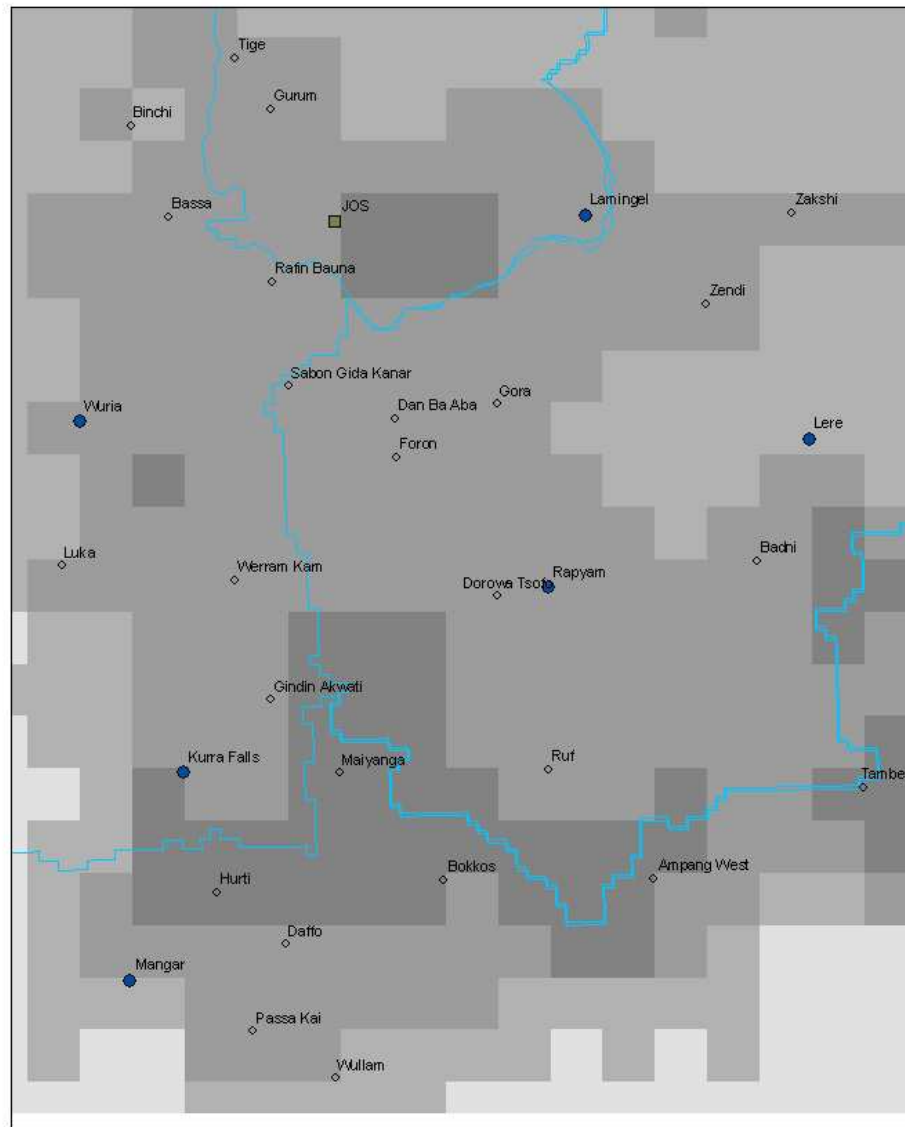


Figure 3.10b: *T. b. brucei* Distribution and prevalence - Early wet season



TBR

- ◊ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

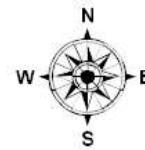
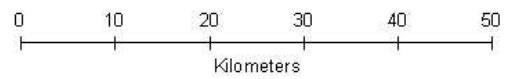
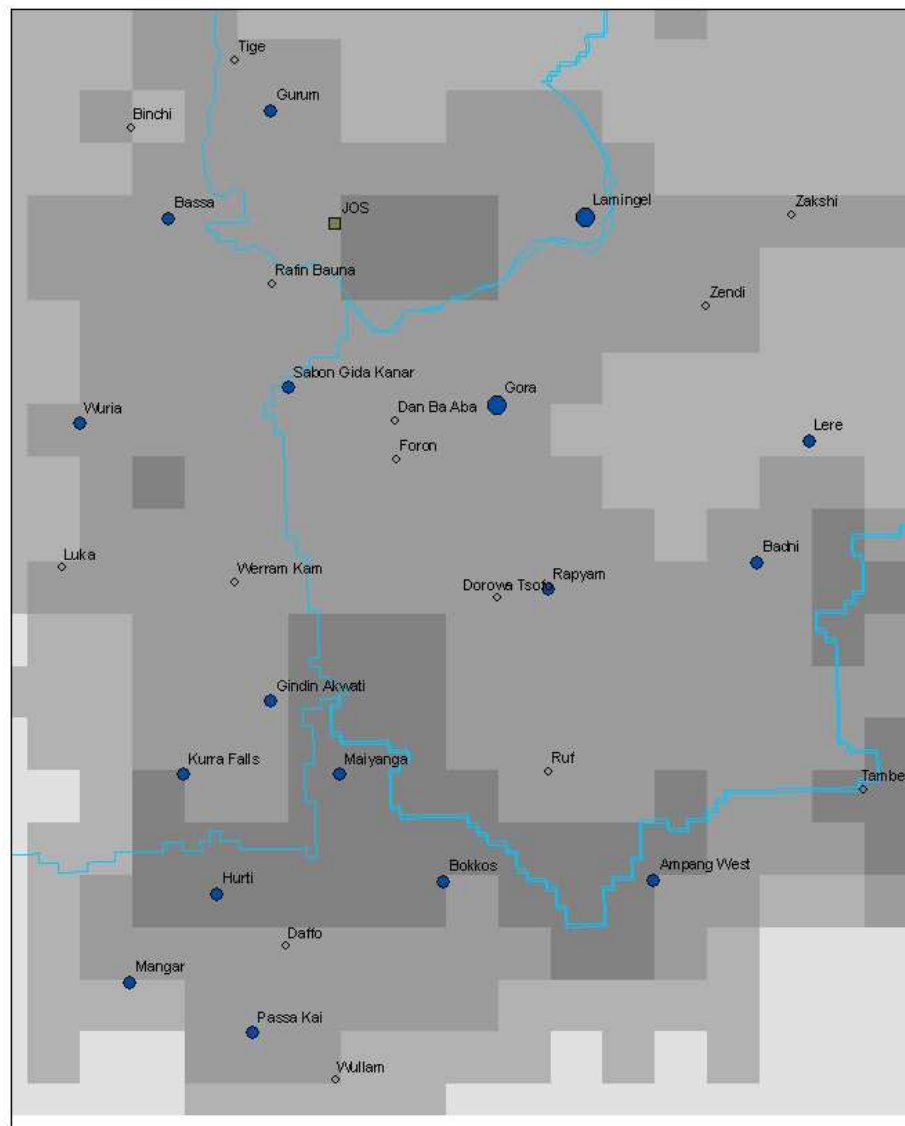


Figure 3.10c: *T. b. brucei* Distribution and prevalence - Late wet season



TBR

- ◇ 0%
- 0.1% - 20%
- 20.1% - 40%
- 40.1% - 60%
- 60.1% - 80%
- 80.1% - 100%

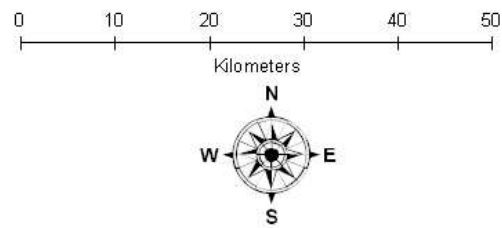


Figure 3.10d: *T. b. brucei* Distribution and prevalence - Annual

There was no clustering of *T. b. brucei* (Moran's I = -0.04, p = 0.425)

Risk factors for *T. b. brucei* infection were wet season migration and the presence of alien migratory cattle as shown in table 3.11. Altitude reduced the risk of *T. b. brucei* infection.

Variables	β	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.1482	< 0.001	0.8623	0.8251	0.9011
Wet season migration	0.7918	< 0.001	2.2075	1.6102	3.0263
Alien migratory cows	1.6462	< 0.001	5.1870	3.4883	7.7130

Table 3.11: Risk factors for *T. b. brucei* infection

3.3.4 *T. congolense* savannah prevalence and risk factors

T. congolense savannah prevalence was 30.7% (22.8% - 38.6%) in the dry season, 25.1% (15.5% - 34.7%) in the early wet season and 25.6% (17.0% - 34.1%) in the late wet season. Total annual prevalence was 27.7% (21.8% - 33.6%). Table 3.12 below shows the prevalence of *T. congolense* savannah across the Jos Plateau. There was significant seasonal variation in prevalence ($\chi^2 = 29.7$, $p = 3.6 \times 10^{-7}$).

	Dry season	Wet season (Early)	Wet season (Late)	Annual
<i>T. congolense</i>	30.7% (22.8% - 38.6%)	25.1% (15.5% - 34.7%)	25.6% (17.0% - 34.1%)	27.7% (21.8% - 33.6%)

Table 3.12: Prevalence of *T. congolense*

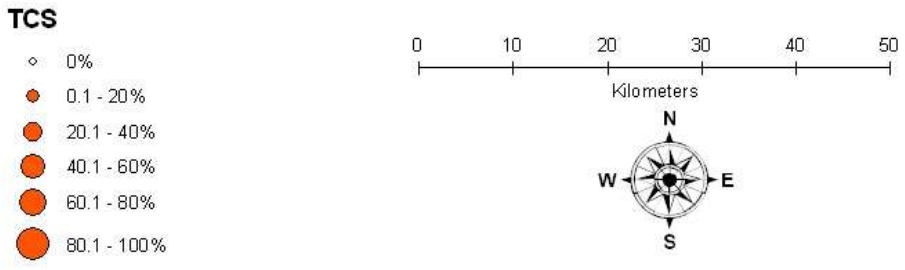
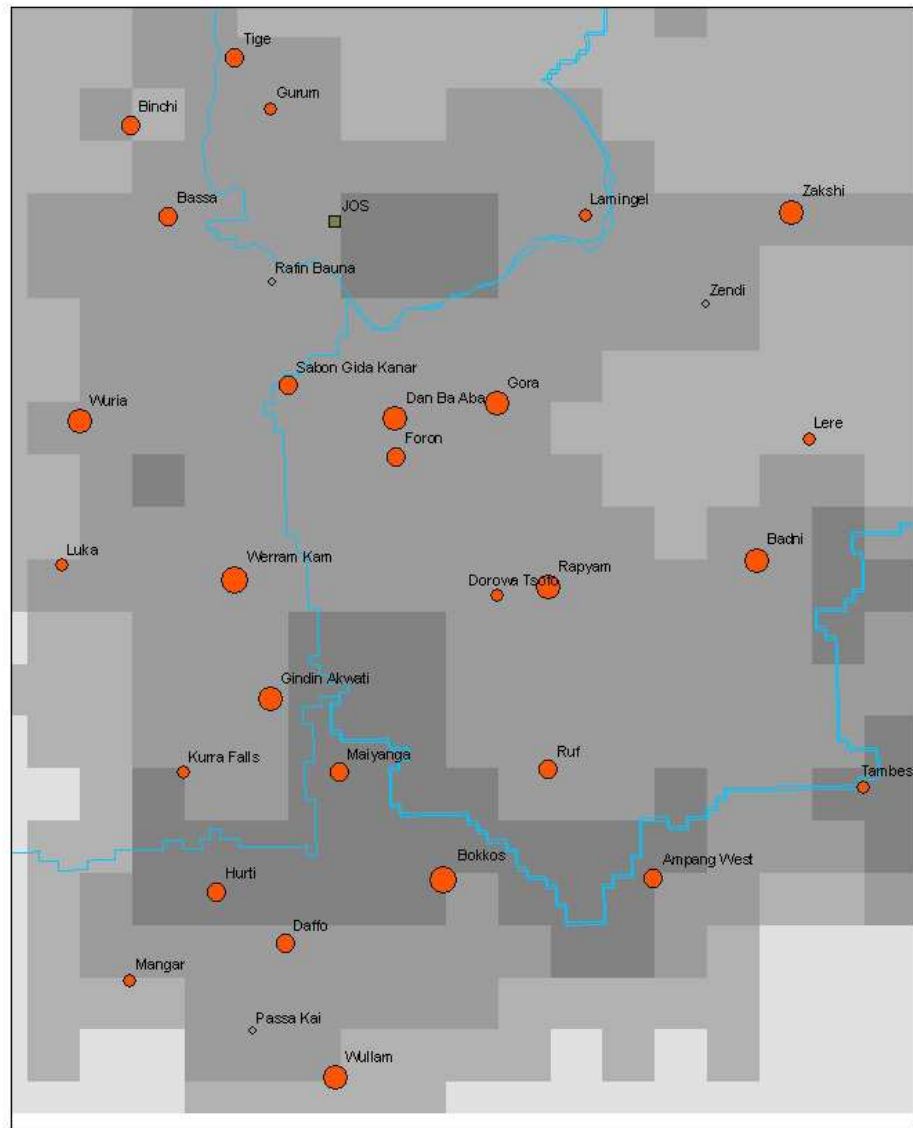


Figure 3.11a: *T.congolense* Distribution and prevalence - Dry season

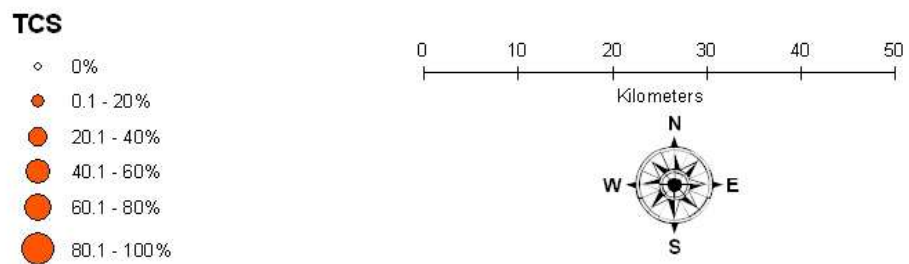
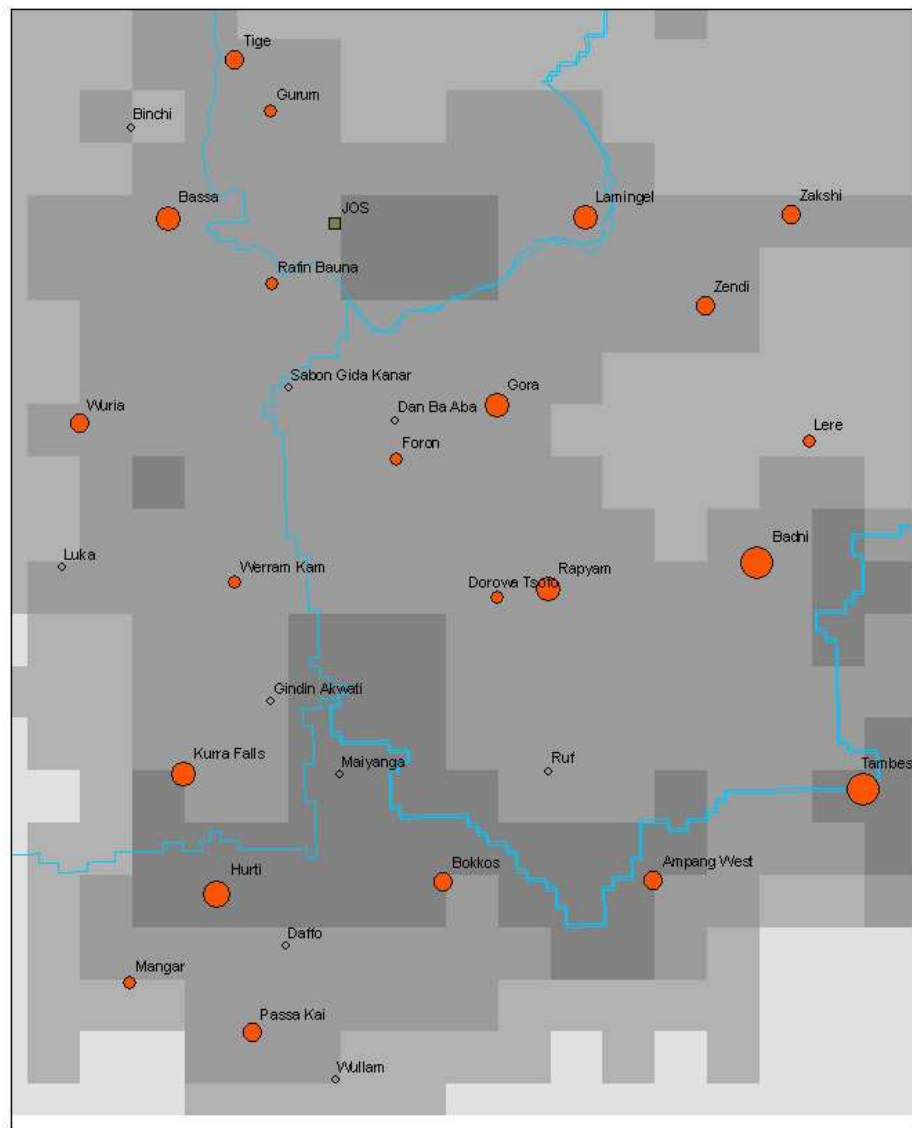
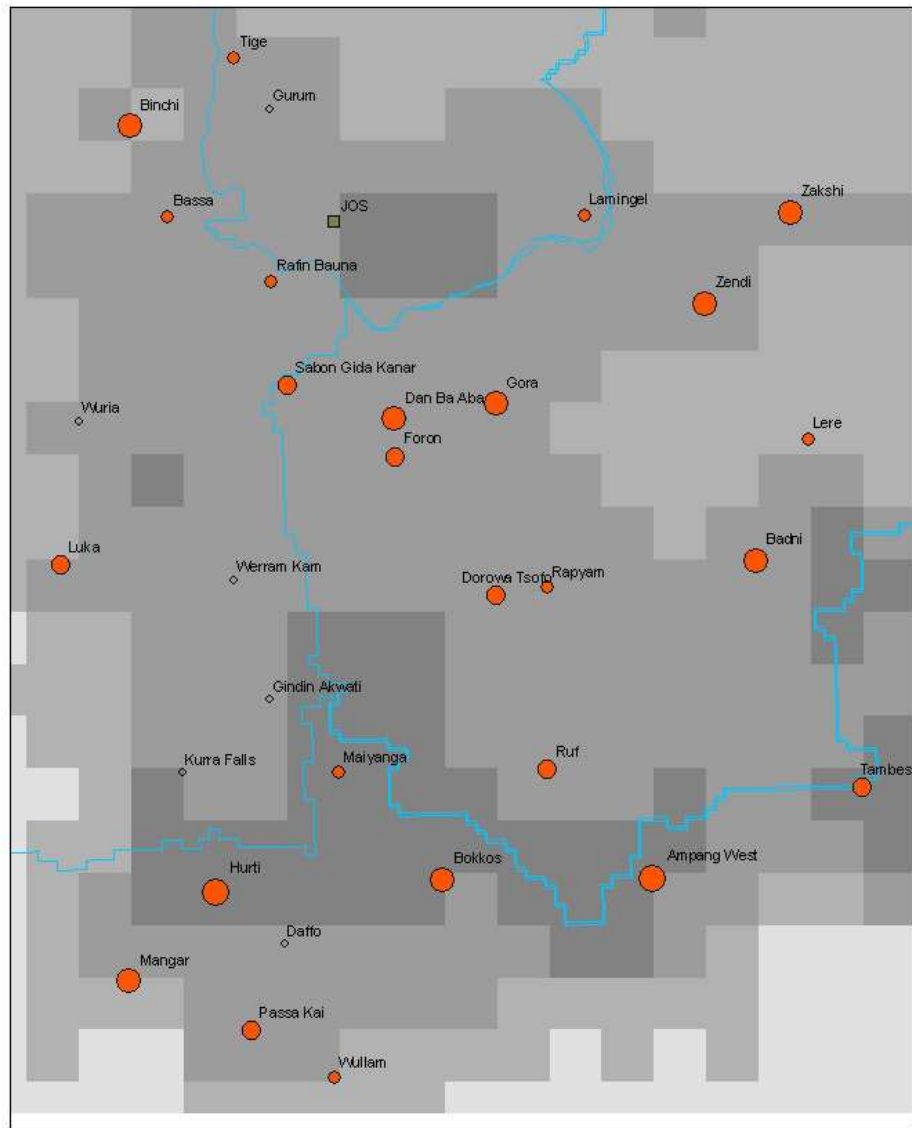


Figure 3.11b: *T.congolense* Distribution and prevalence – Early wet season



TCS

Figure 3.11c: *T.congolense* Distribution and prevalence - Late wet season

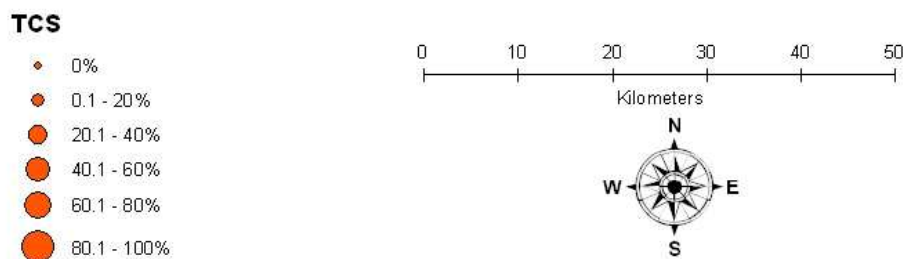
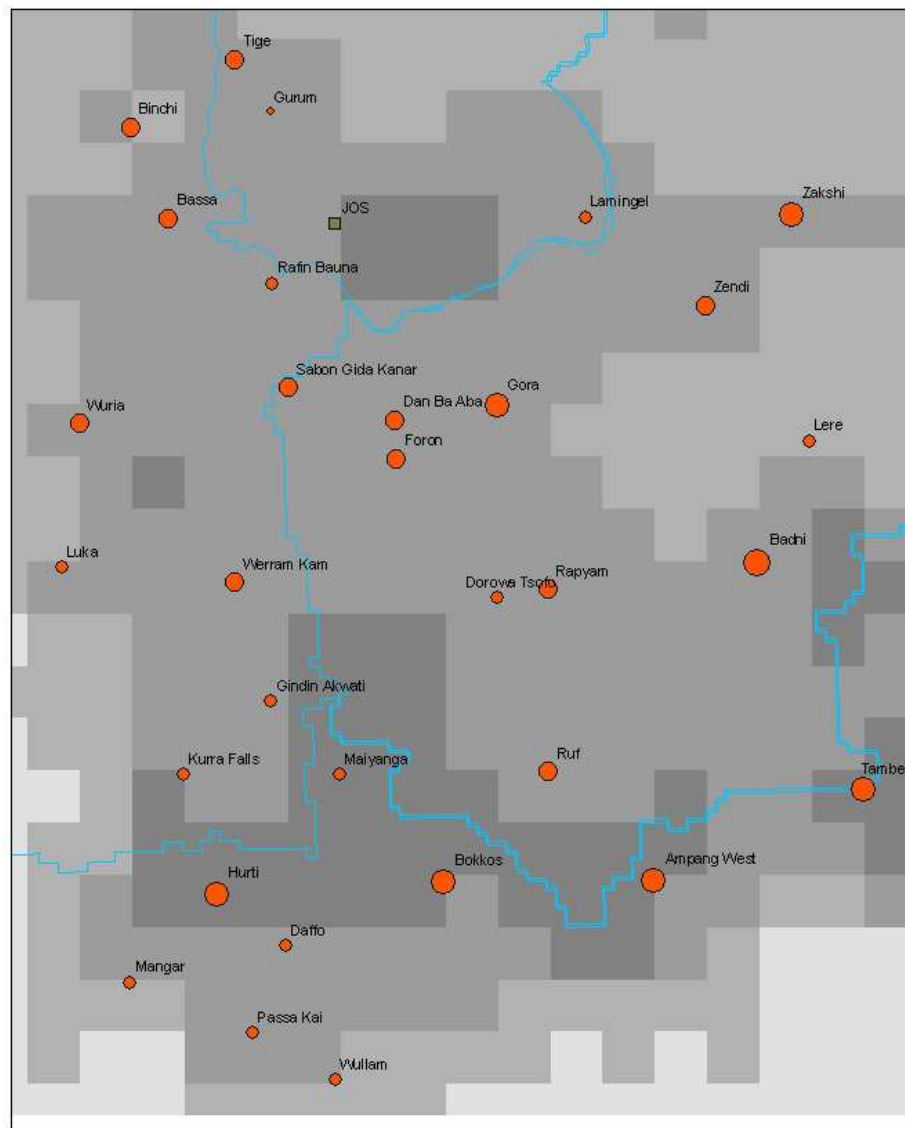


Figure 3.11d: *T. congolense* Distribution and prevalence - Annual

There was no clustering of *T. congolense* (Moran's $I = -0.03$, $p = 0.448$)

The only risk factor for *T. congolense* savannah was wet season migration while dry season migration and the presence of alien migratory cattle reduced the risk of trypanosomiasis as shown in table 3.13.

Variable	β	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.0548	< 0.001	0.9467	0.9281	0.9657
Dry season migration	-0.4005	< 0.001	0.6700	0.5918	0.7586
Wet season migration	0.6144	< 0.001	1.8486	1.6227	2.1059
Alien migratory cows	-0.4868	< 0.001	0.6146	0.5517	0.6846

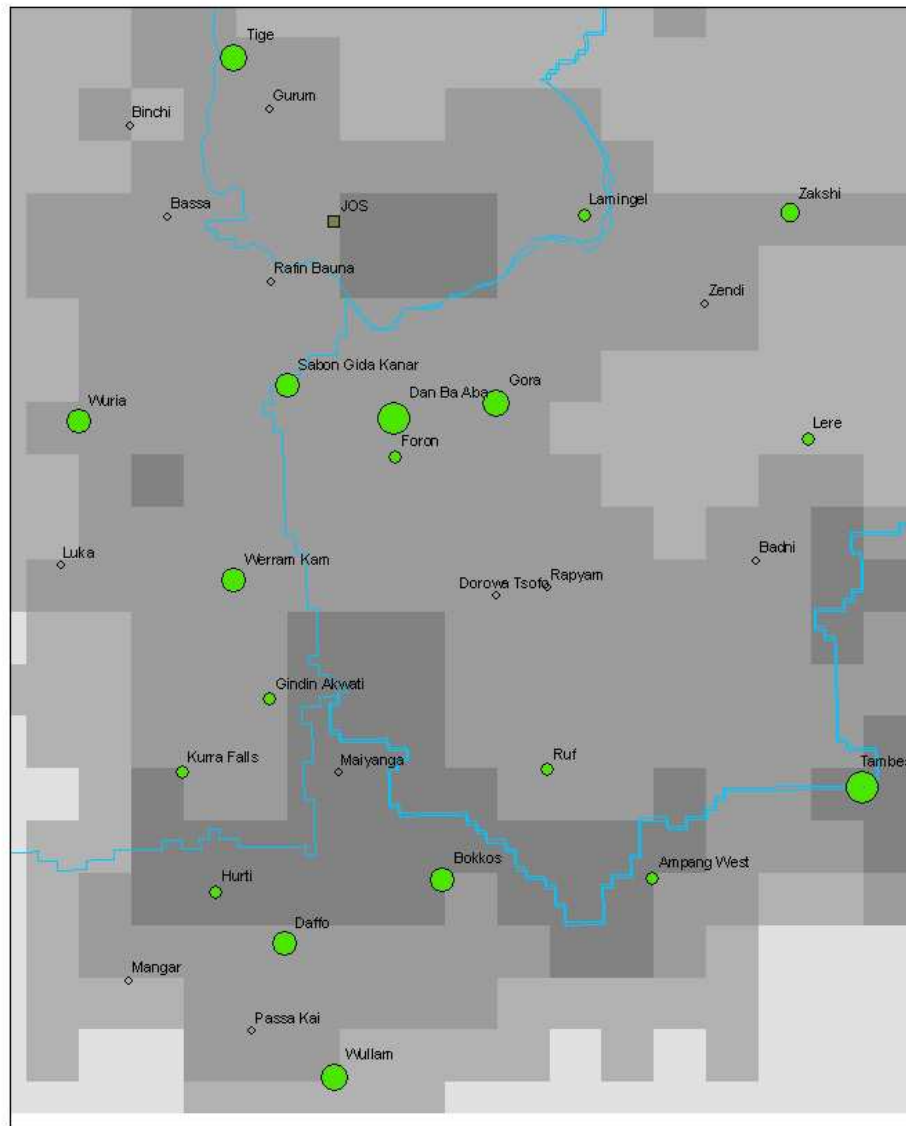
Table 3.13: Risk factors for *T. congolense* infection

3.3.5 *T. vivax* prevalence and risk factors

T. vivax prevalence was 24.8% (13.7% - 36.0%) in the dry season, 22.1% (10.8% - 33.5%) in the early wet season and 29.9% (17.8% - 42.1%) in late wet season. Total annual prevalence was 26,7% (18.2% - 35.3%). Table 3.14 shows the prevalence of *T. vivax* across the Jos Plateau. There was significant seasonal variation in prevalence ($\chi^2 = 35.3$, $p = 2 \times 10^{-8}$).

	Dry season	Early wet season	Late wet season	Annual
<i>T. vivax</i>	24.8% (13.7% - 36.0%)	22.1% (10.8% - 33.5%)	29.9% (17.8% - 42.1%)	26,7% (18.2% - 35.3%)

Table 3.14: Prevalence of *T. vivax*



TV

- ◇ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

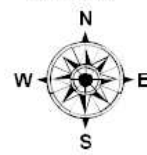
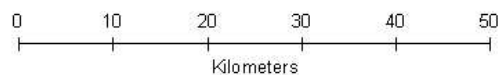
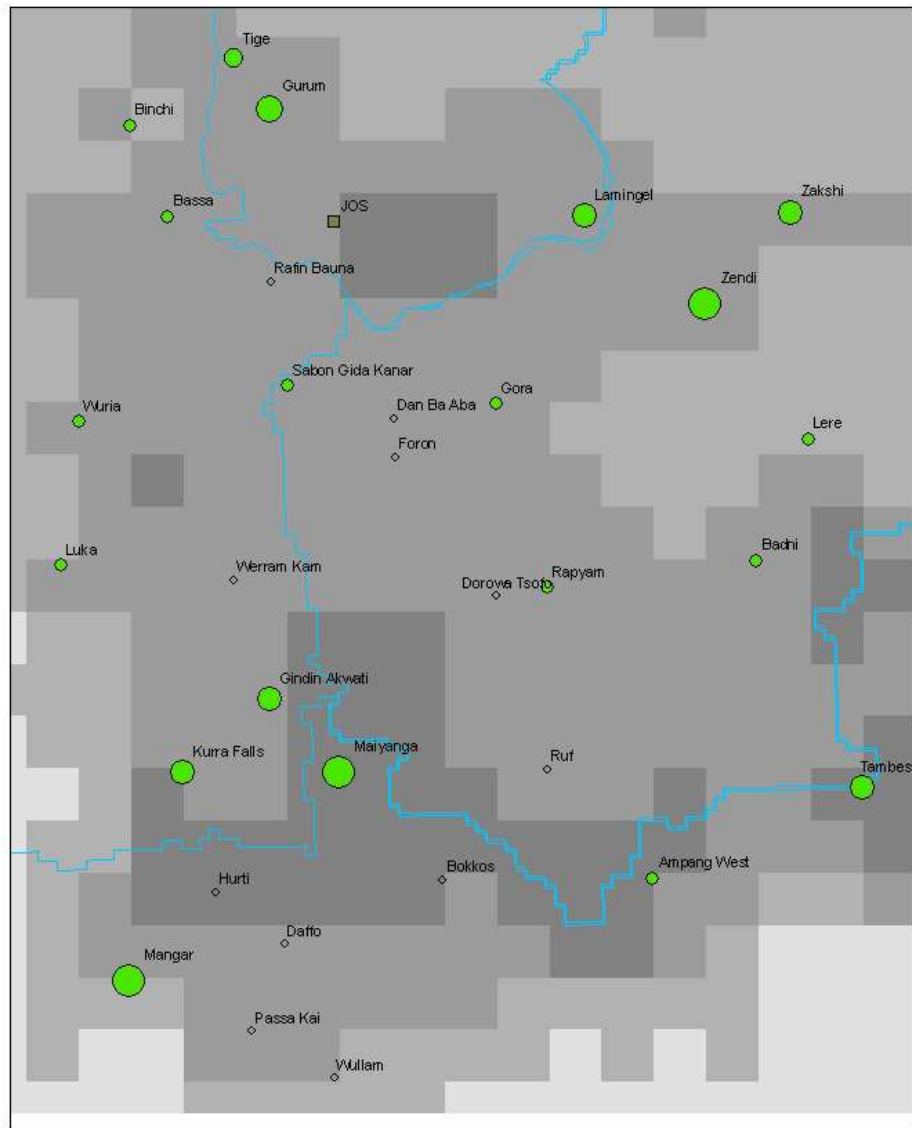


