NIGERIA

INTEGRATED ANIMAL AND HUMAN HEALTH MANAGEMENT PROJECT

FINAL REPORT

Financial costs of disease burden, morbidity and mortality from priority livestock diseases in Nigeria

Disease burden and cost-benefit analysis of targeted interventions

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

The World Bank

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Preface

The World Bank is preparing an Integrated Animal and Human Health Management project for Nigeria. The project will have four components to be implemented by the Federal and State Departments of Veterinary Services (DVS) and Public Health (DPH). The State Departments will implement community-level activities in selected Local Government Areas (LGAs).

To accomplish the goal of the proposed project, the strategic framework has four objectives:

1. Build capacity to search for, identify and prevent newly emerging diseases.
2. Strengthen food safety and thereby break infection chains that promote the transfer of pathogenic organisms to humans.
3. Develop effective, integrated animal and public health management infrastructure (including small-farm biosecurity, grassroots surveillance, rural food safety and sustainable health services) at the Federal, State and LGA levels to minimize disease threats.
4. Reduce the impact of re-emerging livestock diseases that seriously affect the livelihoods of rural populations and thereby have a pro-poor objective.

To provide a reliable basis for determining returns to investment in the proposed project, the International Livestock Research Institute (ILRI) was invited to assist to investigate and document the costs of disease burden, morbidity and mortality related to the following specific priority diseases in Nigeria: Newcastle disease (NCD) in rural poultry, *peste des petits ruminants* (PPR) in sheep and goats, contagious bovine pleuropneumonia (CBPP) in cattle, African swine fever (ASF) in pigs and trypanosomosis in cattle and pigs. ILRI is a member of the Consultative Group on International Agricultural Research with a global mandate for research on livestock issues affecting poor people in developing countries.

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Abbreviations

ABU	Ahmadu Bello University
ASF	African swine fever
AST	Aerial spraying technique
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
CBPP	Contagious bovine pleuropneumonia
C-ELISA	Competitive enzyme-linked immunosorbent assay
CFT	Complement fixation test
DPH	Department of Public Health
DVS	Department of Veterinary Services
ELISA	Enzyme-linked immunosorbent assay
EPI	Expanded program on immunization
FAO	Food and Agriculture Organization of the United Nations
FDL	Federal Department of Livestock
FDLPCS	Federal Department of Livestock and Pest Control Services
FMD	Foot and mouth disease
GDP	Gross Domestic Product
GST	Ground spraying technique
ILRI	International Livestock Research Institute
LGA	Local Government Area
NCD	Newcastle disease
NGN	Nigerian Naira
NIAHHM	Nigeria Integrated Animal and Human Health Management
NITR	National Institute for Trypanosomosis Research
NVMA	Nigerian Veterinary Medical Association
NVRI	National Veterinary Research Institute
OIE	World Organization for Animal Health
PAAT	Programme Against African Trypanosomosis
PACE	Pan-African Programme for the Control of Epizootics
PE	Participatory epidemiology
PCR	Polymerase chain reaction
PPR	*peste des petits ruminants*
SIT	Sterile insect technique
TLU	Tropical livestock unit
USD	United States dollar(s)
VTH	Veterinary Teaching Hospital

Executive summary

Nigeria's agriculture sector generates one-third of its Gross Domestic Product (GDP) and employs two-thirds of the workforce. Its recent growth dominates Nigerian non-oil economic growth. Small-scale, semi-commercial farms, settled agricultural households and transhumant pastoralists dominate production. Livestock is the second largest agricultural sub-sector and features 16.43 million cattle, 34.69 million sheep, 55.15 million goats, 7.18 million pigs and 183.16 million poultry. These provide nutrition and food security, and a range of services including draught power for cropping activities.

Poor animal productivity is widely attributed to the occurrence and endemicity of certain animal diseases. These are often unreported, unconfirmed or poorly documented. The financial losses associated with such outbreaks and costs associated with the disease burden are also rarely documented. Efforts at control of such animal diseases have yielded poor returns due to ineffective or absent control programs, insufficient inputs (such as vaccines), poor vaccination coverage due to limited vaccine supplies and constraints in field mobility and support funds, illiteracy of farmers and poor management systems.

In preparation for the World Bank's Integrated Animal and Human Health Management project for Nigeria, estimates of the economic and financial implications of high disease burden, morbidity and mortality and the costs of implementing various interventions, for all or a combination of priority diseases were required. The Government of Nigeria invited ILRI to provide such estimates for priority diseases: NCD in rural poultry flocks; PPR in sheep and goats; CBPP in cattle; ASF in pigs; and trypanosomosis in ruminants and pigs. For these diseases, and across agroecological zones, the study's objectives were to:

- assess the direct and indirect financial burden of inaction;
- estimate the costs of targeted interventions;
- determine the additional benefits, additional costs and net benefits associated with interventions;
- evaluate of the benefit-cost ratios (BCRs) of targeted interventions; and
- make recommendations on the feasibility of the targeted interventions.

The study featured epidemiology and economic components. Spreadsheet-based economic modelling was effectively combined with participatory epidemiological fieldwork and analysis, and both national and international specialists contributed. Both primary and secondary data were obtained, and stakeholder consultations and expert interviews were conducted. An extensive literature review was compiled.

Disparities between published and imputed information were apparent throughout the study, but key variables such as low vaccination rates were identified. Underreporting of diseases was apparent. PE also confirmed these observations, as well as the importance placed on animal disease by producers in all agroecological zones. Uncertainties in data and missing information were identified throughout, and employed in sensitivity analysis.

Economic analysis estimates the current annual financial burden of PPR, CBPP, trypanosomosis, NCD and ASF amounts to 29.2 billion Nigerian Naira (NGN). This cost of inaction against these diseases is highest for trypanosomosis in cattle and pigs (NGN 10 billion), followed by NCD in rural chicken (NGN 8.9 billion), PPR in sheep and goats (NGN 6.8 billion), CBPP (NGN 2.2 billion) and ASF (NGN 1.3 billion). The highest direct cost of inaction amounting to NGN 8.9 billion is due to NCD while the least is due to ASF (NGN 1.2 billion).

An additional investment of NGN 10.8 billion will be required to eliminate the losses associated with the five diseases. This would lead to NGN 24.4 billion worth of additional benefits with 18% or NGN 2.4 billion accruing due to intervention against PPR, 2% against CBPP, 23% against trypanosomosis, 52% against NCD in rural chicken and 5% against ASF. It is noteworthy that over half the additional benefits are shown to accrue from NCD control and, as such, the control of this disease should be given additional priority especially as chicken-keeping is important for the livelihoods of the rural poor (including women and children), poultry meat and eggs are important for consumption and sale in local markets, and women are usually involved in keeping poultry. Vaccines (eye-drop vaccination) can be administered by the poultry-keepers themselves and delivered through a chain which includes village animal health workers. This means that NCD control benefits an important target group and helps to develop a chain of animal health delivery which stands some chance of being sustainable. PPR vaccination, as well as showing good additional benefits, gives good protection and delivery of vaccine at village level can be done by village animal health workers, thus supporting a potentially sustainable animal health delivery system.

Favourable BCRs were projected for all the priority diseases provided that interventions eliminated at least 80% of direct costs associated with the diseases. The variety of agroecological zones, differential disease patterns and livestock populations, and differential efficacy of interventions all justify differential and elective interventions. Guidelines are provided on their formulation based on the analysis.

At the individual disease level, key findings are that:

- Avoiding the direct costs associated with PPR requires additional investments of NGN 2 billion, for a BCR of 2.14. The Sudan Savannah Zone would account for 48% of the investment but net benefits would be dominated by the Northern Guinea Savannah Zone;
- NGN 1.8 billion will be required to eradicate NCD in rural chicken, leading to a projected NGN 8.9 billion of additional benefits with 40% occurring in the Northern Guinea Savannah which featured a BCR of 6.25. The very high return on NCD interventions reflects the universality of smallholder poultry and the high mortality of the disease*;*
- NGN 1 billion would be applied to CBPP, generating calculated additional benefits of NGN 1.3 billion of which 68% would occur in Northern Guinea Savannah. For this disease, the Sudan Savannah would yield negative return unless interventions were targeted to reduce costs (e.g. reduced surveillance). Such stratification of interventions would yield reduced benefits in some zones.
- The additional benefits of eliminating ASF amount to NGN 1.209 billion for NGN 475 million worth of additional costs, yielding net benefits of NGN 733 million. The distribution of the net benefits featured 40% for the Subhumid Zone and 45% for the Humid Zone.
- Additional costs to control trypanosomosis and its effects on cattle and pigs yield additional benefits that amount to NGN 8.651 billion nationwide. Although the targeted interventions yield NGN 3.173 billion of net benefits at the national level, they may not be justified across all agroecological zones. Fully, 77% of trypanosomosis control costs address vector control. The choice of vector control options would, however, depend on how such options fit an overall goal of developing effective, integrated animal and human health management infrastructures.

Low vaccination can and should be addressed by education of producers along with the provision of context-specific vaccines and delivery systems, including trials for free vaccination for the purposes of promotion. This should be implemented in combination with a campaign to raise awareness of the benefits of vaccination, perhaps modelled on successful campaigns for human vaccination in Nigeria. Opportunities are identified for enhancing the quality of vaccines and treatments offered.

Organizational change is recommended to improve disease reporting, and the use of tools to evaluate costs of inaction and benefits of interventions is advocated. These procedures should be implemented at local level, in recognition of the diffuse pattern of livestock locations and ownership.