Figure 3.12a: *T. vivax* Distribution and prevalence - Dry season



TV

- ◊ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1%

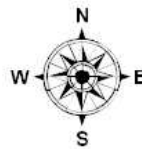
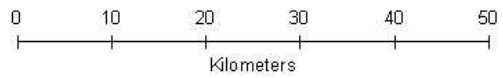
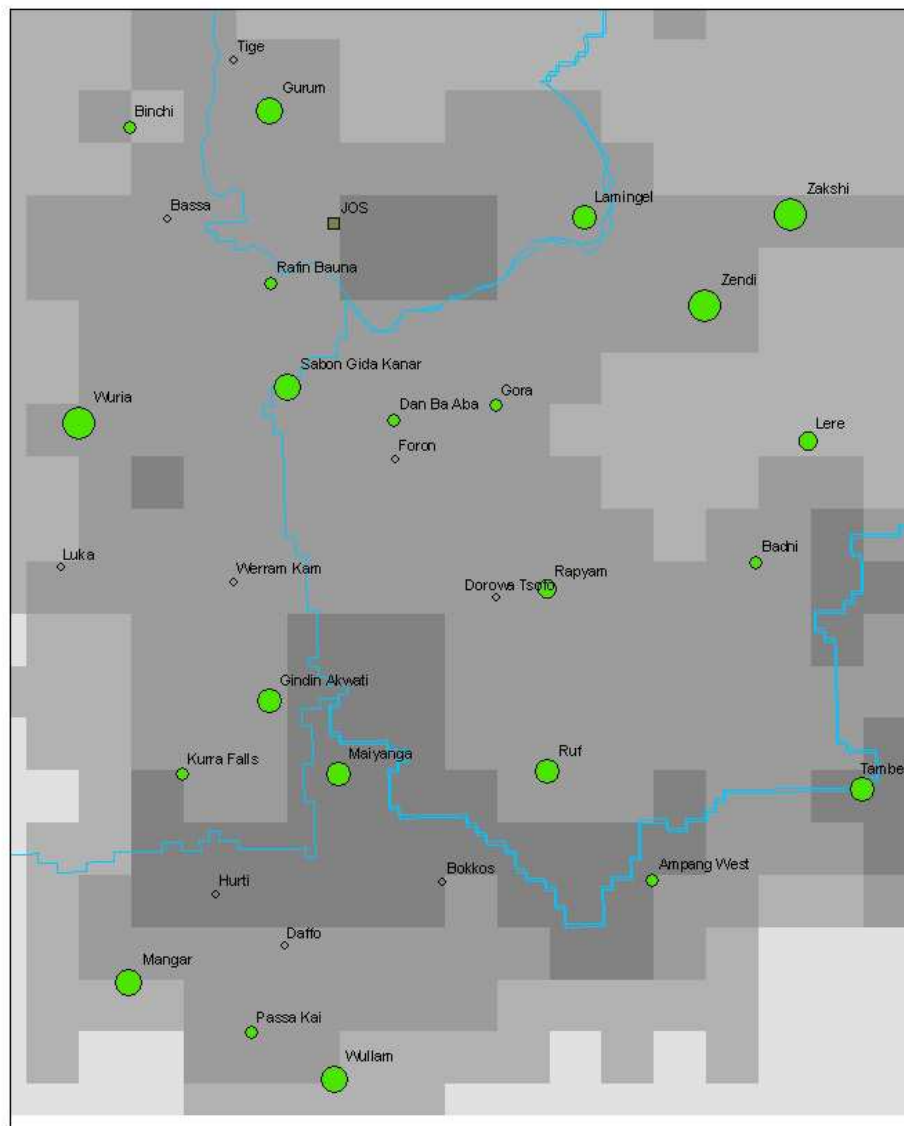


Figure 3.12b: *T. vivax* Distribution and prevalence - Early wet season



TV

- ◇ 0%
- 0.1 - 20%
- 20.1 - 40%
- 40.1 - 60%
- 60.1 - 80%
- 80.1 - 100%

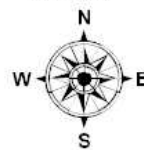
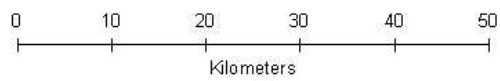


Figure 3.12c: *T. vivax* Distribution and prevalence – Late wet season

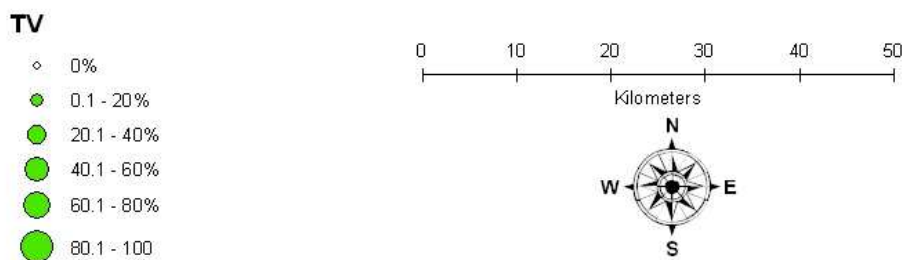
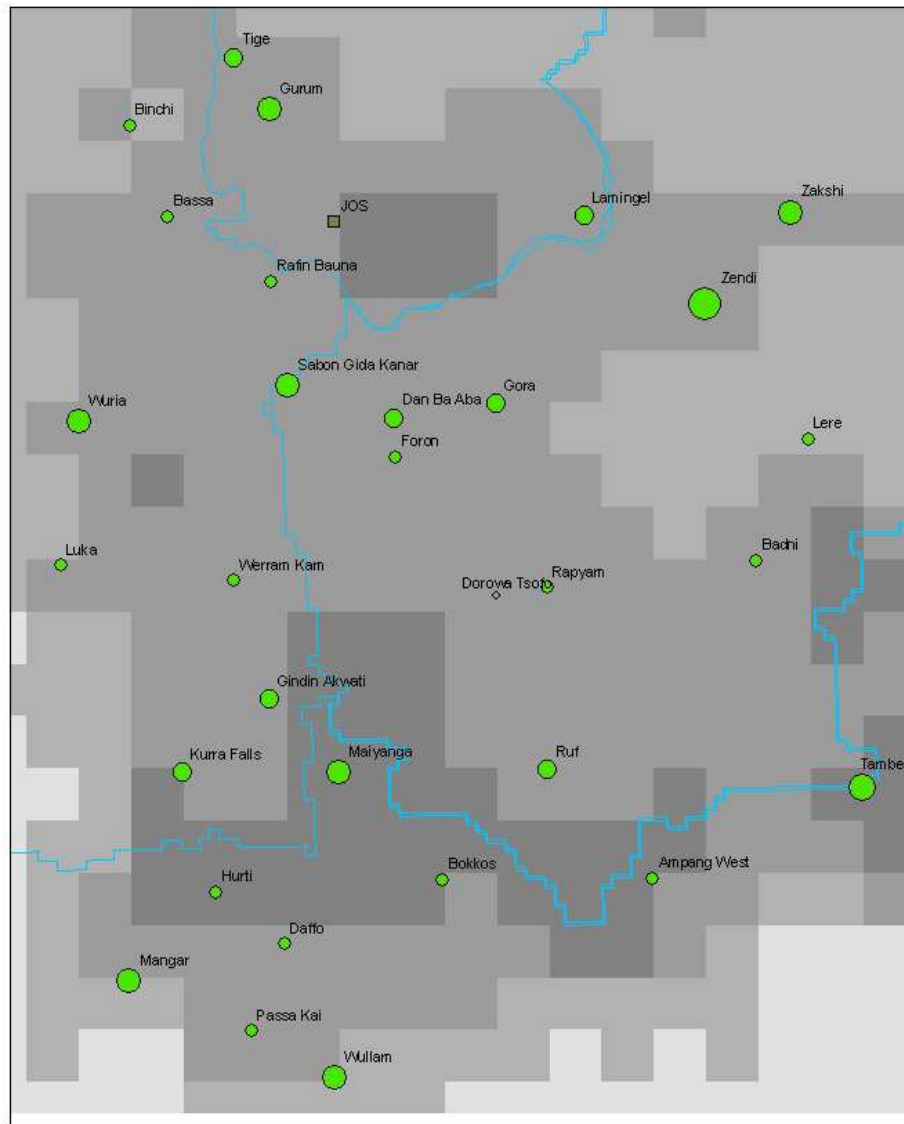


Figure 3.12d: *T. vivax* Distribution and prevalence - Annual

There was no clustering of *T. vivax* (Moran's $I = -0.02$, $p = 0.367$)

The only risk factor for *T. vivax* infection was dry season migration while altitude reduced the risk of infection as shown in table 3.15

Variables	β	p-value	Odds Ratio	95% C.I.	
				Lower	Upper
Altitude	-0.0925	< 0.001	0.9116	0.8937	0.9299
Dry season migration	1.2823	< 0.001	3.6049	3.0645	4.2405

Table 3.15: Risk factors for *T. vivax* infection

3.3.6 Seasonal variation

Three different patterns of seasonal variation were observed in village level data as illustrated in table 3.16 and figure 3.13.

Group 1: 15 of the 30 study villages (50%) were in this group. There was significant seasonal variation in these villages where the prevalence of trypanosomiasis is lowest in the dry season and increases significantly in the wet season ($\chi^2 = 211$, $p = <0.001$)

Group 2: 5 of the 30 study villages (16.7%) were in this group. There was no significant seasonal variation in these villages where the prevalence of trypanosomiasis remains at a constant level all year round. ($\chi^2 = 1.5$, $p = 0.173$).

Group 3: 10 of the 30 study villages (33.3%) were in this group. There was significant seasonal variation in these villages, the prevalence of trypanosomiasis is highest in the dry season, decreases as the wet season begins and increases again towards the end of the wet season. ($\chi^2 = 518$, $p = <0.001$).

Group	Prevalence			Annual
	Dry Season	Early Wet Season	Late Wet Season	
Group 1	23.5% (9.0% - 38.0%)	56.4% (36.5% - 76.3%)	43.7% (29.4% - 58.0%)	41.6% (28.7% - 54.5%)
Group 2	63.1% (18.4% - 100%)	66.0% (36.2% - 95.8%)	52.7% (8.2% - 97.2%)	62.7% (30.6% - 94.8%)
Group 3	67.6% (54.6% - 80.6%)	19.9% (8.0% - 31.8%)	50.9% (31.0% - 70.8%)	46.1% (36.5% - 55.7%)

Table 3.16: Prevalence of trypanosomiasis in seasonal variation groups

Despite this evidence, each group consists of less than twenty five clusters, the minimum number required for the assumptions made by cluster sampling techniques to hold true. This is also responsible for the wide confidence intervals observed.

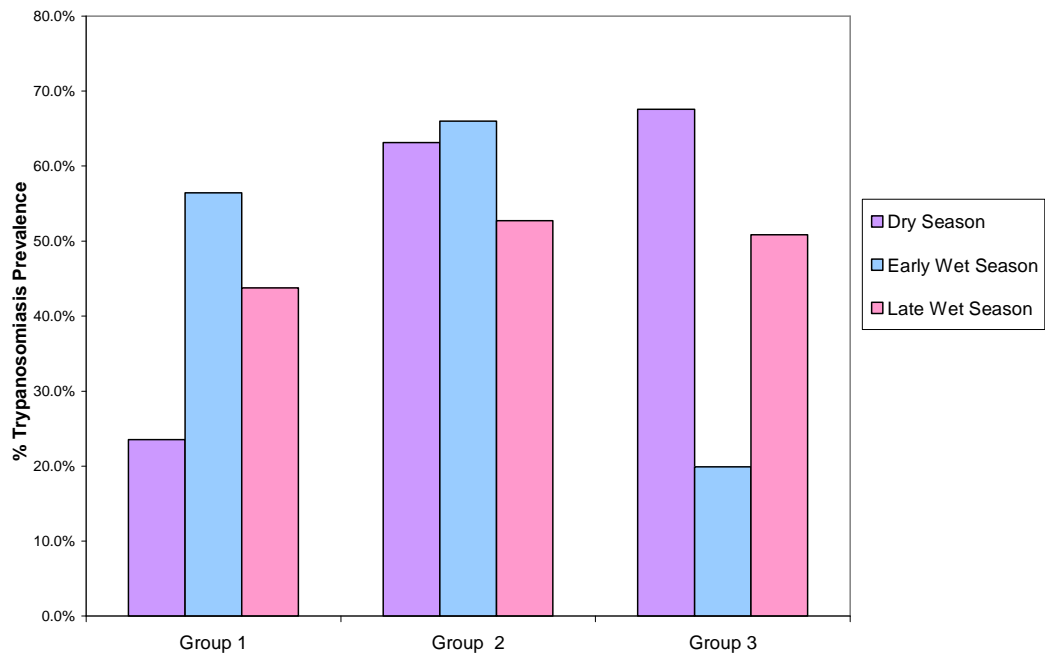


Figure 3.13: Seasonal variation patterns observed

3.3.7 Herd composition

The age, sex, breed and condition score of sampled animals was recorded. Since the sampled animals were a good representative sample of the total herd, this gives an indication of the total herd composition. The sampled animals consisted of 74.1% (73.1 – 75.1%) females and 25.9% (24.9 – 26.9%) males.

When considered by age group, 8.3% (7.5 – 8.7%) of the herd were calves below 6 months old: 3.8% (3.4 – 4.2%) male and 4.5% (4.0 – 4.8%) female. The overlapping confidence intervals indicate that there is no significant difference in sex ratio. 25.3% (24.2 – 26.2%) were juveniles between 6 months and 2 years of age: 12.5% (11.7 – 13.3%) male, 12.8% female (12.0 – 13.6%). The overlapping confidence intervals indicate that there is no significant difference in sex ratio. 66.4% (65.4 – 67.6%) were above 2 years old: 9.6% (8.9 – 10.3%) male and (56.8%) (55.6 – 57.9%) female. There is no overlap in confidence intervals, indicating that there is a significant difference in sex ratio in this age group. There is no overlap in confidence interval between the three age groups, indicating a significant difference in age group composition.

86.8% (86.0 – 87.6%) of sampled cattle were Bunaji, 2.6% (2.2 – 3.0%) were the red Rahaji breed and 10.6% (9.9 – 11.3%) were Bunaji x Rahaji crossbreeds. No other breeds were encountered. There is no overlap in confidence intervals, indicating that there is a significant difference in breed.

The condition scoring exercise showed that 4.1% (3.7 – 4.6%) of sampled cattle were lean, 95.5% (95.0% - 95.9%) were medium and 0.4% (0.2 – 0.5%) were fat.

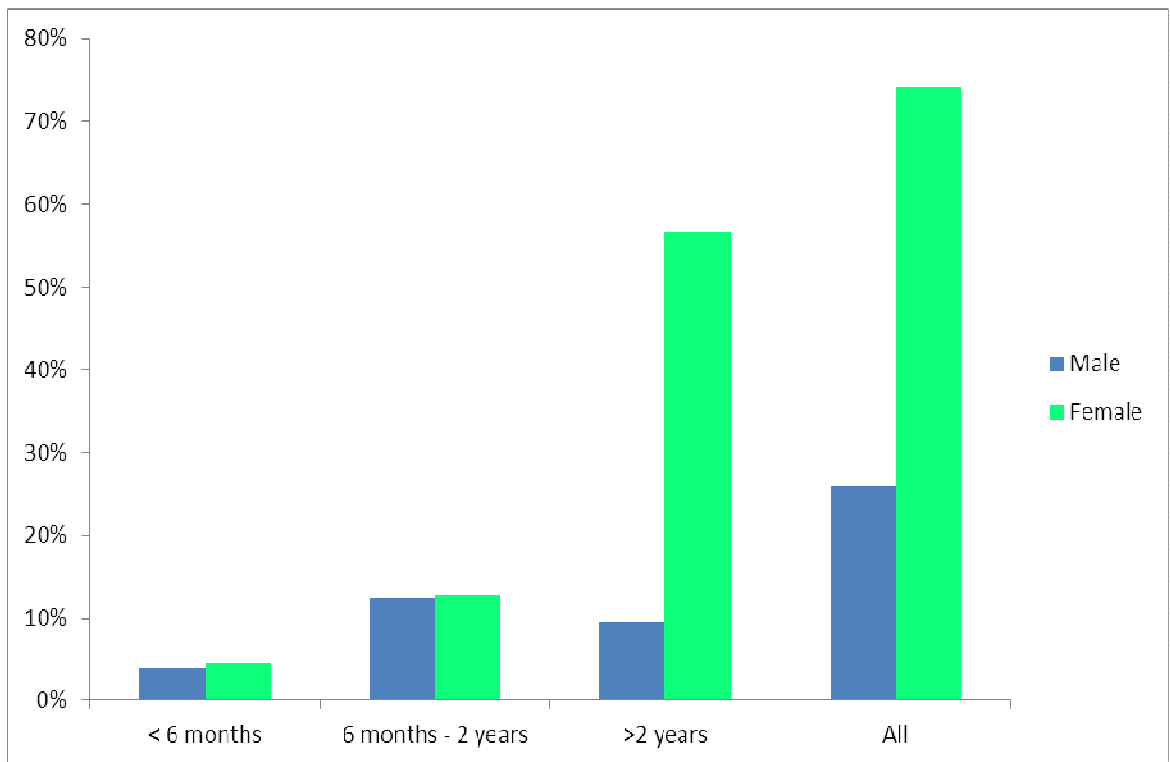


Figure 3.14: Age and sex distribution

3.3.8 Prevalence by sex

The prevalence of trypanosomiasis was 45.7% in males and 46.5% in females. There was no significant difference in prevalence of trypanosomiasis between males and females ($p = 0.436564$)

3.3.9 Prevalence by age

The prevalence of trypanosomiasis was 43.1% (39.0 – 47.1%) in calves less than 6 months, 47.8% (45.5 – 50.1%) in cattle between 6 months and 2 years old, and 46.2% (44.8 – 47.7%) in cattle over 2 years old. There was no significant difference in prevalence between the three different age groups ($\chi^2 = 3.843$, $p = 0.146$).

3.3.10 Prevalence by breed

The prevalence of trypanosomiasis was 46.3% (45.1 – 47.6%) in Bunaji cattle; 50.0% (42.6 – 57.4%) in Rahaji cattle and 44.8% (41.2 – 48.3%) in Bunaji and Rahaji cross cattle. There was no significant difference in prevalence between the three breed classes ($\chi^2 = 1.532$, $p = 0.465$).

3.3.11 Prevalence by condition score

The median condition score of trypanosomiasis infected cattle was 5 (M) whilst the median condition score of uninfected cattle was also 5 (M). The Mann-Whitney test revealed no significant difference in the median condition score of infected and uninfected cattle ($U = 13592263$, $p = 0.199$).

3.4 Discussion

This section discusses and interprets the results presented in section 3.3.

3.4.1 Trypanosomiasis prevalence

The prevalence of trypanosomiasis across the Jos plateau was found to be 46.8% (39.0 – 54.5%). This is comparable to prevalences recorded in single village surveys conducted on the Jos Plateau in previous years: 38.6% recorded by (Kalu 1996b), 37.6% recorded by (Kalu and Uzoigwe 1996) and, 40% recorded by (Anosike *et al.* 2003).

However, these studies were conducted using parasitological techniques which are far less sensitive than the PCR techniques used in this study. It therefore appears that there has been a reduction in prevalence, or that the results of this study underestimate the true prevalence of trypanosomiasis.

PCR offers very high sensitivity and specificity in the diagnosis of trypanosome infections (Artama *et al.*, 1992; Masiga *et al.*, 1992; Majiwa *et al.*, 1994) . Comparative studies show that its sensitivity surpasses that of classic parasitological methods by several orders of magnitude. The reported sensitivity of microscopy after concentration techniques is $2.5 \times 10^2 - 5 \times 10^3$ parasites/ml of blood (Picozzi K *et al.*, 2002) whereas PCR can detect 1 parasite/10ml of blood (1×10^{-1} parasite genetic material/ml) (MacLeod A *et al.*, 1997; Morrison *et al.*, 2007).

Nevertheless, when used in field studies, PCR frequently reports low prevalences, with results comparable to microscopy and no sign of the expected difference between the two methods (Clausen *et al.*, 1998; Picozzi K *et al.*, 2002; Cox *et al.*, 2010). This phenomenon either reflects the actual circumstances or is an artefact due to issues associated with the sampling procedure, the sample-storage system, the PCR method, or a combination of all

of the above. Competing target DNA, residual PCR inhibitors, differences in copy number and/or length of target sequence are some of the imperfections within the PCR process that could be involved. Cluster sampling which was used in this study is known to give reduced precision when compared to simple random or stratified sampling. The use of cluster sampling is justified in situations where constructing a complete list of population elements is difficult, costly, or impossible or where the population is concentrated in "natural" clusters. In both of these situations, economic constraints can make other sampling options unworkable and the reduced costs make up for any losses in precision. In this study, it was impossible to compile a complete list of cattle, herds or households due to the large numbers of people and animals present and the low levels of trust and cooperation encountered during the pre-survey period so the use of cluster sampling was justified and is unlikely to have contributed to the similarity in PCR and microscopy results seen here.

Whatman FTA cards were the sample storage method used in this study, for several reasons. They provide a safe, secure and reliable method for the collection, transportation and room temperature storage of DNA. When samples are applied to FTA treated paper, cells are lysed and nucleic acids are immobilized within the matrix. Amplification or restriction enzyme digestion can then be performed directly on the treated paper without the need for extensive extraction procedures. FTA cards rapidly inactivate all organisms including blood borne pathogens and bacteria, making them safe enough to be shipped via regular postal services without hazardous material labelling. Genomic DNA stored on FTA cards for over 11 years exhibits no loss in PCR proficiency (Whatman International Ltd, UK; DNA testing centre Inc).

It is standard practice to take a single 3mm punch from the FTA card to be used as the sample material in the PCR reaction. This is a small percentage of the material available on the card, and a minuscule proportion of the blood available within the animal sampled. Typically only 1µl of blood ends up in the PCR reaction mix. In addition, DNA applied to FTA cards sits where it is placed and is not evenly distributed across the matrix. All of these factors lead to underestimation of trypanosome prevalence. Cox *et al.* (2010) found 9.7% prevalence using this sampling method but on repeated sampling a final prevalence of 60% was revealed, mostly with low parasite densities. This shows that single punch PCR sampling from FTA cards cannot accurately estimate the prevalence of trypanosomiasis at either animal or herd level.

This underestimation due to uneven distribution of parasite DNA on the FTA matrix is further exacerbated by low parasite densities and trypanosome aggregation as is commonly seen in natural infections of indigenous cattle. In this study, five 3mm punches were used in each PCR reaction to minimise these effects but this may not have completely counteracted the inherent underestimation associated with this method.

It may also be possible that the results presented represent the true situation on the ground and that the rates of trypanosome infections have dropped in recent years. Previous trypanosomiasis studies conducted on the Jos plateau often took place following complaints by farmers. As such they are likely to represent high prevalence areas or outbreak situations. Earlier surveys, particularly those conducted in the 1990s, took place at a time when tsetse flies had only recently invaded the Jos plateau and a less stable epidemiology, characterised by disease outbreaks of high prevalence was more common than in recent times. The mean annual prevalence of 46.8% covers the whole of the plateau and masks the wide range of prevalences recorded at village level 8.8% - 95.6%.

Previous studies were based on a single village at a time and are therefore not necessarily comparable to the area wide prevalence recorded here.

PCR is a very sensitive technique and this must be considered when relating the prevalences recorded here to impacts on animal health and production. The technique detects parasite DNA and so not every PCR positive animal will be clinically ill. This means that the impact of trypanosomiasis on animal health and production is not directly proportional to the number of infected animals.

3.4.2 Risk factors for trypanosomiasis

The different risk factors for trypanosomiasis investigated are discussed in this section.

Results showed that:

- Migration at any time is a significant risk factor for trypanosomiasis
- Alien migratory cattle reduce risk of disease in the absence of seasonal migration but increase risk of disease where there is seasonal migration
- Effect of all risk factors increased during dry season

3.4.2.1 Age, sex and breed

There were no differences in prevalence between different age groups, breeds or genders, indicating that age, sex and breed are not risk factors for trypanosomiasis infection.

3.4.2.2 Migration

Dry season migration increased the risk of trypanosomiasis infection by 1.22 ($p < 0.001$) whilst wet season migration increased risk by 1.26 ($p = 0.02$). Wet season migration

increased risk during the dry season by 2.55 ($p = 0.03$) and during the late wet season by 1.53 ($p < 0.001$). Dry season migration increased risk in the dry season by 1.26 ($p = 0.02$) and in the early wet season by 1.50 ($p = < 0.001$).

These results show that migration at any time is a significant risk factor for trypanosomiasis. This can be ascribed to the increased tsetse challenge en route and at some migration destinations, increased vector/host contact, increased susceptibility due to stress and poor condition associated with trekking and migration. This observation is consistent with several previous reports: The introduction of trucks for transport of trade cattle instead of trekking reduced the incidence of trypanosomiasis arriving at the Jos market from 5.3% to 0% and showed an even more dramatic decrease from 65% to 8.5% at the southern market of Ilorin in the humid zone (Kilgour and Godfrey, 1978). Trucking eliminated the negative effects of trekking by reducing vector/host contact, increasing condition and reducing susceptibility to trypanosomiasis. De La Rocque *et al.* (2001) investigated trypanosomiasis in the Volta river basin of northern Ghana and demonstrated that the epidemiology of trypanosomiasis is closely linked to management and animal husbandry in areas where only riverine tsetse flies are present. An association between migration and tsetse abundance and distribution has also been demonstrated – no tsetse flies were caught at the grazing sites of fully sedentary cattle whereas *G. tachinoides* and *G. palpalis* were present at the grazing grounds of partially sedentary cattle which practiced seasonal migration (Mahama *et al.*, 2005). This demonstrates the effect that migration has on tsetse challenge. When vertebrate hosts are scarce, and cattle move in large numbers, tsetse have been shown to follow them along their stock routes within Nigeria, even into areas with vegetation that would ordinarily be classified as unsuitable (Jordan, 1960).

3.4.2.3 Alien migratory cattle

The presence of alien migratory cattle reduces risk of trypanosomiasis in the absence of seasonal migration by 0.749 ($p = <0.001$). This could be due to the fact that alien migratory cattle act as a buffer between tsetse and local cattle. Alien migratory cattle are more likely to be bitten as they camp in the open rather than in peridomestic areas like the local cattle and their herders are less able to avoid tsetse hotspots than local herdsman. It is therefore likely that the presence of alien migratory cattle reduces the number of tsetse bites on local cattle and therefore reduces their risk of trypanosome infection.

However, the presence of alien migratory cattle increases risk of trypanosomiasis when there is seasonal migration (wet season migration* alien migratory cows OR = 1.52, $p = <0.001$). This may be due to the increased transmission of some contagious disease that predisposes cattle to trypanosomiasis. If this disease is only encountered during migration but is also introduced to the home village by alien migratory cattle, then cattle are doubly exposed to it which may dramatically increase their risk of trypanosomiasis. Whatever the specific reason for this observation, it is clear that increased cattle movement around the region represented by the combination of seasonal migration and the presence of alien migratory cattle increases the risk of trypanosomiasis infection.

3.4.2.4 Altitude

Every 50m increase in altitude reduces risk of trypanosomiasis by 0.91(<0.001). Table 3.17 shows the effect of increasing altitude in the different seasons.

Season	Odds ratio	P value
Dry season	1.06	<0.001
Early wet season	0.82	<0.001
Late wet season	0.89	<0.001

Table 3.17: Effects of increasing altitude on risk of Trypanosomiasis

The observed reduction in risk in the wet season and across the year could be attributed to the association between altitude, population density and cropping intensity rather than any direct effect of altitude on tsetse flies. There is a general tendency for high altitude areas to have high population densities (Baumgartner *et al.*, 2008; Mubanga, 2009) The highest parts of the Jos plateau also have the highest population densities and also the highest cropping intensities in the area. As such, they are also the least attractive areas to tsetse due to the excessively fragmented tsetse habitats.

The opposite effect is seen in the dry season when increasing altitude increases the risk of trypanosomiasis. Again, this may be associated with the high population densities and cropping intensities associated with high altitude areas. Availability of pasture and water in such areas during the dry season is much lower than in less densely populated areas. As such, cattle raised in these areas are on a lower plane of nutrition, in poorer condition and will be more susceptible to trypanosomiasis infection. This effect seems to be a more important factor than the reduced tsetse challenge due to fragmented tsetse habitats in these areas but this is not unexpected as very low populations of riverine tsetse flies have been shown to maintain transmission of trypanosomiasis (Kalu, 1995; Bouyer, 2006; Guerrini and Bouyer, 2007).

3.4.3 *T. b. brucei* prevalence & risk factors

Prevalence of *T. brucei* across the Jos plateau was 2.9% (2.3% – 3.7%). No seasonal variation in prevalence was observed. The results indicate low circulation of *T. brucei* parasites in the area. This is consistent with the results of several trypanosomiasis surveys carried out on the Jos plateau, (Kalu, 1996a; Anosike *et al.*, 2003.) across Nigeria (Kalu, 1995; Kalu *et al.*, 2001) and elsewhere in Africa (Leak *et al.*, 1993; Kalu,

1995; Kalu *et al.*, 2001; Masiga *et al.*, 2002; Mahama *et al.*, 2005; Bouyer, 2006; Mamoudou *et al.*, 2006; Guerrini & Bouyer, 2007; Bett *et al.*, 2008) which consistently report low prevalence or absence of *T. brucei* in cattle, sheep and goats, but high prevalence in pigs (Onah, 1991). *G. tachinoides* and *G. palpalis*, the vectors found on the Jos plateau have a demonstrated capacity to transmit *T. brucei* (Baldry, 1964; Onah, 1991) therefore the low prevalence is most likely due to the reported resistance of indigenous West African cattle to *T. brucei* infections (Kalu, 1995). The Bunaji (Zebu) cattle kept on the Jos plateau are not strictly indigenous cattle but have been kept in West Africa for hundreds of years (Mattioli, 2000). While they are not trypanotolerant like the true indigenous cattle, they have acquired a certain degree of resistance to trypanosome infections compared to exotic breeds e.g. Friesians. It is therefore reasonable to assume that this resistance to *T. brucei* infection is present on the Jos plateau and is a contributing factor to the low prevalence of *T. brucei* in cattle.

The presence of alien migratory cattle increased the risk of infection by 5.815 ($p = <0.001$). This indicates that there is little local transmission of *T. brucei* on the Jos plateau (due to the aforementioned resistance in cattle which are the main bovid vector) and that this parasite is introduced into the area by infected alien migratory cattle. When local tsetse flies feed on such animals they are then able to transmit *T. brucei* to local cattle. Thus the presence of alien migratory cattle is closely associated with *T. brucei* infection and increases the risk of infection 5 - fold.

Based on this assumption, we would expect all forms of migration to increase the risk of infection as cattle pass through areas of *T. brucei* transmission. However, only wet season migration increases the risk of infection by 1.863 ($p = <0.001$). This may be attributed to

the increased tsetse abundance associated with the wet season and the increased vector/host contact, increased susceptibility due to stress and poor condition and increased contact with *T. brucei* transmission areas associated with migration. Dry season migration on the other hand reduces the risk of infection by 0.6768 ($p = 0.005$).

The main differences between wet and dry season migration are the difference in availability of food and water and the change in tsetse abundance and distribution. During the dry season, tsetse abundance is reduced but dispersal is low so tsetse apparent density is high. This is particularly so in the case of riverine tsetse flies which concentrate in gallery forests and thickets along riverbanks during the dry season. In contrast, during the wet season, tsetse abundance is high, but dispersal is also high and so tsetse apparent density is low. It is likely that the low dispersal of flies during dry season may be linked to the reduced risk of *T. brucei* but it is not clear why this should be so.

Altitude reduced the risk of infection by 0.852 ($p = <0.001$). This could be attributed to the association between altitude, population density and cropping intensity rather than any direct effect of altitude on tsetse flies. There is a general tendency for high altitude areas to have high population densities (Baumgartner *et al.*, 2008; Mubanga, 2009). The highest parts of the Jos plateau also have the highest population densities and also the highest cropping intensities in the area. As such, they are also the least attractive areas to tsetse due to the excessively fragmented tsetse habitats.

3.4.4 *T. congolense* prevalence & risk factors

The prevalence of *T. congolense* across the Jos plateau was 27.7% (21.8% - 33.6%) with significant seasonal variation in prevalence was observed. The prevalence of *T. congolense* was high in absolute terms but also in terms of the percentage of total trypanosome infections. This was unexpected because *T. vivax* has always been the most prevalent species recorded in the area (Kalu, 1996a; Anosike *et al.*, 2003.) However, *T. congolense* was found in 60% of infected animals. The majority of past studies used parasitological techniques with low specificity for differentiating trypanosome strains (Picozzi K *et al.*, 2002). *T. vivax* is larger and more motile than *T. congolense* and is therefore more easily identified by microscopy so the predominance of *T. vivax* in previous studies might be due to this inherent limitation in the technique.

T. congolense is also more pathogenic than *T. vivax* (Taylor and Authie, 2004), therefore the observed high prevalence has negative implications for animal health and productivity. If more trypanosome infections are due to *T. congolense*, more animals have severe infections and production losses and mortality will be higher.

The only risk factor for *T. congolense* savannah was wet season migration (odds ratio = 1.85, $p = <0.001$). This may be attributed to the increased tsetse abundance associated with the wet season and the increased vector/host contact, increased susceptibility due to stress and poor condition associated with migration. Conversely, dry season migration reduced risk of *T. congolense* infection by 0.67 ($p = <0.001$). The lower dispersal of tsetse flies at this season may be responsible for this.

The presence of alien migratory cattle also reduced the risk of trypanosomiasis by 0.6861 ($p = <0.001$). This could be due to the fact that alien migratory cattle act as a buffer

between tsetse and local cattle. Alien migratory cattle are more likely to be bitten because they camp in the open rather than in peridomestic areas like the local cattle and their herders are less able to avoid tsetse hotspots than local herdsmen. It is therefore likely that the presence of alien migratory cattle reduces the number of tsetse bites on local cattle and therefore reduces their risk of trypanosome infection.

3.4.5 *T. vivax* prevalence & risk factors

The prevalence of *T. vivax* was 25.9% representing 1848 of the 7143 cattle sampled. The cluster adjusted annual mean prevalence of this parasite across the Jos plateau was 26.7% (18.2% - 35.3%). No significant seasonal variation in prevalence was observed. The prevalence recorded is consistent with previous results in this area (Kalu, 1996a; Kalu, 1996b; Kalu and Uzoigwe, 1996; Kalejaiye, 2004).

The only risk factor for *T. vivax* infection was dry season migration (odds ratio = 3.60, $p = <0.001$). This may be attributed to the increased tsetse apparent density associated with the dry season and the increased vector/host contact, increased susceptibility due to stress and poor condition associated with migration.

Altitude reduced the risk of infection by 0.91 ($p = <0.001$). This could be attributed to the association between altitude, population density and cropping intensity rather than any direct effect of altitude on tsetse flies. There is a general tendency for high altitude areas to have high population densities (Baumgartner *et al.*, 2008; Mubanga, 2009). The highest parts of the Jos plateau also have the highest population densities and also the highest cropping intensities in the area. As such, they are also the least attractive areas to tsetse due to the excessively fragmented tsetse habitats.

3.4.6 Seasonal variation patterns

Three different patterns of seasonal variation were observed in village level data.

Within group 1 villages, prevalence was low in the dry season, peaked in the early wet season and decreased in the late wet season. This follows the expected seasonal variation of tsetse transmitted trypanosomiasis as tsetse populations are low and of limited distribution in the dry season and increase and become more widely distributed as the wet season progresses (Davies, 1977).

In group 2 villages, the prevalence of trypanosomiasis remained at a constant level all year round. There was no significant difference in seasonal prevalence. This disease pattern points to a persistent population of tsetse flies which transmits trypanosomiasis all year round and is not affected by seasonal variations in the environment. This is similar to the situations described by (Kalu, 1995; Bouyer, 2006) and (Guerrini and Bouyer, 2007) where low populations of riverine tsetse flies restricted to riverine gallery forests were able to maintain transmission of trypanosomiasis. Such tsetse populations are usually located at human and cattle watering points along the river that ensures high vector/host contact. This constant food supply and the persistence of gallery forests even during the dry season protect these tsetse populations from prevailing ecological conditions and allow them to persist unchanged throughout the year.

In group 3 villages, trypanosomiasis peaked in the dry season, decreased dramatically in the early wet season and increased again in the late wet season. Similar results were recorded by Kalu and others (2001) : >40% prevalence in the dry season and much lower wet season prevalences of 9 – 29%. There are three likely drivers for this reversed epidemiological picture.