Chapter 1: Introduction

1.1. *Justification for the study*

Nigeria's agriculture sector remains the mainstay of the national economy, generates one-third of GDP and in 2005 accounted for a staggering 83% of the growth rate of 8.2% registered by the entire non-oil sector. About two-thirds of the total work force of the country is engaged in agriculture with over 90% of agricultural output being produced by small-scale, semi-commercial farms, settled agricultural households and transhumant pastoralists. Livestock production is the second largest agricultural sub-sector of the Nigerian economy contributing about 10% of agricultural GDP (CBN 2008). According to the Federal Department of Livestock (FDL) (2010), livestock and poultry population estimates in Nigeria as at 2009 stood at 16.43 million cattle, 34.69 million sheep, 55.15 million goats, 7.18 million pigs and 183.16 million birds, which only increased slightly from their 2004 figures despite the increasing population and intensifying demand for animal protein that go with improved standards of living. This rather slow growth – with the exception of commercial poultry production – is attributable to limited technological inputs, weak animal health services, poor access to market and credit, and production losses from endemic diseases.

The livestock industry is the principal source of animal proteins (meat, milk and eggs) which are vital for body growth and maintenance. According to the Food and Agriculture Organization of the United Nations (FAO), 35 g of animal protein per person per day is considered a basic requirement which can only be sourced from livestock (FAO 1996). The difference in animal protein availability and consumption had become a big differentiating factor between developed and developing countries, thus while an average Nigerian gets about 4.5 g of animal protein per person per day, the animal protein consumption per person per day in the developed countries of Europe is about 52 g (Atinmo and Akinyele 1983; Ikede 1987; Arowolo 1996). The livestock industry also provides employment, source of income, draught power, fuel, fertilizer and hides and skin for the large majority of human population, and in most low-income settings ownership of livestock is a repository of saved money that can be drawn on by sale of the livestock when the need arises (Ikede 1987; FAO 1996). This aspect of the role of livestock in the socio-economy of low-income people cannot be ignored if the first of the Millennium Development Goals (eradication of extreme poverty and hunger) is to be attained.

The occurrence and endemicity of certain animal diseases, followed by poor nutrition, stand above all other factors in their contribution towards poor productivity and output from the livestock sector (Ikede 1987; Adene 1991; Arowolo 1996). Animal diseases of varying morbidity and mortality plague livestock in Nigeria and seasonally threaten to wipe out specific animals in some areas of the country; these outbreaks and epizootics are often unreported, unconfirmed or poorly documented if at all reported (Table 1). In addition, the financial losses associated with such outbreaks and costs associated with the disease burden are rarely documented. For instance, a large proportion (about 94%) of the Nigerian poultry population are local/village chickens that are on free range, and waves of NCD outbreaks often completely kill off birds in several localities during periods of outbreaks (Fatumbi and Adene 1979); these outbreaks and the economic losses associated with them are rarely documented. Also, the ASF outbreaks that had spread uncontrolled throughout the country led to massive mortality of pig populations in most areas where outbreaks had occurred (Majiyagbe et al. 2004); in most areas, these outbreaks and their financial implications are not investigated, reported, or documented. Recurring waves of PPR outbreaks (George et al. 2001) had prevented the small ruminant population from significantly contributing its quota to the supply of animal protein needs of Nigerians and the income of the sheep/goat owners, and these numerous outbreaks and their economic implications are rarely properly reported and documented.

Table 1: Reported vaccination figures and disease incidence in 2008 for the five priority diseases in Nigeria

Name of priority diseases	2008 vaccination figures	2008 reported disease incidence
ASF (pigs)	Not applicable	650
CBPP (cattle)	54,492	7973
NCD (chicken)	791,934	78,526
PPR (sheep and goats)	293,537	34,099
Trypanosomosis	Not applicable	125,684

Each value is the total reported figure for the whole nation
Source: FDL (2010)

Efforts at control of these animal diseases have not yielded enough dividends because of several factors including absent or improperly implemented control programs, insufficient inputs (such as vaccines), poor vaccination coverage of several localities due to limited vaccine supplies and constraints in field mobility and support funds, illiteracy of farmers and poor management systems (FAO 1996; FDL 2010). It is estimated that NCD in unvaccinated village poultry has 45% background mortality. PPR in sheep and goats, CBPP in cattle and ASF in pigs have background morbidity rates of up to 50%, with mortality rates of about 50% for PPR, 25% for CBPP and 100% for ASF.

The World Bank is preparing an Integrated Animal and Human Health Management project for Nigeria. The project will have four components to be implemented by the Federal and State DVS and DPH. The first component of the proposed project aims to conduct national livestock vaccination campaigns including private-sector participation in vaccine production and delivery to grassroots levels. However, the economic and financial implications of high disease burden, morbidity and mortality from priority diseases as well as the costs of implementing various levels of coverage of interventions for all or a combination of priority diseases are not well-known and considerations based on them could adversely affect projected economic and financial rates of return of the proposed project.

To ensure that inputs into the proposed project are well-informed, the Government of Nigeria invited ILRI to assist to investigate and document the costs of disease burden, morbidity and mortality related to the following specific priority diseases in Nigeria:

- NCD in rural poultry flocks;
- PPR in sheep and goats;
- CBPP in cattle;
- ASF in pigs; and
- trypanosomosis in ruminants and pigs.

1.2. Objectives of the study

The overall objective of this study was to assess the financial impacts of inaction against five priority diseases in Nigeria. The specific objectives were to do the following for each of the five priority diseases at national and agroecological levels:

i. assess the direct and indirect financial burden of inaction including costs of death of animals; weight loss; lost milk, eggs and draught power; treatment during illness etc.;
ii. estimate the costs of targeted interventions including treatment, vaccination, surveillance, vector control and sanitary measures;
iii. determine the additional benefits, additional costs and net benefits associated with baseline interventions;
iv. evaluate of the BCRs of targeted interventions based on sensitivity analysis; and
v. make recommendations on the feasibility of the targeted interventions given the underlying uncertainties permeating the various scenarios.

1.3. The research approach

The study was designed with two components – an epidemiology component and an economic component. The epidemiology component was designed to gather data to feed a spreadsheet model of the economic component to determine the cost of not controlling CBPP, trypanosomosis, ASF, PPR and NCD in Nigeria. Two research teams, one for each component, were constituted. Each team had national expert working with ILRI staff in addition to an ILRI-recruited consultant. For both components and for primary data collection, an extensive checklist of data necessary for the economic model was provided to the teams (Annexes 1 and 2). Secondary data were sourced principally from peer-reviewed journal papers and conference proceedings, and books and publications of the FDL, Faculties of Veterinary Medicine, Veterinary Teaching Hospitals (VTH), the National Veterinary Research Institute (NVRI) and the National Institute for Trypanosomosis Research (NITR).

Initial stakeholder consultations were also held. Officials of the FDL, academics from four Nigerian universities teaching veterinary medicine, the Director of Research of the NVRI, the Director General/Chief Executive Officer of the NITR, Directors of Veterinary Services from selected states and representatives of the private-sector were among those that met with ILRI scientists and consultants on 08 April 2010 at the International Institute of Tropical Agriculture, Ibadan, to deliberate and address the outcome from the problem formulation for the study. Each participant received copies of the Terms of Reference of the study including a summary of the technical details to study in advance of the meeting. The stakeholders advised that the time available for study was too short especially given primary concerns about availability and quality of data in the area. They advised a stepwise approach to data collection starting from published information, then nationally available secondary sources and finally rapid appraisals as necessary.

Following the approach agreed with stakeholders, a rapid assessment was conducted to obtain supplemental information on the epidemiology and impact of these diseases, herd population structures, livelihoods and farm-level cost information. Because of the limited time available, the assessment was not designed to provide data representative of the State or agroecological zone assessed. Rather, it was designed to provide information for comparative purposes to the data harvested from other sources.

1.3.1. PE for rapid assessment

The rapid assessment was carried out in four agroecological zones of Nigeria – Kano State in the Sudan Savannah, Niger State in the Northern Guinea Savannah, Enugu in the Subhumid Zone, and Oyo State in the Humid Zone. In the Humid Zone, interviews were also carried out in Lagos State, targeting semi-commercial smallholder swine producers. Fieldwork was conducted by six PE specialists, working in teams of two, and took place over six days in each zone (Cameron 1997; Mariner and Paskin 2000).

A rapid assessment checklist (Annex 2) was developed in consultation with the PE specialists, the project economists and the epidemiologist. Questions and exercises were standardized between teams and an *aide memoire* developed to ensure consistency. Due to the similarities in clinical presentation between PPR and foot and mouth disease (FMD) in small ruminants, clinical case definitions were developed for these two diseases for use in the assessment (Annex 3). A case definition developed in 2008 to clinically differentiate highly pathogenic avian influenza from NCD in Nigeria was also used. All six specialists worked in the Humid Zone, discussing findings and ensuring consistency in methodology each evening after fieldwork. Each team subsequently conducted fieldwork in one other zone.

The village was the unit of analysis (Cameron 1997). Prior to fieldwork, team members and/or facilitators visited villages to seek permission from leaders to conduct interviews in the area. The majority of interviews were of volunteer focus groups intended to be representative of the genders, ages, ethnicities and wealth classes found in the area. However, some interviews consisted of one gender or individual, depending on cultural norms. The following exercises were used to gather qualitative and semi-quantitative information.

1.3.1.1. Semi-structured interviews

Open-ended questions were used to collect general information and introduce all topics. The time period covered was April 2009 through March 2010. Interviewees were asked to list livelihood activities and production challenges, to provide information on breeding parameters, production parameters and production costs, and to indicate the availability and cost of disease control services. This method provided an estimation of the rate at which each livelihood activity and production challenge occurred, as well as estimates on specific economic parameters.