The dry season lasts for 7 months and is a time of intense stress for cattle on the Jos Plateau as there is very little food and water available. Cattle must walk 5-6km a day in search of adequate grazing and malnutrition is a grave concern. (Pullan, 1980a) found that starvation was responsible for a third of all cattle deaths on the Jos plateau and that these deaths occurred towards the end of the dry season.

Recent agricultural expansion by farming communities has prompted reclamation of pasture lands that pastoralists previously used. Introduction of irrigated farming also means that several ponds and rivers are surrounded by vegetable plots, restricting the access of cattle to drinking water. This exacerbates the effects of the harsh dry season and in many villages, has forced pastoralists to migrate to areas with lower land pressure and more abundant resources [and higher tsetse challenge (Mahama *et al.*, 2005)] to avoid conflict and livestock mortality (Blench, 2003). Figures 3.15 and 3.16 illustrate the impact of these factors on cattle rearing.

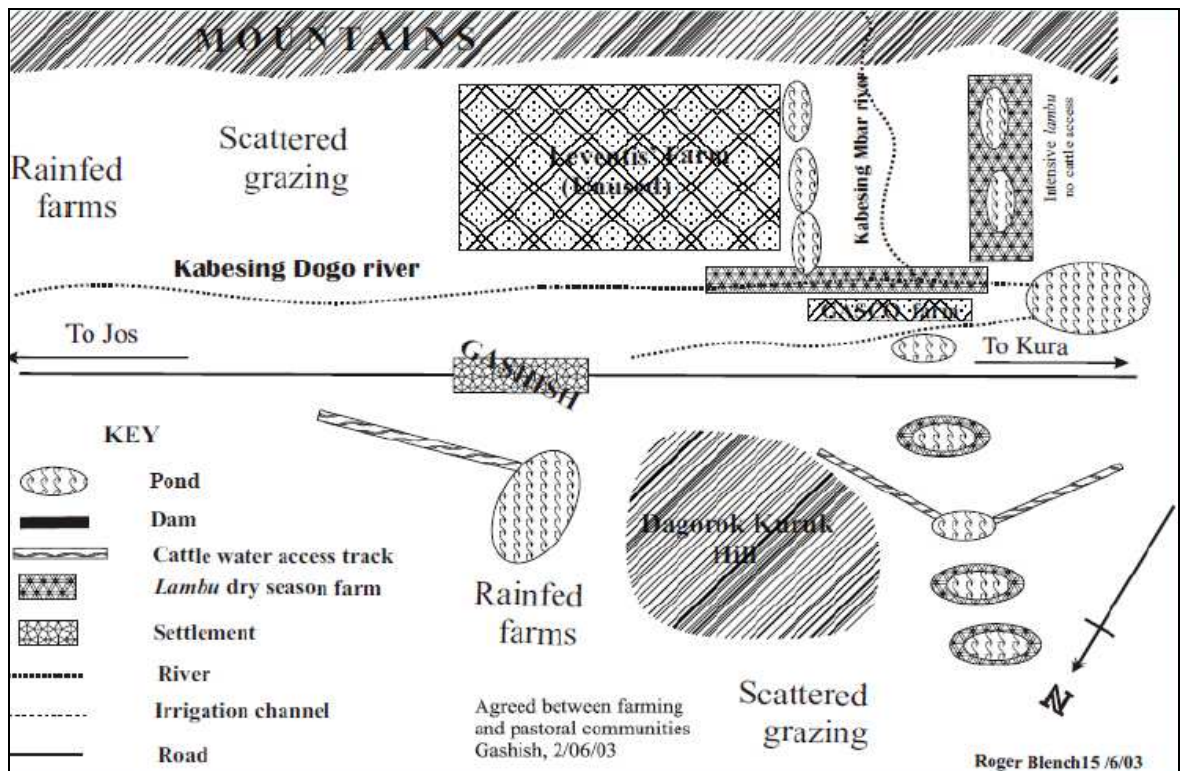


Fig. 3.15: Resource use map of Gashish showing dry season farming and cattle access to water (Blench 2004)

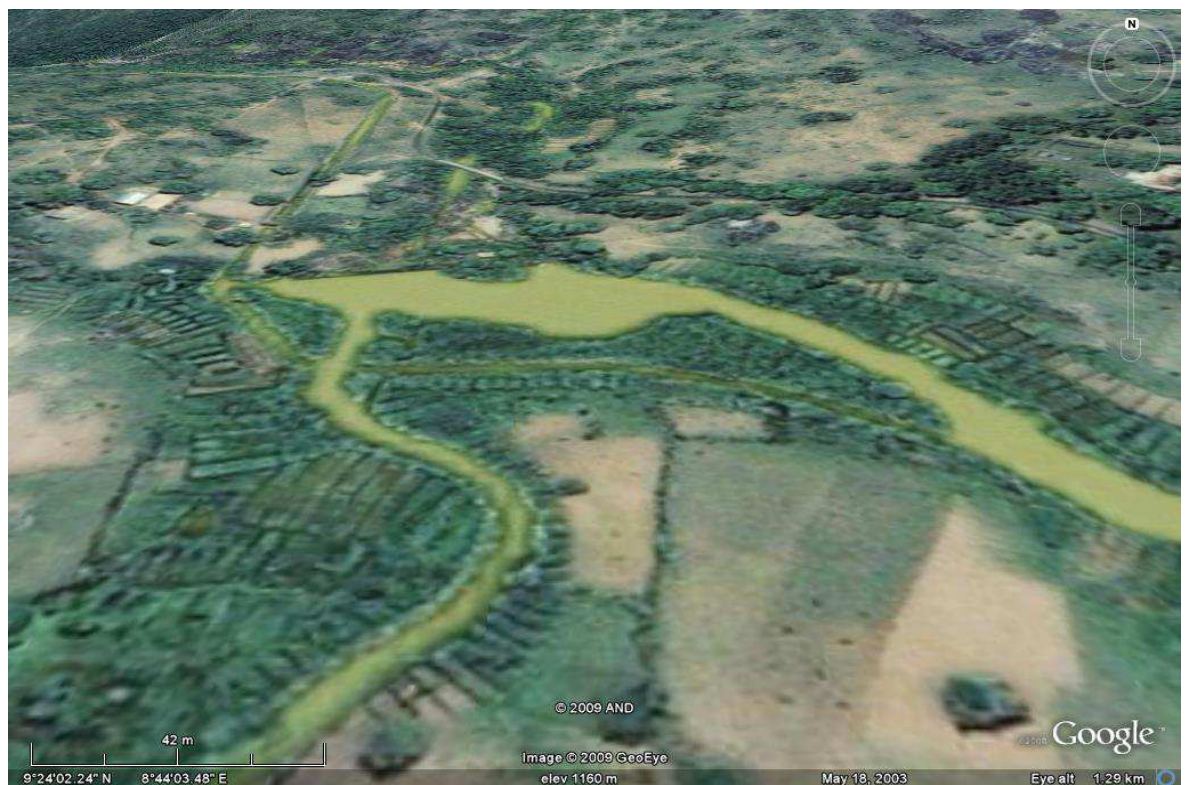


Fig. 3.16: Wet season satellite image of Gashish River surrounded by vegetable plots (Google Earth, 2009)

The dry season is associated with low humidity and high temperatures that have negative effects on tsetse population growth by the following mechanisms (Randolph *et al.*, 1992; Torr and Hargrove, 1999; Bett *et al.*, 2008):

- Reduced fecundity
- Increased mortality
- Reduced interlarval period which implies that tsetse must feed more frequently between reproductive cycles or produce pupae on fewer meals. Both of these factors increase pupal mortality.
- Reduced fat levels in flies which emerge in the dry season; when coupled with the poorly developed musculature of teneral flies, these two factors combine to make starvation a real threat.
- Increased rates of feeding leading to increased feeding related mortality

So, tsetse populations are much smaller in the dry season than in the wet season. However, tsetse correlations with trypanosomiasis in vertebrate hosts are due to dispersal as well as population size. The harsh climatic conditions limit tsetse dispersal and force them to congregate in gallery forests where temperatures are lower, humidity higher and shade abundant. Bush burning during the dry season also restricts the distribution of tsetse flies and confines them to gallery forests. In contrast, the favourable conditions in the wet season support increased tsetse populations and high dispersal in the environment. The dry season is therefore the period with the highest relative tsetse abundance and highest tsetse apparent density. Only a few streams and rivers persist throughout the rainy season and both cattle and the small residual populations of tsetse flies are concentrated at these points, providing a very high level of host-vector contact. Dry season peaks in prevalence were also recorded by Leak and others (1993) in Ethiopia and Kalu and others (2001) in Nigeria. In both

instances, the presence of riverine tsetse flies and the high tsetse apparent density and high vector/host contact associated with the dry season were cited as the main reasons.

The tsetse flies found on the Jos plateau are the riverine species *Glossina tachinoides* and *G. palpalis* (Kalu, 1996a; Majekodunmi, 2006). Drastic tsetse habitat changes are capable of leading to elimination of some tsetse species but the persistence of others (Bourn, 2000). Which outcome you get depends on the ability of tsetse flies to adapt to changing conditions by using micro-climatic niches (Challier, 1973; Gruvel, 1975; Itard and Cuisance, 2003; Terblanche *et al.*, 2007) and opportunistic feeding behaviour (Krafsur, 2009). Over the years, the general trend observed is a decline in the morsitans group populations and persistence of palpalis group flies (Bouyer *et al.*, 2005; Dao, 2008a; Courtin *et al.*, 2009; Rayaisse *et al.*, 2009). Increasing rates of urbanisation, agricultural expansion and population growth seen across Africa cause tsetse habitat fragmentation and are responsible for much of the decline of morsitans group flies. On the other hand, palpalis flies are highly adaptable to changing conditions, leading to persistence, increased density and expansion of this group of tsetse flies. *G. tachinoides* can exist in isolated pockets of forest, thickets, and other habitats unsuitable for other tsetse species (Kalu *et al.*, 2001). *G. palpalis gambiense* exhibits learning behaviour by developing a preference for whatever host it first encounters which enhances its adaptive capacity (Bouyer and al. 2007). *G. tachinoides* has high transmission capacity for nagana and has been implicated in hyperendemic trypanosomiasis area where very low populations of 0.07 and 0.14 f/t/d maintained high levels of infection - >40% prevalence (Kalu *et al.*, 1991). This is possible because the relationships between riverine tsetse and their hosts are usually prolonged and personal, so the close vector/host contact facilitates high transmission of trypanosomiasis (Kalu 1995). *G. tachinoides* and *G. palpalis* have also demonstrated the ability to adapt to human environments, as they are

found in both urban and peridomestic environments (Baldry 1964; Onah 1995; Dede *et al.*, 1998; de Deken *et al.*, 2005; Courtin *et al.*, 2009; Van den Bossche *et al.*, 2010). Expansion of *G. palpalis* and *G. tachinoides* belts onto the Jos plateau has been reported (Onah 1995; Kalu 1996b; Dede *et al.*, 1997; Dede *et al.*, 1998) with peridomestic activity in the 1990s and Dede and others (2004), Yanan and others (2004), Dede and others (2005) and Majekodunmi 2006 report persistence of these flies in the area.

This combination of natural resource conflict, stress, malnutrition, poor condition and high tsetse challenge has succeeded in ensuring very high transmission from a small population of vectors and high prevalence of trypanosomiasis in the dry season. In the early wet season, food and water become more widely available and tsetse populations become more dispersed. The combination of improved condition in the animals and reduced vector-host contact leads to a reduction in trypanosomiasis prevalence. By the late wet season, tsetse populations have increased considerably and despite the increased dispersal, there is a higher tsetse challenge and a consequent increase in trypanosomiasis prevalence in cattle.

3.5 Conclusions

This longitudinal survey of bovine trypanosomiasis showed a high overall prevalence of trypanosomiasis [46.8% (39.0 – 54.5%)] with high variation at village level (8.8% - 95.6%). Variations in seasonal prevalence were also observed. Risk factors for trypanosomiasis infection were migration and the dry season. Increasing altitude and the presence of alien migratory cattle reduced risk of infection but there was a positive correlation between migration and the presence of alien migratory cows which increased the risk of infection. There was no effect of age, sex or breed on trypanosomiasis infection.

This study has made several additions to the body of knowledge. We now have trypanosomiasis prevalence and distribution figures for the whole of the Jos plateau and a better understanding of the specific ecological risk factors affecting the epidemiology of the disease in this environment. Atypical seasonal variation patterns have also been discovered and discussed. The considerable influence of husbandry and management factors on the epidemiology of T&T has also been established and further light has been shed on the specific ways that transhumance and seasonal migration affect the disease.

The results present an overall picture of a dynamic epidemiology affected by many biotic and abiotic factors. The traditional triangle of host/vector/parasite factors must be extended to include livestock management and ecological factors such as vegetation, climate and land use to understand the epidemiology of trypanosomiasis in this area. This is not a new concept as there is ample evidence for the influence of both biological and management factors in the epidemiology of trypanosomiasis.

Both tsetse seasonal variation and husbandry/management impact on the epidemiology of trypanosomiasis (Mahama *et al.*, 2005). Leak *et al.* (1993) showed that only 36% of

seasonal variation in trypanosomiasis prevalence is explained by variation in tsetse challenge. Extensive management, agropastoral management and pastoralism enhanced trypanosomiasis and that the dry season was a risk factor for trypanosomiasis infection (Kalu *et al.*, 2001). Higher prevalence in extensively managed stock – 14.4%, almost double the 7.45% were recorded in intensively managed animal showing that extensive livestock management is a risk factor for trypanosomiasis (Kalu, 1995). Poor nutrition and starvation over the dry season and whether or not farmers used feed supplements were found to be more important factors than disease in the mortality, low reproductive performance and low productivity of cattle on the Jos plateau (Pullan, 1979; Pullan, 1980a; Pullan, 1980b).

The results of this study suggest that management and husbandry factors determine whether or not animals become infected while biological factors (i.e. tsetse, vegetation) determine seasonal variation and infecting trypanosome species. The dry season high prevalence seen in seasonal variation group 3 effectively illustrates how these different factors combine to drive epidemiology of the disease. The participatory rural assessment in chapter 4 will provide detailed data on animal husbandry and management practices and how they can be positively influenced to reduce T&T prevalence and its negative effects in the area. Data from chapter 4 will also serve to illustrate the effects of the T&T levels described in this chapter on cattle productivity and pastoral livelihoods.

Chapter 4: Pastoral Livelihoods, Herd Productivity and Knowledge, Attitude and Practices

4.1 Introduction

Small-scale agriculture is a major contributor to the economies of Sub-Saharan countries, especially for the rural populations. It also plays an essential role in food production and the protein provided by livestock products is an important component of this. There are 120 million pastoralists worldwide, 50 million of these in Sub-Saharan Africa where they constitute 12% of the rural population (Rass, 2006). The ability of pastoralists to fulfil their role as food producers is directly dependent on the viability of their livelihoods and the factors affecting their livelihood strategies.

This chapter considers the current state of pastoral livelihoods and investigates the viability of the livelihoods of pastoralists on the Jos plateau, with emphasis on the risk of animal disease and current disease control strategies. This data will provide information not only on how these socio-economic factors interact with the ecological factors identified in chapter to influence trypanosomiasis prevalence and distribution but how they are affected by the disease, leading to a more complete understanding of T&T on the Jos plateau.

4.1.1 Pastoralist Livelihoods

Livelihood strategies are the combination of activities that people choose to undertake in order to achieve their livelihood goals. They include productive activities, investment strategies and reproductive choices. The choice of strategies is a dynamic process in which people combine activities to meet their changing needs (Eldis.org, 2010).

The livelihoods of pastoral people depend on three things (Rass 2006; Eldis.org , 2010) :

- Access to assets such as land, livestock, pasture, water, animal health services, community networks, markets, credit and education
- The environment in which these assets are combined for production and consumption, specifically the political, organisational and institutional infrastructure they operate within. These policies, processes and institutions affect their ability to use these assets to achieve positive livelihood outcomes.
- The dynamic context of risks, and seasonal and continuous trends that affect assets and their environment and determine the vulnerability of livelihoods.

4.1.2 Assets & Wealth Groups

Livestock are the main livelihood resource of pastoralists, performing multiple roles to satisfy economic, social and ecological needs. They provide cash through sales of live animals and animal products; subsistence products for the household (meat & milk), social alliances (gifts, bride price), and storage of wealth (Catley ,2000). Herd size is usually the greatest determinant of household wealth. The minimum number of livestock units required to sustain a pastoral household is estimated as 15 cattle (FEWSNet, 2004/5). However, table 4.1 shows that this minimum number has decreased over the last thirty years. This decrease is attributed to growing market

participation and livelihood diversification, underlining the fact that the capacity to make profitable use of assets can be just as important as the assets themselves.

Source	Minimum TLU required per household	Minimum Cattle required per household
Jacobs, 1963	70	49
Dahl & Hort, 1976	45	32
Little <i>et al</i> , 2001	28	20
FAO, 2006	21	15

Table 4.1: Livestock requirements for survival of pastoral households (Rass 2006).

Access to pasture and associated water sources to sustain their livestock is the other fundamental asset of pastoralists. Despite its importance, these access rights are not easily quantifiable and serve more as a measure of vulnerability than an indicator of wealth. Agro-pastoralists are less dependent on access to pasture as they own their own land and their livestock can graze crop residues after harvest. The amount of land owned by agro-pastoralists is a good indicator of wealth (Rass 2006).

Successful management of large herds for the maximum benefit of the household requires the labour from a certain number of family members of both genders. So, household size and availability of household labour for herding are also indicators of wealth. Larger households tend to be wealthier than smaller households. This is because the household head tends to be older and will have accumulated more livestock and wives, and therefore children than a younger head of household. Secondly, many poorer households do not own enough livestock to support a large

family and are often forced to send family members out as hired herders to wealthier households or to urban centres to earn additional income. Poorer households depend more on remittances and pensions from family members in towns than wealthier households. Wealthier households with surplus members not required for herding tend to engage in trading activities rather than urban migration, employment or self-employment (Rass, 2006).

Wealth group information gathered by Famine Early Warning System (FEWS) from different pastoral groups across Africa has produced guidelines for wealth group ranking of households as shown in table 4.2.

Wealth Group	Household size	Livestock	Area Planted
Poor	3 – 5	5 – 10 cows, 10 – 26 shoats	1-2 hectares with household labour
Middle	7 – 8	15 – 50 cows, 35 – 100 shoats	3 hectares with household labour
Better off	8 – 13	50+ cattle, 100+ shoats	5 hectares with household labour and hired hands

Table 4.2: Wealth grouping criteria (FEWSNet 2004/5)

4.1.2 Livelihood Risks

Livelihood risks are defined as uncertain events that can damage wellbeing. The uncertainty involves the occurrence, timing and magnitude of the negative event. Risks can be classified according to the level at which they occur. Idiosyncratic risks are those that affect specific individuals or households. Covariant risks are those that affect specific groups of households or all households in a region. Pastoralists face

the idiosyncratic risks of human illness and livestock disease and death. They face the covariant risks of drought, epidemic diseases, market exclusion, natural resource conflict, political marginalisation and pasture degradation. The management of covariant risks requires public sector engagement and investment whilst idiosyncratic risks are best dealt with by the affected household (Rass, 2006). Table 4.3 contains some examples of the different types of risks involved.

Type of Risk	Idiosyncratic Risk – Individual Household	Covariant Risk – Several Households	Covariant Risk – All Households
Natural	-	Rainfall	Flood/Drought
Health	Illness, Injury, Death Disability, Old age	Pandemic	-
Social	Crime Domestic violence	Tribal War Inter – clan violence	Civil strife War Social Upheaval
Economic	-	Unemployment Resettlement Livestock disease	Terms of trade shock Market Exclusion Epidemic
Political	-	Riots	Political default on social programmes coup d'état
Environmental	-	Pollution Deforestation Degradation	Desertification

Table 4.3: Risks to Pastoral Livelihoods (World Bank 2000/2001)

Vulnerability is a measure of the lack of resilience to risks and seasonal and long-term trends. Therefore, it is not only an important feature of poverty but also a potential cause. Vulnerability is closely linked to asset ownership - the more assets people have the less vulnerable they are. The greater the erosion of assets, the greater the level of vulnerability – poor herders are more likely to end up with an unviable herd size than wealthier herders, even when they lose the same relative

amount of livestock (Rass, 2006). Although access to assets is an important determinant of vulnerability, the opportunities/capability to make profitable use of assets must also be considered.

4.1.2.1 Market exclusion

Pastoralists are at risk of exclusion from local and international markets because of high marketing costs. The livestock trade is the dominant feature of inter-regional trade in West Africa where the Sahelian nations (Burkina Faso, Mali, Niger) traditionally export livestock to the humid coastal countries (Cote D'Ivoire, Ghana, Nigeria). This trend is mirrored within Nigeria where cattle are predominantly produced in the north for consumption in the south (Kilgour and Godfrey, 1978). The producers in northern Nigeria are dependent on the south for a market for their products and the consumers in southern Nigeria are dependent on the north for their supply of livestock and animal products. In spite of this, northern producers are often excluded from the lucrative and expanding coastal markets by prohibitively high marketing costs (Hoffman, 1998; CILSS, 2003). Livestock production in Burkina Faso, Niger and Mali is globally competitive at US\$1,500/tonne compared to US\$1,900 in the United States and US\$3,199 in Europe (Boutonnet *et al.*, 2000). However, the cost of transporting beef from the Sahel to the coast in West Africa is US\$230/tonne compared to the shipping cost from Europe of US\$80/tonne (Yade *et al.*, 1998). 83% of the purchase price of cattle traded in inter-regional markets is attributed to cross – border marketing costs including transportation and handling, duties, taxes and illegal road taxation (Williams, 2002). These high transportation and transaction costs increase the terminal market price two to four times over the producer price (Akiliu *et al.*, 2002). So it is often cheaper/ more convenient to

supply the high demand of coastal markets with livestock product imports from Europe and the Americas at the expense of local and regional producers.

Besides exclusion from export markets, pastoralist also risk exclusion from local markets. Most rural areas have poor roads and inadequate transportation facilities so the high cost of transportation relative to the number of animals sold limits the direct participation of pastoralists at livestock markets. They are usually forced to sell at the farm gate to middle – men to avoid these costs. This effectively creates a ‘single buyer market’ where these middle men can fix their own price. Poor access to market and pricing information and the urgent need for cash puts pastoralists at a further disadvantage in these transactions. The few pastoralists who do go to markets get low prices for their animals. They cannot afford to take their animals back home if they do not make a sale that significantly reduces their bargaining power.

Table 4.4 shows the trading chain and actors involved in the trade of cattle from rural Sokoto in north - west Nigeria, through a local livestock market to the target market in Ibadan in the south – west. The role of Fulani pastoralists in the livestock trade is limited to production and manual tasks at the market, with the exception of a few long – distance traders. The buying and selling (and high profit margins) is dominated by Hausa.

Role	Ethnic Group	Location
Breeders	Hausa & Fulani	Rural Areas, Sokoto
Rural Assemblers	Hausa	Rural Areas, Sokoto
Brokers	Hausa	Local Market, Sokoto
Transport agents	Hausa	Local Market, Sokoto
Long distance traders	Hausa, Fulani	Local Market, Sokoto
Wholesalers	multiple ethnic groups	Target Market, Ibadan
Retailers	Hausa, few Yoruba and Igbo	Target Market, Ibadan
Drovers	Fulani and Hausa	Target Market, Ibadan
Loaders	Hausa	Target Market, Ibadan
Guardsmen	Hausa, Fulani	Target Market, Ibadan
Butcher	Hausa	Target Market, Ibadan
Consumers	Men and women of all tribes	Target Market, Ibadan

Table 4.4: Livestock Market Actors (Adamu *et al.*, 2005)

4.1.2.2 Drought/Dry season

Pastoralists are particularly vulnerable to periods of low rainfall, whether unexpected droughts or annual dry seasons. Lack of rainfall reduces the water and pasture available to support livestock. Animals become emaciated and may die of starvation. The nutritional stress makes them more susceptible to disease. Many are sold pre-emptively at knock down prices. Pastoralists are also directly affected: drinking water is in short supply, food becomes scarce and more expensive, the milk yield of cattle is no longer sufficient to feed the household and increased time and effort must be spent herding cows so as to find adequate forage. Vulnerability to drought is not identical across households, but is determined by the initial household wealth status. A poor household with a herd of 20

cows is more seriously affected by 50% herd mortality than a wealthier household with a herd of 200.

4.1.3.3 Conflict

Conflict between farmers and pastoralists has existed since the beginnings of agriculture. Highly mobile pastoralists are often associated with negative, violent stereotypes: raiding, warfare and particularly in Nigeria, large scale military conquest due to the 1804 Jihad of Usman Dan Fodio and the subsequent Fulani conquest of northern Nigeria (Kaberry, 1959; Huraoult, 1964; Huraoult, 1969; Huraoult, 1970; Gallais, 1972; Blench, 1984; De Haan, 1997; Van Driel, 1999; Tonah, 2000; Blench, 2001). However, the nature of these conflicts has changed over time, influenced by demographic and veterinary transformations in the colonial era, the flow of oil revenues in the 1970s and the current increase in civil strife, religious division and subsequent politicisation which influences government responses to conflict. All this is underpinned by the ever increasing competition for natural resources fuelled by increasing human and livestock populations and environmental degradation (Blench, 2003).

The major factors confining Fulani pastoralists to the northern Sahel in the past were the fear of major losses from trypanosomiasis and other diseases within the southern tsetse belts, and their vulnerability to armed raids which were very common in the pre – colonial era. However, the abundance of natural resources in the southern lands has long been a major attraction for the Fulani. In spite of the limiting factors, over the years there has been a gradual expansion into southern lands, leading to increased contact between farmers and pastoralists (Fricke, 1979; RIM, 1984.; RIM, 1992). The limitations posed by animal disease have been greatly reduced by advances in veterinary medicine and effective control

of tsetse and epizootic diseases. More recently, the deregulation of veterinary services and the increased availability of veterinary drugs (particularly trypanocides and pour-on insecticides) directly to livestock owners have made year round settlement in humid zones practical. The relative peace and stability in rural areas produced by the colonial era from 1910 onwards the so called *pax Britannica* further encouraged southern expansion (Blench 2003) and was the main impetus for Fulani expansion and settlement onto the Jos plateau (Awogbade, 1983). The high demand and high prices of livestock products in the humid zones are an added incentive to enter these areas.

The lifestyle of pastoralists make them heavily dependent on the exchange/or purchase of grain for survival. There are several livelihood strategies available to the Fulani for supplying this need and managing their increased contact with farming communities (Blench 2003):

- Living on good terms with farmers and building up effective exchange mechanisms where dairy products and manure are exchanged for grain and access to pasture and other natural resources. However, this is not always possible. The products/services that the pastoralists can provide are attractive to the farmers but are by no means necessary so the pastoralists remain at a disadvantage and must continually depend on the good will of the farming communities
- If pastoralists are unable to maintain viable exchange relations but continue to enjoy the good will of farmers, they may settle in the area and engage in mixed farming to provide their own grain.

- If pastoralists are unable to maintain cordial relationships with farmers, they may be forced to adopt flexible movement patterns where they encounter new farming communities every year.
- If pastoralists are unable to come to terms with farmers at all, then they often resort to intimidation to gain access to pasture and other natural resources.

The most significant feature of rural dynamics in Nigeria in the 20th century has been demographic expansion and the consequent expansion of cultivation. Aside from demographic expansion agricultural expansion has been fuelled by technological advances: improved seed varieties, irrigation pumps and the introduction of new crops like maize and Irish potatoes. Projections estimate the population of the Nigerian region in pre – colonial times as ~ 5 million. When compared with the 2006 census estimate of 150 million it becomes immediately apparent how it was possible for pastoralists and farmers to co exist in the past and just how much things have changed since then (Blench, 2003). The major changes affecting farmer – herder conflict have been (Blench 2003):

- Agricultural expansion and the resulting increase in competition for dwindling pasture
- Declining importance of dairy products and manure in the face of increasing availability of powdered milk and government subsidised fertilisers
- The collapse of the cattle track network designed to separate livestock from farms and prevent trampling of crops.
- Rapid movement of pastoralists into new terrain where language, religion, culture and land tenure systems are unfamiliar and the cattle track system does not exist.

Fulani pastoralists are at a decided disadvantage when it comes to adapting to these changes and exploiting them in their favour. Sedentary herders have better access to western education, communications and infrastructure and are more conversant with current financial systems, legislation and power dynamics. Pastoralists lack all of these advantages and are regularly outmanoeuvred by the farming communities. This often limits the livelihood strategies available to pastoralists, forcing them to intimidation and violence as a last resort.

Fulani pastoralists share common religious practices with the settled farmers they live amongst in the northern Sahel. Rapid expansion into southern areas has brought them into contact with predominantly Christian farmers at the same time as inflammation of religious differences and polarisation of Nigeria into a Muslim north and Christian south. This has allowed for farmer-pastoralist clashes based on natural resource conflict to be re-interpreted as religious conflicts.

Previous central military governments were able to maintain higher levels of fairness and equality amongst the different ethnic and religious groups than the current democratic decentralised administration. The present decentralised political government operates by placing power in the hands of indigenous communities so that minorities like the Fulani no longer have a voice or any tangible representation at local, state or federal government level. When there is competition for natural resources, the farming communities easily gain the upper hand and the trend is for marginalisation of pastoralists and other minorities. Government response to violent clashes is again, usually biased against minority groups and is often of the 'too little, too late' variety as government is often unwilling to involve itself in the tension between majority/minority groups. The farming and pastoral

communities on the Jos plateau are divided along ethnic, religious, professional and political lines. All of these factors come into play, making it one of the most volatile areas in the country.

4.1.3.4 Animal disease

The idiosyncratic risk of animal disease is one which may easily turn into the covariant risk of epidemic disease, capable of eliminating entire herds and spreading over wide areas. Livestock production is constrained by livestock disease. This effect is particularly severe in developing countries where livestock diseases reduce livestock outputs by 30%, twice the observed reduction in developed countries (F.A.O., 1990). The decrease in productivity is largely due to endemic diseases: trypanosomiasis, tick –borne diseases and helminthiases (Machila, 2004).

The presence of tsetse and trypanosomiasis compromises the availability and value of animal products, inhibits mixed farming and decreases cattle density by 36 – 70% (Hendrickx *et al.*, 2000). Bovine trypanosomiasis reduces the offtake of meat and milk by 50%, reduces calving rate and increases calf mortality by 20% (Swallow, 2000). Trypanosomiasis also exacerbates other endemic diseases due to its immunosuppressive effects on infected animals (Machila, 2004). In fiscal terms, direct production losses due to morbidity and mortality of trypanosomiasis are estimated at USD4.5 billion per annum (Budd, 1999), while the indirect annual costs are estimated at USD 134 million across Africa (Kristjanson *et al.*, 1999).

Coordinated control of endemic diseases, including tsetse and trypanosomiasis was in the past, delivered by the government through large-scale programmes and the provision of subsidised veterinary services. However, the current climate of free markets and

privatisation of veterinary services has transferred responsibility for the control of endemic diseases to the herders, reduced access to veterinary professionals, increased the cost to herders of animal health products and services, and provided them with direct access to veterinary drugs (Kamara *et al.*, 1995; Kamuanga *et al.*, 1997; Doran and van den Bossche, 1998; Sinyangwe and Machila, 1998; van den Bossche *et al.*, 2000; de Haan, 2004). This general decline in livestock disease control has consequently reduced overall animal health and increased both the misuse and overuse of drugs.

Trypanocides are the most widely used veterinary drugs in sub Saharan Africa, and they are often used regardless of the clinical signs observed. This indiscriminate use raises concerns about drug resistance. Resistance has been confirmed in isolated cases but the true extent of the problem remains unknown (Geerts & Holmes, 1998; Geerts *et al.*, 2001; Eisler *et al.*, 2004). It is important to prevent or delay the onset of drug resistance because there is little prospect for the development of new trypanocidal drugs since the largely poor, rural market for the drugs does not compare favourably with the high costs of research and development. Frequent use and overuse of trypanocides also increases the risk of drug toxicity and adverse reactions.

To effectively control livestock disease, herders need accurate diagnostic tools/differential diagnosis techniques, access to drugs and vaccines against endemic diseases, and the knowledge to use them competently. However, the reality is that these tools are not always available to rural herders and animal health workers (Odeyemi, 1999a).

Agricultural extension can be used to provide herders with the knowledge they need to use available animal health tools effectively. For this to be effective it is necessary for animal health professionals and extension workers to have a good understanding of the social and

cultural factors affecting livestock disease control (Awogbade, 1979; Machila *et al.*, 2003; Van der Ban and Hawkins, 1996). Efforts to deliver extension services without this basic understanding have been plagued by low uptake or rejection by herders. They are viewed as efforts to eradicate their traditional methods and practices and replace them with often, inappropriate technologies. Agricultural innovation is a combination of technical and human factors (Thuranira, 2005). If there is a gap between the innovators (extension workers) and the acceptors of innovation (herders), it will undermine extension efforts and the expected objectives will not be achieved. To ensure the success of extension programmes, participatory approaches must be included in all stages of the development cycle – research, implementation and monitoring & evaluation. Local communities should be involved in problem investigation, collection of background information, planning of interventions and analysis of intervention impacts. This empowers local communities, gives them access to and control over the development process, utilizes local knowledge and expertise, prevents the production of inappropriate innovations and increases herder uptake of interventions

Growing human and livestock populations and increasing competition for resources means that even when pastoralists are able to effectively manage all the risks affecting them, current livelihood strategies will become less viable with time. Long term policies/strategies need to be put in place to manage the increasing imbalance between humans, livestock and the environment (Rass, 2006). This includes identifying investment opportunities for pastoralists and providing enabling facilities for them to take advantage of these opportunities. Such opportunities include moving from a land based, livestock only enterprise to ranching, more intensive management systems, mixed farming, multiple species, concurrent off farm employment, involvement in other sectors of the livestock

industry (see table 4.4) and cash investment in unrelated trade/business. Enabling factors would include access to credit facilities, public sector investment in labour intensive infrastructure to provide employment opportunities and incentive schemes to train and/or hire pastoral ethnic minorities. However, the most pressing need is for investment in risk management strategies so that pastoralists can improve their current livelihoods to a point where there is room for diversification (Sandford, 1994; Little, 1999; Morton and Meadows, 2000; Pantuliano, 2002; Rass, 2006). This would provide a situation where diversification is common and is a matter of choice rather than one where exit strategies are a more common matter of necessity.

4.2 Aims and Objectives

The Jos plateau has undergone a change in its tsetse and trypanosomiasis risk and concurrent social and economic changes. The literature on pastoral livelihoods and customs focuses on pastoralist located in the arid/semi-arid zones but little on those located in the sub humid zone (Catley, 2000; Catley and Leyland, 2001; Catley *et al.*, 2002). This chapter examines the effects of these changes on pastoral livelihoods using the approach detailed below.