1.3.1.2. Simple ranking

Interviewees were asked to list all of the livestock species kept in the village over the past year. Responses were written or drawn separately on note cards. Interviewees were then asked to rank the note cards in order of importance in terms of the numbers kept, with the most numerous species in the village as number one. The note cards were then withdrawn and the interviewees were asked to repeat the exercise but ranking the note cards in terms of the different species' contribution to a family's livelihood, with number one representing the species most important to a family's survival and wellbeing. This method provided an estimate of the relative importance of the different livestock species.

1.3.1.3. Proportional piling

Interviewees were asked to describe the diseases that affected their livestock over the past year. Diagnoses were made based on clinical and epidemiological features, and observations of affected animals when available. When a diagnosis could not be made, the traditional name for the disease was retained. One species at a time, circles were drawn on flipchart paper for each disease. Interviewees were given 100 counters (usually beans) and asked to place them in the circles in different sized piles to show the relative importance of each disease in terms of prevalence over the past year. The counters were then withdrawn and the interviewees asked to show the relative importance of each disease in terms of their impact on a family's livelihood over the past year.

Similarly, to determine age distribution within herds and flocks, circles were drawn to represent the different age classes for a species. For example, for swine, circles were drawn to represent piglets, weaners, gilts, castrated growers, boars, female breeders, castrated finishers and culled female finishers. Interviewees were asked to place counters in the circles in different sized piles to show the relative proportion of each age class in the village's swine population.

To determine mortality rates by age class, interviewees were provided with 100 counters to represent an age class. They were then asked to divide the pile to show the relative proportion of that age class that died during the past year, and the proportion that survived. The beans were then removed, a new age class introduced, and the exercise repeated until all age classes for a species were covered.

A separate exercise with two circles representing breeding males and females in the population was carried out. Interviewees were asked to divide 100 counters to represent the relative proportion of males to females in the breeding population over the past year. Four more circles were then drawn, two under each sex. Interviewees were then asked to move counters from the breeding males to a new circle to indicate the proportion of that population that was introduced over the past year, followed by moving counters to a separate new circle to indicate the proportion of that population that was removed over the past year. The exercise was then repeated for breeding females.

These exercises provided estimates of the annual herd/flock level incidence and impact of livestock diseases over the past year, as well as production parameters including age distributions with morbidity and mortality for each age class, breeder male to female ratios with exits and entries.

1.3.1.4. Relative incidence scoring

Interviewees were asked to divide a pile of 100 counters into two piles representing the relative proportion of those in the herd or flock that got sick in the past year, and those that stayed healthy. The 'sick' pile was then divided into those that were affected by each of the diseases of concern for that species, and the remainder into a pile for other diseases. For instance, for cattle, interviewees were asked to divide the 'sick' pile into three piles showing the relative proportion of those cattle that were affected by 'CBPP', 'trypanosomosis' and 'other diseases'. Finally, each of these piles was divided into the proportion of animals that died from that disease, and the proportion that recovered. This method provided an estimate of the incidence of each disease of concern in each species over the past year, as well as case fatality, morbidity and mortality rates.

1.3.1.5. Analysis

A database was created and descriptive analysis carried out in Microsoft Excel. Frequencies are reported for 'yes/no' livelihoods activities and crops grown data. Means with standard deviations are reported for livestock proportions and importance. Medians with 10^{th} and 90^{th} percentiles are reported for results according to species. Where $n \leq 2$, standard deviations or percentiles are not shown. Data by state correlate with survey team, therefore comparisons between states should be made with caution as it is not possible to separate the measured effect from the survey team. Therefore, while differences between regions are described, they are only statistically analyzed where the effect of state could be removed via modelling. Village selection was not randomized and the number of villages surveyed is small, particularly in Kano and Niger. Therefore, the results cannot be interpreted to be representative of state or zone, but only representative of the villages where the surveys were done.

1.3.2. Economic modelling methods

A static and structured spreadsheet model was used to assess the costs of inaction on NCD in rural chicken flocks, PPR in sheep and goats, CBPP in cattle, ASF in pigs and trypanosomosis in cattle and pigs. The direct costs of each of these diseases refer to the monetary values of physical losses due to the disease (Bennett et al. 1999). These physical losses are the results of morbidity and mortality associated with each disease. Morbidity losses have two components. The first is the declining productivity that leads to losses in milk production, meat production (or live weight), draught power and egg production. The second is the loss of output as a result of dead animals that can no longer produce. The derivation of morbidity losses depends on the manner in which the disease evolves. For instance, for CBPP, it involves a transition rate to account for the fact that there is relatively significant lag between the time an animal is exposed and the time at which it starts developing symptoms of the disease (Mariner et al. 2006). This was not considered in more acute diseases such as NCD, PPR and ASF. Mortality induces losses associated with the cost of dead animals. The number of dead animals is found as a product of mortality rate and the proportion of livestock population at risk. Disease burden is defined as the sum of direct costs of the disease, which include cost of mortality and cost of morbidity, and the incurred costs of treatment, vaccination and surveillance.

The first step in this process was to determine the population at risk, which depends on the degree to which livestock population is protected by existing prophylactic measures. In that regard, background information on livestock across agroecological zones, vaccine availability, treatment availability and the degree to which disease surveillance programs are implemented are important. The data required are livestock population number, livestock production parameters, price/cost data and epidemiological parameters. The livestock population data are disaggregated by species, age, sex, breeds and production systems. Livestock production parameters are also collected by species and agroecological zones. The price/cost data to use as inputs in the spreadsheet model include price of milk, price of meat, price of eggs, cost of feed, price of live animals by species and age category, cost of treatment, cost of vaccination, cost of vector control, cost of sanitary measures and cost of disease surveillance. The data used in this study are presented in Annex 4A to 4D and are all for the year 2009 or adjusted to that year when applicable.

The epidemiological parameters involve disease incidence rate, affection rate (i.e. morbidity rate, mortality rate and case fatality rate), rate of vaccination coverage, extent of disease surveillance, disease treatment rate and impact of affection on productivity. These data were gathered from secondary sources, published studies and through PE targeting key informants across the four agroecological zones. The purpose of the PE was to come up with the best estimates of these epidemiological data, as it is customary for countries to under-report their disease status, leading to inaccurate assessments of disease costs. Thus, the combination of secondary sources and PE data lead to a more accurate state of knowledge on these diseases (Mariner et al. 2006).

In this exercise, data collected through PE were compared and contrasted with data collected from secondary sources and judgements were made about the magnitude of the parameter estimates to use. Hence, the incurred costs of treatment, vaccination, sanitary measures and vector control used to calculate the disease burden are elective, based on data collected through PE, or from secondary sources, or from our assessment based on the two. The costs of surveillance are set to 1.9 United States dollars (USD) per livestock unit (Alleweldt et al. 2009). The livestock units are derived from Chilonda and Otte (2006) who found for the purpose of monitoring livestock sector performance across regions of the world, livestock units are a better indicator than tropical livestock unit (TLU) or stock number. For sub-Saharan Africa, a bovine is equivalent to 0.5, a pig to 0.2, a small ruminant to 0.1 and a chicken to 0.01 livestock unit. The costs of carried out treatment, vaccination, vector control and disease surveillance are referred to as actual intervention costs and include for activities conducted by private and public entities.

After deriving the disease burden, this study sought to answer questions regarding the feasibility of additional investments to curb disease burden on Nigeria's economy. To sort out whether such additional investments would make economic sense, benefit-cost analysis (BCA) was conducted. The BCRs were derived using the direct costs of the disease as the additional benefits that Nigeria would incur if additional investments on treatments, sanitary measures, vaccinations, vector controls and surveillance programs were implemented. Hence, this study assumed some targeted levels of interventions (vaccination, epidemiologic surveillance, treatment, vector control and implementation of sanitary measures) necessary to eliminate the direct costs associated with each disease. The difference between the total cost of the targeted interventions and total cost of actual interventions is defined as the additional costs needed to yield the derived additional benefits. The targeted levels of interventions are informed by Nigeria's and other countries' experiences and the degree of complexity and costs of the proposed interventions. Moreover, the difference between additional benefits and additional costs associated with each disease is referred to as the net benefits that additional investments on these interventions would yield. The BCRs are the ratios of additional benefits to additional costs. Total costs of targeted interventions, additional benefits, additional costs, net benefits and BCR were evaluated at the national level and across all agroecological zones. All the monetary values are expressed in Nigerian Naira (NGN) and where applicable the exchange rate between the USD and the NGN was set to USD 1 for NGN 150.

Finally, there is an underlying uncertainty permeating into this whole process, which can be accounted for by conducting sensitivity analyses on the input variables, including epidemiological parameters, using reasonable ranges of variation of the input data. Another method is to collect all input data in three different categories: high, medium and low, which would yield results in similar categories. A different approach was applied in this study, which consisted of conducting sensitivity analysis on the additional benefits and looking at how the BCR would be impacted if the additional costs were only suppressing the individual disease effects at 90%, 80%, 70%, 60%, 50%, 25%, and 10% and make judgements whether the investments would make economic sense under these different scenarios.

1.4. Structure of the report

The study is introduced in Chapter 1 (this chapter) with discussions on the justification for the study and the research approaches used. Chapter 2 provides a brief description of the agroecological zones and livestock production systems in Nigeria while in Chapter 3, the epidemiology of the five priority diseases is discussed both from the point of view of existing literature and from the findings of the rapid assessment. The results of the economic model are presented in Chapter 4 while Chapter 5 summarizes the findings, making recommendations on the feasibility of targeted interventions regarding the priority diseases at both agroecological and national levels.

Chapter 2: An overview of livestock production systems of Nigeria

2.1. Major agroecological zones

Nigeria has four major agroecological zones namely (from south to north); humid (rainforest), subhumid (derived—southern Guinea—savannah), Northern Guinea Savannah, and the semi-arid (Sudan Savannah). The northernmost fringes of the country have relatively small portions of the arid (Sahel Savannah) zone (Figure 1). The rainfall is unimodal (mainly May to September) and is followed by a long dry season (October to April). Rainfall decreases from over 4000 mm per annum along the coastline in the south to about 500 mm in the northern extremes. Fodder production follows the same moisture gradient and decreases potentially from 10 t/ha in the south to less than one t/ha in the north.

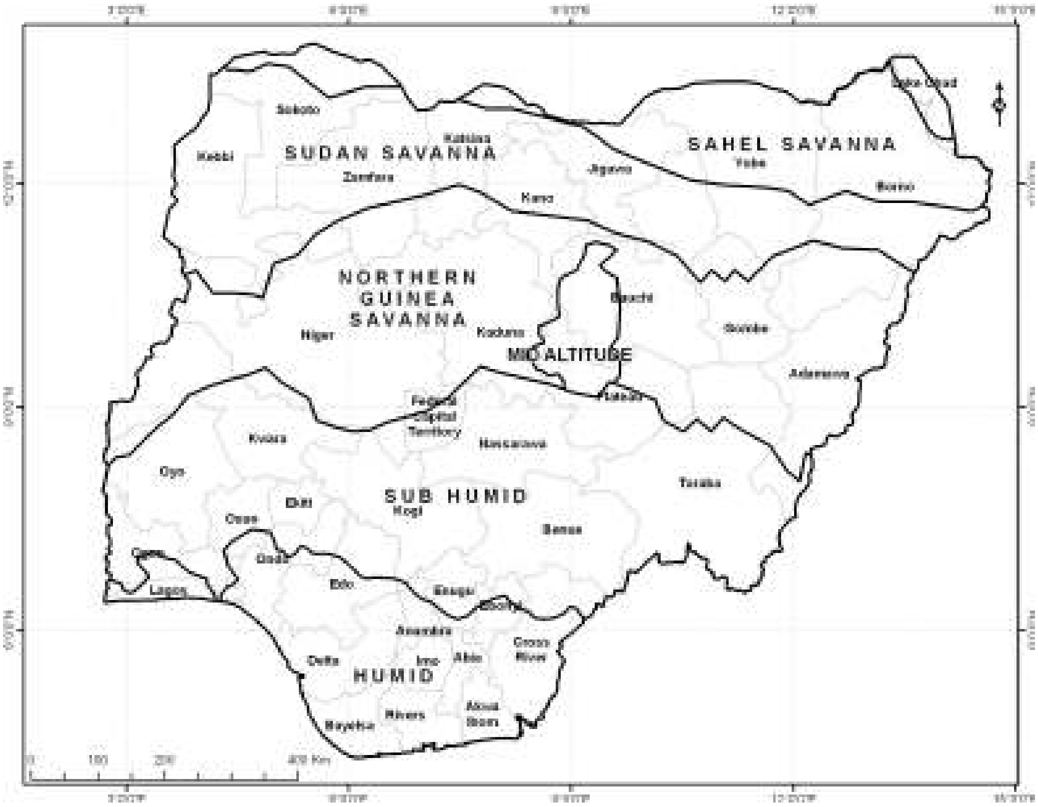

Figure 1: Map of Nigeria showing the major agroecological zones.

Due mainly to high disease challenge in the Humid Zone and to a lesser extent the Subhumid Zone (especially of trypanosomosis) the distribution of the ruminant livestock population does not necessarily follow the availability of pasture. For example, the Humid Zone with higher potential for fodder production has a stocking density of one cattle, 63 goats and 28 sheep per km^2 compared to 23 cattle, 42 goats and 37 sheep per km^2 in the semi-arid zone with much lower fodder production. It is, therefore, not surprising that the subhumid and semi-arid zones alone hold 94% of all cattle, 75% of all goats and 82% of all sheep in Nigeria. For monogastrics, mainly considering poultry and pigs, the picture is reversed with the Humid Zones accounting for 96% of all pigs and 75% of the entire poultry population.

2.2. Common livestock breeds

The decision of farmers on which breeds of livestock to keep is also influenced by agroecological factors. In the semi-arid and sub-Humid Zones the main cattle breeds are the Bunaji (White Fulani), Rahaji (Red Bororo or Abore), Sokoto Gudali, Adamawa Gudali, Wadara, Awazak and the fat-horned Kuri. The main breeds of sheep in the same region are Yankasa, Balami and Uda. For goats, the Sokoto Red is the most popular with numerous Buzuruwa and West African Dwarf goats. With the high tsetse challenge in the Humid Zone, farmers tend to keep only cattle breeds that can tolerate trypanosomes, usually the non-zebu. Such breeds include Muturu (non-zebu), Keteku (a cross between Muturu and zebu) and N'Dama (non-zebu). However, a new dimension to cattle production in the Humid Zone is the apparent successful settlement of pastoralists in the zone in the past two decades with thousands of their zebu cattle (Blanch 1994). In this zone, West African Dwarf sheep and West African Dwarf goats are predominant. The common local pig is an Iberian type, usually black or pied. There are a few exotic breeds e.g. Large White, Landrace, Duroc, Hampshire and their crosses intensively.

2.3. Production systems

Ruminant livestock are traditionally kept in three major production systems, namely, extensive (e.g. pastoral), semi-intensive (e.g. mixed crop-livestock farming) and intensive (urban and peri-urban) systems. The semi-intensive is the most important system for ruminants as it accounts for 80% of the population of cattle, sheep and goats, followed by the extensive system which accounts for 18%. Although the urban and peri-urban system covers only 2% of the ruminant population, its stocking density of 14.6 TLU/km^2 is higher than that of the semi-intensive system (13.3 TLU/km^2) or the extensive system (9.4 TLU/km^2) (Fernandez-Rivera et al. 2004).

The two main poultry management systems according to Sonaiya (1990) are extensive (including free-range and backyard subsystems) and intensive (including semi-intensive confinement and commercial confinement subsystems). Commercial holdings account for about 10% of total poultry (FDLPCS 1992). The majority of pigs are kept in villages under traditional (extensive) management with significant numbers in semi-intensive production systems. Pigs are kept in seasonal confinement in the north and middle belt but are usually confined in the south, except in the Niger Delta region (FDLPCS 1992).

In the context of this study, for both ruminants and monogastrics, diseases associated with intensification are more likely to have higher incidence in the intensive urban and peri-urban system compared to the others.

Chapter 3: The epidemiology of ASF, CBPP, NCD, PPR and trypanosomosis in Nigeria

In this chapter, an overview of the epidemiology of the priority diseases is presented, both from the point of view of existing literature and from a discussion of the findings of the rapid assessment. A summary of the findings is first presented followed by detailed reviews of the epidemiology of the individual diseases.

3.1. Summary

Literature review showed that since the earliest reported outbreak of ASF that led to the death of about 15,000 pigs in Ogun and Lagos States, the disease had spread uncontrolled to all parts of the country, and as at 2004, more than half a million pigs had been reportedly killed by the disease with accompanying huge financial losses and other socio-economic implications. The seroprevalence of ASF had increased consistently across the years from 7.5–12.8% reported in 2002 to as high as 49.7% reported in 2005 and 55% reported in 2009.

Despite the earlier vaccination campaigns against CBPP, the disease persists with abattoir based survey accompanied by seroprevalence studies yielding 18.8–32.0% prevalence, with its associated losses due to mortality, morbidity and organ (lung) condemnation at meat inspection. Although abattoir records-based retrospective studies of lungs condemned for CBPP gave relatively low percentages of lungs condemned (most probably because lungs are only condemned when they are very badly damaged), it is obvious that the disease remains a major hindrance to cattle rearing.

Local free-range chickens constitute about 94% of the total estimated poultry population of about 183.16 million in Nigeria. Waves of NCD outbreaks consistently deplete this population of poultry, as the birds are not routinely vaccinated against the disease (vaccination is the main method of control of NCD in Nigeria). Almost all farmers and smallholder chicken owners admit that NCD is the chief disease constraint to poultry production in Nigeria, and seroprevalence studies in local chickens across the states of Nigeria gave prevalence rates ranging from 38.0% to as high as 76.1%. The financial and economic costs of these numerous outbreaks that often almost wipe out chickens in different localities at different times mostly remain unreported and undocumented.

PPR remains the major disease constraint to small ruminant production, and in the absence of a defined control program, seroprevalence of the disease had remained consistently high across more than 30 years of the earliest documented seroprevalence studies (43.2% for goats in 1979, and 37.7% and 41% for goats and sheep respectively in 2009). Outbreaks of PPR and its associated losses remain very high and either under-reported or unreported.

Trypanosomosis has now become widespread all over the country as outbreaks and relatively high infection rates had been reported even in the highlands of Jos Plateau, which was formerly regarded as tsetse and trypanosomosis free.

The consistent endemicity and increased incidence/prevalence (in some cases) of these diseases with their associated financial and economic losses can be blamed on the absence or non-implementation of specific control programs targeted and designed for the peculiar management systems and circumstances of the livestock industry in Nigeria.