- Study the effects of these changes on pastoral livelihoods on the Jos plateau in particular and the sub humid zone in general
- Gather data for quantitative analysis of animal productivity and profitability to herders, livelihood analysis and wealth ranking
- Acquire baseline data for intervention planning and delivery in the future

- Determine which social, economic, ecological and cultural factors influence animal health and disease control by herders.
- Investigate knowledge, attitude and practices of animal disease, and trypanosomiasis in particular

4.3 Materials and Methods

This section gives details of the methods used to gather information on pastoral livelihoods, animal productivity and profitability and knowledge, attitudes and practices of herders on animal disease and trypanosomiasis. Methods used to analyse and interpret this data are also included as appropriate.

4.3.1 Participatory Rural Appraisal

Participatory rural appraisal (PRA) is a family of sample survey methods that allow local people to share and analyse their knowledge and experiences and to make plans based on this information. PRA methods include mapping, matrix scoring, seasonal calendars, trend and change analysis and analytical diagramming. They are very visual and group oriented, facilitating information sharing, analysis and action amongst the stakeholders themselves. In spite of their collective name, these methods are not restricted to rural areas or appraisal exercises. They are equally applicable to urban areas and to all stages of the project/research cycle (Chambers, 1994a, b, c; World Bank, 1996).

PRA belongs to a wider family of rapid, participatory research methodologies amongst which the closest relative of PRA is rapid rural appraisal (RRA) (Catley, 1997; Chambers, 1994c). RRA is the direct predecessor of PRA and was developed during the 1970s when

there was growing dissatisfaction with existing methods. Large-scale surveys and long questionnaires were found to be inaccurate, unreliable and difficult to administer and analyse. Researchers also became more aware of the spatial, people specific, seasonal and diplomatic biases introduced to such surveys by the phenomenon of rural development tourism. There was a growing recognition that rural people themselves were most knowledgeable about subjects affecting their lives and that they should be actively involved in information gathering exercises. RRA was therefore developed to meet these needs (Chambers, 1994c). It differs from PRA in that it is extractive elicitive, with data collection by outsiders being the primary aim. In contrast, PRA takes a sharing/empowering approach where the main aims are investigation, analysis, learning, planning, action, monitoring and evaluation by the insiders (Chambers, 1994b).

The advantage of PRA is that it gives local communities access and control over the process of understanding and analysing their lives in direct contrast to extractive methods that are seen as disempowering to communities. It is quicker and more cost effective than long term studies and uses a wide range of multidisciplinary information. It enables on the spot assessment and direct response to actual village level problems. It is accessible to many users, including the illiterate and those without statistical skills. It also facilitates collection of standardised field data for use in more sophisticated databases. The downside is that it may lack precision and detail (Snow & Rawlings, 1999). The main requirements for the execution of a PRA sample survey are (World Bank, 1996):

- Participation: local input is essential to the value of PRA as a distinct methodology
- Teamwork: implementation requires a multidisciplinary team of people with different skills and backgrounds. This should include local people who share the knowledge, customs, beliefs and perspectives of the target population
- Flexibility: PRA is usually practiced as a combination of methods. This allows the collation of information of different qualities and precisions. Researchers are free to pick the particular methods and combinations best suited to their study. These will depend on their specific objectives, the size and skills of the research team and the time and resources available. It is important to clearly define the objectives of the study so as to determine the minimum resources and information required to fulfil them. This will facilitate appropriate choice of methods most likely to produce the required information.
- Triangulation: At least three techniques should be used to investigate the same problem. The results from each can be used to cross check the others. Triangulation or agreement between the three methods used indicates accuracy. This ensures that the information collected during PRA exercises is accurate and reliable. Discrepancies between them indicate that more information is needed and that a traditional, more intensive survey is better suited to that situation.

PRA employs mainly qualitative methods which may be used on their own or alongside more formal quantitative methodologies. Accordingly, data produced by PRA exercises is qualitative rather than quantitative and is most useful for describing situations. When used

alongside quantitative methods, it provides local information with which to supplement and interpret quantitative data. However, most qualitative data can be transformed into quantitative. If this occurs early in the data collection process, it can be summarised numerically and subjected to the same statistical analysis as quantitative data.

Some PRA methods produce quantitative data in the first place e.g. proportional piling and scoring/ranking.

Information Required	Information Required
Social organisation	Natural resource maps
Wealth groups	Wealth ranking
Relative livestock ownership	Proportional piling
Livestock role in household economy	Livelihood analysis
Preferred type of livestock reared	Livestock species scoring
Income from livestock	Proportional piling
History of livestock diseases	Timelines
Priority livestock diseases	Livestock disease scoring
Seasonal variation in livestock disease	Seasonal calendars
Livestock productivity	Progeny histories and seasonal calendars

Table 4.5: Uses of different PRA methods (Catley, 1997)

4.3.2 Structured Questionnaires

The questionnaire is a standard method for collecting survey data where the objective is to measure the exposure of respondents to the variables being investigated in the study. Questionnaires can be administered face to face in interviews or remotely using the postal system, worldwide web or telephone. Due to the lack of these communication facilities in many developing countries, interviews are the most common method of questionnaire administration (Thrusfield, 1995). The structured questionnaire used was designed to collect data on knowledge, attitudes, practices & perceptions of tsetse & trypanosomiasis, animal husbandry, disease and mortality, disease control strategies, transhumance, income and expenditure, herd size and composition, household assets and herd productivity. The questionnaire contained both open and closed ended questions as well as a variety of PRA techniques. This was to reap the benefits of both methods - formal, structured questionnaires and participatory rural assessment.

4.3.3 Focus Group Discussions

Herders were unwilling to respond to questionnaires individually so the structured questionnaire as outlined in 5.3.2 above was administered in focus group discussions with results for most sections recorded as village results. However, individual information was collected from each member of the group for land ownership, mortality, herd size and herd dynamics and productivity to allow quantitative analysis of the data.

Focus group discussions were held in each of the 30 study villages as detailed in chapter 2. The group consisted of all herders whose cattle had been sampled. The structured questionnaire was used to facilitate discussion and record responses and was administered in all cases by myself using an interpreter. The group size varied from 5 – 15 members.

4.3.4 Ranking, scoring & proportional piling

Various ranking exercises were applied to evaluate different issues. Simple listing and ranking was used to investigate disease presence and prioritisation. Proportional piling using stones was used to investigate sources of mortality, income & expenditure and to assign percentages to each listed source.

4.3.5 Wealth Ranking

Respondent households were assigned to wealth groups according to the categories devised by FEWSNet (FEWSNet, 2004/5). Households with less than 15 cows or less than 3 hectares of cultivated land were considered poor; those with 15 – 50 cows or 3 – 5 hectares of cultivated land were in the middle wealth group and those with more than 50 cows or more than 5 hectares of cultivated land were considered better off.

4.4 Results

4.4.1 Land Ownership

All respondents owned land which was used for growing crops and keeping livestock. Respondents measured their land in acres (0.4 hectare). The average amount of land owned was 17.9 acres with 10.9 acres used for growing crops and 7.0 acres dedicated to livestock.

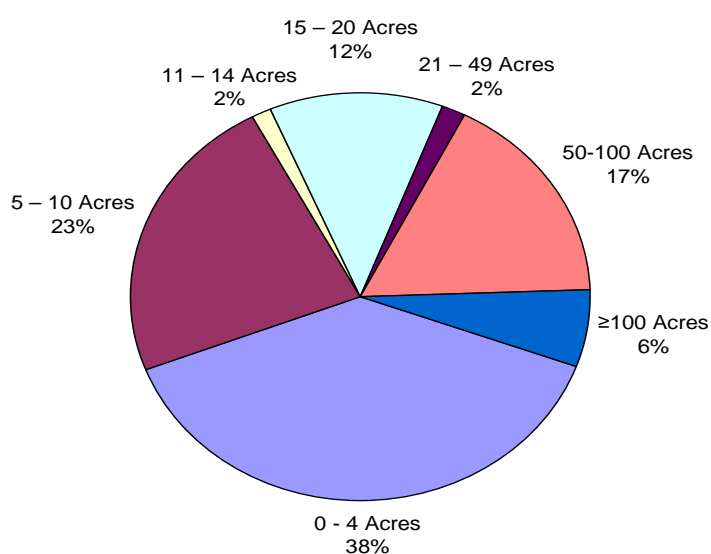


Figure 4.1: Land ownership

4.4.2 Crop Farming

All respondents were engaged in crop farming. 100% of respondents grew maize, 91.7% grew vegetables (potatoes, lettuce, carrots, peas, cabbage, etc) and 76.4% grew millet. All respondents grew more than one crop and the average number of crops grown was 4.2. 40.5% of respondents used pesticides and 91.9% used fertilisers on their crops. These were mostly bought at local markets and occasionally from Jos. 91.9% of respondents used manure from their own cows on their crops. All respondents tilled their land by hand and no draught power was used.

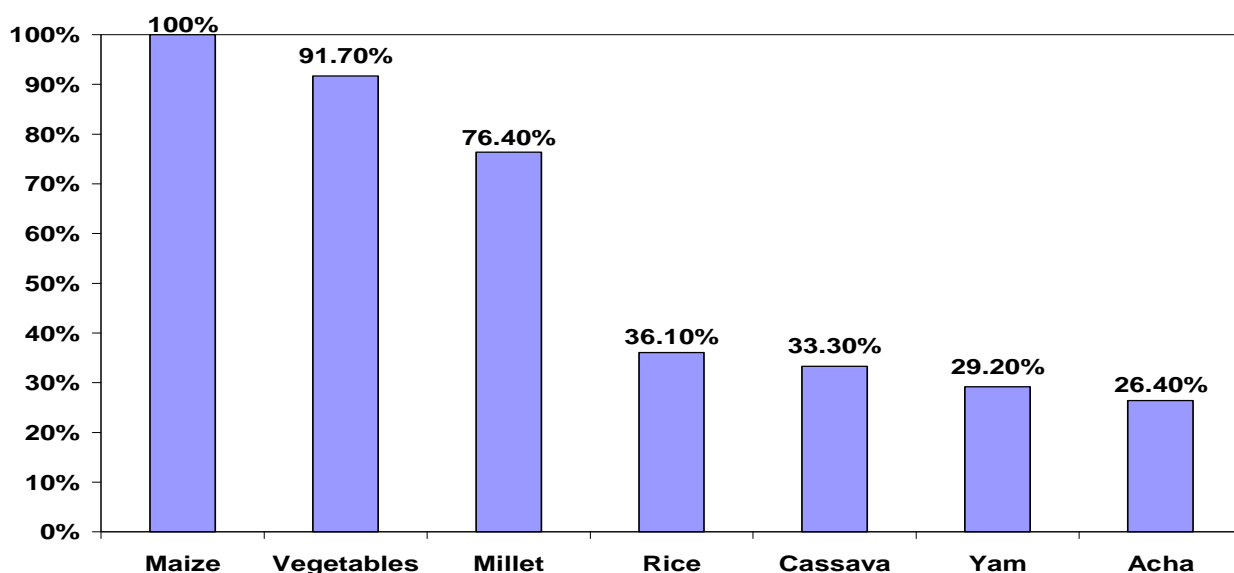


Figure 4.2: Crops grown

4.4.3 Livestock Ownership

Cattle keepers were selected for interview so all respondents kept cattle. The majority of respondents also kept sheep, goats, chickens and dogs. Only 17.6% of respondents kept pigs. All respondents kept more than one species of livestock and the average number of species kept was 4.6.

Species	% respondents
Cattle	100%
Sheep	87.8%
Goats	87.8%
Chickens	77%
Dogs	94.6%
Pigs	17.6%

Table 4.6: Livestock ownership

4.4.4 Herd Size and composition

Herd size was very variable, ranging from 7 to 5,015 cattle. The herd size distribution was bimodal, with peaks in the range 10 – 20 cattle and 50 – 100 cattle. The average herd size was 250 cattle. However, when the 4 herds with >1000 animals were removed, the average herd size fell to 78 cattle. Please see Chapter 3 for information on herd composition and structure.

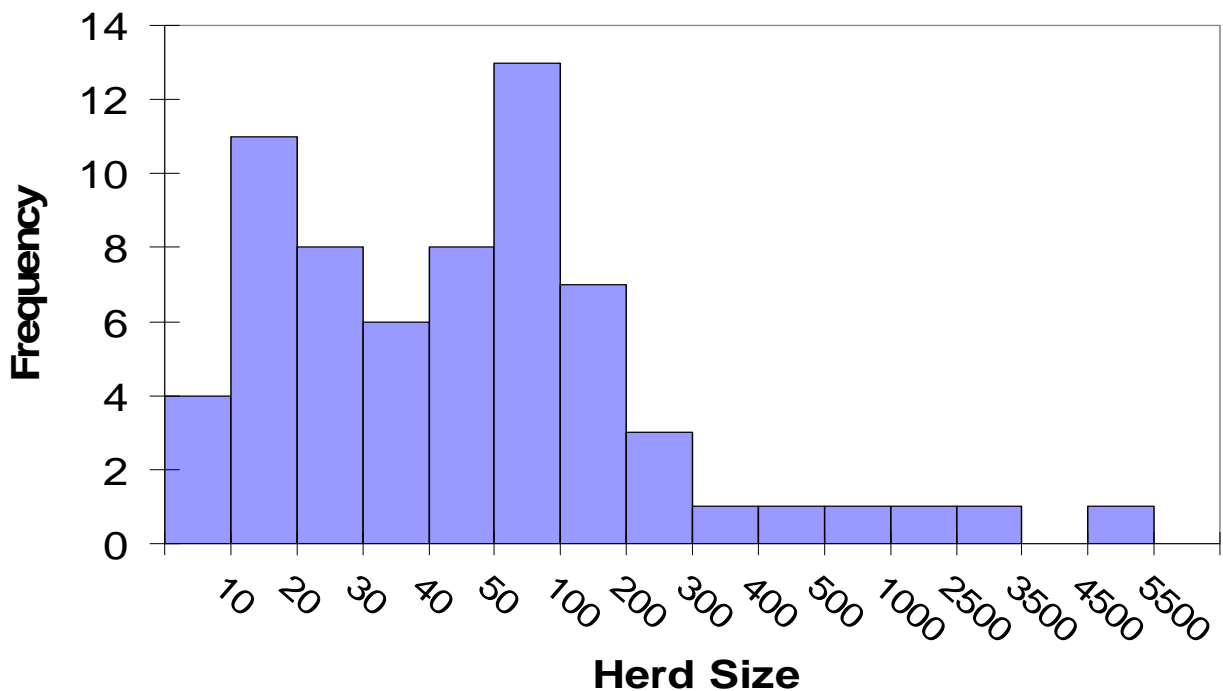


Figure 4.3: Herd size distribution

4.4.5 Source of Income

Livestock were the most important source of income for respondents, accounting for 60% of total income. Crops (25%) and milk (15%) were both ranked second in importance. Thirty percent of respondents relied on only one source of income, sale of livestock. 54% had 2 sources of income – 39% from livestock and crops and 15% from livestock and milk.

Sixteen percent gained additional income from off-farm activities, mostly mining and sale of firewood, and in one instance, Islamic teaching.

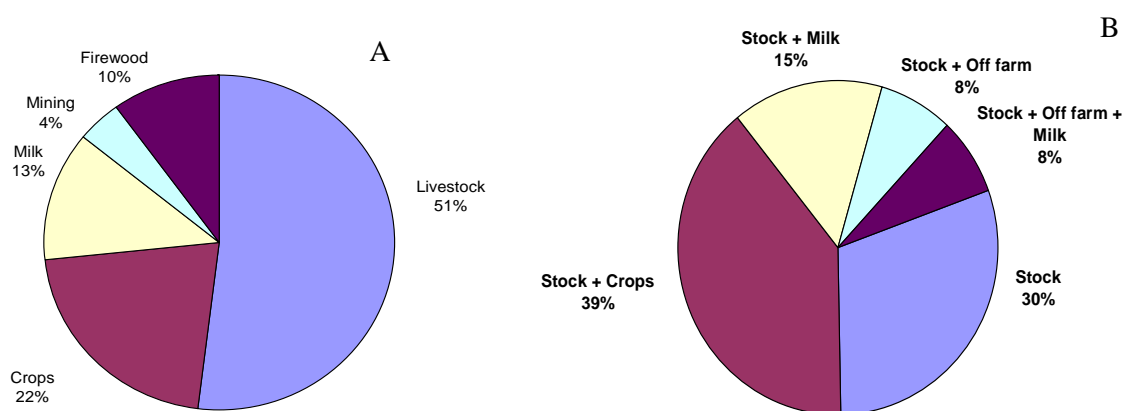


Figure 4.5 A: Sources of income; B: Income diversity

4.4.6 Wealth Grouping

Respondent households were assigned to wealth groups according to the categories devised by FEWSNET. Households with less than 15 cows or less than 3 hectares of cultivated land were considered poor; those with 15 – 50 cows or 3 – 5 hectares of cultivated land were in the middle wealth group and those with more than 50 cows or more than 5 hectares of cultivated land were considered better off. Analysis of livestock holdings revealed that 43.9% of households were ‘better off’, 50% were in the ‘middle’ group and only 6.1% were ‘poor’. Analysis of land holdings showed that 37.9% of households were ‘better off’, 7.6% were in the ‘middle’ group and 54.5% were ‘poor’.

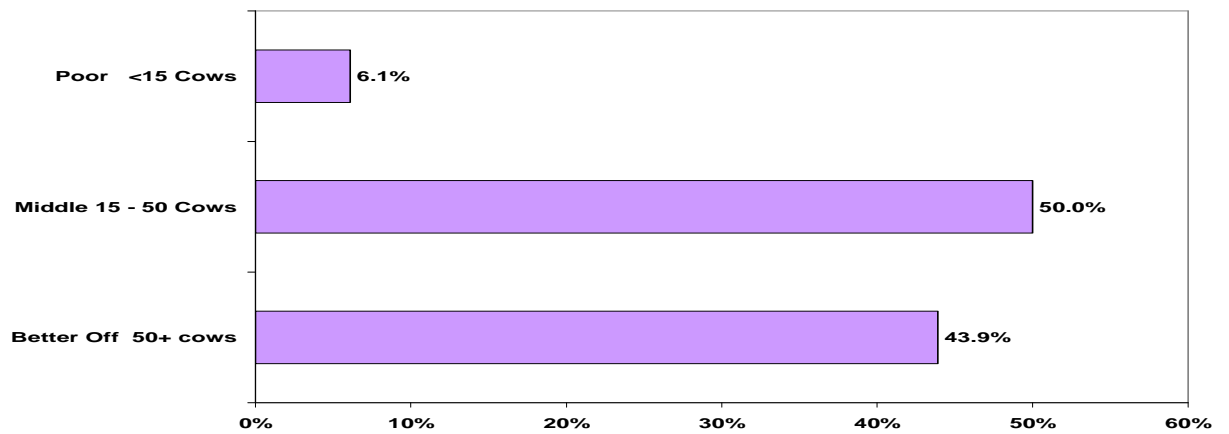


Figure 4.6: Wealth groups by livestock holdings

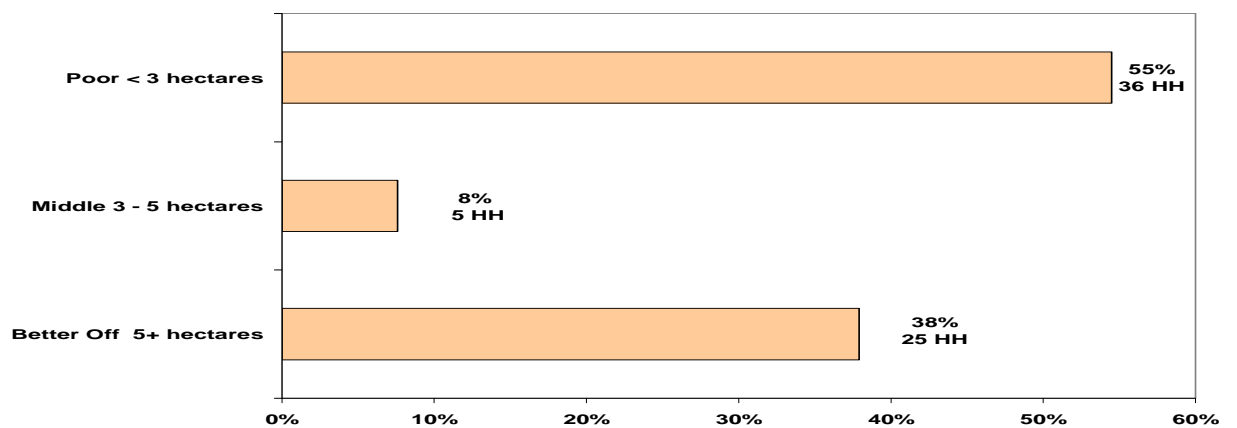


Figure 4.7: Wealth groups by land holdings

4.4.7 Production Costs

The most significant cost associated with cattle production was veterinary drugs, accounting for 43% of total costs. Food (hay and mineral supplements) was ranked second in importance and accounted for 22% of total expenditure. Veterinary services (15%) and ropes & fencing (9%) were both ranked third in importance. Taxes had the lowest rank and accounted for 11% of total expenditure.

4.4.8 Herd Dynamics & Productivity

Information on herd size, births, deaths, sales, purchases and prices was collected using structured from individual members of focus group discussions using a structured questionnaire. Mean values per herd/household are presented below. The mean starting stock recorded was 252.61 (61.98 – 443.24) while the mean closing stock was 249.39 (59.54 – 439.97). The mean percentage change in herd size was a decrease of 3% (-3% - +9%).

	Starting Stock	Closing Stock	% Change in Herd Size
Mean	252.61 (61.98 – 443.24)	249.39 (59.54 – 439.97)	-3% (-3% - +9%)
Median	50.5	49.5	0.01
Minimum	6	7	-0.82
Maximum	5030	5015	0.875

Table 4.7: Stock levels and % change in herd size

The mean number of births per herd was 14.61 representing 5.78% (4.0 – 7.57%) of the herd. The mean number of deaths was 8.88 representing 3.52% (2.14 – 4.89%) of the herd. There were 964 births from 11,087 adult cows, resulting in a calving rate of 8.7%. Of the 964 calves, 122 died, giving a calf mortality rate of 12.7%. The mean number of calf deaths was 1.85 (0.89 – 2.81).

	Births	Calf Deaths	Deaths
Mean	14.61 (10.11 - 19.11)	1.85 (0.89 – 2.81)	8.88 (5.4 – 12.36)
Minimum	0	0	0
Maximum	100	20	75

Table 4.8: Births and Deaths

The mean number of slaughters was 0.65 per herd. The mean number of sales per herd was 8.14 representing 3.22% (2.12 - 4.28%) of the herd. The mean number of purchases was 2.61 representing 1.03% (0.40 – 1.66%).

	Slaughter	Sales	Purchase
Mean	0.65 (0.21 – 1.09)	8.14 (5.47 – 10.81)	2.61 (1.02 - 4.2)
Minimum	0	0	0
Maximum	10	50	50

Table 4.9: Sale, slaughter and purchase information

The mean price of stock purchased was NGN 37,065.79 (31,796.44 – 42,335.14) or USD 308.88 (264.97 – 352.79) whilst the mean price of stock sold was NGN 37,065.79 (31,796.44 – 42,335.14) or USD 680.87 (609.23 – 752.51).

	Price Bought (USD)	Price Sold (USD)
Mean	308.88 (264.97 – 352.79)	680.87 (609.23 – 752.51)
Minimum	10,000	30,000
Maximum	100,000	180,000

Table 4.10: Cost and sale prices of cattle

Potential offtake is defined as births minus deaths. It indicates the number of animals that can be removed from the herd without reducing the original herd size and provides an estimate of the productivity of the herd (Pullan and Grindle, 1980). The mean potential offtake was 10% (5% - 15%) whilst actual offtake was 11% (8% - 14%).

	Potential Offtake	Actual Offtake
Mean	10% (5% - 15%)	11% (8% - 14%)
Minimum	-33%	0
Maximum	88%	88%

Table 4.11: Potential and actual offtake

4.4.9 Disease and Mortality

Liverfluke was considered the most important disease, being cited as a problem by 98.6% or all but 1 of the respondents and never ranked lower than 3rd in importance. Trypanosomiasis was the second most important disease, cited as a problem by 94% of respondents and ranked from the first to the fifth in importance. Foot and mouth was the third most important disease, cited as a problem by 46% of respondents and ranked from first to fifth in importance. Pneumonia was the 4th most important disease, cited by 40% of the respondents and ranked from second to sixth in importance.

Disease	Median Rank	Mean Rank
Liverfluke	1	1.3
Trypanosomiasis	2	2.2
Foot & Mouth	3	3.3
Pneumonia	3.5	3.4

Table 4.12: Herder perception of livestock disease

A total of 568 cattle deaths were recorded by respondents. 197 (33.62%) of these were due to liverfluke, 194 (33.11%) were due to trypanosomiasis, 44 (7.51%) to pneumonia, 16 (2.73%) to foot & mouth and 135 (23.04%) to other causes.

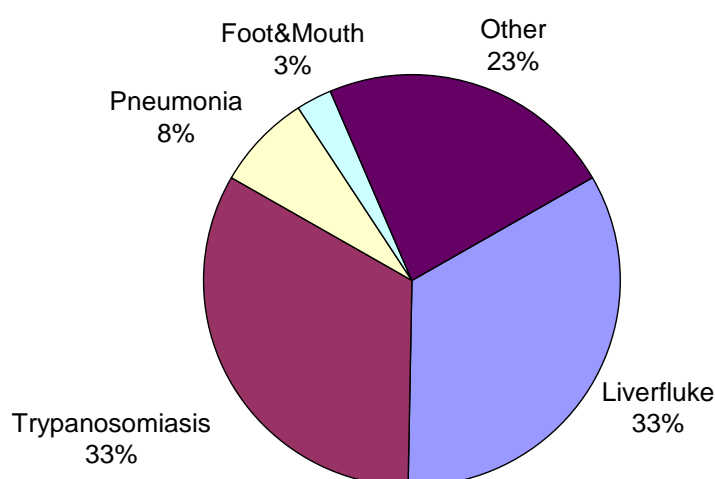


Figure 4.8: Mortality by disease

4.4.10 Knowledge, attitudes and practices: tsetse

Flies were cited as a problem by 23 villages (76.67%) and tsetse flies were specifically mentioned as a problem by 20 (66.67%) of the 30 villages in the study. Herders in all 30 villages (100%) knew about tsetse flies whilst those in 24 villages (80%) knew that they caused animal trypanosomiasis. Herders in 22 villages (73.33%) were able to identify tsetse flies. 17 villages (56.67%) employed some sort of protection for their cattle against tsetse flies. Of these 17, 8 villages (47.06%) used commercial pour-on products; 3 villages (17.65%) used smoke from fires lit with aromatic leaves/wood; 3 villages (17.65%) sprayed their animals with herb tinctures; 2 villages (11.76%) moved their animals to avoid tsetse flies and 1 village (5.88%) used a commercial insecticide spray. Individuals from 2 villages were able to name the pour-on used as Cypermil, a 5% Cypermethrin product.

When asked about local tsetse populations, 9 villages (30%) considered tsetse to be abundant; 5 villages (16.67%) considered tsetse fairly common; tsetse were only found in a few places in 8 villages (26.67%); tsetse were rarely seen in 1 village (3.33%) and were never seen in 7 villages (23.33%).

When asked about local wild game populations in their villages, wild animals were often seen in 4 villages (13.33%); they were seen occasionally in 5 villages (16.67%); they were rarely seen in 3 villages (10%) and were never seen in 18 villages (60%).

4.4.11 Knowledge, attitude and practices: animal trypanosomiasis

All respondents recognised trypanosomiasis as a problem distinct from other diseases. When asked to rank trypanosomiasis for importance amongst the disease affecting their cattle, 9 villages (30%) considered it the most important disease; 16 villages (53.3%)

considered it amongst the top 3 diseases and 5 villages (16.7%) recognised it as a problem but did not consider it a priority.

The trypanosomiasis control strategy of all villages in the study was curative treatment. Curative treatment was preferred by 22 villages (73.3%) because it was the most effective way to control trypanosomiasis; by 4 villages (13.3%) because it was the easiest; by 3 villages (10%) because it was the only available strategy and by 1 village (3.33%) because it was the cheapest.

Twenty nine villages (96.7%) in the study used drugs specifically to treat trypanosomiasis. 15 villages (50%) used Diminazene only; 1 village (3.3%) used Isometamidium only; 1 village (3.3%) used a mixture of Diminazene and Isometamidium; 11 villages (36.7%) used both drugs and 2 villages (6.7%) did not know the name of the drugs they used against trypanosomiasis. These drugs were purchased from agro-veterinary merchants by 20 villages (66.7%); from a veterinarian by 1 village (3.3%); from the National Veterinary Research Institute by 1 village (3.3%) and from both veterinarians and agro-veterinary merchants by 7 villages (23.3%) and from both NVRI and agro-veterinary merchants by 1 village (3.3%).

Trypanocides were diluted using bottled/package water only by 13 (43.3%) villages; using well/stream water only by 8 villages (26.6%) and by water from both types of sources by 7 villages (23.3%). Of the 15 villages using water from natural sources, only 7 villages (46.7%) boiled the water before use. Only 10 villages (33.3%) diluted trypanocides using the correct amount of water per sachet of the drug. Herders treated their animals in all villages except one where a veterinarian was called in to treat animals with trypanocides purchased by the herders. All herders dosed animals incorrectly.

4.4.12 Natural Resource Conflict and Migration

Of the 30 study villages, 22 villages (73.4%) practice transhumance: 3 (10.0%) during the dry season only, 5 (16.7%) during the wet season only and 14 (46.7%) during both seasons. 8 villages did not practice transhumance. Twenty-six (86.7%) of villages are situated by established cattle routes on which migratory cattle regularly pass by. Figure 4.9 shows the seasonal calendar and migration periods.

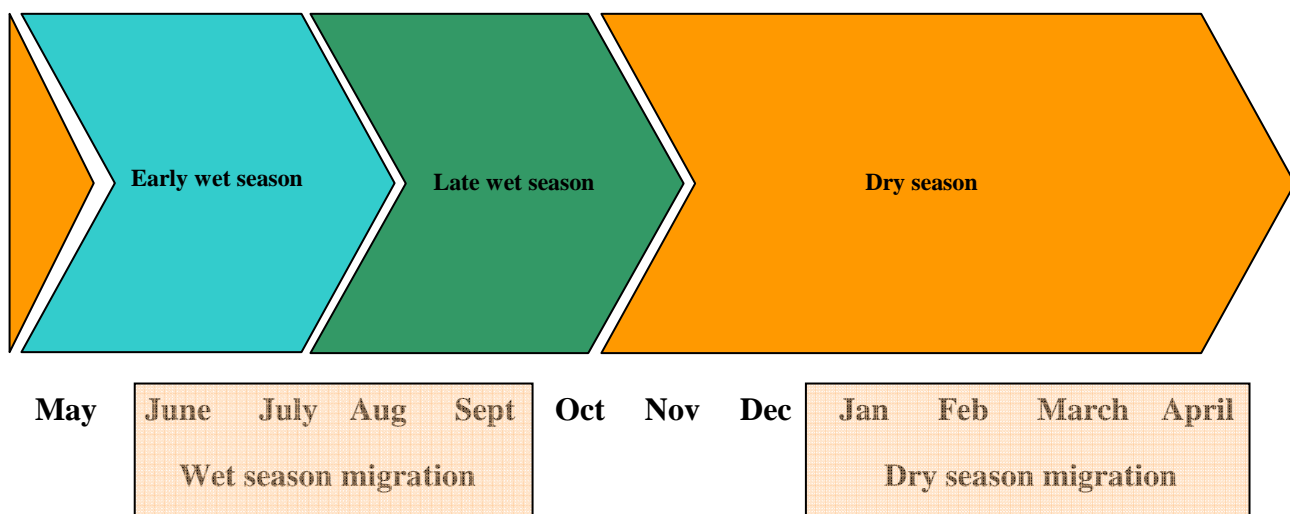


Figure 4.9: Seasonal calendar

There were three observed patterns of mass cattle movement across the plateau:

1. Alien migratory cattle: Cattle from other areas regularly cross the plateau on their annual North-South-North migration. This affects almost all areas of the plateau and is compounded by the fact that one of the major cattle highways of West Africa stretching from Chad to Mali crosses the Jos plateau.

2. Dry season migration in search for adequate pasture and water: The majority of land on the plateau is devoted to arable farming. The land left for grazing is inadequate for the vast numbers of cattle. The situation is manageable during the rainy season when grass is plentiful but during the dry season, food is scarce and malnutrition is a real problem, especially because supplementary feeding of crop residues is not practiced. In many of the communities with large herds the majority of cattle are moved to dry season grazing grounds further south. Very few cattle, mostly cows with young calves are left behind. This is the most common reason for migration of cattle otherwise resident on the plateau.

3. Rainy season migration for:

- a) Freely available grazing and water:** When the Fulani first settled on the Jos plateau they were granted grazing rights to land unfit for rainfed farming of cereals, which included areas adjacent to rivers and ponds. Increasing use of fertilisers and irrigation pumps and the switch from growing cereals to vegetables has seen farmers reclaim these areas and deny pastoralist access to former scrubland and riverine plots and the lush pasture and access to water they provide.
- b) Avoidance of farmers' crops:** Increasing populations and land pressure have intensified farmer/pastoralist conflicts and increased the frequency of animals trampling crops. In many areas these issues have been resolved simply by asking pastoralists to remove their cows from the village from the time the crops appear above ground until harvest.

c) **Avoidance of tsetse/biting flies:** In areas with severe fly nuisance, cattle are moved to more favourable areas of the plateau or to nearby lowlands. This is the least common reason for migration of cattle otherwise resident on the plateau.