3.2. ASF

ASF is a highly contagious and septicaemic viral disease of domestic pigs, which is characterized by marked haemorrhages in the internal organs, cyanosis of the skin and mortality closely approaching 100% in some cases (Mebus 1988; Majiyagbe 1999). It is caused by an Asfivirus, and argasid ticks and wild porcine species play very vital roles in its epizootiology (Majiyagbe et al. 2004). The virus is hardy, highly resistant to low temperatures and somewhat resistant to higher temperatures, remaining infective in carcasses for up to 18 months. This allows for infection through direct and indirect contact such as through feed and other fomites. It can also multiply in tick vectors (*Ornithodoros* sp). Death is per-acute or within 4-7 days after the onset of fever, with mortality reaching 100% with virulent strains, 30–70% with moderately virulent strains and low with low virulent strains. No reliable vaccine exists, as the presence of the virus does not appear to provoke neutralizing antibodies (Blood and Radostits 1989). Multiple diagnostic tests are available, including virus isolation and haemadsorption, fluorescent antibody testing, polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA) (OIE 2010d). Nigeria last reported ASF to the OIE in 2009 (OIE 2010b).

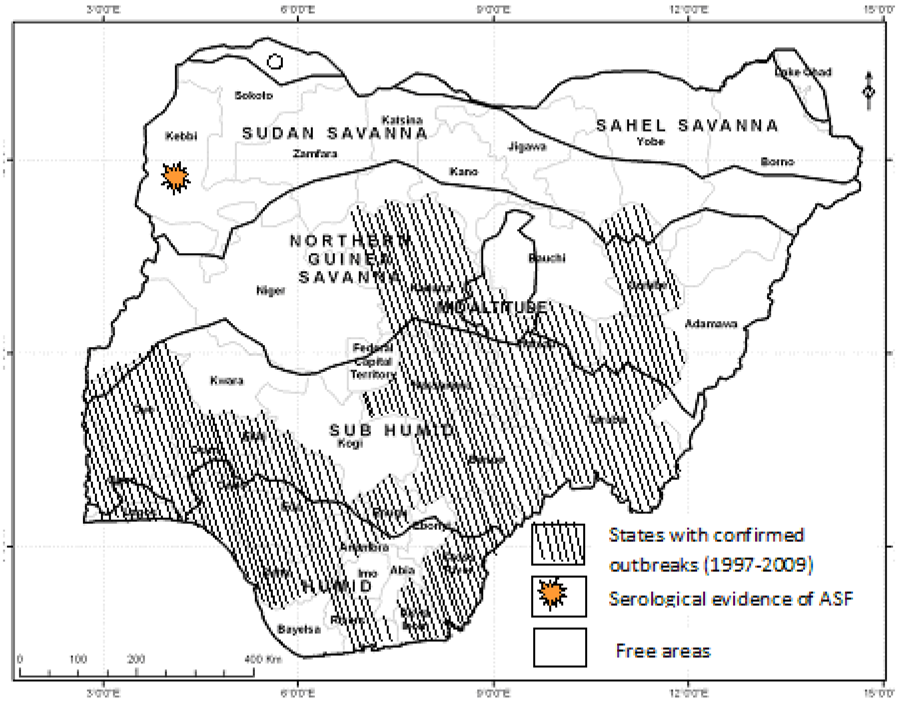

Figure 2: Map of Nigeria showing the distribution of ASF.

The disease was first described in Kenya (Montgomery 1921). In Nigeria, ASF was first reported in September 1997 in free-ranging pigs in the four LGAs within the common boundary of Nigeria and the Republic of Benin where it led to the death of about 12,000 pigs. Later in December 1997, the disease was reported in Badagry, Lagos State and this outbreak was traced to 'across the border pig trading' with the Republic of Benin. Initial investigation carried out in these states (Ogun and Lagos) showed that within one month of its occurrence a total of 15,000 pigs (12,000 in Ogun State and 3000 in Lagos State) had died of the disease (Majiyagbe et al. 2004) (Table 2). The disease later spread from these primary foci to other parts of the country. The disease was confirmed through laboratory tests in 14 states, namely Ogun, Lagos, Osun, Ondo, Ekiti, Delta, Anambra, Enugu, Akwa Ibom, Rivers, Oyo, Benue, Kaduna and Plateau, covering the southwest, southeast and central states of the country (Majiyagbe et al. 2004) (Figure 2). Other states of the Federation including Niger, Nasarrawa, Kebbi, Kwara, Kogi, Taraba, Bayelsa, Ebonyi, Imo and Cross River and the Federal capital territory also reported suspected outbreaks (though these were not confirmed in the laboratory) (Majiyagbe et al. 2004) (Figure 3). Thus as at 2004, virtually all pig producing communities in the country were experiencing outbreaks of the disease (Majiyagbe et al. 2004). The officially recorded pig deaths caused by ASF across the country (as at 2004) were above 500,000 pigs, which translated to a huge financial loss with serious and damaging socio-economic implications.

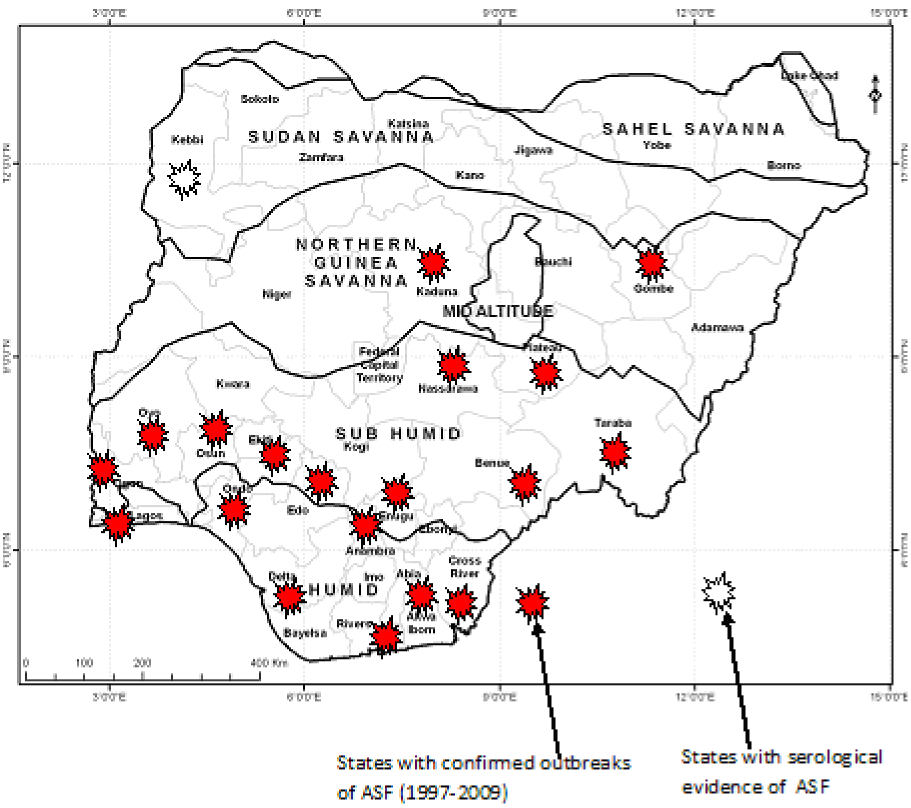

Figure 3: Locations of confirmed outbreaks and serological evidence of ASF in Nigeria (1997-2009).

As a viral disease, there is no cure for ASF, and control of the disease is hinged on tick control, slaughter and disposal on infected pigs, imposition of quarantine and movement restrictions, separation of domestic and wild pigs and replacement of the free-range management pattern with intensive methods.

Table 2: Some of the reported outbreaks of ASF in Nigeria with their mortality rates and associated estimated financial loss

ASF outbreak	No. of pig deaths	% mortality recorded	Estimated financial loss	Source
1997 in Ogun State	12,000	NA	NA	Majiyagbe (2004)
1997 in Lagos State	3000	NA	NA	Majiyagbe (2004)
2001 in Ibadan, Oyo State	31,916	91%	USD 0.94m	Babalola et al. (2007)
Kumo Gombe State	2816	90%	NGN 18m	Mailafa (2008); Mailafa and Iliya (2009)

NA: Not available

3.2.1. ASF seroprevalence studies

Earlier seroprevalence studies by Luther et al. (2002) on the incidence of antibodies to ASF virus in pigs reported relatively lower prevalence of 7.5% (200 samples tested) for Plateau State and 12.8% (195 sera tested) for Kaduna State. More recent reports showed a higher prevalence of 49.7% (151 samples tested) in Jos Plateau (Owolodun et al. 2005) and 55% (100 samples tested) in Zuru Kebbi State (Bala et al. 2009).

Table 3: Some of the results of seroprevalence studies for ASF in Nigeria

Location and year of seroprevalence study	No. of pigs sampled	Prevalence (%)	Source
Plateau State, 2002	200	7.50%	Luther et al. (2002)
Kaduna State, 2002	195	12.80%	Luther et al. (2002)
Jos Plateau, 2005	151	49.70%	Owolodun et al. (2005)
Zuru Kebbi State, 2009	100	55%	Bala et al. (2009)

3.2.2. Initial conclusions from ASF literature review

ASF is now widespread all over the country, and based on results of seroprevalence studies (Table 3), it can be concluded that the incidence/prevalence of the disease had been increasing significantly across time with an astronomical rise from 7.5% for Plateau State and 12.8% for Kaduna State reported in 2002 (Luther et al. 2002) to 49.7% reported in Jos Plateau in 2005 (Owolodun et al. 2005) and 55% reported in Zuru Kebbi State in 2009 (Bala et al. 2009). This conclusion is arrived at being mindful of the fact that these seroprevalence results were obtained in the northern part of the country which was not the initial foci of outbreaks and consequent spread of the disease in Nigeria and also that most pigs in Nigeria are not located in the North for religious reasons. It should also be stated that because of the poor or no reporting and documentation of the financial losses associated with the numerous outbreaks in different parts of the country, the real financial losses due to ASF outbreaks in the country will go beyond the estimated losses reported for the 2001 Ibadan outbreak (Babalola et al. 2007) and the Kumo Gombe State outbreak (Malaifa 2008; Malaifa and Iliya 2009) (Table 2).

3.3. CBPP

CBPP is a highly contagious bronchopneumonia of cattle associated with consolidation of the lung, fibrinous pleurisy, fluid accumulation in the pleural cavity and 'marbling' of the lungs. It is caused by *Mycoplasma mycoides* subspecies *mycoides* (Cassel et al. 1985; Terlaak 1992). The disease is spread by intimate contact between infected and susceptible cattle through inhalation of infected droplets released by an infected animal while coughing (Cassel et al. 1985). Thus, production systems that bring animals together in close housing in Humid Zones show higher herd prevalence rates than more extensive systems in arid zones, while cattle movements and systems with complex contact patterns such as pastoral production are important for the spread of the disease (Mariner et al. 2005; Masiga et al. 1996). Acute cases show painful, difficult breathing with lowered and extended head and cough, progressing to recumbence and death in 3–4 weeks. Infective carrier states that are not detectable clinically or serologically exist, with 25% of recovered animals infected with pulmonary sequella (Blood and Radostits 1989; Masiga and Domenech 1995). The World Organization for Animal Health (OIE) recommended procedures for diagnosis include a modified Campbell and Turner complement fixation which has a low sensitivity (70%), competitive ELISA and PCR (OIE 2010a). In enzootic areas annual vaccination is recommended and several vaccines are available. However, severe vaccine reactions including death can occur and the type of vaccine used should be tested in breeds from the target area before widespread use. Treatment is recommended in endemic areas, with Tylosin (10 mg/kg body weight, intramuscular, twice daily for three days) (Blood and Radostits 1989). Morbidity rates can reach 90% in susceptible herds with mortality ranging from 10–70% and recovered animals may become carriers and source of re-infection and infection of other animals (Cassel et al. 1985; Terlaak 1992). One recent study found morbidity to be below 5% in Burkina Faso but above 25% in Chad, with mortality rates of 5–10% in Chad and below 5% in Burkina Faso (Kane 2002). Nigeria last reported CBPP to the OIE in 2009 (OIE 2010b). Between 1998 and 1997 Aliyu et al. (2000) found the prevalence of post-mortem CBPP-like lung lesions in slaughterhouses in five states in northern Nigeria to be 0.29%. Prevalence varied significantly between states, but there was no significant difference between years. Average annual vaccination coverage in the study area was 9.5%. A spreadsheet model study of the economic impact of CBPP included several of Nigeria's neighbours, finding the BCR of CBPP control to be 1.91 in Burkina Faso, 1.61 in Chad and 1.95 in Niger (Tambi et al. 2006). However, the authors noted that the only control measures considered in their model were vaccination and treatment, therefore the model likely underestimated the costs of CBPP as other control measures were in use in the study areas.

It is a disease of major economic importance in Nigeria because its severe respiratory symptoms, protracted course and endemicity in the cattle-rearing northern parts of the country lead to considerable loss in productivity that translates to heavy financial losses (Fayomi and Aliyu 1997; Aliyu 2002). In 2003, the Nigeria Animal Diseases Information System under the auspices of Pan-African Programme for the Control of Epizootics (PACE) classified Nigeria as an endangered zone based on her CBPP status (PACE 2003).

Based on the occurrence of CBPP, Nigeria had been divided into three zones as follows (Onu 2004) (Figure 4):

i. The exposed zone comprising Kaduna, Kano, Jigawa, Benue, Kogi, Plateau States and Lafiagi in Borgu District of former Kwara State.
ii. The enzootic zone made up of Bornu, Yobe, Bauchi, Sokoto, Kebbi, Adamawa and Taraba States.
iii. The free zone, which is the rest of the country.

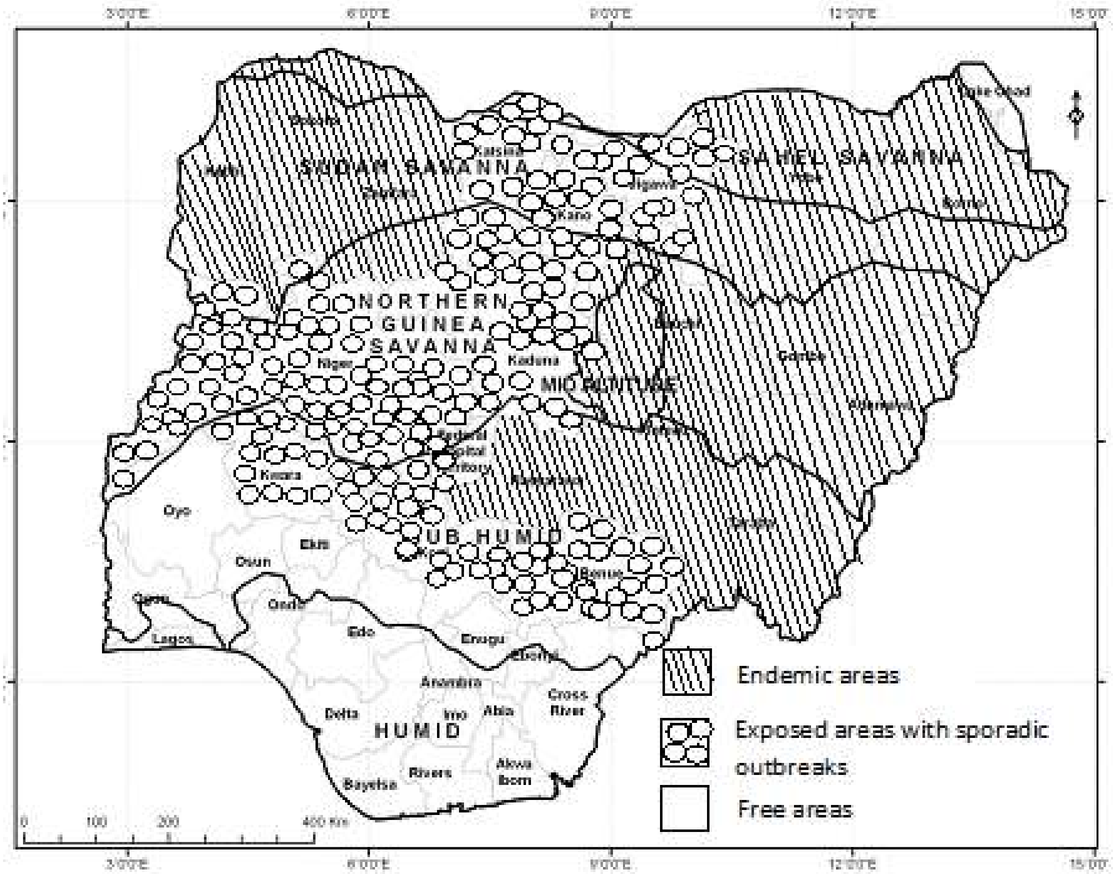

Figure 4: Map of Nigeria showing the distribution of CBPP.

3.3.1. CBPP control, seroprevalence and abattoir studies

Despite vaccination campaigns in Nigeria, CBPP continues to occur with increased frequency (Aliyu et al. 2000). The launching of the Joint Project No. 28 eradication program for CBPP in the early 1970s greatly reduced the incidence of the disease in Nigeria. However, due to low vaccination coverage (FLD 2010), CBPP continues to occur with increased frequency leading to heavy losses due to mortality and morbidity, organ condemnation and cost of vaccination programs.

The control of CBPP in Nigeria is based on an immunoprophylactic vaccination program because cattle in Nigeria are not confined. For eradication purposes, slaughter and disposal of all affected and exposed animals will be appropriate, with strict quarantine. Cattle infected with CBPP can be treated with an antibiotic, Tylosin (10mg/kg body weight twice daily for three days); this is known to be effective but there are chances of some recovered animals being carriers. In any case, eradication programs are difficult to accomplish, especially in the context of extensive livestock production systems and intervention strategies to deal with this and other diseases in Africa are increasingly focusing on control.

A study on the prevalence of CBPP in the five northern states of Nigeria between 1988 and 1998 (Aliyu 2002) showed that an average of 30 outbreaks were reported annually from all the states, and based on available data the annual economic loss due to CBPP in the northern states then was estimated at NGN 498 million, which the author considered an underestimation. An abattoir-based study carried out in Maiduguri, Mubi and Song areas of northern Nigeria showed that out of 500 cattle from which sera samples and lung tissues were obtained (Aliyu et al. 2003), 18.8% had lesions suggestive of CBPP, 27.4% were seropositive using complement fixation test (CFT) while 32% were seropositive using competitive ELISA (C-ELISA) diagnostic technique.