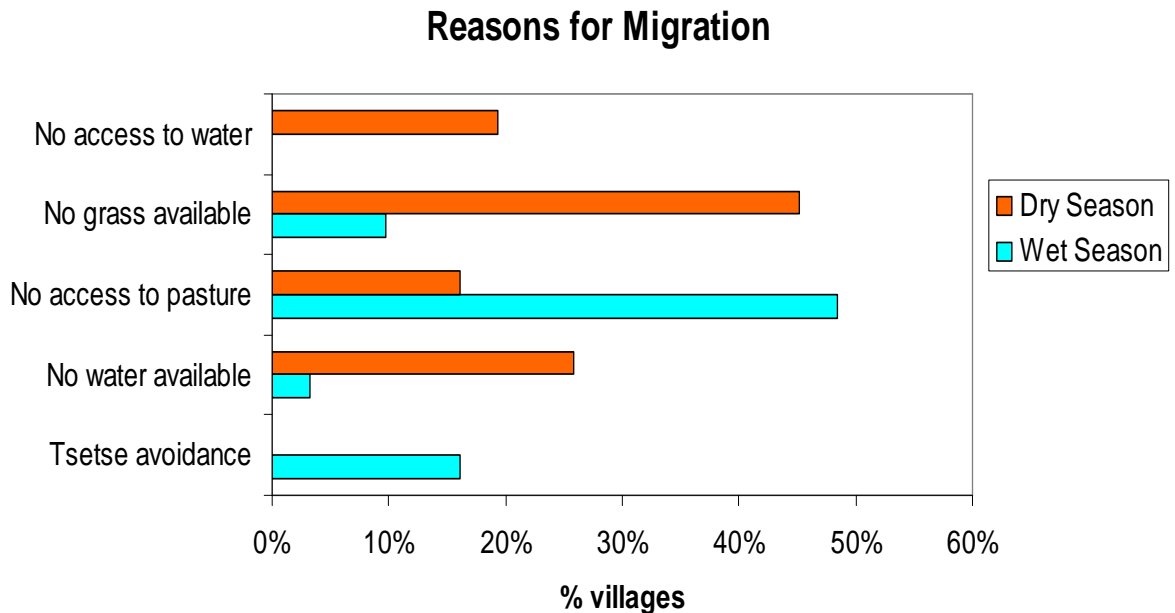


Figure 4.10: Reasons for seasonal migration

Dry season migration takes place between December and April and on average lasts 3 months. Rainy season migration takes place between April and October and on average lasts 2 months. The majority of the rainy season destinations are in Bauchi state to the east of the Plateau. Dry season destinations are more varied; half of them being on the eastern side of the Jos Plateau. The destinations vary in distance from 1 day to 3 weeks trek but the average distance is 5 days trek.

Sixteen villages (69.6%) split their herds for migration, leaving behind gravid cows and those with young calves for two reasons: to spare these vulnerable animals the rigours of the journey and to provide the household with dairy products.

21 villages (91.3%) believe that migration affects disease negatively. Of these, 14 villages reported higher incidence of disease at their destinations, one village reported presence of tsetse at their destination. Five reported the stress of the journey as a significant morbidity and 1 reported sudden death of migrating animals. Only in two villages was the destination thought to harbour less disease but this was weighed against disease and stress occurring on route.

16 villages (69.6%) believe that migration specifically affected trypanosomiasis while seven (30.4%) believe it has no effect on trypanosomiasis. Nine believed that there was higher incidence of trypanosomiasis at their destinations, while 2 believed that incidence was lower at the destinations. Four villages reported the stress of the journey leading to acute clinical episodes of trypanosomiasis and sudden death.

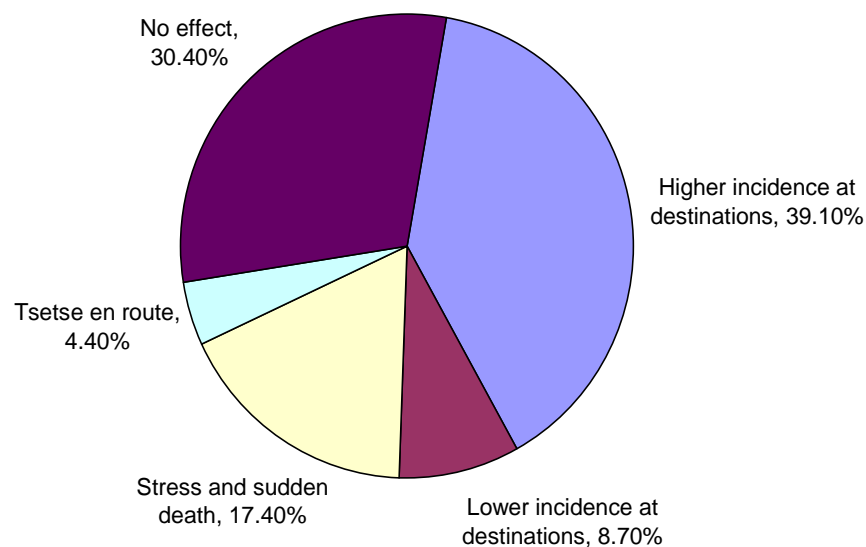


Figure 4.11: Effects of migration on cattle health

4.5 Discussion

4.5.1 Livelihood assessment

This section discusses and interprets the results of this study concerning assets and livelihood strategies of Fulani pastoralists on the Jos plateau.

4.5.1.1 Land ownership and crop farming

Land ownership was ubiquitous, with all respondents owning a piece of land. The majority of respondents (61%) owned 1 – 10 acres. However, several respondents (23%) owned over 50 acres of land, bringing the average amount of land owned to 17.9 acres. Of this 17.9 acres, on average 10.9 were used for cropping whilst 7 were used for livestock. This illustrates the general trend of land use primarily for cropping purposes. Livestock were generally grazed on commons/ unused land and only tethered at night on land owned by the respondent.

All respondents engaged in crop farming. Maize, vegetables (potatoes, lettuce, carrots, peas, cabbage etc) and millet were the most popular crops but several others were also grown based on personal preference and on average each respondents grew 4 types of crops. Respondents also commonly used manure from their own cows (91.9%), commercial fertilisers (91.9%) and pesticides (40.5%) to enhance crop yield and quality.

This shows that the pastoral Fulani group have become agro-pastoralists who own land and grow their own staples (maize, millet) as well as cash crops (vegetables). They are even willing to invest cash in agricultural inputs such as pesticides and fertilizer. The successful adaptation to agro-pastoralism has resulted in higher food security and income diversification for the Fulani on the Jos plateau. Typically, pastoralists are highly

dependent on cash purchase of food to satisfy their nutritional need but the widespread adaptation to agro pastoralism reduces this dependency and frees up cash for other uses. The adaptation to agro pastoralism and reduced dependence on food purchase is also an indication of wealth status. Poorer pastoralists typically purchase 70% of their food requirements whereas those who are better off only purchase 15% of requirements with 80% being supplied by their own crops. (FEWSNet, 2004/5)

This transition may be due to the break down of viable exchange relations between pastoralists and local farmers, forcing the Fulani to acquire land and grow their own food, instead of getting it from farmers in exchange for dairy products and manure. It may also simply be a natural income diversification strategy enabled by the long-term settlement of Fulani in this area. This is almost certainly the case in the 23% of respondents who own large amounts of land and sell most of their crops for cash. However, it is likely that the former reason is responsible for the widespread uptake of arable agriculture observed.

It is interesting to note that the Fulani, along with local farmers, mostly grow crops that provide little or no residues for animals to graze on.

4.5.1.2 Livestock & herd sizes

All respondents owned livestock other than cattle, with most of them keeping small ruminants and chickens for household consumption and/or sale and dogs for hunting and/or security. Only 17.6% respondents, all indigenous Christians, kept pigs.

The number of cattle owned by each respondent was very variable, with a range of 7 cattle (10.6 % of respondents). Only 16 respondents (24.2%) of respondents owned more than a

hundred cattle while only 4 (6%) owned a thousand or more cattle. The average herd size was 250, falling to 78 after the four largest herds were excluded from analysis.

4.5.1.3 Herd composition

The age, sex and breed of animals sampled during the longitudinal trypanosomiasis survey were recorded (see chapter 3). Results show that the sampled animals were 76% females and 24% males. Further analysis revealed that there were equal numbers of each gender in calves aged <6 months and juveniles aged 6 months – 2 years, but in adult cattle aged >2 years, the number of females was 6 times the number of males. This shows that equal numbers of male and female calves are born but that a large number of males exit the herd when they reach the age of two. The high percentage of adult females in the herd is characteristic of a dairy herd, where the husbandry system is geared towards maximum milk production.

The majority of animals (86.8%) were of the white Bunaji breed. The rest of the herd were of the red Rahaji breed (2.6%) or Bunaji x Rahaji crosses (10.6%). The white Bunaji cattle are considered more docile and less susceptible to disease, possibly because their light colour makes them less visible to tsetse flies. The red Rahaji cattle are regarded as wilder animal, better adapted to cope with harsh conditions but more susceptible to disease. The Bunaji are the preferred breed on the Jos plateau and other areas in the subhumid and humid zones because there is abundant food and water compared to the Sahel regions, they are easier to herd and cause less damage to crop farms, and they are less susceptible to the diseases found in these areas. The Rahaji are preferred in the Sahel regions in the far north of Nigeria and Niger because they can cope better with the limited resources available and are less susceptible to the depredation of cattle raiders/wild animals. The Fulani of the Jos

plateau cross their Bunaji with Rahaji animals to retain some of these characteristics in their herds.

4.5.1.4 Wealth groups

The results in this section showed a discrepancy between wealth grouping by land and wealth grouping by livestock holdings. Grouping by livestock holdings showed that 43.9% of households were 'better off', 50% were in the 'middle' group and only 6.1% were 'poor'. But grouping by land holdings showed that 37.9% of households were 'better off', 7.6% were in the 'middle' group and 54.5% were 'poor'. This shows that although few of the Fulani on the Jos plateau are poor in terms of livestock, many are still land poor.

There is a continuous distribution amongst wealth groups by livestock holdings but the distribution of wealth groups by land was bimodal: respondents either owned a lot of land, or very little, with few households in the middle category. This pattern of land ownership may be due to differences in land tenure customs, or the duration of settlement of different groups of Fulani. Fulani that have been settled for longer are more likely to be granted permission to acquire land, but they are also more likely to be attracted by the advantages of mixed farming, than those who have only recently settled in an area. This distribution may also be linked to the amount of labour required to till large pieces of land once acquired. Larger, wealthier households are more likely to have spare hands for farm labour, or spare cash to hire labourers. The majority of Fulani with large land holdings contract the tilling and weeding to labourers from the indigenous population but family labour was used for harvesting (pers. comm.). There were no reports of animal traction used by either Fulani or indigenes for tilling their land.

The results of wealth grouping by livestock holdings show that few herders are in the poor (6.1%) group while the majority are in the middle (50%) and better off groups (43.9%) on the Jos plateau compared to average figures from FEWSnet wealth analysis which showed 10% pastoral households to be poor, 10% better off and 80% in the middle group (FEWSNet, 2004/5). This is consistent with the pastoral poverty incidence of 28% recorded by (Rass, 2006) for Nigeria, the lowest in West Africa, compared to 48% in neighbouring Chad and Niger, which had the highest poverty incidence amongst pastoralists in West Africa. Despite this comparatively well-to-do status, most of their wealth is invested in their livestock. This means that their day-to-day living standards are lower than would be expected and that their livelihoods are vulnerable to the risks of disease, droughts and conflict.

4.5.1.5 Income

The main sources of income were the sales of livestock (60% total income), crops (25% total income) and milk (15%). A few respondents engaged in off farm activities like mining and sale of firewood.

Livestock sales were the major income earner for all respondents. 30% of respondents relied on only one source of income, sale of livestock. 54% had 2 sources of income – 39% from livestock and crops and 15% from livestock and milk. Sixteen percent gained additional income from off-farm activities, mostly mining and sale of firewood, and in one instance, Islamic teaching.

Income diversity is reasonable as 70% of households have more than one source of income but 30% are still reliant on one income source – livestock sales. Only 16% engaged in off farm activities mostly labour intensive mining/sale of firewood rather than

investment/trade. This is an indicator that pastoral livelihoods in this area maintain a certain degree of vulnerability - higher income diversity reduces vulnerability to risks/shocks in any one income-generating sector.

There is general agreement on the need to invest in alternative non-herding livelihood options for pastoralists driven by the appreciation of the inexorable human population increase on degraded rangelands. There are 3 variables that influence herders' decisions to diversify as well as their choice of diversification strategy. Conditional variables determine whether or not prevailing conditions are conducive to diversification e.g. external income transfers, human population density, livestock holdings and availability of pasture. Opportunity variables determine available opportunities for diversification e.g. distance to the nearest city/market/town, education, available services and infrastructure. Local response variables facilitate or constrain the impact of the other variables e.g. age, gender, wealth differentiation. Conditional variables of increasing populations and restricted access to pasture and water have created an environment conducive to income diversification. Such conditions usually result in involuntary diversification as the current livelihood strategies of poor herders fail and they are forced to seek supplementary or alternative sources of income.

Only a few wealthy herders show voluntary diversification and invest their accumulated savings in extra income businesses (Morton & Meadows, 2000). However, on the Jos plateau, the proportion of better off herders is higher and so the local response variable of comparative wealth and the opportunity variables of land acquisition, proximity to towns, good road networks, good market access, high demand and high price for vegetables has encouraged voluntary diversification into growing cash crops in 39% of respondents for whom these crops bring in 25% of their income. The fact that the remaining 60% of

respondents were unable to take advantage of these conditions to diversify into growing cash crops is supported by the results of the wealth grouping by land holdings that show that 54.5% of respondents were 'land poor'. Those in this category lack the opportunity variable of land acquisition and would not be able to diversify into cropping.

The other main source of income for income diverse households was the sale of milk. The capital assets model argues that income from livestock is in the form of products where animals are capital assets which produce a stream of valuable products (milk, offspring) while held and have capital value when sold/slaughtered. Milk is also the main subsistence product of cattle. Pastoralists can rarely afford to eat meat as slaughtering an animal for meat means they must forfeit any milk and future offspring it would produce as well as cash from the eventual sale. There is therefore constant competition for milk, between human consumption, calf consumption and sale which may be responsible for the low percentage of households (28%) gaining income from the sale of milk. (Niamir, 1982) shows that only better off pastoral households consume milk while poorer households prefer to sell it and buy grain to eat. Weight for weight, grain has much higher calorific content than milk and is therefore a more economic and efficient food source. The low number of households gaining income from milk is also as expected based on the wealth grouping results - a higher number of better off households will reserve their milk for consumption by humans and calves while only the few poorer households will sell theirs.

Another important obstacle to diversification into the dairy trade is market exclusion, for which there are two reasons. Firstly, the main potential for pastoral dairy is in the informal market that serves high urban demand but pastoralists in remote areas simply do not have access to this market. Secondly, the entire trade in pastoral dairy faces stiff competition from imported powdered milk and intensive, peri-urban dairy farms. This competition

tends to reduce demand for pastoral dairy products that are viewed as unhygienic on comparison. This lack of demand is a very important blow to market access as well as any prospects for its improvement - demand for pastoral dairy products is has been identified as the limiting factor to market participation and an important pre-condition for interventions designed to increase market access for pastoralists e.g. improved road network and conditions, establishment of milk collection centres (Michael, 1987; Little, 1989; Rass, 2006). Di Domenico (1989) provides evidence of long distance, trans-regional trade in dairy products by Fulani women in Nigeria facilitated by good transport facilities and active social ties between Fulani based in southern cities where demand was high and those based in northern rural areas where the majority of the milk was produced. Since income from the pastoral dairy trade is controlled by women, this has serious implications for gender empowerment and household economics.

4.5.2 Herd productivity

Reproductive efficiency was very low, with a calving rate of 8.7%. The optimum calving rate is 100% i.e. one calf per cow per year. However, results from studies on Fulani herds under similar traditional management lead us to expect 50% calving rate in these circumstances. The excessively low calving rate seen here is most likely due to the practice of allowing calves to suckle their dams for very long periods of up to two years. This is done for 2 reasons. First, to provide robust nutrition for calves, given the uneven availability of pasture and second, to ensure a constant supply of milk for sale and household needs. Lactation length is a significant factor in the determination of calving interval because the stress of lactation delays onset of oestrus until the calf is weaned. Coupled with the effects of disease and poor nutrition, this means that on average, each

cow produces a calf once every 3 years. The average calving interval for Fulani White cows in Nigeria is 13 – 14 months under intensive management (Wheat and Broadhurst, 1968; Wheat *et al.*, 1972; Oyedipe *et al.*, 1982) and 24 – 27 months under traditional management (Pullan, 1979; Otchere, 1983).

The deliberately prolonged lactation period signifies the preference of the Fulani for maximum milk yield at the expense of calf production. This decision is influenced by several factors including household milk needs, market demand for pastoral milk, size of herd, price ratio of meat: milk, access to markets and the dairy versus beef potential of the herd involved. The Fulani of the Jos plateau are less dependent on milk for their nutritional needs as they are agro pastoralists who grow their own crops. For the same reason, they are also less dependent on cash from the sale of milk to buy grain. Moreover, demand for pastoral milk in the area is quite low so it is not clear why this preference for milk yield at the expense of calf production still prevails; especially when we consider the fact that sale of livestock is the major source of income for all herders in this study. It may simply be that they have stuck to their traditional dairy management systems out of habit, rather than because it is the most appropriate livelihood strategy for today.

Calf mortality is low at 12.7% compared to expected values of 20 – 40% but this is not enough to compensate for the poor reproductive performance.

	Observed	Expected
Calving Rate	8.7%	~50%
Calf Mortality	12.7%	20 – 40%

Table 4.13: Observed and expected cattle and mortality rates (Pullan and Grindle 1980; Wagenaar *et al.*, 1986)

Mortality was low at 3.52%, much lower than the 16.3% recorded by (Wagenaar *et al.*, 1986) and 8.05% recorded by (Pullan and Grindle, 1980). This may be because of generally lower levels of disease than in the past as well as increased access of herders to curative drugs.

Sales were equivalent to 3.22% of the herd, again much lower than the 5.6% recorded by (Wagenaar *et al.*, 1986) and 10.35% by (Pullan and Grindle, 1980). This may be because the Fulani on the Jos plateau are now all agro pastoralists and are less dependent on cash from sale of cattle to buy food. Purchases were equivalent to 1.03% of the herd, comparable to the 1.15% recorded by Pullan and Grindle (1980).

Potential offtake was 10% and actual offtake 11%. Actual offtake was the same as that recorded by Pullan (1980), but the potential offtake is lower than the 14.7% recorded in that study. This points to reduced productivity over time. This reduction in productivity is probably linked to increased land pressure and environmental degradation and its knock-on effects on cattle nutrition and management. It may also be linked to the presence of trypanosomiasis (absent from the plateau at the time of the study by Pullan) which is primarily a disease of production.

Actual offtake (11%) was more than potential offtake (10%) indicating that herders are unable to meet their need for cash from livestock sales without reducing the size of their herd. This factor is probably responsible for closing stock levels (249.39) being lower than starting stock (252.61) and the -3% average change in herd size. Figures obtained previously from (Pullan and Grindle, 1980) were compared to those collected in this survey.

	1975	2008
Starting Stock	125.5 (19.21 – 231.79)	252.61 (61.98 – 443.24)
Closing Stock	141.38 (16.2 – 266.56)	249.39 (59.54 – 439.97)
% Change in Herd	+7.81% (-16.99 - +25.58%)	+3% (-3% - +9%)
Births	28.47% (4.0 – 53.0%)	5.78% (4.0 – 7.57%)
Deaths	8.05% (0 – 55.27%)	3.52% (2.14 – 4.89%)
Sales	10.35% (5.29 – 52.63%)	3.22% (2.17 – 4.28%)
Purchases	1.15% (0 – 2.33%)	1.03% (0.40 - 1.66%)
Price Bought	N 115,755.02 (17,333.89 – 214,176.15) \$769.50 (115.24 - 1,423.85)	N 37,065.79 (31,796.44 – 42,335.14) \$246.33 (211.31 - 281.35)
Price Sold	N 84,132.43 (28,327.94 – 139,936.92) \$559.13 (188.26 – 923.00)	N 81,704.92 (73,107.59 – 90,302.25) \$543.00 (485.86 - 600.13)
Potential Off take	14.7% (8.15% - 21.25%)	10% (5% - 15%)
Actual Off take	11.7% (2.22% - 21.3%)	11% (8% - 14%)

Table 4.14: Herd productivity parameters 1975 & 2008

There were no significant differences between the two data sets. However, there are some apparent changes that can be deduced from the figures:

- Mean herd size has increased and is more variable. This could be due to increased polarisation into better off versus poor households or to a simple increase in the number of better off households. Wealth grouping results support the latter because although there is a higher proportion of better off households, there are also a high proportion of households in the middle category.
- Variability in change in herd size per annum has decreased, showing that herd sizes are more stable.

- The number of births is less variable, but seems to be decreasing, pointing to a reduction in productivity of cattle.
- Variability in both potential and actual offtake has decreased, pointing to increased stability. However, actual offtake in this study is more than potential offtake that indicates reduced productivity. The decrease in potential offtake from 14.7% to 10% is also a sign of declining productivity.
- Sale and cost prices are both less variable but surprisingly, the sale price of cattle in 2008 appears to be the same as it was in 1975 after prices were adjusted for inflation.

When taken together, these factors indicate that the overall livestock enterprise is more stable and less vulnerable to risks/shocks, therefore livelihood vulnerability has decreased but overall productivity has also decreased.

4.5.3 Knowledge, attitudes and practices concerning tsetse and trypanosomiasis

Results show that trypanosomiasis is an important disease, well recognised by herders on the Jos plateau. Knowledge of trypanosomiasis and general diagnostic ability is good amongst herders, but they lack the correct knowledge and resources for treatment and control of disease. Herders are also well informed about tsetse flies and their association with trypanosomiasis but again, lack appropriate knowledge and resources for vector control. Poor availability of veterinary services and poor uptake by herders of the services available is a significant factor. Vulnerability to the risk of animal disease depends on access to vet services for preventive and curative treatments. Structural adjustment and

liberalisation programmes in Nigeria and across Sub-Saharan Africa included privatisation of many animal health services. Without adequate support for the private sector to enable them fill the consequent gap in animal health care delivery. This left the majority of remote pastoral areas without access to veterinary services. The people are poor, poorly educated and widely dispersed and unable to effectively demand services from a private sector that is not capable of delivering to them. Odeyemi (1999b) showed that provision of animal health care by professional veterinary staff isn't viable in marginal pastoral areas as service fees, drug costs and cost to the herder of reaching the veterinarian/accessing the service is often worth more than the value of the animal in question.

Risk management strategies are classified in order of preference as risk reduction, risk mitigation and risk coping strategies. The disease control strategies of herders on the Jos plateau that only risk coping strategies are in use here. Risk reduction strategies include vaccination and other prophylactic treatments whereas risk mitigation strategies include things such as dry season supplementation (animals on a higher nutrition plan are better able to withstand disease). The prevalent disease control strategy practiced on the Jos plateau was curative treatment, which is aimed at coping with disease once animals have become infected.

4.5.3 Effects of Conflict, Competition & Migration

Results show that 73.3% of all study villages practiced transhumance and that over half of these practiced both wet and dry season migration. The reasons for transhumance can be broadly divided into two: poor availability of pasture/water due to climatic/ecological reasons and poor access to available pasture/water due to social reasons. Poor availability of resources is the main driver for dry season migration, being the reason cited by 71% of

respondents almost twice the number that cited poor access as the reason for migration. Poor access to available resources is the major driver for wet season migration being the reason cited by 48.4% of respondents, almost 4 times the number (12.9%) who cited lack of resources as the reason for migration.

It is easy to see how the poor pasture and dwindling water supplies caused by the long harsh dry season force herders to move their cattle to areas where the dry season is shorter and its effects less severe. The issues surrounding lack of access to abundant pasture and water during the wet season are more involved and require a study of the relationships between Fulani pastoralists and the indigenous farming peoples.

Farmers on the plateau previously practiced rain fed agriculture based on cereals that grew well on eroded soils and produced high quality residues for animals. This facilitated a stable system of exchange between farmers and pastoralists: grain for dairy products and crop residues for manure. At this time, mine ponds and river valleys were of little use to farmers but were valuable to pastoralists who were given free access but not ownership rights. Dry season farming of new crops – maize, sugarcane and Irish potatoes was introduced in 1960s and greatly encouraged by World Bank funded agricultural development programmes in the 1970s. Year round large-scale vegetable gardening also began in the 1980s, assisted by the appearance of small petrol irrigation pumps. These are all fertiliser-based crops that produce no useful cattle residues so the farmer-pastoralist exchange system has broken down.

Advances in livestock management and disease control have also led to agricultural expansion on the part of pastoralists. Increasing human and livestock populations and consequent environmental degradation has led to a reduction in tsetse habitats and

trypanosomiasis risk. The effective control of rinderpest and other endemic diseases, development of effective antibiotics and trypanocides and the current easy access to these drugs has increased the population, productivity and marginal value of cattle. This interaction of reduced disease risk and increased productivity promotes increases in human and livestock populations. Availability of trypanocide treatments have been shown to increase conversion efficiency and reduce disease risk in cattle, both of which increase calving rates and pasture exploitation. Both factors also increase cattle value and encourage increased cattle acquisition leading to a double increase in cattle density. Reduced treatment costs per cow further reduce disease risk so low cost treatments are capable of increase overgrazing exponentially.

These factors lead to overpopulation and overexploitation of land/pasture that accelerates environmental degradation and reduces environmental carrying capacity and the sustainability of the current land use scheme. Overgrazing in the past and subsequent erosion is responsible for much of the poor availability of pasture currently seen on the Jos Plateau. Baumgartner *et al.* (2008) carried out a 25 year study in the Ethiopian highlands which showed how tsetse and trypanosomiasis control, and technological advances unleashed the biotic potential of both people and animals, leading to a fifty fold increase in cultivated land, 33% reduction in pasture and increase in family size from 3.5 – 5 people per household. These results were observed in amongst agropastoral people where there is potential for conflict between groups but when applied to the Jos plateau where crop farmers are of a different tribe and religion from cattle herders then the potential for conflict is obvious.

Given the increasing land pressure and agricultural expansion by both parties previous land use schemes became unsustainable and have broken down. All riverine plots which

previously provided lush pasture and access to water are now extremely valuable to farmers, access rights of pastoralists have been revoked and they have been effectively excluded from the enjoyment of natural resources that were previously held in common.

The outbreaks of urban violence in Jos and its environs emphasise the growing natural resource conflict in the rural areas. In many other areas in Nigeria and around the world, competition for natural resources has resulted in herder-farmer conflict but this is uncommon on the Jos plateau. Traditional conflict mitigation/resolution mechanisms are active and have successfully managed to develop schemes for the shared use of key resources. Figure 4.12 illustrates a natural resource use map agreed between both communities.

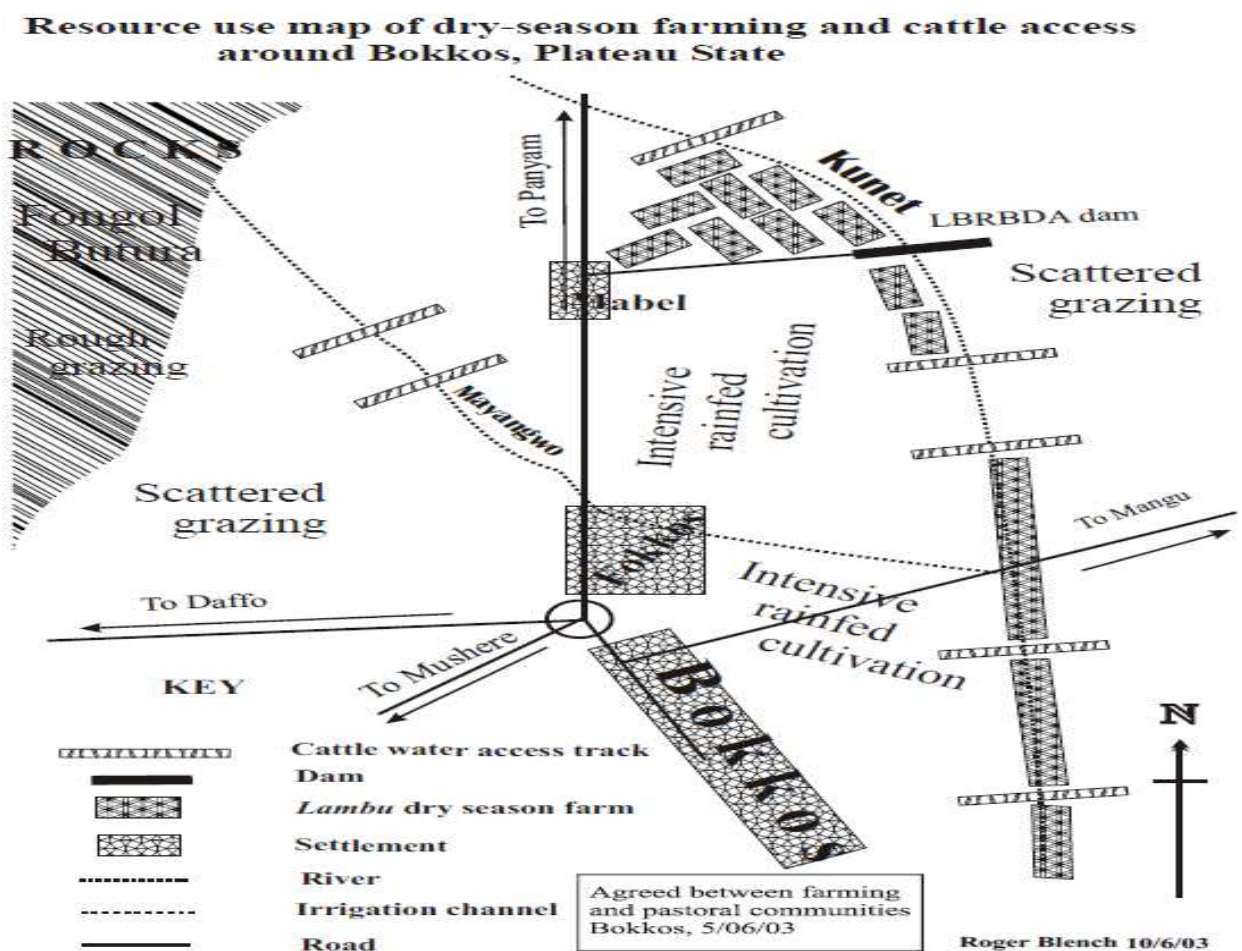


Figure 4.12: Land use scheme agreed between farmers and herders (Blench, 2003)

All such agreements have favoured the farmers and pastoralists have adapted to increasing marginalisation by sending their cows off the plateau for longer periods each year. There are several important consequences if the increase in transhumance in response to these factors, including:

- Some established stock routes now closed
- Increased labour required to herd migrating cows
- Increased security risks
- Reduced income for pastoralist women
- Reduced long term investment in the industry
- Poorer health in cattle
- Malnutrition due to scant sources of food and water en route
- Stress and fatigue of trekking
- Increased morbidity of any underlying diseases
- Increased contact with disease and disease vectors both en route and at the final destination, including tsetse and trypanosomiasis

This is reflected in the herder perceptions of the effects on migration that show that migration does in fact take its toll on their cattle and that the benefits of migration come at a considerable cost:

Effect on Trypanosomiasis	% of Villages
Higher incidence at destinations	39.1%
Lower incidence at destinations	8.7%
Stress and sudden death	17.4%
Tsetse en route	4.4%
No effect	30.4%

Table 4.15: Effects of migration on trypanosomiasis in cattle

Wet season migration is an unfortunate consequence of natural resource competition and marginalisation of pastoralists by farming communities. Natural resource conflict is centred on key resource sites particularly important to livestock but which also offer cropping possibilities. This definition of key resource sites implies that they are essential for pastoralists but optional for farmers. Livestock have been shown to occupy relatively small patches of land (key resource sites) within the wider landscape and exclusion from these key areas significantly disrupts their transhumance cycle, necessitating this second wet season migration. Especially exclusion from access to wetlands, river valleys and other water resources which farmers wish to reserve for intensification of crop production (Niamir-Fuller and Turner, 1999; Southgate and Hulme, 2000; Woodhouse *et al.*, 2000). Such exclusion often leads to cattle entering fields because of the need for forced access, leading to conflict over damaged crops.

There are also many long-term, indirect effects to this climate of recurring violence, marginalisation of pastoralists and constant risk of conflict. Such prevailing factors often work to reverse ongoing development processes in pastoral livelihoods – herders are less likely to invest in new assets/technologies or to practice income diversifications in such an atmosphere of uncertainty. Structural marginalisation of pastoralists is seen as discrimination which makes them prone to radicalisation and recruitment by insurgent

groups and conflict entrepreneurs. Political resistance movements in Algeria, Kenya, Ethiopia, Sudan, Somalia, Uganda, Mali and Sudan have emerged in pastoral areas that were economically and politically discriminated against in the preceding 20 years. In Nigeria, competition over resources is often given ethnic and religious overtones, which greatly expedites progression into violent conflicts and this is a major factor in the current situation on the Jos plateau. The effects of marginalisation and radicalisation of pastoralists in neighbouring countries has also been felt as there is increasing use of assassins from Chad and Niger. So marginalisation can fuel conflict, especially where there is an imbalance of power coupled with ignorance by policy makers on pastoral livelihoods. Pastoralist ignorance of the policy making process may also increase their sense of discrimination. National policies tend to favour settlement of pastoralists without taking account the implication of sedentarisation on their livelihood strategies. This is an indication that the marginalisation of pastoral peoples is so deeply rooted in the nation building process that it must be regarded as a structural problem.

4.6 Conclusion

This survey of pastoral livelihoods, knowledge, attitudes and practices of Fulani herders on the Jos plateau has shown that the majority of pastoral households in the study area are better off or in the middle wealth categories and only a few are poor in terms of livestock holdings. However, many households are poor in terms of land holdings while a few are better off. Income diversity is reasonable as only 30% of respondents are still reliant on one source of income: livestock sales. Livestock sales remain the major source of income for all households while crops, milk and off farm activities played a role in income diverse households.

Results on transhumance, herd productivity analysis and comparison to previous productivity levels on the Jos plateau show that vulnerability to disease has decreased over the years but natural resource conflict has increased with consequent negative effects on productivity. Overall vulnerability has decreased and there is increased stability in the cattle enterprise but overall productivity has decreased and reproductive rates were particularly low.

The amount of wealth concentrated in livestock, number of land poor households and those still reliant on one source of income suggest that there is still a degree of vulnerability to the risks of drought/dry season, disease and conflict in pastoral livelihoods in the area.

Knowledge, attitudes and practices results show that knowledge of tsetse and trypanosomiasis and general diagnostic ability is good amongst herders but they lack the correct knowledge and resources for treatment and control. Poor availability and uptake of veterinary services adds to the problem so gap in veterinary service provision must be bridged. Curative treatment is the main livestock disease control measure in use and the risk of animal disease could be more effectively managed by the strategic use of curative and prophylactic drugs and insecticide treatments to reduce disease.

Dry season migration is an important but costly way to avoid starvation when one considers the stress of long journeys, aggravation of sub clinical infections, security risks and disease encountered en route. Feeding hay/silage, concentrates and digging wells for exclusive livestock use is an effective and feasible solution. Wet season migration is subject to the same negative factors and is an unfortunate consequence of natural resource competition and marginalisation of pastoralists by farming communities.

The new data summarised in the preceding paragraphs effectively describes the livelihood strategies of the resident Fulani of the Jos plateau and provides the first update on the subject since 1980 (Pullan, 1979; Pullan, 1980a; Pullan, 1980b; Pullan & Grindle, 1980). The effects of wider socioeconomic trends on these livelihood strategies has also been shown. The gaps in animal health care provision by pastoralists have been identified as have those in provision of and access to animal health care by government and the private sector. The herd productivity and financial data, when taken together with the prevalence data from chapter 3 bring us one step closer to quantifying the economic losses due to T&T to pastoralists in this area. The participatory exercise has also engaged local communities in the process of understanding and hopefully improving their current situation. This has laid a foundation of trust and increased both their ability and inclination to participate in advocacy and policy making.