Table 4: Results of the abattoir-based studies on CBPP in Maiduguri, Mubi and Song areas of northern Nigeria

Study type	No. of cattle examined or serum tested	% of lungs with lesions of CBPP or % of cattle seropositive for CBPP
Examination of lungs for lesions suggestive of CBPP	500	18.8%
Seroprevalence study (CFT)	500	27.2%
Seroprevalence study (C-ELISA)	500	32%

Source: Aliyu et al. (2003)

In a retrospective abattoir-based study utilizing abattoir records of lungs condemned at meat inspection because of lesions suggestive of CBPP at Kano abattoir, Fayomi and Aliyu (1997) reported 862 lungs condemned for CBPP out of 293,491 cattle slaughtered (0.29%) during a five-year period (1985-89), and the worth of the condemned organs was estimated at NGN 28,446. Another five-year retrospective study at Mubi Adamawa (Halle et al. 1998) reported that 238 lungs were condemned for CBPP out of 43,810 cattle slaughtered (0.54%), and the worth of organs condemned was estimated at NGN 28,580. Onu (2004) reported an abattoir-based retrospective study at the Sokoto Metropolitan abattoir between 1990 and 1994; out of the 162,111 cattle slaughtered, 3338 (2.1%) had their lungs condemned as a result of CBPP and the worth of the condemned lungs was estimated at NGN 237,780 (USD 10,321). Aliyu and Kyari (2005) reported the results of an 11-year (1992-2002) abattoir-based retrospective study in Plateau state in which 0.72% of lungs were condemned out of 185,300 cattle slaughtered.

Table 5: Some results of abattoir-based retrospective studies on CBPP in Nigeria

Study location and duration	No. of animals slaughtered	No. of lungs condemned for CBPP (% in brackets)	Estimated financial worth of lungs condemned	Source
Kano abattoir (1985-89)	293,491	862 (0.29%)	NGN 24,466	Fayomi and Aliyu (1997)
Mubi, Adamawa (1991-95)	43, 810	238 (0.54%)	NGN 28,580	Halle et al. (1998)
Sokoto Metropolitan (1990-94)	162,111	3338 (2.1%)	NGN 237,780	Onu (2004)
Plateau State (1992- 2002)	185,300	1334 (0.72%)	NA	Aliyu and Kyari (2005)

NA – Not available

3.3.2. Initial conclusions based on CBPP literature review

The incidence of CBPP among cattle can be stated to be very high when the reports of Aliyu et al. (2003) which involved examination of lungs in combination with seroprevalence studies (Table 5) are considered. Though other reports (retrospective studies based on abattoir records of lungs condemned as a result of CBPP) reported lower prevalence, it must be noted that lungs are only condemned in the abattoir when they are 'so badly damaged', thus lungs with obvious lesions of CBPP which did not completely involve the whole lungs may have missed being condemned. However, information on seroprevalence in other parts of the country is needed. It is worthy of note that the financial costs recorded were for only the condemned lungs, yet this only accounts for a very small percentage of the real financial loss attributable to the disease burden.

3.4. NCD in local birds

NCD is a highly contagious disease of poultry and other birds caused by a virus in family Paramyxoviridae, genus *Avulavirus* that occurs in velogenic, mesogenic and lentogenic strains (Alexander 1996). It is spread through the air and contact with oral and gastrointestinal discharges as well as fomites, and has a long survival time at ambient temperatures. Morbidity tends to be high, but mortality depends on the species infected and virus form, ranging from negligible with lentogenic strains to 100% with velogenic strains (Fraser et al. 1991). Multiple diagnostic options are available including isolation with haemagglutination inhibition, and PCR (OIE 2010f). Nigeria last reported NCD to the OIE in 2009 (OIE 2010b).

The disease is characterized by respiratory disorders, greenish diarrhoea, reduction/cessation of egg production and torticollis/twisting of the neck as a result of the pathologies that the virus induces in the respiratory, digestive, reproductive and nervous systems of the affected birds (Hanson 1978). NCD is associated with very high morbidity and mortality and in most developing countries it is the single most important health problem of poultry and constraint to massive poultry production (Adene 1991; Saidu et al. 2006).

According to the 2009 FDL national livestock and poultry population estimate, Nigeria has about 183.16 million domestic birds, 94% of which are local chicken while the remaining 6% are exotic birds (FDL, 2010). These local birds play an important role in providing animal protein (meat and eggs) to all and income to low-income smallholder farmers (Fatumbi and Adene 1979; Johnston 1990; Duru et al. 2008). These local birds are raised under extensive system of management where they roam freely and scavenge for food. They hardly receive any prophylactic treatment or vaccination thus they are believed to act as reservoirs and carriers of diseases for exotic breeds (Wosu and Okeke 1989; Saidu et al. 2006).

The first documented confirmed case of NCD in Nigeria was reported by Hill et al. (1953) and subsequently the disease has been observed and reported in both local and exotic chicken in every part of the country (Fatumbi and Aden 1979; Ezeokoli et al. 1984; Gomwalk et al. 1985; Wosu and Okeke 1989). With the very high morbidity and mortality associated with outbreaks, NCD remains the single major disease that has considerably limited the ability of the poultry industry in Nigeria to meet the dietary protein needs of the population (Ojo 2003; Amos 2006).

NCD as a viral disease does not have a cure. Rather, vaccination of susceptible flock is the major control strategy used. However, the vaccines currently available and the vaccination programs commonly followed were designed for intensively reared exotic birds. Most (if not all) of the local chicken that constitute about 94% of the total poultry population of the nation remain uncovered by vaccination.

3.4.1. NCD seroprevalence studies

Several questionnaire- and interview-based surveys show that NCD is the single most important poultry disease plaguing farms in Nigeria, and in most of the surveys 100% of farmers identify NCD as the major disease constraint facing their poultry farms (Berepabo et al. 1991; Duru et al. 2008; Furo and Ambali 2008).

A seroprevalence study by Adu et al. (1986) showed that 41.04% (307 out of 748) of local chicken sera samples collected from different parts of Nigeria tested positive for NCD. Oyewola et al. (1996) in their seroprevalence study of local chickens in Ibadan reported a seroprevalence of 38.0% (221 serum samples tested). A seroprevalence study carried out by Baba et al. (1998) in local chickens in Borno State showed that 40% of 242 village chickens sampled were positive for NCD, while the study by Wosu and Okeke (1989) on local chickens in Enugu State showed a seroprevalence of 76.1%. Another study conducted in Borno State in the far northeast of Nigeria found a seroprevalence rate in indigenous chickens using haemagglutination inhibition serology of 36.5%, including 46.9% in adult birds and 23% in birds less than 12 weeks old (Tewari et al. 1992). Haruna et al. (1993) report on an outbreak of NCD in guinea fowl in Vom, central Nigeria with a case fatality rate of 24.3%.

Table 6: Some of the results of the seroprevalence studies on NCD in local chickens in Nigeria

Study location	No. of chickens sampled	Prevalence (%)	Source
Different parts of Nigeria	748	41.04%	Adu et al. 1986
Enugu State	276	76.1%	Wosu and Okeke 1989
Ibadan, Oyo State	221	38.0%	Oyewola et al. 1996
Borno State	242	40.0%	Baba et al. 1998

Almost all retrospective studies of clinical case reports across numerous animal health service providers across the country show that NCD is the most commonly occurring poultry disease. A retrospective study by Abdu et al. (1985) on poultry diseases diagnosed at the Avian Clinic of the Ahmadu Bello University (ABU) VTH Zaria from 1981 to 1984 showed that of all the 437 avian cases handled, NCD was the most frequently diagnosed and accounted for 19.5% of all cases presented. A similar study by Oranusi and Onyekaba (1986) in the Niger Delta area also showed that NCD is the most frequently encountered disease of birds accounting for 54.3% of all diseases diagnosed. Halle et al. (1999) carried out a ten-year (1986-95) retrospective study of the prevalence and seasonality of NCD at the ABU VTH Zaria and reported that out of 2999 poultry diseases diagnosed NCD was the most frequent, accounting for 31.2% of all the poultry diseases diagnosed. Another ten year (1990-99) retrospective study at ABU VTH Zaria by Saidu et al. (1998) showed that NCD is the most frequently diagnosed poultry disease, and accounted for 32.3% of 2513 cases diagnosed. A six-year (1995-2000) retrospective study in Maiduguri, Borno State (Ambali et al. 2003) also showed that NCD is the topmost poultry health problem on record, while a 10-year (1995-2004) retrospective study of the major constraints limiting poultry production in Gombe State also showed that NCD is the most important poultry health problem encountered by farmers and out of the 2121 cases of poultry disease, NCD accounted for 14.7%.

3.4.2. Initial conclusions based on NCD literature review

NCD remains a major problem to both local and exotic chickens and the case of local chickens is far worse as they are not currently being protected by vaccines, a situation reported by all the seroprevalence and retrospective studies. The relatively high seroprevalence (76.1%) reported in Enugu State (Eastern Nigeria) is worthy of note when compared with the seroprevalence presented for Borno State in the North (40%) and Ibadan Oyo State in the West (38%) and the overall from different parts of Nigeria (41%) (Table 6).

3.5. PPR in sheep and goats

PPR is a highly contagious disease of sheep and goats caused by a *morbillivirus* in the Paramyxoviridae family, enzootic in many West African countries where it was first diagnosed in 1942. It infects wildlife but the epidemiology remains poorly understood (Couacy-Hymann et al. 2005). The disease occurs in epidemic waves that take advantage of the development of critical populations of native animals that grow after the passing of a previous epidemic. Transmission requires close contact (Taylor and Abegunde 1979). Thus, the disease is more common in extensive pastoral systems with outbreaks in village and urban settings tending to be small and to die out. In its acute form mortality ranges from 10-95%, with higher mortality in young animals and goats. Morbidity and mortality rates tend to be lower in endemic situations (Blood and Radostits 1989). Diagnosis is via agar gel immunodiffusion detection of more virulent forms, counter immunoelectrophoresis, ELISA and PCR among other techniques (OIE 2010e). A homologous PPR vaccine is available and work is underway to develop DIVA vaccines (Diallo et al. 2007). Although there is no cure for the disease, treatment for secondary bacterial and parasitic infections increases recovery rates. Odo (2003) found PPR prevalence in goats in southeast Nigeria ranged from 0-18% depending on the breed. Nigeria last reported PPR to the OIE in 2009 (OIE 2010b).