This study has provided concrete background information on the study area that will enable robust planning of animal health and productivity interventions. It has also laid a lot of the practical and logistical groundwork that will enable a smooth introduction of these interventions. In view of the information now available, the most appropriate interventions in terms of feasibility, efficacy, acceptability and herder uptake can be selected. They will be based on the seasonal calendar and migratory patterns to facilitate incorporation into established herder routines. However, the large herd sizes and high levels of heterogeneity will make it challenging to produce a single strategy that is feasible, efficacious and sustainable and some variety/adaptations will be required.

Chapter 5: Evaluation of FAMACHA Charts as a pen-side test for Trypanosomiasis

5.1 Introduction

This chapter explores anaemia as a diagnostic sign of trypanosomiasis and the efficacy of two pen-side methods for detecting anaemia and predicting trypanosomiasis: a portable haemoglobinometer and a mucous membrane colour chart. The portable haemoglobinometer is considered the most accurate method currently available for pen-side/field use but the mucous membrane colour chart could be a cheaper, simpler alternative suitable for use by Fulani pastoralists if proved accurate. Gaps in pastoral access to professional veterinary care were identified in chapter 4 and simple, pen-side diagnostic tests like this would go a long way to bridge the gap.

In this study, 329 cattle from 7 villages across the Jos plateau were assessed for anaemia using both methods and trypanosomiasis using the polymerase chain reaction. The aims of the study were to evaluate FAMACHA cards as a test for anaemia and as a test for trypanosomiasis in White Fulani cattle on the Jos plateau.

5.1.1 Anaemia as an indicator of infectious diseases

Anaemia is a pathological state characterised by insufficient haemoglobin due to reduced quality or quantity of circulating red blood cells (RBCs). It has several aetiologies broadly classified into regenerative and non-regenerative anaemia. Regenerative anaemia is due to RBC destruction (haemolytic anaemia) or RBC loss (haemorrhage) while nonregenerative anaemia is due to decreased production of RBC. Gastrointestinal parasites, haemoparasites and ectoparasites are all important causes of anaemia especially in areas where these diseases are endemic.

Anaemia is a common problem worldwide and is of enormous medical and veterinary public health concern, particularly in developing countries. It is a major clinical sign of many parasitological infections endemic to Africa e.g. malaria (Pasvol, 2005), babesiosis (Vial & Gorenflot, 2006), anaplasmosis (Magona *et al.*, 2008), theileriosis (Magona *et al.*, 2008), schistosomiasis (De Bont and Vercruyse, 1998; Webster *et al.*, 2009), fascioliasis (Hawkins, 1984), helminthiasis (Koukounari *et al.*, 2006), tick infestation and trypanosomiasis (Maudlin *et al.*, 2004).

Anaemia plays many different roles in its association with these diseases. It is primarily a consequence of infection. The presence and type of anaemia is a valuable marker of presence and intensity of infection (King *et al.* 2006), parasite burden (Latham *et al.*, 1983) and morbidity due to infection (Pasvol, 2005; Webster *et al.*, 2009). It can also indicate infection by particular parasite species or combinations (Latham *et al.*, 1983; Taylor and Authie, 2004). It is a less obvious morbidity behind more apparent physical signs of disease but it is a significant disability and is actually directly responsible for some of the other consequences of infection e.g. loss of condition, weakness (Vial and Gorenflot, 2006), reduced productivity (Latham *et al.*, 1983) and abortion (King *et al.*, 2006). Thus, it is both a cause and consequence of disease. Anaemia may compromise the success of antiparasite treatment and may persist after the parasite has been cleared, requiring separate, specific treatment.

Anaemia is a condition of multiple, complex aetiologies which makes it difficult to assess or attribute to any specific condition. It may be due to infection or co-morbidities such as malnutrition, micronutrient deficiency, co-infection with a different parasite, HIV/AIDS, haemoglobinopathies. There are also inconsistencies in the literature regarding the definition of anaemia. In cases of co-infection or areas where several anaemia-causing

diseases are endemic, the degree to which each condition contributes to anaemia is difficult to define. In cattle, cut off haemoglobin concentrations of 88 – 144g/L have been recorded (Webster *et al.*, 2009).

Despite these potential drawbacks, identification of morbidity indicators like anaemia are vital for sustainable disease control and it remains a logistically practical, inexpensive and valuable measure of parasite associated morbidity amenable to large scale control programme monitoring and evaluation when a non invasive, field friendly test such as the Hemocue haemoglobinometer is used (Koukounari *et al.*, 2006; Webster *et al.*, 2009).

5.1.2 Anaemia in bovine trypanosomiasis

Despite the fact that anaemia is a clinical indicator of several livestock diseases, it is especially severe in trypanosomiasis, and differential diagnosis is facilitated by taking epidemiological factors into account. Anaemia develops at the onset of parasitaemia and its severity is determined by factors including virulence of the infecting parasites and the breed, age and nutritional status of the host. It is the most prominent sign of infection (Grace *et al.*, 2007) and can be observed as pallor of the mucous membranes. The ability to control anaemia is the feature of trypanotolerant cattle most closely associated with their ability to remain productive under tsetse-trypanosomiasis challenge (Naessens, 2006; Read *et al.*, 2008).

The early, acute phase of trypanosomiasis is characterised by fever and haemolytic anaemia followed by loss of performance in livestock. Haemorrhagic anaemia is also observed with haemorrhagic strains of *T. vivax* in East Africa. The degree of anaemia is correlated to the extent of loss of performance and is widely regarded to be one of the

major contributors to death of trypanosome infected animals (Taylor and Authie, 2004). Packed cell volume (PCV) falls from normal values of $\geq 30\%$ to 15%. The main induction mechanism is RBC destruction due to extra vascular phagocytosis in the spleen, liver, lungs, lymph nodes and bone marrow. Erythrophagocytosis is caused directly by the parasite: opsonisation by trypanosome antigen and RBC damage by trypanosome enzymes; and indirectly by the host immune response: complement activation, over-reactive mononuclear phagocyte system (Taylor and Authie, 2004).

In the late, chronic phase, PCV continues to fluctuate and reduction in performance and reproduction persist. Erythrocyte destruction continues but dyserythropoiesis seems to take over as the main underlying mechanism of anaemia. There are two proposed pathways for the role of erythropoiesis: the first is impaired bone marrow function so that there is no replacement of erythrocytes lost to haemolysis. The second is that bone marrow function remains normal but is unable to keep up with the rate of RBC destruction. Trypanotolerant cattle able to control anaemia show increased levels of erythropoietin receptors and lower levels of inflammatory cytokines known to downregulate erythropoietin compared to trypanosusceptible cattle (Taylor and Authie, 2004).

5.1.3 Measuring anaemia in resource-poor settings

Detection of anaemia in veterinary medicine relies on the assessment of PCV by the microhaematocrit centrifugation technique. A microhaematocrit tube is filled with blood and centrifuged, allowing the proportion of blood volume occupied by RBCs to be measured (Uilenberg, 1998). This technique is reliable and cheap to run and allows simultaneous assessment of plasma (for total protein concentration, lipaemia etc) and identification of haemoparasites such as trypanosomes. Despite these advantages it is not

ideal for use in field settings because it requires a power source, expensive bulky equipment and vehicles to transport these to the field. The international reference method for detecting anaemia in humans is measuring haemoglobin concentration using the photometric cyanmethemoglobin method in which blood is diluted with cyanide compounds to produce cyanmethemoglobin. The colour intensity of cyanmethemoglobin is then measured using a spectrophotometer and the optical density recorded is proportional to the concentration of haemoglobin (Callan *et al.*, 1992). Again, this is a very accurate method but the equipment and reagents required make it unsuitable for field use. In resource-poor settings, clinical assessment is often the only available option and appraisal of mucous membranes is often used for subjective assessment of anaemia, jaundice and hydration status. This is quite inaccurate with 33%-57% sensitivity and 79%-84% specificity which is too low to monitor changes in prevalence of mild to moderate anaemia. (Shulman *et al.*, 2001; Critchley and Bates, 2005). Since these accepted methods for detecting anaemia are unsuitable for field use in resource poor settings, there is a clear need for the development of a reliable and accurate test for use in these areas. An ideal test should (Bates *et al.*, 2007):

- be accurate enough to detect the anticipated changes in haemoglobin levels induced by the disease(s) involved
- not require mains electricity
- require only minimal training and supervision
- use whole blood so that no dilution steps are required
- be rapid
- be inexpensive

Low technology systems have been developed in both human and veterinary medicine for use in these settings, based on haemoglobin concentration (Haemoglobin Colour Scale and HemoCue handheld haemoglobinometer) and mucous membrane assessment (FAMACHA[®] colour scale).

5.1.3.1 Haemoglobin Colour Scale

The Haemoglobin Colour Scale (HCS) is an inexpensive method for estimating human haemoglobin concentration from a drop of blood by means of a colour scale. A finger-prick blood sample is soaked into special chromatography paper and its colour is compared with high quality digital pictures of blood of known haemoglobin concentration soaked into the same type of paper. These pictures represent ‘standard’ haemoglobin concentrations of 4 – 14g/dl in 2g/dl increments. It is ideal for use in resource-poor settings because it can be used by non-laboratory staff after a few hours training, is accurate up to 2g/dl, is durable under tropical conditions and recurrent costs are less than \$0.05 per test (Medina-Lara *et al.*, 2005). It is also better than clinical diagnosis for detecting mild/moderate anaemia in pregnant women and children. It has 24% – 97% sensitivity and 41 – 100% specificity for anaemia with better results in laboratory settings than field settings (Critchley and Bates, 2005; Lindblade *et al.*, 2006). Although developed for use in humans. It has been tested as an attractive method for field diagnosis of bovine anaemia with favourable results – sensitivity of 81% and 94% and specificity of 62% and 93% respectively in East and West Africa (Magona *et al.*, 2004; Grace *et al.*, 2007).

The drawbacks of the HCS are that it requires specific chromatography paper and cannot detect changes in anaemia of less than 2g/dl. The heterogeneity in efficiency

in different studies has led to calls for a shift from efficacy studies to more policy relevant research to integrate the method into primary health care systems (Critchley and Bates, 2005).



Figure 5.1: Haemoglobin Colour Scale

5.1.3.2 HemoCue

This is currently the most widely used method for measuring haemoglobin in field and point of care settings (Bates *et al.*, 2007) and is considered the method of choice for evaluating anemia in remote areas (Sari *et al.*, 2001). It produces a direct readout of haemoglobin concentration to one decimal place using a drop of blood in a plastic cuvette. The cuvettes are coated with nitrite azide that lyses whole blood and converts free haemoglobin to azidmethemoglobin. This stable azide is measured by the HemoCue

photometer at 2 wavelengths: 570nm to determine the haemoglobin concentration and 880nm to correct for turbidity (Posner *et al.*, 2005). This azidemethemoglobin method is an improvement of cyanmethemoglobin in many ways. It is just as reliable as the cyanmethemoglobin method {99.5% correlation (Bates *et al.*, 2007)} and is not subject to the major source of inaccuracy of this international standard, namely turbidity due to cell stroma, proteinaemia or lipaemia. The azide conjugate removes the need for toxic reagents and the reaction is four times faster than the cyanide conjugate, giving results in 40-45s.

Errors in the azidemethemoglobin method are due to air bubbles in cuvettes and cuvette deterioration due to adverse climatic conditions or improper storage (Posner *et al.*, 2005). Air bubbles will give incorrect readings, however this is rare as cuvettes are filled by capillary action and should be visually inspected before inserting into the Hemocue. The reagent lining inside the cuvettes is hygroscopic and deteriorates at high temperature and humidity. Although they have a shelf life of 2 years, the manufacturer recommends they are used within three months of opening (HemoCue; 1999). Sari *et al.* (2001) conducted a study to compare the accuracy of cuvettes opened on the same day to those opened 2 – 25 days before use during a tropical field survey. They found a significant difference in the prevalence of anaemia returned by the two groups of cuvettes with test performance value haemoglobin concentration of samples recorded as 2.75g/l higher with the older cuvettes. There was no significant difference with cuvettes opened up to 12 days before use but after 12 days false high values of haemoglobin are produced and anaemia is underestimated. It is therefore recommended that cuvettes should be used 3 months after opening in temperate climates and 3 – 12 days after opening in tropical climates (HemoCue; 1999; Sari *et al.*, 2001; Posner *et al.*, 2005).

The Hemocue device itself is robust, easily portable at 1kg and powered by 5AA batteries or a 6V adaptor. It comes with an inbuilt quality checking mechanism and is ideal for use in field, clinic, operating theatre and critical care sites (Posner *et al.*, 2005). It gives consistent results in both routine practice and large field surveys and is accurate at a wide range of haemoglobin concentrations for capillary and venous blood in humans, livestock and companion animal species (von Schenck *et al.*, 1986; Callan *et al.*, 1992; Chevalier *et al.*, 2003; Magona *et al.*, 2004; Posner *et al.*, 2005). It requires only 10µl of whole blood which is useful for patients with small blood volumes or severe anaemia and does not require any dilution or concentration steps. It is very user friendly, requires minimal training for use by unskilled personnel and there is little inter-observer error (Sari *et al.*, 2001; Magona *et al.*, 2004; Posner *et al.*, 2005; Bates *et al.*, 2007). However, the device is sensitive to temperatures above 30°C and shuts down in these conditions which makes it less than ideal for some tropical locations (Magona *et al.*, 2004).

The Hemocue 301 is an improved version designed to deal with the major drawbacks of the standard Hemocue 201 haemoglobinometer. The relatively high recurring costs of cuvettes and their deterioration under adverse climatic conditions have made it impractical for use in many under resourced countries. This deterioration is due to the inner lining of nitrite azide that is hygroscopic. The Hemocue 301 therefore uses polystyrene cuvettes without any reagent. These improved cuvettes are 30% - 40% cheaper and can be stored at 10°C - 40°C for 3 months after opening (Morris *et al.*, 2007). The haemoglobinometer itself has been modified so that instead of measuring anaemia as azidemethemoglobin, it measures it as a thin layer of unconverted oxyhaemoglobin. It is also less sensitive to high ambient temperatures. Medina-Lara *et al.* (2005) recommend Hemocue as the method of

choice for assessing anaemia in resource poor settings, as it was the most reliable and clinically useful method; however, it was also the most expensive. The improvements in the 301 model make it cost effective and reduce the error associated with using ineffective cuvettes (Morris *et al.*, 2007).



Figure 5.2: Hemocue haemoglobinometer and microcuvettes

5.1.3.3 FAMACHA[®]

The FAMACHA system is a novel clinical assay for the assessment and subsequent treatment of *Haemonchus contortus* infection in sheep to slow down the development of anthelmintic resistance. The system is based on a colour chart with five colour categories depicting varying degrees of anaemia - ranging from the normal red, through pink to practically white in severe anemia. The ocular mucous membranes of sheep are compared to the chart and then scored from severely anaemic (pale) through

anaemic to non-anaemic (red) and those animals considered in danger of succumbing to the effects of haemonchosis are treated. It is part of a targeted strategic treatment programme aimed at moving farmers away from block treatment which is largely responsible for the current high rates of anthelmintics resistance (Kaplan, 2006). When compared with conventional treatment programmes, it reduces disease at herd level and leaves a large percentage of the animals untreated, maintaining a reservoir of susceptible parasites in refugia. It may also improve the genetic resistance of herds to *Haemonchus contortus* (Kaplan, 2006). 20% of the heard usually harbour 80% of the parasites and act as super-shedders, transmitting to the rest of the head (Woolhouse *et al.*, 1997). FAMACHA allows the identification of these susceptible animals that can then be culled whilst animals with consistently good FAMACHA scores can be used for improved breeding schemes. There is evidence for heritability of FAMACHA scores and heamatocrit values (van Wyk and Bath, 2002).



Figure 5.3: FAMACHA anaemia guide for sheep

FAMACHA was developed and validated for use in 2000 in South Africa. It has been validated for use in sheep and goats in South Africa, the United States, Kenya, Brazil, Guadeloupe and Ethiopia (Vatta *et al.*,2001; Ejlersen *et al.* 2006; Mahieu *et al.*, 2007; Sissay *et al.*, 2007; Molento *et al.*, 2009b) and for use in cattle in Mali, Burkina Faso and Guinea (Grace *et al.*, 2007).

The 2004 study on validation of FAMACHA for sheep and goats by Kaplan *et al.* (2004) illustrates many of the important factors to be considered before use. The haematocrit/PCV method was taken as the reference standard for detecting anaemia. In establishing the properties of a test, cut off values are assigned to define the level of a test result that is needed to make/reject a diagnosis. Since no precise PCV value has been established at which anaemia crosses a threshold of clinical importance, different cut off values for anaemia were evaluated to optimise the FAMACHA system.

	Sensitivity	Specificity	PPV	NPV	Correct Dx	% Treated
FAMACHA categories D & E anaemic						
PCV 15%	82.6%	89.1%	17.4%	99.5%	89.0%	12.9%
PCV 19%	64.1%	91.3%	37.6%	96.9%	89.0%	12.9%
FAMACHA categories C,D & E anaemic						
PCV 15%	100%	56.9%	6.1%	100%	58.0%	44.6%
PCV 19%	92.2%	59.2%	15.6%	98.9%	58.0%	44.6%

Table 5.1: Performance of FAMACHA as a test for anaemia in sheep (Kaplan *et al.*, 2004)

From table 5.1, it is clear that the choice of cut off values is very important. Using a lower PCV cut off value maximises sensitivity but reduces specificity. When categories C, D and E are considered anaemic, sensitivity is high but specificity is low and when only

categories D & E are considered anaemic, the reverse is the case. Sensitivity and specificity are inversely proportional, as expected for categorical variables (Thrusfield, 2007). The proportion of the herd treated is also markedly different for the two FAMACHA cut off values evaluated. In practical terms, sensitivity is often more important than specificity as the consequence of not treating an infected animal (false negative due to low sensitivity) is mortality, much more serious than the consequences of treating a non-infected animal (false positive due to low specificity). For all cut off values, negative predictive values are uniformly high and positive predictive values are uniformly low, due to the tendency of this test to return false positives. Going by the test performance value of sensitivity and specificity, cut off values of 15% PCV and FAMACHA categories D & E give the best results and the authors recommend that treatment can safely be restricted to animals that fall within this group. Lambs, periparturient and lactating ewes, and other animals stressed by disease or poor condition which fall in category C should also be treated. They also gave the following guidelines for FAMACHA use:

- FAMACHA is not easy to use and proper training is required before use
- Animals should be examined with FAMACHA every 2-3 weeks during the at risk periods and weekly during critical periods
- It must only be used as part of a rational treatment regime. Since animals are not treated until they are showing clinical signs, veterinary advice and drugs with proven efficacy should be readily available.

	Sensitivity	Specificity	PPV	NPV	Correct Dx	%Treated
FAMACHA categories D & E anaemic						
PCV 15%	83.3%	70.9%	9.0%	99.2%	71.0%	30.8%
PCV 19%	57.6%	72.8%	22.9%	92.5%	71.0%	30.8
FAMACHA categories C,D & E anaemic						
PCV 15%	100%	32.9%	4.9%	100%	35.0%	68.2%
PCV 19%	93.9%	35.5%	16.9%	97.7%	43.0%	68.2%

Table 5.2: Performance of FAMACHA as a test for anaemia in goats (Kaplan *et al.*, 2004)

Table 5.2 above shows test results in goats. The pattern is similar except that both sensitivity and specificity are lower and the test performance is slightly poorer in goats than in sheep, the species for which this test was originally developed. Vatta *et al.* (2001) recorded 25.7% sensitivity and 90.9% specificity with cut off values of 19% PCV and FAMACHA categories D & E and 80.4% sensitivity and 53.7% specificity with cut off values of 19% PCV and FAMACHA categories C, D & E. Sensitivity is lower than the results of Kaplan *et al.* (2004) and suggests that FAMACHA is less suitable for use in goats and more work is required to optimise its use in this species.

5.2 Materials and Methods

5.2.1 Study design

Seven villages were randomly selected from a cohort of 30 villages already selected for the longitudinal survey of bovine trypanosomiasis. Eighty cows were selected for sampling from individual herds within each village.

5.2.2 Hemocue 201

Blood was collected from selected cows by venipuncture and one drop was applied directly to Hemocue Hb 201 microcuvettes which were immediately placed in the Hemocue Hb 201+ haemoglobinometer (Hemocue AB, Angelholm, Sweden) and the hemoglobin concentration read and recorded.

5.2.3 FAMACHA

The ocular membranes of selected cattle were compared to the FAMACHA chart and scored by a veterinarian and an animal health assistant after a brief training session.

5.2.4 PCR methods

Blood was collected from cows by venipuncture and applied directly onto Whatman FTA cards. Cards were air dried at room temperature for at least one hour and then stored in sealed envelopes with desiccant. Molecular diagnosis of trypanosomiasis was carried out by polymerase chain reaction as laid out in Chapter 3, sections 3.3 – 3.7.

5.2.5 Statistical analysis

5.2.5.1 Sensitivity & Specificity

Binary classification tests where there are only two outcomes can be evaluated by measuring their sensitivity and specificity. Sensitivity is the proportion of correctly identified positives, whilst specificity is the proportion of correctly identified negatives. The ideal test has 100% sensitivity and specificity and gives completely reliable results. If a test has high sensitivity then a negative result indicates the absence of disease. A positive result from a test with high specificity strongly suggests the presence of disease. There is usually a trade-off between these two measures: highly specific tests often have low sensitivity and vice versa.

$$\text{Sensitivity} = \frac{\text{number of true positives}}{\text{number of true positives} + \text{false negatives}}.$$

$$\text{Specificity} = \frac{\text{number of true negatives}}{\text{number of true negatives} + \text{false positives}}.$$

Two related measures for evaluating diagnostic tests are the positive and negative predictive values. The positive predictive value (PPV) is the proportion of subjects with positive test results who are correctly diagnosed. It reflects the probability that a positive test reflects the underlying condition being tested for. The negative predictive value (NPV) is the proportion of subjects with a negative test result who are correctly diagnosed. It reflects the probability that the test will classify a truly healthy person as healthy. Both of these measures depend on the prevalence of the outcome of interest.

5.2.5.2 Pearson's correlation coefficient

Two variables or sets of data may be independent of each other, or dependent upon each other in some way. Pearson's correlation coefficient is a measure of dependence which measures linear correlation. It is obtained by dividing the covariance of the two variables by the product of their standard deviations. The value of Pearson's correlation coefficient is between +1 (perfect positive linear correlation) and -1 (perfect negative linear relationship).

5.3 Results

5.3.1 Anaemia prevalence

The mean haemoglobin concentration was 100.98g/l (99.10 – 102.86g/l), with values ranging from 53 – 172g/l. There were no significant differences in haemoglobin concentration when analysed by sex ($\chi^2 = 0.14$, $p = 0.71$); age ($\chi^2 = 4.24$, $p = 0.12$); breed ($\chi^2 = 0.77$, $p = 0.68$); and condition score ($U = 12420$, $p = 0.17$).

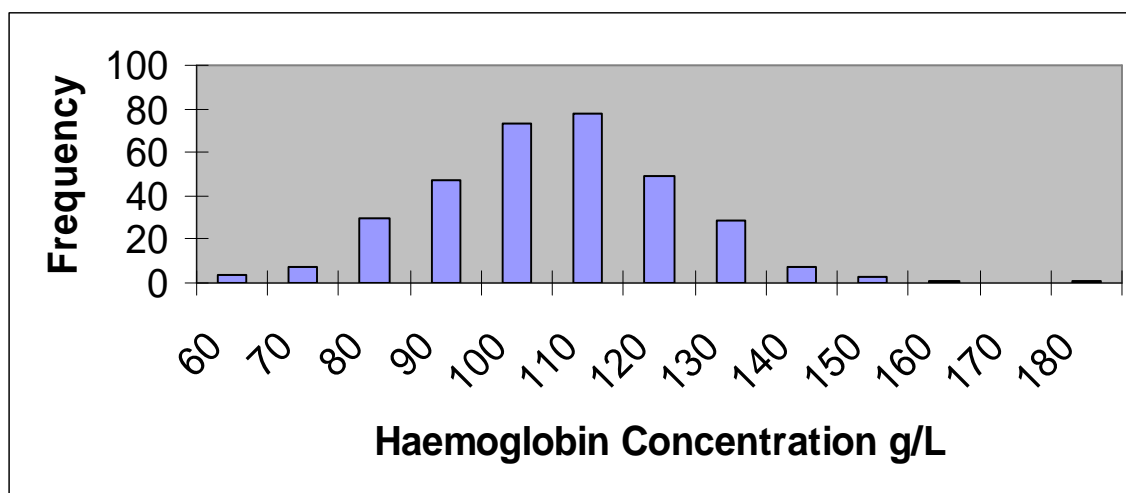


Figure 5.4: Distribution of haemoglobin concentrations amongst sampled cattle

5.3.2 FAMACHA as a test for anaemia – FAMACHA vs. Hemocue

Table 5.2 shows the sensitivity, specificity and positive and negative predictive values of FAMACHA[®] as a diagnostic test for anaemia compared to Hemocue. Different cut off points for anaemia are shown for both FAMACHA and Hemocue, along with their effects on the accuracy of the test. When FAMACHA categories C, D&E were considered anaemic, sensitivity and specificity of FAMACHA are low across the full range of Hb cut off points. When FAMACHA categories D&E were considered anaemic, sensitivity of FAMACHA is low for all Hb cut off points but increases as Hb cut off decreases. Specificity however shows the opposite trend, increasing as Hb cut off point decreases.

Table 5.2 indicates that the ideal cut off points for anaemia would be 70 g/L Hb or 30% PCV or FAMACHA categories D&E.

Hb g/L (PCV)	Sensitivity	Specificity	PPV	NPV	% Treated
FAMACHA categories C, D, E considered anaemic					
70 (20%)	50%	49%	3%	97%	49.2%
80 (23%)	63%	48%	11%	89%	49.2%
90 (26%)	55%	53%	28%	79%	49.2%
100 (30%)	54%	55%	51%	58%	49.2%
FAMACHA categories D,E considered anaemic					
70 (20%)	20%	93%	8%	97%	7.6%
80 (23%)	16%	93%	20%	91%	7.6%
90 (26%)	12%	94%	40%	76%	7.6%
100 (30%)	8%	93%	52%	54%	7.6%

Table 5.3: Performance of FAMACHA in cattle

Figure 5.5 is a box plot of the haemoglobin concentration associated with the different FAMACHA categories. There was a significant correlation between haemoglobin concentration and FAMACHA score [$\beta = 0.158$ (0/119 – 0.197), $p = 0.004$].

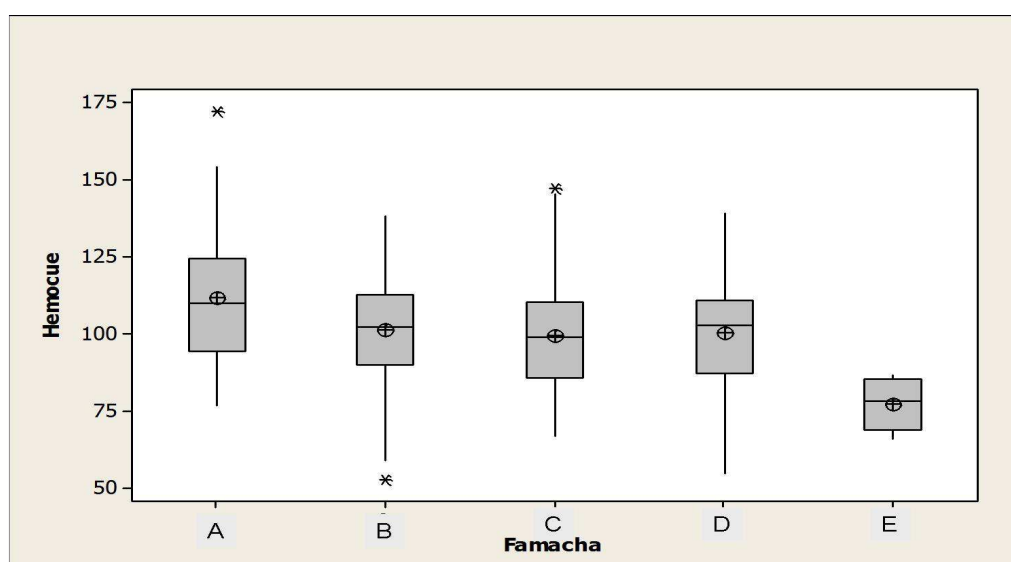


Figure 5.5: Association between haemoglobin concentration and FAMACHA categories

5.3.3 FAMACHA as a test for trypanosomiasis – FAMACHA vs PCR

Table 5.4 below shows the sensitivity, specificity, positive and negative predictive values of FAMACHA as a test for trypanosomiasis.

	Sensitivity	Specificity	PPV	NPV	% Treated
C,D,E positive	48%	50%	46%	52%	7.6%
D, E positive	7%	92%	44%	53%	49.2%

Table 5.4: Performance of FAMACHA as a test for trypanosomiasis

There was no significant difference in anaemia status between animals infected or uninfected with trypanosomiasis ($\chi^2 = 1.40$, $p = 0.24$).

5.3.4 Anaemia as a test for trypanosomiasis – Hemocue vs. PCR

Table 5.5 shows the sensitivity, specificity and positive and negative predictive values of anaemia (measured by HemoCue) as a diagnostic marker for trypanosomiasis. Different cut off points for anaemia are shown, along with their effects on the accuracy of the test. The highest cut off point for anaemia 100g/l Hb or 30% PCV gives poor sensitivity and specificity. Lowering the cut off point maximises specificity while minimising sensitivity. Table 6.1 indicates that the ideal cut off point for anaemia would be 70 g/l Hb or 30% PCV. There was no significant correlation between haemoglobin concentration and trypanosomiasis [$\beta = 0.001$ (0.0008 – 0.002), $p = 0.987$]

Hb g/L (PCV)	Sensitivity	Specificity	PPV	NPV	Avg	% Treated
70 (20%)	3%	97%	40%	53%	50%	3%
80 (23%)	10%	91%	50%	54%	50.5%	9.7%
90 (26%)	29%	78%	53%	55%	53.5%	25.2%
100 (30%)	45%	53%	46%	52%	49%	46.5%

Table 5.5: Performance of anaemia as a test of Trypanosomiasis

5.4 Discussion

5.4.1 FAMACHA as a test for Anaemia

The FAMACHA chart was easy to use and well received by farmers who were very enthusiastic about possible methods to improve on-farm diagnosis and treatment. Indeed there is evidence that apart from any health benefits it may have, it is a very useful extension tool which greatly improves farmer uptake of improved management schemes and encourages thorough examination of animals at regular intervals (Molento 2009a).

When FAMACHA categories C, D & E were considered anaemic, FAMACHA had 50% - 63% sensitivity and 48% - 55% specificity. When categories D & E were considered anaemic, sensitivity was 8% - 20% and specificity was 93% - 94%. There was a positive correlation between FAMACHA score and haemoglobin concentration. Overall, the test performance was not very good and it has proved more specific than sensitive. Such tests are mostly useful for confirming the results of previous tests or in situations when the costs of false positives are high e.g. slaughter.

When categories D & E only were considered anaemic, performance was 20% sensitivity and 93% specificity at a haemoglobin cut off value of 70g/l. However, using these criteria results in many false negative animals and only 7.9% of the animals would be treated. The performance for categories C, D & E was 63% sensitivity, 48% specificity with a haemoglobin cut off value of 80g/l. Using these criteria gives fewer false negatives and a treatment rate of 49.2%. Given the low cost of treating healthy animals (false positives) and the potentially high cost of not treating anaemic animals (false negatives) i.e. production losses and mortality, it would be preferable to use the latter set of values:

FAMACHA categories C, D & E and 80g/l of haemoglobin. The results also suggest that the ideal haemoglobin cut off value lies somewhere between 70g/l and 80g/l.

This poor performance may be because the FAMACHA system was simply not developed for use in cows. It was developed for use in sheep where it works very well. It is also used widely in goats where test performance is lower than in sheep but still acceptable. Kaplan et al 2004 evaluated the test on both species and recorded maximum test performance value values of 85.8% in sheep and 77.1% in goats when FAMACHA categories D & E and 15% PCV (50g/l haemoglobin). Vatta *et al* (2001) recorded a maximum test performance value of 67.8% in goats. Goats are much more closely related to sheep than cows and it seems that the colours on the FAMACHA chart just do not match as well in cows as they do in sheep and goats.

FAMACHA Score	PCV Range		Hb Concentration (g/l)	
	Sheep ^a	Cows	Sheep ^a	Cows
A	≥28%	24.3 – 51.6	≥93	81 - 172
B	23 – 27%	16 – 41	77 – 90	53 - 138
C	18 – 22%	20 – 44.1	60 – 73	67 – 147
D	13 – 17%	16.5 – 41.7	43 – 57	55 – 139
E	≤12%	23.1 – 26.1	≤40	77 - 87

Table 5.6: Association between haematocrit scores, haemoglobin levels and FAMACHA categories ^a adapted from (Vatta *et al.*, 2001)

Table 5.6 shows the haematocrit and haemoglobin ranges associated with each FAMACHA category. It is clear that the categories do not match so well in cows. There are substantial overlaps between categories, a large gap between categories D & E and category C seems to be out of place. If the categories were rearranged to read A, C, B, D, E better results are achieved as seen in table 6.7 below.

Hb g/L (PCV)	Sensitivity	Specificity	PPV	NPV	% Treated
FAMACHA categories B, D, E considered positive					
70 (20%)	70%	50%	41.9%	98.1%	50.8%
80 (23%)	50%	49.2%	9.6%	90.1%	50.8%
90 (26%)	54.2%	50.4%	26.9%	76.5%	50.8%
100 (30%)	49%	47.8%	45.0%	51.9%	50.8%
FAMACHA categories C,D,E considered positive					
70 (20%)	50%	49%	3%	97%	49.2%
80 (23%)	63%	48%	11%	89%	49.2%
90 (26%)	55%	53%	28%	79%	49.2%
100 (30%)	54%	55%	51%	58%	49.2%

Table 5.7: Performance of FAMACHA as a test for anaemia in cattle using different categories

When animals in categories B, D & E are considered anaemic at a haemoglobin cut off value of 70g/l, test performance is maximised with 70% sensitivity, 50% specificity. Using these criteria gives a higher false positive rate but greatly reduces the number of costly false negatives. It also allows the most anaemic animals to be selected for treatment. This performance is comparable with the results of Grace *et al.* (2007) who evaluated FAMACHA in cattle and recorded 95% sensitivity, 22% specificity at C, D & E, 80 g/l and, 92% sensitivity, 30% specificity with D & E, 80g/l. They record much higher sensitivities and lower specificities. This disparity might be due to the high numbers of trypanotolerant N'Dama and Baoule cattle sampled in their study. There is evidence for differences in mucosal pigmentation affecting the use of FAMACHA in different breeds of sheep (Moors and Gauly, 2009) and different breeds of African cattle (Githiori, 2009). Further improvements to test performance could be achieved if the FAMACHA chart was adapted for use specifically with cattle.

5.4.2 FAMACHA as a test for Trypanosomiasis

When categories C, D & E were considered anaemic, FAMACHA had 48% sensitivity, 50% specificity and 7.9% of the cows would have been treated for trypanosomiasis. When categories D & E were considered anaemic, FAMACHA had 7% sensitivity, 92% specificity and 49.5% of the cows would have been treated for trypanosomiasis. There was no difference in anaemia status between trypanosomiasis positive and negative animals, and no correlation between trypanosomiasis and haemoglobin concentration. Overall, test performance is poor, regardless of which FAMACHA cut off values are used. There are three possible reasons for this: FAMACHA is a poor indicator of anaemia; PCR is detecting infections not associated with clinical signs; the underlying assumption that trypanosomiasis is responsible for most of the anaemia burden is wrong. The FAMACHA test performance values for anaemia are consistently higher than those for trypanosomiasis regardless of cut off values used which supports the idea that trypanosomiasis is either not responsible for most of the anaemia present, or that a good number of the infections detected by PCR are not associated with disease.

5.4.3 Hemocue as a test for Trypanosomiasis

Hemocue test performance for trypanosomiasis was also poor. There was no significant correlation between haemoglobin concentration and trypanosomiasis ($\beta = 0.001$, $p = 0.987$). Anaemia as a test for trypanosomiasis performs best (29% sensitivity, 78% specificity) when a haemoglobin cut off value of 90 g/l (27% PCV) is used. This is quite poor and does not fit with the accepted reduction in PCV during trypanosomiasis from normal levels >30% to 15%. These results also support the view that either PCR is detecting non-clinical infections or that trypanosomiasis is not the major cause of anaemia in this area.

The polymerase chain reaction is a molecular technique used to diagnose disease by identifying parasite DNA within the host. It is very sensitive, able to detect a single parasite per μl of blood (Masake *et al.*, 1997). Therefore a positive PCR result does not always indicate disease. It may simply indicate DNA from dead parasites or subclinical infections with very low parasitaemia that may be self-limiting. Marcotty *et al.* (2008) compared the PCV and PCR-RFLP as tests for trypanosomiasis. They found that PCR-RFLP had 96% sensitivity and 100% specificity while PCV had 53% sensitivity and 98% specificity with a cut off value of 24% PCV or 89% sensitivity and 94% specificity with a cut off value of 26% PCV. This performance is comparable to the results presented here: Anaemia performs best with a cut off value of 90g/l or 27% PCV and specificity is high. However, they record high sensitivity, only slightly lower than that of PCR-RFLP whereas the sensitivity of anaemia for trypanosomiasis in this study is low. This suggests that in this study trypanosomiasis is not the only cause of anaemia.

Questionnaire data on farmer perceptions of disease at both village and individual level indicate that liver fluke is the most important disease in study villages (see chapter 4), followed by trypanosomiasis. Pullan (1980) found that liver flukes and streptothricosis were the most important diseases of cattle on the Jos plateau. *Fasciola gigantica* and *Dicrocoelium hospes* are the liver fluke species present in Nigeria. There are no prevalence figures for the Jos plateau but in other areas of northern Nigeria, prevalence of *F. gigantica* is 5.7%, 1.7%, 65.4% and for *D. hospes* 42.7%, 35.4%, 56.0% (Schillhorn van Veen *et al.*, 1980; Nwosu and Srivastava, 1993; Ulayi *et al.* 2007). Since anaemia is one of the major outcomes of these infections, it is likely that liver flukes are responsible for some of the anaemia burden in this study, which would explain the poor performance of anaemia as an indicator for trypanosomiasis. Further studies on the prevalence of liver flukes and

their contribution to the anaemia burden in cattle on the Jos plateau are required to fully assess the potential use of the FAMACHA chart in this area.

5.5 Conclusion

The purpose of this chapter was to evaluate FAMACHA charts as a pen side diagnostic test for African animal trypanosomiasis. Whilst anaemia is a clinical indicator of several endemic diseases of cattle e.g. babesiosis (Vial and Gorenflot, 2006), anaplasmosis (Magona *et al.*, 2008), theileriosis (Magona *et al.*, 2008), fascioliasis (Hawkins, 1984), helminthiasis (Koukounari *et al.*, 2006), tick infestation, it is the main characteristic of trypanosomiasis (Murray and Dexter, 1988). Widespread privatisation and reduced availability of veterinary services has shifted the responsibility for the diagnosis and treatment of endemic livestock diseases onto individual farmers assisted by community animal health workers and agroveterinary vendors (De Haan, 2004). Field based diagnostic techniques that provide support to these resource- and information- poor areas are more important than ever in this climate. These tools provide information that can be used to identify sick animals and monitor productivity and treatment. These include tools like the haemoglobin colour scale (HCS), Hemocue haemoglobinometer and FAMACHA charts for assessing anemia. Apart from their adaptations for use in field settings, these tools are particularly attractive because they provide an indication of disease rather than infection. Given the endemic nature of disease, continuous disease transmission, multiple infections and associated interactions, and the various populations of disease resistant and/or tolerant livestock, indicators of pathology or reduced productivity are far more useful than demonstration of infection. Anaemia is a good indicator of both these parameters in trypanosomiasis: It appears in the earliest stage of infection and progresses thereafter

(Taylor and Authie, 2004); the continued productivity of trypanotolerant cattle under trypanosomiasis challenge is attributed to their ability to control anaemia (Naessens, 2006). This chapter has focused on evaluating the efficacy of FAMACHA charts as a test for anaemia, and the efficacy of FAMACHA charts and the Hemocue haemoglobinometer as a test for trypanosomiasis in white Zebu cattle on the Jos plateau, Nigeria.

Results showed that the FAMACHA chart, developed for use in sheep was a poor test for anaemia in cattle (50% sensitivity, 49% specificity,) but could give much better results if the present categories progressed from least anaemic to most anaemic in the following order: A, C, B, D, E (70% sensitivity, 50% specificity). The colours on the chart did not represent discrete ranges of haemoglobin concentration in cattle as they do in sheep and this test could be further improved if a bovine version was developed specifically for use in cattle.

Performance of both FAMACHA and HemoCue as tests for trypanosomiasis was poor and did not compare favourably with results from similar studies. Given the anecdotal evidence of high prevalence of liver flukes in the area, it is probable that this poor performance is due to the fact that liver flukes are responsible for some of the anaemia recorded in this area.

In summary, this study has shown that the FAMACHA chart is a reasonable test for anaemia in white Zebu cattle but could be improved if adapted specifically for use in cattle. Previous studies have shown that HemoCue and FAMACHA are very good tests for trypanosomiasis in African cattle where trypanosomiasis is the main cause of anaemia. Both tests performed poorly in this study, probably due to other underlying causes of anaemia in the area, notably liver flukes for which there is abundant anecdotal evidence.

Further studies on liver flukes and other possible causes of anaemia in this area are necessary to clarify this. Despite its limitations, this test may still have important roles to play in this area. FAMACHA charts are a very effective extension tool and would have a positive impact on any future animal health schemes in this area. Further investigation is required into the clinical outcomes, costs and benefits and adoption pathways for this penside diagnostic test. The data from chapter 4 identified several flaws in the current livelihood strategies of the Fulani on the Jos plateau, including poor access to professional veterinary services and production losses linked to disease. If the FAMACHA card could be developed into a successful diagnostic test for anaemia it would contribute to the enhancement of pastoral livelihoods by:

- Increasing the accuracy of clinical diagnosis by pasoralists when/where there is no vet
- Encouraging pasoralists to treat only sick animals and delay the onset of drug resistance
- Increasing their familiarity with and dependence on diagnostic tests before treatment
- Reducing production losses due to anaemia and disease.

On the whole, this study has shown the potential of the FAMACHA card in a new species and in a new area, identified specific areas where it could be improved and illustrated the impact it would have on pastoral livelihoods if it was used successfully as a penside diagnostic test for anaemia.

Chapter 6: General Conclusion and Recommendations

6.1 Overview

The Jos Plateau was historically thought to be free of tsetse flies and trypanosomiasis but since the emergence of the disease in the early 1980s cattle herders on the plateau have experienced increased morbidity and mortality and reduced productivity in their cattle and many households face increased poverty (Pullan, 1980). Recent changes in land use and a decline in security have led to marginalisation of pastoralists by farming communities and increased transhumance (Bourn *et al.*, 2001). The Jos Plateau holds ~ a million cattle, ~7% of the national herd and the health of this livestock affects both the national and regional economy (RIM, 1992). Large-scale tsetse elimination and control programmes carried out by the Nigerian government in the past have proved unsustainable. Decentralisation of veterinary services in Nigeria, as elsewhere across Sub-Saharan Africa, has seen the focus of government support shift from providing a comprehensive animal health service to control of epidemic transboundary diseases (e.g. African swine fever and avian influenza) and the control of endemic diseases has been left in the hands of livestock owners themselves. Farmers in Sub-Saharan Africa consider trypanosomiasis to be the most severe constraint to livestock keeping and routinely treat livestock with trypanocides but in the absence of any diagnostic exercise the extent of the problem in Nigeria is unknown. Demand for trypanosomiasis control is evident from livestock and animal health providers who administer ~ 35 million doses of trypanocides each year despite the expense (\$35 million). Farmers, concerned about vector-borne diseases of livestock, regularly use trypanocides and acaricides (Kamuanga *et al.*, 1997).

The study aimed to:

- Characterise the current epidemiology of the disease on the Jos plateau
- Determine the major risk factors for AAT on the Jos Plateau
- Determine the knowledge, attitudes and practices of livestock owners on the Jos plateau in relation to animal health and productivity
- Gather information for the planning of interventions against trypanosomiasis

In this study 7143 cattle were sampled in a longitudinal prevalence survey of cattle to capture seasonal variations in prevalence. Molecular diagnosis of trypanosomiasis and logistic regression to determine risk factors for trypanosomiasis infection was carried out on these samples. The study was therefore able to acquire data on disease prevalence and baseline data for the planning and delivery of interventions against trypanosomiasis.

A sub set of 338 animals were tested for both anaemia and trypanosomiasis to determine the prevalence of anaemia in cattle and to evaluate the FAMACHA chart as a test for anaemia in cattle. The relationship between anaemia and trypanosomiasis was also investigated to determine if it is a reliable indicator for trypanosomiasis. The study was therefore able to determine the likelihood of using the FAMACHA chart in improving the diagnostic capability and treatment habits of livestock owners on the Jos plateau.

Information on livestock productivity and knowledge, attitude and practices of livestock owners was collected on 30 study villages and 66 individual herds/households. Quantitative analysis of animal productivity and profitability to

herders, livelihood analysis and wealth ranking was done. The study was therefore able to determine which social, economic, ecological and cultural factors influence animal health and disease control by herders.

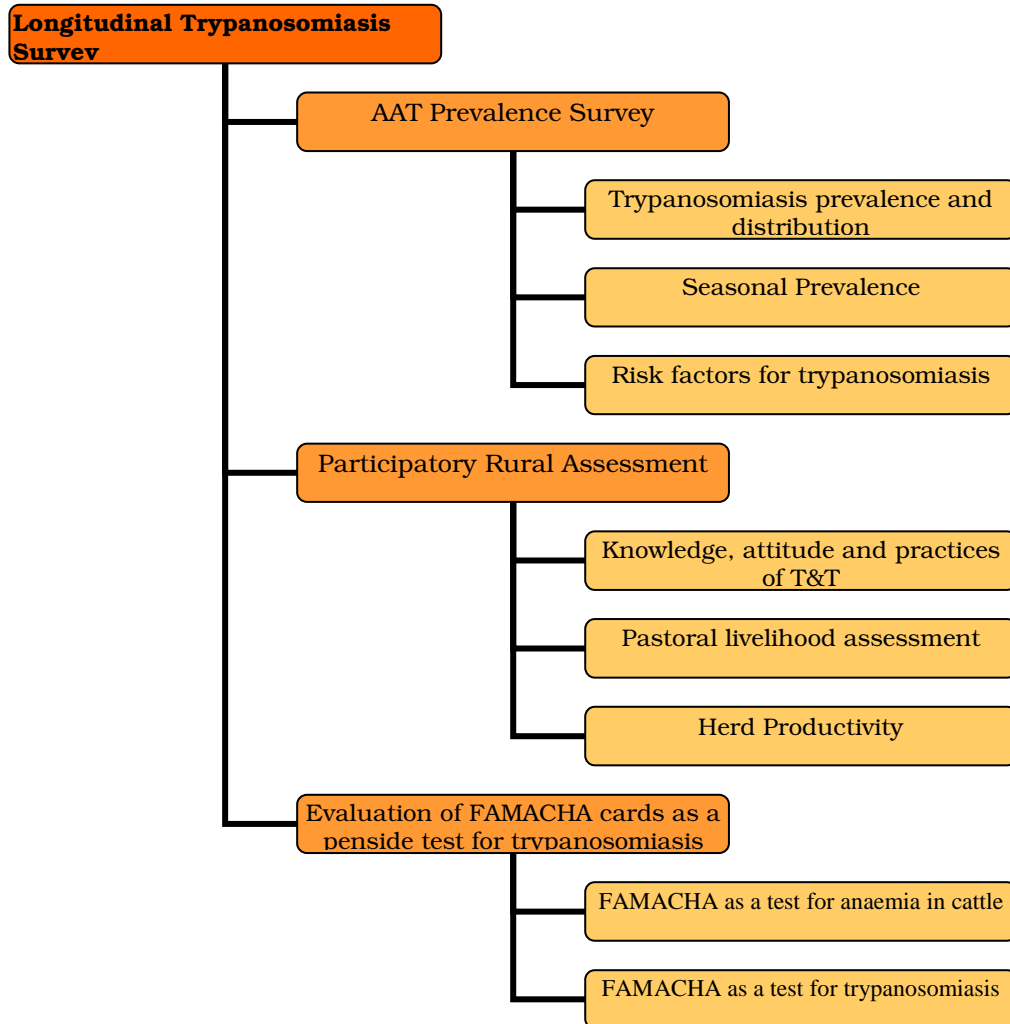


Figure 6.1: Study Outline

6.2 Pastoral Livelihoods

Given the multitude of risks and the extreme vulnerability of asset-poor pastoralists, policy makers must invest in pastoral development and implementation of risk management policies and strategies. Covariant risks require public sector engagement while idiosyncratic risks need household level solutions. The preferred approach is for prevention rather than cure i.e. to first reduce the likelihood of risk, and then mitigate the negative impacts of shocks so that the need for coping strategies is minimised. Irrespective of the type of risk, poor pastoralists are more likely to end up with an unviable herd size so risk management strategies should be geared towards supporting poorer households which have a reduced ability to absorb shocks.

Conflicts can be prevented by the establishment and enforcement of rules over natural resource use, collective acceptance of the rules and continuous renegotiation of diverging demands. There is little outright conflict over natural resources on the Jos plateau as traditional rulers have agreed on rules for natural resource use and are able to enforce them, however, there is no continuous consultation process which takes into account changing needs and seeks to satisfy both communities. The rules for natural resource use favour farmers over herders who are facing severe marginalisation. Increased dry season migration, herd splitting and the innovation of wet season migration are their coping strategies for dealing with this state of affairs, all of which have negative impacts on animal health and productivity. This marginalisation is also largely responsible for the large number of pastoral households that are land poor. Mechanisms for addressing this issue include a review of land tenure and natural resource use laws by an impartial body

committed to equitable use of available resources and establishment of grazing reserves where pastoralists have absolute rights and enjoy the free use of all available resources.

However, marginalisation in terms of access to natural resource use is caught up in the current climate of tribal, religious and political polarisation and the consequent tensions between groups. Sadly, any hope of government intervention or fair reviews of land tenure and natural resource use laws is unlikely. Establishment of grazing reserves would effectively improve the lot of pastoral people and solve many natural resource use issues, but it is an admission that all efforts towards peaceful coexistence of farmers and herders has failed and it will foster stereotypes, suspicion and general ignorance of each others' lifestyles. This enhances the potential for tribal, religious and political conflict and increases opportunities for manipulation by conflict entrepreneurs who are a prominent force in Nigeria. The risk of violent conflict is now a feature of life on the Jos plateau. This pervasive risk negatively impacts pastoral livelihoods as it deters livestock keepers from investing their resources in the management of other prevailing risk e.g. disease control programmes, supplementary feeding, pasture improvement or investment in alternative sources of income.

Improvements in natural resource management should also aim to prevent environmental degradation. Widespread erosion due to previous tin mining and serious overgrazing by large numbers of both resident and transient cattle are partly responsible for the current levels of land pressure and natural resource competition on the Jos plateau. A common complaint of farming communities is that pastoralists care little for the land and are not interested in investing in land/pasture improvement schemes and there is some truth in this,

as seen by the level of environmental degradation due to overgrazing in the past 30 years. Despite the fact that many are permanently settled in this area and now own land of their own, the Fulani response to environmental degradation has simply been to increase the grazing range of their cattle and where this is not possible, to migrate to areas where abundant natural pasture still exists. Unfortunately, sustainable land management is more likely to occur if the arable farming communities are responsible for land management and this does not bode well for pastoral access to land and other natural resources.

Even if all risks faced by pastoralists are suitably managed, their long term well being would decline as a result of increasing human and livestock populations on limited and degraded land which leads to increasing imbalances between the supply and demand for natural resources. The progressive reduction in shrub and grassland available to pastoralists for grazing shown in Figure 6.2 illustrates this clearly. So while it may be possible for individual pastoral households to improve the viability and sustainability of their livelihoods, the same cannot be said for the wider pastoral community if substantial changes are not made to current livelihood strategies.

The main change that would ease current demands on natural resource use would be to switch to a more intensive husbandry system which is less reliant on ranging/grazing and instead involves supplementation of grazing with hay and concentrates (brewery residues, cottonseed cake, etc) digging wells/boreholes exclusively for use by livestock and more proactive preventive measures against disease. Figure 6.3 illustrates interactions between the environment, natural resources, livestock production and pastoral livelihoods. The dotted line indicates that less than 100% of waste is recycled so we can see how soil

fertility must decline with time unless inputs to the system are made in form of soil improvements. Losses due to disease and negative husbandry practices are also seen affecting soil fertility, livestock productivity and the viability of pastoral livelihoods.

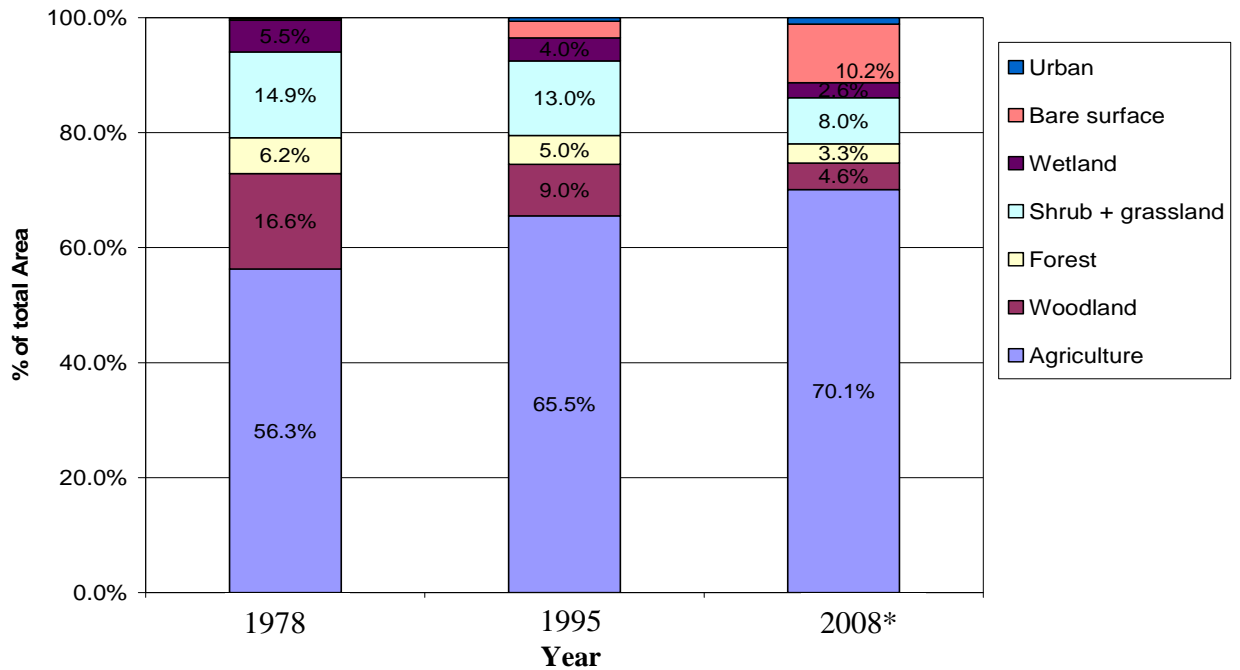


Figure 6.2: Land use changes in Nigeria in 1978 and 1995 with projected changes for 2008 (adapted from Bourn et al, 2001)

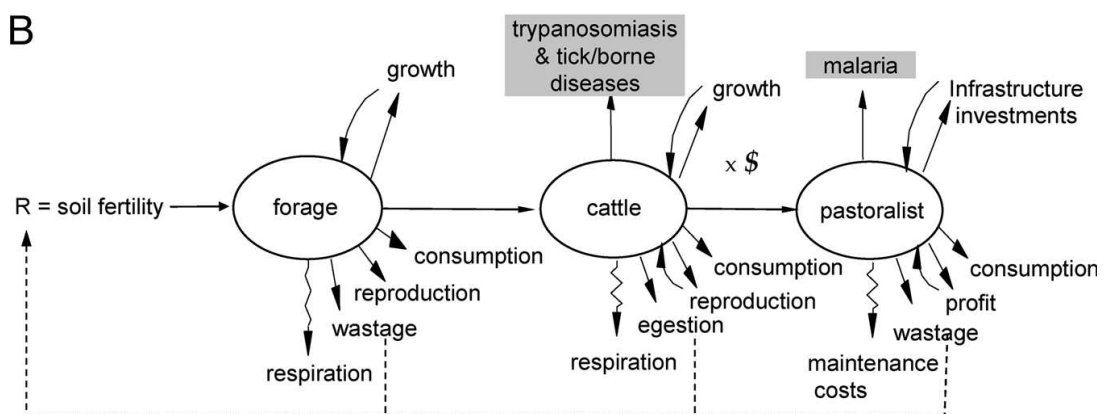


Figure 6.3: An agropastoral system with disease constraints (Gutierrez et al., 2009)

It is necessary to determine which non-livestock investments will be acceptable to and successful for pastoralists. Training and credit should then be provided to enable them pursue these opportunities to diversify income and reduce pressure on the land. (Freeman *et al.*, 1998) point out that credit for livestock holders is less than 10% of all agricultural credit and none of this 10% is available to pastoralists so there is definitely room for improvement. Training to help poor/destitute pastoralists get jobs where they can utilise the skills they already have and their links to the pastoral economy e.g. marketing rural products, marketing veterinary/agribusiness products, leather processing, commercial livestock management (Pantuliano, 2002). Development of investment skills is important for the success of alternative income schemes and pastoralists often lack these skills. Primary and secondary education enhance the acquisition of these skills (Machila *et al.*, 2003) but there is a conflict of interest as it also limits the exposure of children to pastoral activities. It is possible (& often the practice) to educate some of the children while the others remain at home to learn pastoral skills. This is another reason why large families are often wealthier, since they have a larger labour force, but often have a larger skill set too, with household members who have both modern and traditional skills.

6.3 Livestock productivity

Livestock productivity is based on two things – good health and optimal management. The low productivity levels seen in this study can therefore be improved by dealing with the shortcomings identified in animal health and husbandry.

Presently, there is little government provision of animal health services to combat endemic diseases or to improve livestock productivity. These are seen as private goods and

therefore the herders' own responsibility. The private sector is expected to provide these services to livestock owners on a commercial basis but it has failed spectacularly to fill the gap left by the abrupt withdrawal of free/subsidised government services and to live up to the expectations of livestock owners created by that system. Results of the KAP survey have shown that despite their willingness to invest time and money, herder efforts to improve animal health and control livestock disease make little positive impact. To enhance livestock productivity, livestock owners must improve their current animal health methods, beginning with a switch to preventive strategies from their current dependence on curative strategies. Livestock diseases can be effectively managed by the strategic use of vaccines, drugs & insecticides such that their impact on production is minimised and a healthy balance is struck between investment in these inputs and the returns in terms of increased productivity. To achieve this, thorough health education of pastoralists, adequate provision and uptake of veterinary services and an enabling environment to facilitate these activities is essential.

Health education for pastoralists should include such subjects as the common causes of diseases (including zoonotic diseases) and means of preventing infection, common drugs and indications and the correct dosage and administration of these products. Introduction of community based animal health workers is a powerful measure to deliver this health education, increase the coverage of preventive animal health services for epidemic diseases (both public sector goods) and simultaneously provide curative and preventive services for endemic diseases (a private good). They can also be involved in disease surveillance and transboundary disease prevention on behalf of the public sector. The innovative one health

movement has enhanced the concept of community based animal health workers by combining their activities with those of community based health workers so that a single system delivers both medical and veterinary advice. This intersectoral approach has so far proved to be a cost effective strategy for poverty alleviation and the reduction of disease burdens which is particularly suited to pastoral people (Rass, 2006).

Writing about the Nigerian veterinary services, (Awogbade, 1979) states that *“the time has come to look at the traditional pastoral organization and the role Nigerian veterinarians should play in bringing their services closer to the pastoral communities.... The major issue now is how to extend effective veterinary services to the pastoral population without upsetting the existential game they play in their natural environment.”* This remains the case. There is a general ignorance of the pastoral production system and way of life, such that veterinarians often do not realise how costly proposed changes may be to current pastoral lifestyles and livestock management strategies. At the same time, there is a lot of confusion and suspicion on the part of pastoral communities that acts as an effective barrier to uptake of those services that are available. Consumer recognition of the desirability of veterinary and extension services is essential for increased uptake and this is why comprehensive health education and campaigns to inform pastoralists of the long and short-term goals of extension services and veterinary interventions are essential. The prevailing perception amongst veterinarians is that there is little money to be made in a pastoral practice when weighed against the difficulties involved in delivering services to rural areas and dealing with the prejudices of pastoral communities. This can be tackled by changing the veterinary curriculum to make it more productive and service oriented.

Veterinary students should start to contribute to pastoral livestock healthcare while still studying as this will make them more open to the options of a pastoral practice and the business opportunities it can offer.

Improvements in animal husbandry also have a substantial role to play in improving livestock productivity. We have seen that the exceedingly low reproductive performance recorded in this study is linked to the management bias towards dairy production that prolongs the lactation period after each calf at the expense of the calving interval. The basis for this management bias is a cultural and historical one – in the past, pastoralists relied on the sale or exchange of dairy products for cash or grain; the sale of livestock for beef could be limited to cull animals and the occasional need for a lump sum of cash and this was enough to meet market demands for beef.

However, things have changed: the market for pastoral dairy products has dwindled steadily in the face of imported powdered and condensed milk; the price that pastoral dairy products are able to command is very low as they are less desirable to consumers than the competition; many pastoral families have become agropastoral and now grow their own food as found in this study and so their dependence on the sale/exchange of livestock products for grain has declined; urban populations and the demand for beef has risen steadily over the years and local production is no longer able to meet demand.

It is a common accusation from those in the beef industry that the Fulani prefer to hoard their animals to increase their social status rather than to release animals into the market. This study found that livestock sales accounted for 60% of income and milk only 15%

whilst (Pullan and Grindle, 1980) found that some Fulani households on the Jos plateau made two-thirds of their income from milk and only one-third from livestock sales, illustrating the impact of these wider changes on Fulani livelihoods. On account of these changes, a switch from dairy to beef oriented management would go a long way to increase livestock productivity and market participation of pastoral communities. Reducing lactation periods would increase reproductive performance and lead to a larger annual increase in herd size. This in turn would increase potential offtake and allow the pastoral communities to make a more significant contribution to the beef industry.

Seasonal droughts during the dry season and the associated lack of food and water have been shown to contribute significantly to low productivity and susceptibility to disease. The current risk coping strategy is to move cattle to areas with more abundant resources but this is not without costs as reported by herders in this study. Few of the herders in this study practiced supplementary feeding and those that did fed mostly salt lick and other micronutrients. The use of hay and concentrates to supplement grazing in the dry season was virtually absent. The benefits of dry season supplementary feeding have been shown to improve fertility, increase growth rates and increase prices obtainable at market. Pullan and Grindle (1980) report that feeding just 300g per animal per day was enough to substantially reduce dry season weight loss in cattle on the Jos plateau. They also report that the potential returns on feeding supplements such as cottonseed cake are favourable as the beef: cottonseed price ratio was 7.8:1. Most studies on supplementary feeding have been done on ranches but the returns from strategic supplementary feeding of herds under

traditional management may be considerably higher than with ranch herds since fertility is so low to start with.

Dry season supplementary feeding seems to be an obvious low-cost method of improving productivity. If wells or boreholes could be dug for the exclusive use of livestock, this would remove the second main reason for dry season migration: lack of water. A more settled lifestyle will encourage pastoralists to invest more in their livestock and help to further establish their rights of access to natural resources. There have been many calls for settlement of the pastoral Fulani in grazing reserves or on heavily capitalised ranches where their cattle can be intensively managed. However, pastoralism is the best if not the only means to make use of arid/semi arid lands and although the pastoral production system achieves lower yields than ranching, it is more productive per unit of land (Rass, 2006). These are sound economic reasons for investment in pastoral production, and when the need to produce more food to increase food security is considered, it becomes clear that there is a need to implement an extensive livestock production system that draws on the centuries of experience of pastoral peoples, but also embraces innovations that allow it to be economic and to compete effectively in the current economic climate.

6.4 Epidemiology of Trypanosomiasis

The study of bovine trypanosomiasis amongst cattle on the Jos plateau was conducted to gather information on the prevalence and distribution of the disease. It revealed a high overall prevalence of bovine trypanosomiasis (46.8%) with high variation at village level (8.8% - 95.6%) but no geographical clustering. Village level variations in seasonal

prevalence were also recorded with 50% of villages showing peak trypanosomiasis prevalence in the wet season as expected, 33.3% showing peak trypanosomiasis prevalence in the dry season and 16.7% of villages showing no seasonal variation at all. Transhumance and the dry season were identified as risk factors for infection whilst increasing altitude and the presence of alien migratory cattle reduced risk of infection. Age, sex and breed of cattle had no effect on prevalence or risk of trypanosomiasis.

The results show a dynamic epidemiology driven by both natural and management factors. The way these different factors combine to influence the prevalence and distribution of disease is important as it points us towards the most effective methods for combating disease and its sequels: mortality and production losses. Results suggest that management and husbandry factors determine whether or not animals are exposed to the risk of infection while biological and ecological factors determine the features of infection e.g. seasonal variation, infecting trypanosomes species, severity of infection.

Another important feature of the epidemiology of trypanosomiasis on the Jos plateau is the absence of geographical clusters and the fact that the village seems to be the unit at which different factors combine to produce a specific epidemiological picture. This is for two reasons: firstly, cattle in the same village are subject to the same ecological factors; secondly, management practices seem to be uniform within a village but differ significantly between villages. Villages in seasonal variation groups 1 and 2 illustrate the effect of specific ecological factors on the epidemiology of trypanosomiasis with little influence from management factors. Villages in seasonal variation group 3 show the effect of both management and ecological factors on the epidemiology of trypanosomiasis.

The identification of migration and the dry season as the two most important risk factors for infection strengthen this point. Despite the fact that both ecological and management factors are involved, ecological factors seem to be more important: the epidemiology of trypanosomiasis in two of the three seasonal variation groups is based in ecological factors; also, risk factor analysis shows that the dry season increases the effects of all risk factors for infection. Therefore while changes in management will contribute to the management of trypanosomiasis in this area, creative solutions that allow pastoralists to conduct a viable livestock enterprise in the face of current ecological conditions at village level are required if the tsetse and trypanosomiasis problem is to be curtailed. These solutions must be developed at village level and it is essential that livestock owners are involved in the planning, evaluation and implementation of such interventions.

6.5 Evaluation of the FAMACHA card as a penside test for trypanosomiasis

The FAMACHA card was developed as a test for anaemia in sheep to enable penside diagnosis of hookworm infections. It is used within a strategic treatment programme designed to reduce indiscriminate anthelmintic use by restricting treatment to anaemic animals. This targeted treatment reduces anthelmintic resistance, efficiently reduces disease at herd level, maintains a refuge of parasites in untreated animals and identifies animals with high susceptibility to hookworms, which facilitates improved breeding. Trypanosomiasis has many of the same problems – indiscriminate use of trypanocides, a tradition of mass treatment and drug resistant trypanosomes (Machila *et al.*, 2003). It would be equally useful to have such a test for trypanosomiasis in cattle, especially since

there is currently no reliable penside diagnostic test available for rural African settings. The results of the KAP survey showing 100% incorrect trypanocide use by all respondents and limited knowledge of use and specificity of veterinary drugs highlights the need for such a product.

Evaluation of the FAMACHA chart as a test for anaemia in cattle on the Jos plateau showed poor results: 50% sensitivity, 49% specificity, 49.6% test performance value. However, the categories A - E on the chart did not represent discrete ranges of haemoglobin concentration in cattle as they do in sheep and much better results could be obtained if they progressed from least anaemic to most anaemic in the following order: A, C, B, D, E: 70% sensitivity, 50% specificity, 60% test performance value). These results could be further improved if a bovine FAMACHA card was developed specifically for use in cattle.

Performance of anaemia as an indicator of trypanosomiasis was poor and did not compare favourably with results from similar studies. Given the anecdotal evidence of high prevalence of liver flukes in the area, it is highly probable that this poor performance is due to the fact that liver flukes are responsible for some of the anaemia recorded in this area. Trypanosomiasis certainly does not seem to be responsible for much of the anaemia observed in these cattle, so the value of the FAMACHA card as a penside diagnostic test becomes doubtful. Further studies are required to determine the causes of anaemia in cattle on the Jos plateau, and to investigate the relationship between trypanosomiasis infection detected by PCR, clinical illness and losses in productivity. It may be easier and more to

the point to invest these resources in achieving effective coordinated control of endemic livestock diseases and so avoid this academic exercise.

6.6 Conclusion

The results of this work have shown the complex nature of the epidemiology of trypanosomiasis on the Jos plateau and the many different biological, ecological, social and economic factors that affect animal health in the area. Pastoral livelihoods have become more stable over the last 3 decades and only 6% of households are classified as poor, the large amount of wealth concentrated in livestock and high number of land poor households and those still reliant on a single source of income suggest that there is still a degree of vulnerability to the risks of drought/dry season, disease and conflict in pastoral livelihoods in the area. Overall livestock productivity has decreased due to negative aspects of current management and disease control strategies.

This study has produced data which fills several gaps in the body of knowledge about the epidemiology of T&T on the Jos Plateau. Chapter 4 has provided up to date information on herd structures, reproductive performance, productivity, disease, management factors, economic factors and T&T knowledge, attitudes & practices associated with pastoral cattle in the area for the first time since the early 1980s. When this information is put together in a pastoral livelihood analysis, it clearly identifies areas where interventions are required to improve pastoral livelihoods as well as what interventions would be appropriate, in terms of efficacy and acceptability.

Chapter 3 provides detailed, up to date data on prevalence and distribution of trypanosomiasis, what species of trypanosomes are circulating in cattle, and which ecological and management factors affect the epidemiology of each trypanosome species. Also available are seasonal variation profiles and the ecological and management factors affecting them; infections profiles for different ages/sexes/breeds of cattle.

The multidisciplinary nature of this study is demonstrated by the wide variety of techniques used to gather and analyse this new data, including:

- Clinical skills
- Molecular Parasitology
- Pastoral livelihood assessment
- Participatory rural assessment
- Questionnaire survey
- Focus group discussions
- Economic assessment
- Statistical analysis
- GIS analysis

The data from this combination of techniques has given a well rounded view of the true T&T situation on the Jos plateau, focusing on the major stakeholders, Fulani pastoralists but also providing material for engagement with other stakeholders: veterinarians, agroveterinary merchants, pharmaceutical companies, all three tiers of government and the

scientific community. The overall result is a more complete picture than that which a less multidisciplinary study would have given.

6.7 Recommendations

Pastoralism is the primary agricultural production system for cattle and small ruminants in Nigeria. This notwithstanding, investment in pastoral development has gone down in the last few decades due to the belief that they contribute little to the national economy. This belief is fostered by the fact that there is little quantitative information on pastoral peoples and their livestock outputs. There are several factors which characterise the current situation of pastoralists. Firstly, increasing human and livestock populations and concurrent environmental degradation are reducing the relative abundance of natural resources. Secondly, expansion of arable agriculture from the humid/subhumid zones into arid/semi-arid areas, movement of pastoralists from arid/semi-arid areas into the humid/subhumid zones, and expansion of both groups into new microhabitats within their shared environments has amplified competition for natural resources and increased the tendency to establish private property rights over these resources. Thirdly, pastoral lifestyles and preferences are changing. Their market integration has increased and so has their exposure to market risks, including competition from large, capital-intensive production units. They are therefore more vulnerable to risks that are beyond the direct control of individual pastoralists, their households and their communities. This means that there is an increase in the burden of responsibility that government and policy makers should bear to improve the situation.

The primary challenge of policy makers is to create an economic and institutional environment that reduces the vulnerability of pastoralists to risk and to reverse the long-term trends that negatively affect pastoral livelihoods. Such an environment will also reduce conflict over natural resources and enable pastoralists to effectively cope with weather and market risks and escape poverty and contribute to economic development. Policies designed to reduce idiosyncratic risks are already embedded in the standard poverty reduction strategies of most developing countries in sub Saharan Africa e.g. education, public health and microfinance programmes all aimed at enhancing the capacity of citizens to cope with specific individual or household risks, regardless of their initial assets or position. Policies designed to address vulnerability to covariant risks vary according to the risk in question. Each risk will require a specific set of policies/strategies in contrast to general policies which impact on idiosyncratic risks. Despite this variation, these policies should all be based on the common principles of risk reduction, risk mitigation and risk coping strategies respectively, in order of importance.

Government and policy makers can create an enabling environment for the changes recommended in this chapter by instituting policies and strategies as outlined below.

Disease control

- Attempts should be made to create intermediate veterinary personnel to encourage grassroots animal health services
- Reduce costs and increase coverage of service delivery by community based paraprofessionals
- Support their legal recognition (Peeling and Holden 2004) and formulate regulations for licensing them.
- Veterinarians should be encouraged and supported to establish mobile veterinary clinics and perambulatory services to increase coverage of rural populations. Extension workers/CBAHW will first be required to sensitise rural communities and assess the demand for services, so as to make the enterprise cost-effective and profitable to service providers
- Promote closer collaboration between veterinary and medical services and consider sharing infrastructure & personnel in mixed teams, which slowly transforms disease prevention and control from vertical to horizontal model
- To ensure that pastoral people benefit from research in the field of animal health and production (and indeed further afield), programmes to adapt research outputs for field application efforts should be made for the immediate transfer of such information to the pastoral population.
- Affordable, sustainable options for farmer-led control of tsetse and other vectors should be developed and made available to livestock owners.

- Ensure adequate supply of veterinary drugs and vaccines at fair prices
- Ensure good regulation of the veterinary pharmaceutical industry to reduce the presence of fake drugs on the market.

Market Access

- Reduce high transport and transaction costs by eliminating illegal road taxation
- Invest in public infrastructure like roads, trekking routes and watering points to ease the marketing process.
- Give incentives for private investment in marketing infrastructure – market places, holding pens, fodder stores, etc.
- Implement interventions that increase competition within the industry (e.g. market information systems and open auctions) and reduce opportunities for monopsonistic traders.
- Reorganise/regulate market chain where unreasonably high margins are made by middlemen, brokers and butchers by establishing independent trading organisations.

Conflict avoidance and resolution

- Empower pastoral organisations at different levels to voice their interests and influence policies and development strategies.
- Enhance knowledge of pastoral livelihoods of policy makers

- Identify investment opportunities for pastoral people & provide training and credit to enable them pursue these opportunities to diversify income and reduce pressure on the land.
- Create a labour market for pastoral people by creating labour intensive infrastructure and ethnic minority employment policies.

Enforcement of these policies is key if any benefit is to be gained from them. Many of these recommendations have been made several times by many workers in the past 5 decades and unfortunately, they are yet to be implemented. This illustrates three things: the poor record of the Nigerian government in making necessary improvements to this sector; the failure of the private sector to provide services withdrawn by the public sector; and the fact that someone or something must stand in the gap, if these changes are to be made.

6.8 Future work

In 2008, a call for applications to the Combating infectious diseases of livestock for international development (CIDLID) scheme was made by the joint funders – BBSRC, DFID and the Scottish government. The purpose of the scheme was to support high-quality basic and strategic biological and biotechnological research into infectious diseases of the principal livestock species in Sub-Saharan Africa and South Asia, and to forge productive partnerships between scientists in the UK and developing countries by enhancing the livelihoods of the poor of Sub-Saharan Africa and South Asia by generating underpinning scientific knowledge that will improve farm animal health, welfare and productivity and enable more effective, sustainable management of livestock diseases. The Welburn

Research Group submitted an application for community based control of trypanosomiasis on the Jos plateau which drew strongly on the work done in this thesis and the grant awarded in December 2009.

Community based interventions against Tsetse and Trypanosomiasis on the Jos Plateau, Nigeria

Abstract

Livestock underpin poor rural livelihoods in sub-Saharan Africa, but animal health is constrained by both epidemic and endemic diseases. The former are managed by national and regional control programmes whereas individual farmers control endemic diseases, with communities and local organisations providing support in decentralised and privatised systems. Animal trypanosomiasis constitutes a major endemic problem in tsetse-infested regions, reducing livestock product yields and devaluing farmers' investments - costing livestock producers and consumers an estimated US\$1340 million annually. The Jos Plateau in North-Central Nigeria is a major cattle keeping area, holding ~ a million cows (7% of the national herd) kept by settled pastoralists practicing seasonal migration. It became tsetse infected in the early 1980's and trypanosomiasis is a recent problem in the area. While trypanosomiasis can be seen as a dual constraint to rural development its control presents a double benefit: improvements in livestock health having positive outcomes for human health well-being and development. We aim to develop novel integrated control strategies based on an understanding of the epidemiology of trypanosomiasis in domestic livestock, Epidemiological theory will be integrated with quantitative field studies where pastoralists contend with trypanosomiasis and co-exist with subsistence farmers in an area with high land

pressure. Research will target (i) pastoralists for whom simple and practical decision support tools are needed for livestock management and (ii), district and national level policy makers requiring decision support for endemic disease control.

Summary

The project aims to develop novel ways of controlling animal trypanosomiasis. The Jos plateau in Nigeria is a heavily populated area home to almost a million cows kept by settled pastoralists who live alongside subsistence farmers. Trypanosomiasis causes severe production losses in livestock in this area, as it does throughout Sub Saharan Africa. It affects the livelihoods of the poorest and most disenfranchised populations living in rural communities. The parasites that cause trypanosomiasis are transmitted by tsetse flies feeding on blood from an infected host. Treatment of the disease is both affordable and effective: a single treatment with a cheap injectable drug is sufficient to clear the animal of all circulating trypanosomes. Therefore, although these parasites are a double constraint to development, their control is equally of double benefit to humans and their livestock. In the absence of large scale tsetse control programmes, sustainable methods of trypanosomiasis control need to be found. It is not appropriate or possible to treat every animal without the risk of resistance to the drugs developing. It is thus necessary to target interventions to high-risk carriers of disease amongst livestock and wildlife. In this project, we aim to (i) maximise livestock health through integrated disease management (ii) Identify the major risk factors for trypanosomiasis at different times and locations (iii) formulate a policy for effective government support of community based disease management. The project will enable policy makers, public

institutions, communities and individual smallholder farmers to identify appropriate and cost-effective methods for the sustainable farmer based control of trypanosomiasis in livestock.

Impact Summary

The project will have the following key outputs which will impact on the control of animal trypanosomiasis in the Sahel region of sub-Saharan Africa: (i) a new set of intervention methodologies for control of animal trypanosomiasis calibrated and validated for use in the Sahel region of West Africa; (ii) appropriate-technology decision support tools for diagnosis and treatment of animal trypanosomiasis validated for use in this transmission zone; (iii) quantitative estimates of the economic burden of animal trypanosomiasis; (iv) Framework for effective, sustainable support of community based disease control strategies by government agencies. These outputs will be made available through appropriate dissemination pathways as a package of decision support tools appropriate for medical and veterinary policy makers, primary animal healthcare providers and rural populations in Africa. Dissemination pathways will include workshops, project reports, peer-reviewed scientific publications, press releases and briefing of local, governmental and international institutions. Dissemination will commence as soon as results become available in the second year of the project and continue until its conclusion. Finally, the project will provide CPD training to scientific and veterinary staff in Nigeria

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APPENDIX

Appendix 1: KAP Questionnaire

Date **Administrator**.....
Village **Latitude**
LGA **Longitude**
State **Altitude**

1. Household

- 1.1 Name of **Respondent:**
- 1.2 Gender of **Respondent:** Female/Male
- 1.3 Age of Respondent:
- 1.4 Relationship of Respondent to head of household: (**Self**)
- 1.5 Name of Household head:.....
- 1.6 How many acres of land do you own?

Total No. Acres	
% used for livestock	
% used for crops	

- 1.7 Where do you get your water from

	Drinking water	Household use
Piped Water		
Borehole		
Well		
River		

2. Crops

- 2.1 What crops do you grow? How many acres of each?

Crop	Acres	Crop	Acres
Maize		Millet	
Acha		Yam	
Tamba		Groundnut	
Cocoyam		Cassava	
Rice		Vegetables	

- 2.2 Are insecticides used on any of the crops?

Which crops?	
Name of insecticide	
Source of insecticide	
Method of application	

- 2.3 Is fertiliser used on any crops?

Which crops?	
Name of fertiliser	
Source of insecticide	
Method of application	

- 2.4 Is manure used on any crops?

Which crops?	
Source of manure	

3. Livestock

3.1 What type of livestock do you keep?

Livestock	Yes/ No	Breed
Cattle		
Goats		
Pigs		
Chickens		
Sheep		
Horses/ Donkeys		

3.2 Ask your informant about horses and donkeys in his village. Is it that:

A: There are no horses or donkeys in the village because it is impossible to keep them alive

B: There are some, but they suffer high mortality and need frequent replacements; they do not breed successfully and there is a high foal mortality and/or they need special management to keep them healthy, e.g. they need to be stalled, grazed near the village and not in the forest

C: The numbers are stable, they do not need to be stalled but they need regular veterinary attention

D: The village has a healthy, breeding population of horses and donkeys

F: People don't keep horses or donkeys because it is not part of their tradition or because they cannot afford them

3.3 What are the most important problems/diseases affecting your livestock?

Disease	Species affected	Number affected	Number died	Main symptoms	What is your disease control strategy? A: Ignore B: Avoidance C: Prophylactic treatment D: Curative treatment	Why do you choose this disease control strategy? A: Easiest B: Most widely available C: Cheapest D: Most effective	Who gave treatment? What treatment was given?
Disease 1							
Disease 2							
Disease 3							
Disease 4							
Disease 5							
Disease 6							

3.4 What is the disease control strategy for trypanosomiasis?

- A: Ignore
- B: Avoidance
- C: Prophylactic treatment
- D: Curative treatment

3.5 Why do you choose this disease control strategy?

- A: Easiest
- B: Most widely available
- C: Cheapest
- D: Most effective

3.6 Do cattle owners/herdsmen recognise trypanosomosis/AAT as a problem distinct from other diseases?

- A: Yes
- B: No

3.7 How important is AAT to your informant?

- A: Severe, the most important problem
- B: Among the first three most serious
- C: Recognised, but other problems have higher priority
- D: Occurs, but not a problem
- E: Not present or not recognized

3.8 Do you use drugs to treat your animals specifically for trypanosomosis?

- A: Yes
- B: No

3.9 Where do you get the drugs?

Source	Tick if applicable
Local vet	
Agro vet shops	
Other	
Other	

3.10 How do you prepare/dilute trypanocides for use?

Name of Drug	Dilution rate (amount of water to amount of drug)	Water source	Do you boil the water? Yes/No	Dose rate (How much solution per animal)

3.11 Do you give your livestock feed supplements?

Livestock	Yes/No	Name of supplement
Cattle		
Goats		
Sheep		
Chickens		
Pigs		

4 Herd Input and Offtake

4.1 How many cattle have died in the past 1 year?

4.2 How many calves have been born and how many have died in the past one year

Calves born	
Calves dead	

4.3 Have you acquired or given away/sold livestock in the past one year?

Livestock	Yes/No	Number
Sale		
Purchase		
Slaughter		
Exchange		
Other		
Other		

4.4 How many cows did you have this time last year?

4.5 How many cows do you have now?

5 Transhumance

5.1 Do you practice transhumance? A: Yes B: No

5.2 Why do you practice transhumance?

A: Lack of water

B: Lack of food

C: Lack of land

D: Avoidance of tsetse/other flies

E: Other

5.3 Where do you stay in the rainy season

5.4 When do start your journey there? (Date of rainy season migration).....

5.5 When do you get there? (Duration of rainy season migration).....

5.6 Why do you choose this location?

.....
.....

5.7 What is your migration route?

First stop	Second stop	Third stop

5.8 Why do you choose this route?

.....
.....
.....

5.9 Where do you stay in the dry season?

5.10 When do you start your journey there? (Date of dry season migration)

5.11 When do you get there? (Duration of dry season migration)

5.12 What is your migration route?

First stop	Second stop	Third stop

5.13 Why do you choose this route?

.....

5.14 Who makes the trip?

	Tick		Tick		Tick
All cows		All goats		Some chickens	
Some cows (which?)		Some goats		All dogs	
All people		All sheep		Some dogs	
Some whole families (which?)		Some sheep			
Men only		All chickens			

5.15 Do you feel that migration affects disease? A: Yes B: No

5.16 How?

.....

5.17 Particularly trypanosomiasis?

.....

6 Flies

6.1 Do you think flies are a problem in this area?

6.2 Which particular type of flies?

6.3 Do you know about tsetse flies?

6.4 Do you know what disease they cause?

6.5 Can you identify them? A: Yes B: No

6.6 How do you protect yourselves/your livestock from tsetse?.....

.....

6.7 Do you use any insecticide spray, dip or pour on? A: Yes B: No

6.8 What is the name of the product?

6.9 At the time of year when they are most common, are they:

A: Abundant B: Fairly common C: In a few places

D: Seen only rarely E: Never seen

- 6.10 Are any of the following kinds of wild animals found in the survey area?
 Wild pigs (warthog and bushpig), Antelopes (especially bushbuck) or Reptiles (crocodiles and monitor lizards)?
 Are they:
 A: Seen often B: Seen only occasionally
 C: Seen very rarely D: Never seen

Production Costs

- 7.1 What costs are associated with rearing cattle?
 7.2 What percentage of total costs is spent on each?

Cost	Rank	% of total costs
Food		
Drugs		
Labour		
Stock		
Transport		
Vet fees		
Tax		
Other		
Other		

- 7.3 Are there seasonal variations in these costs?

Dry season

Wet season

- 7.4 What unexpected expenses may arise?

Income

- 8.1 What are your sources of income?
 8.2 How important is each source?

Source	Rank	Percentage
Livestock		
Milk		
Meat		
Labour		
Crop produce		
Other		
Other		

Appendix 2: Herd productivity figures (Pullan and Grindle, 1980)

Herd Inputs

	Births	Purchase
Mean	40.25 (5.6 – 74.9)	1.63 (0 – 3.3)
Minimum	5	0
Maximum	130	6

Herd Outputs

	Deaths	Sales
Mean	11.38 (0 – 22.87)	14.63 (7.48 – 21.78)
Minimum	0	2
Maximum	35	28

Stock levels

	Starting Stock	Closing Stock	% Change in Herd Size
Mean	125.5 (19.21 – 231.79)	141.38 (16.2 – 266.56)	7.81% (-16.99% - +25.58%)
Median	84	86	8.57%
Minimum	18	14	-22.22%
Maximum	393	460	44.74%

Offtake

	Potential Offtake	Actual Offtake
Mean	14.70% (8.15% - 21.25%)	11.76% (2.22% - 21.3%)
Minimum	6.50%	2.80%
Maximum	30.30%	36.10%

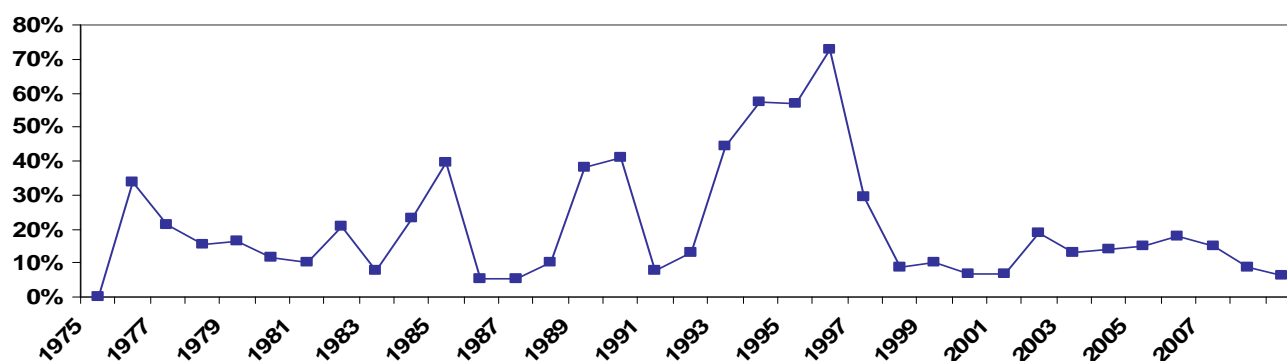
Cattle Sale Price

	Price Sold	Inflation Adjusted Price Sold
Mean	N 165.33 (24.75 – 305.91)	N 115,755.02 (17,333.89 – 214,176.15)
Minimum	N 100.00	N 70,013.12
Maximum	N 199.00	N 139,326.10

Cattle Cost Price

	Price Bought	Inflation Adjusted Price Bought
Mean	N 120.17 (40.46 – 199.88)	N 84,132.43 (28,327.94 -139,936.92)
Median	N 93.50	N 65,462.26
Minimum	N 45.00	N 31,505.90
Maximum	N 261.00	N 182,734.23

Inflation Rate



Appendix 3: Herd Productivity Data

ID	Name	Village	Starting Stock	Births	Births %	Calf Deaths	Deaths	Slaughter	Sales	Purchase	Price Bought	Price Sold	Closing Stock	Hectares of Land	Change in Herd #	Potential Offtake	Actual Offtake	Offtake Difference
A1	Mamel Bapa	Ampang	322	10	3.1%	0	3	0	30	1	60,000	70,000	300	2.8	-6.8%	2.2%	9.3%	-7.1%
Ba 1	Abdulahi Umaru	Bassa	2,480	100	4.0%	20	50	10	50	50	35,000	165,000	2,500	1	0.8%	1.2%	2.0%	-0.8%
Bd 1	Abubakar Aliyu	Badni	50	35	70.0%	8	5	0	0	0	28,000	45,000	82	1.2	64.0%	44.0%	0.0%	44.0%
Bd 2	Suleiman Husein	Badni	30	18	60.0%	0	15	0	1	3	28,000	45,000	35	6.4	16.7%	10.0%	3.3%	6.7%
Bi1	Gambo Galadima	Binchi	96	15	15.6%	6	5	0	30	0	0	120,000	70	0.8	-27.1%	4.2%	31.3%	-27.1%
Bo 1	Abubakar Eggi	Bokkos	101	15	14.9%	0	15	1	5	5	45,000	115,000	100	0.8	-1.0%	0.0%	5.0%	-5.0%
Da 1	Julde Umar	Daffo	25	8	32.0%	0	1	0	4	2	35,000	50,000	30	0.8	20.0%	28.0%	16.0%	12.0%
Da 2	Mukaiila	Daffo	20	0	0.0%	0	0	0	2	2	35,000	50,000	20	0.4	0.0%	0.0%	10.0%	-10.0%
Db 1	Abdullahi	Dan ba Aba	26	5	19.2%	3	2	0	3	7	35,000	75,500	30	0.4	15.4%	0.0%	11.5%	-11.5%
Db 2	Bedu Ismaila	Dan ba Aba	45	6	13.3%	4	3	0	4	0	0	75,500	40	6	-11.1%	-2.2%	8.9%	-11.1%
DT 1	Umaru Bareya	Dorowa Tsofo	5,030	15	0.3%	1	13	1	15	0	0	100,000	5,015	0	-0.3%	0.0%	0.3%	-0.3%
F1	Yusuf Ardo Umar	Foron	97	40	41.2%	10	10	2	20	5	42,500	90,000	100	8	3.1%	20.6%	20.6%	0.0%
F2	Mallam Saidu	Foron	33	5	15.2%	2	4	0	2	0	0	90,000	30	1.6	-9.1%	-3.0%	6.1%	-9.1%
F3	Mallam Idi	Foron	27	4	14.8%	2	3	2	4	0	0	90,000	20	2	-25.9%	-3.7%	14.8%	-18.5%
F4	Alhaji Abdullahi	Foron	114	10	8.8%	5	6	0	6	3	42,500	90,000	110	0.8	-3.5%	-0.9%	5.3%	-6.1%
Gi 1	Idris Gidado	Gindin Akwati	196	32	16.3%	0	2	1	25	0	0	90,000	200	0.8	2.0%	15.3%	12.8%	2.6%
Gi 2	Adam Mohamed	Gindin Akwati	70	10	14.3%	0	4	1	15	0	0	90,000	60	20	-14.3%	8.6%	21.4%	-12.9%
Go 1	Ardo Yakubu	Gora	17	15	88.2%	0	0	0	6	0	0	30,000	25	20	47.1%	88.2%	35.3%	52.9%
Go 2	Yakubu Mohamad u	Gora	25	0	0.0%	0	0	0	5	0	0	60,000	20	20	-20.0%	0.0%	20.0%	-20.0%
Go 3	Idris Galadima	Gora	42	12	28.6%	1	0	0	4	0	0	45,000	49	5.2	16.7%	26.2%	9.5%	16.7%

ID	Name	Village	Starting Stock	Births	Births %	Calf Deaths	Deaths	Slaughter	Sales	Purchase	Price Bought	Price Sold	Closing Stock	Hectares of Land	Change in Herd #	Potential Offtake	Actual Offtake	Offtake Difference	
Go 4	Haruna Jibrin	Gora	57	4	7.0%	1	0	0	50	0	0	45,000	10	1.6	-82.5%	5.3%	87.7%	-82.5%	
Gu 1	Ishaku Ciroma	Gurum	3,144	100	3.2%	6	50	0	3	3	25,000	85,000	3,100	2	-1.4%	1.4%	0.1%	1.3%	
H1	Abdul Shanono	Hurti	227	9	4.0%	1	13	1	25	4	30,000	140,000	200	2.4	-11.9%	-2.2%	11.0%	-13.2%	
H2	Idris Umar	Hurti	71	4	5.6%	0	5	0	20	0	0	140,000	50	3.6	-29.6%	-1.4%	28.2%	-29.6%	
H3	Yunusa Shuaibu	Hurti	32	11	34.4 %	1	2	0	10	0	10,000	140,000	30	1.6	-6.3%	25.0%	31.3%	-6.3%	
K1	Madaki Abdul Rasak	Kurra	199	25	12.6 %	2	20	1	6	5	40,000	130,000	200	0.8	0.5%	1.5%	3.0%	-1.5%	
La 1	Bayaro Adamu	Lamingel	48	7	14.6 %	0	3	1	3	2	25,000	110,000	50	1.2	4.2%	8.3%	6.3%	2.1%	
La 2	Adamu Abubakar	Lamingel	25	9	36.0 %	2	2	1	2	3	30,000	120,000	30	4	20.0%	20.0%	8.0%	12.0%	
Le 1	Mohamed Adama	Lere	41	7	17.1 %	0	15	1	3	3	25,000	60,000	32	0.8	-22.0%	-19.5%	7.3%	-26.8%	
Le 2	Suleiman Gami	Lere	70	8	11.4 %	0	31	0	3	1	27,500	75,000	46	8	-34.3%	-32.9%	4.3%	-37.1%	
Le 3	Madaki Ragari	Lere	62	10	16.1 %	0	20	1	2	1	25,000	70,000	50	1.6	-19.4%	-16.1%	3.2%	-19.4%	
Lu 1	Yau Idi	Luka	35	13	37.1 %	0	1	0	10	0	0	95,000	37	2	5.7%	34.3%	28.6%	5.7%	
Lu 2	Bala	Luka	64	30	46.9 %	4	5	0	15	0	0	60,000	70	6	9.4%	32.8%	23.4%	9.4%	
Lu 3	Muhamadu	Luka	41	10	24.4 %	0	1	0	7	4	26,000	77,500	47	8	14.6%	22.0%	17.1%	4.9%	
Lu 4	?	Luka	65	15	23.1 %	0	7	0	3	0	0	77,500	70	0.8	7.7%	12.3%	4.6%	7.7%	
Ma 1	Idris Haruna	Maiyanga	120	20	16.7 %	0	10	1	1	2	20,000	70,000	130	2	8.3%	8.3%	0.8%	7.5%	
Ma 2	Hamza	Maiyanga	142	15	10.6 %	0	6	1	1	1	30,000	120,000	150	20	5.6%	6.3%	0.7%	5.6%	
Mn 1	Ahmado Aidokari	Mangar	475	25	5.3%	6	25	0	4	6	45,000	180,000	470	20	-1.1%	-1.3%	0.8%	-2.1%	
Mn 2	Saidu Haruna	Mangar	212	21	9.9%	4	15	0	3	4	29,000	105,000	215	20	1.4%	0.9%	1.4%	-0.5%	
P1	Abdul Karim	Passa Kai	98	9	9.2%	0	7	0	20	0	0	62,500	80	20	-18.4%	2.0%	20.4%	-18.4%	
P2	Aminu Husseini	Passa Kai	77	8	10.4 %	0	7	0	10	2	20,000	62,500	70		-9.1%	1.3%	13.0%	-11.7%	

ID	Name	Village	Starting Stock	Births	Births %	Calf Deaths	Deaths	Slaughter	Sales	Purchase	Price Bought	Price Sold	Closing Stock	Hectares of Land	Change in Herd #	Potential Offtake	Actual Offtake	Offtake Difference
RB 1	Ibrahim Buba	Rafin Bauna	456	15	3.3%	4	50	0	20	3	30,000	80,000	400		-12.3%	-8.6%	4.4%	-12.9%
RS 1	Adamu Abdullahi	Rafin Sainye	51	15	29.4%	0	5	1	10	0	0	37,000	50	8	-2.0%	19.6%	19.6%	0.0%
RS 2	Abdullahi	Rafin Sainye	64	9	14.1%	0	4	1	8	0	0	37,000	60	8	-6.3%	7.8%	12.5%	-4.7%
Ru 1	Ishaku Dachum	Ruf	6	2	33.3%	0	3	0	0	0	0	0	7	40	16.7%	-16.7%	0.0%	-16.7%
Ru 2	James Bulam	Ruf	24	6	25.0%	0	2	0	2	0	0	45,000	26	44	8.3%	16.7%	8.3%	8.3%
Ru 3	Paul Dawullang	Ruf	18	2	11.1%	0	2	0	1	0	0	45,000	17	1.2	-5.6%	0.0%	5.6%	-5.6%
Ru 4	Haruna Jantai	Ruf	14	4	28.6%	0	2	0	1	0	0	45,000	15	0.8	7.1%	14.3%	7.1%	7.1%
Ru 5	Peter Gudam	Ruf	10	4	40.0%	1	4	0	1	0		45,000	11		10.0%	-10.0%	10.0%	-20.0%
SG K1	Wakili Saibu	Sabon Gida Kanar	310	30	9.7%	20	10	10	10	10	100,000	150,000	300	2.8	-3.2%	0.0%	3.2%	-3.2%
Ta 1	Aliyu Ardo	Tambes	20	7	35.0%	0	0	0	0	5	45,000	0	32	1.2	60.0%	35.0%	0.0%	35.0%
Ta 2	Adamu Idda	Tambes	29	12	41.4%	0	1	0	0	0	0	0	42	1.6	44.8%	37.9%	0.0%	37.9%
Ta 3	Umar Huseini	Tambes	53	6	11.3%	0	3	0	0	2	45,000	0	58	1.6	9.4%	5.7%	0.0%	5.7%
Ti1	Haruna Adamu	Tige	27	9	33.3%	0	0	0	2	1	32,500	70,000	35	1.6	29.6%	33.3%	7.4%	25.9%
Ti2	Muhamadu Umar	Tige	81	20	24.7%	0	0	0	3	2	32,500	70,000	100	1.2	23.5%	24.7%	3.7%	21.0%
We 1	Davou Bot	Werram	12	3	25.0%	0	0	0	1	1	35,000	46,000	15	1.6	25.0%	25.0%	8.3%	16.7%
We 2	Dadin Chung	Werram	14	4	28.6%	0	1	0	2	0	0	45,000	15	2.8	7.1%	21.4%	14.3%	7.1%
We 3	Kwasu Dalyop	Werram	24	5	20.8%	0	0	0	1	2	35,000	93,000	30	4	25.0%	20.8%	4.2%	16.7%
We 4	Jaktun Davou	Werram	8	6	75.0%	0	0	0	2	3	45,000	70,000	15	14.8	87.5%	75.0%	25.0%	50.0%
Wu 1	Tambaya Dem	Wuria	14	4	28.6%	0	2	1	1	4	45,000	90,000	14	2.8	0.0%	14.3%	7.1%	7.1%
Wu 2	Sati Bagu	Wuria	9	1	11.1%	0	1	0	1	0	0	90,000	8	4	-11.1%	0.0%	11.1%	-11.1%

ID	Name	Village	Starting Stock	Births	Births %	Calf Deaths	Deaths	Slaughter	Sales	Purchase	Price Bought	Price Sold	Closing Stock	Hectares of Land	Change in Herd #	Potential Offtake	Actual Offtake	Offtake Difference
Wu 3	Pam Janga	Wuria	13	5	38.5 %	0	2	0	4	6	45,000	90,000	18	3.2	38.5%	23.1%	30.8%	-7.7%
Wu 4	Jak	Wuria	11	1	9.1%	0	3	0	1	1	45,000	90,000	9	2.4	-18.2%	-18.2%	9.1%	-27.3%
Wu 11	Edward Ambong	Wullam	70	4	5.7%	0	5	0	9	0	0	65,000	60	2.4	-14.3%	-1.4%	12.9%	-14.3%
Za 1	Idris Umar	Zakshi	971	55	5.7%	3	25	1	25	13	80,000	70,000	1000	20	3.0%	2.8%	2.6%	0.2%
Ze 1	Alhaji Gambo	Zendi	212	20	9.4%	5	75	2	0	0	0	0	150	20	-29.2%	-28.3%	0.0%	-28.3%

Appendix 4: SOS Nigeria Press Release

PRESS RELEASE FOR LAUNCH EVENT - 3 June 2010 Abuja, Nigeria

SCIENTISTS AIM TO SAVE FULANI US\$33 MILLION A YEAR A promising new initiative is launched today in Abuja, Nigeria

A new 4-year research-for-development initiative in the Jos Plateau aims to prevent an estimated 168,000 cattle deaths a year, costing the plateau's Fulani cattle keepers more than US\$ 33 million. A third of these losses are due to the deadly tsetse-transmitted cattle disease trypanosomiasis (sleeping sickness). Tsetse flies invaded the previously tsetse-free plateau in the 1980s, since when the Fulani have struggled to cope with this serious livestock disease.

The new animal health initiative, a collaboration led by the Nigerian Institute for Trypanosomiasis Research (NITR) and the University of Edinburgh, UK, has attracted a US\$ 1.5 million grant from the UK's BBSRC.

Ayodele Majekodunmi, the partnership's coordinator, said: 'I am delighted that this week we have been able to bring together in Abuja over 30 experts from the national and international veterinary and medical research and development communities to help us ensure the success of this project. The Nigerian experts have been complemented by the presence of colleagues from East Africa, UK and France who have been involved in a successful public-private partnership in Uganda called Stamp Out Sleeping Sickness (SOS). The SOS campaign was based on a 10-year research programme which provided the evidence for an entirely new way of controlling tsetse-transmitted sleeping sickness in Uganda. It has succeeded in halting the spread of this disease in Uganda and in the process has created employment opportunities for young veterinary graduates. I am also delighted that the veterinary pharmaceutical company CEVA Santé Animale, in collaboration with their local distributor Adamore Nigeria Limited, has donated the drugs, valued at US\$ 20,000, needed for our research programme.'

Sue Welburn of the University of Edinburgh said: 'The Uganda experience was a key factor in securing funding for the Nigerian project, which aims to adapt the methods used in Uganda to the situation on the Jos Plateau. I am confident that, as in Uganda, the Nigerian initiative can have a real and lasting impact on the health of the Fulani's cattle with likely spill-over benefits to human health.'

For further information contact Professor Sue Welburn: sue.welburn@ed.ac.uk