PPR is recognized as the most important constraint to small ruminant production in Nigeria because of its endemicity and records of morbidity (100%) and mortality (90%) (Nduaka and Ihemelandu 1973; Opasina 1985; Majiyagbe 1992). In sub-Saharan Africa where sheep and goat rearing accounts for about 20% of all meat produced, and in Nigeria where sheep and goats constitute a large part of the economy base of smallholder arable farmers, PPR and its devastating effects on small ruminant herds severely limits and often decimates small ruminant holdings and depletes already poor households of their source of income (Taylor and Abegunde 1979; Opasina 1985; George et al. 2001). Since the earliest documented report of PPR in Western Nigeria in the 1930s, the disease has been reported in all other regions of the country with records of morbidity and mortality ranging from 50–100% and 21–100%, respectively and economic/financial losses due to mortality, poor feed conversion and productivity, and cost of medication (Durtnell and Eid 1973; Nduaka and Ihemelandu 1973; Durojaiye et al. 1983; Ezeibe and Wosu 1997; George et al. 2001).

There is no cure for PPR, though affected animals are commonly managed with a combination of antibiotics, anti-diarrhoeals and fluid therapy (Wosu 1989; Ajala et al. 1997; Ezeibe 2000). Control is currently by vaccination using the PPR vaccine (Kazeem et al. 2002). The vaccination coverage is reportedly very poor as out of the estimated 87.67 million small ruminants' population in Nigeria in 2008 (33.87 million sheep and 53.80 million goats), only 293,537 (0.33%) were reportedly vaccinated (FDL 2010).

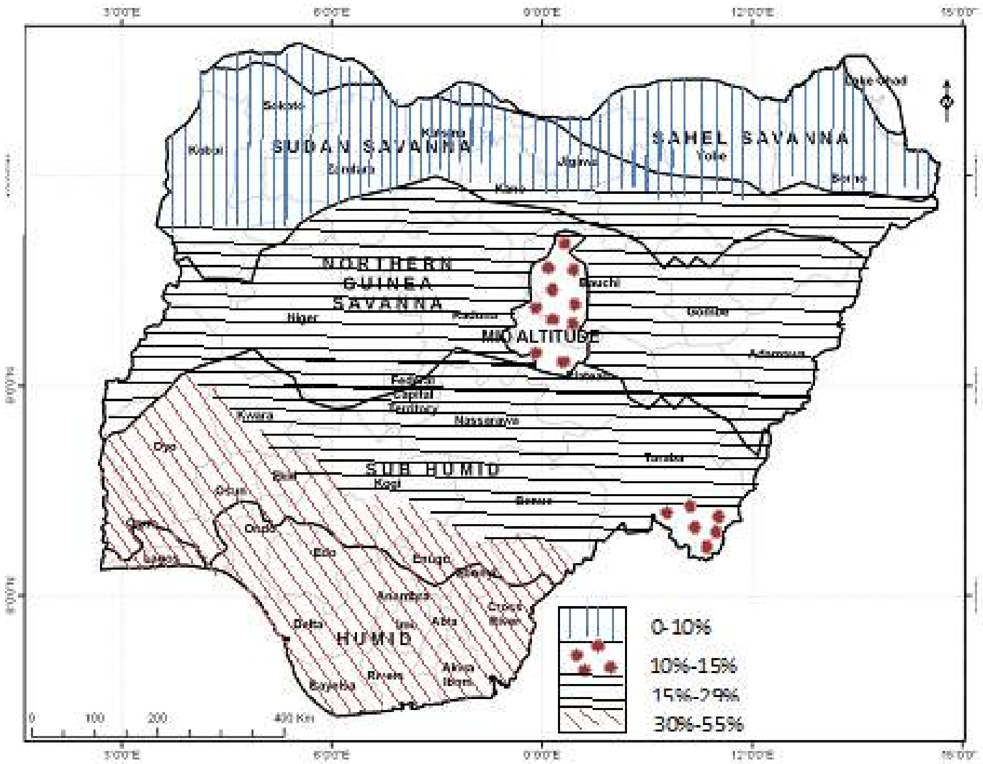

Figure 5: Map of Nigeria showing the distribution and prevalence of PPR.

3.5.1. PPR seroprevalence studies

The earlier documented reports of PPR in Nigeria in the 1930s and the later reports from other regions of the country recorded morbidity and mortality ranging from 50–100% and 21–100%, respectively and heavy economic/financial losses (Durtnell and Eid 1973; Nduaka and Ihemelandu 1973; Durojaiye et al. 1983; Ezeibe and Wosu 1997; George et al. 2001). A three-year retrospective study by Anaette et al. (2003) based on clinical reports showed that between 1998 and 2000, out of the 286 goats diagnosed with PPR, 237died, giving a case fatality rate of 83%.

A seroprevalence study by Taylor (1979) in Maiduguri showed that 43.2% of goats sampled were positive for PPR. Another seroprevalence study by Abegunde et al. (1980) showed that 37% of sheep and 45% of goats in Ibadan were seropositive for PPR. Oyejide et al. (1988) reported a seroprevalence of 30% for goats and 24.5% for sheep in Oyo State. Also, 12.1% and 16.3% seroprevalence were recorded for goats and sheep, respectively, in Plateau State by Oyejide et al. (1988). An abattoir-based prevalence study at the Maiduguri Central abattoir by El-Yuguda et al. (2009) showed a seroprevalence of 41% for sheep and 37.7% for goats.

Table 7: Some of the results of the seroprevalence studies on PPR in sheep and goats in Nigeria

Study location and animal sampled	Prevalence (%)	Source
Maiduguri (goats)	43.2%	Taylor (1979)
Ibadan (sheep)	37.0%	Abegunde et al. (1980)
Ibadan (goats)	45.0%	Abegunde et al. (1980)
Oyo State (sheep)	24.5%	Oyejide et al. (1988)
Oyo State (goats)	30.0%	Oyejide et al. (1988)
Plateau State (sheep)	16.3%	Oyejide et al. (1988)
Plateau State (goats)	12.1%	Oyejide et al. (1988)
Maiduguri (sheep)	41.0%	El-Yuguda et al. (2009)
Maiduguri (goats)	37.7%	El-Yuguda et al. (2009)

3.5.2. Initial conclusions based on PPR literature review

There was no significant change in the seroprevalence of PPR from the earliest documented seroprevalence studies by Taylor in Maiduguri in 1979 (43.2% for goats) to the 2009 studies by El-Yuguda et al. carried out in the location (41.0% for sheep and 37.7% for goats) (Table 7). This suggests that the prevalence of the disease remained high over the 30-year period from 1979 to 2009. It is worthy of note that the reported prevalence for Plateau State was comparatively lower than that of Oyo and Ibadan in the West and Maiduguri in the North (Table 7).

3.6. Trypanosomosis

Tsetse-transmitted trypanosomosis affects cattle, small ruminants and pigs, as well as other species including wildlife. Ruminants are mostly affected by *Trypanosoma congolense, T. vivax* and *T. brucei*. *T. simiae* is the most important trypanosome in pigs. The disease can be acute or chronic and is usually chronic in cattle. The severity of infection differs with species of trypanosome as well as the age and breed of the host. Poor condition in cattle and other stress factors tend to increase the severity of the disease and to cause relapse in chronically infected animals. Diagnosis methods include direct examination of fresh blood or the buffy coat and PCR (OIE 2010c). Trypanotolerant animals tend to dominate the species of cattle kept in tsetse fly zones. Several drugs are available for treatment but tend to have narrow therapeutic indices, making correct dosage essential. Vector control is an important component of any trypanosomosis control program and includes a variety of strategies such as insecticides for animals and the environment, brush clearing, and tsetse screens and traps (Blood and Radostits 1989). Nigeria last reported trypanosomosis to the OIE in 2009 (OIE 2010b). From 1985-86 Opasina and Ekwuruke (1988) found that trade cattle originating from northern Nigeria were infected with *T. congolense* and *T. vivax* at rates of 7.7% and 0.8%, respectively, for a total infection rate of 8.5%. The authors stated that in southern Nigeria, cattle production was largely limited to trypanotolerant species due to the high density of tsetse flies. In northern Nigeria, the prevalence of trypanosomosis increases during the rainy season as populations of the vector increase. Kalu (1994) measured the prevalence of trypanosome infection in trypanotolerant cattle in Benue, northern Nigeria and found that 9.1% of animals sampled were positive for trypanosomes including *T. vivax, T. congolense* and *T. brucei*. *T. gambiense,* the causative agent for human sleeping sickness, has also been recorded in Nigeria (Gray 1972). Resistance to trypanocidal drugs is a growing problem in West African cattle, particularly in the cotton zones (Clausen et al. 2010).

The disease is characterized by anaemia, weight loss, reduced milk yield, impairment of immune function, reproductive disorders and death if affected animals are not treated (Onyiah 1997; Omotainse et al. 2004). The disease occurs throughout the tsetse belt of Africa between latitudes 14°N and 29°S stretching right across the rain forests of Africa extending to the dry areas of the Sahara in the North and the more diffuse southern dry areas of Namibia, adjacent parts of South Africa, Botswana and Angola (PAAT 2001). Tsetse infestation is considered to be one of the most serious pest problems in the world; it covers 36 countries and a total area of 10 million km^2 in Africa within which trypanosomosis limits the keeping of domestic livestock thus denying struggling rural populations the advantages of meat, milk, animal traction and manure to which is added its devastating effects on humans (FAO 1994). Agricultural produce worth USD 4.75 billion is estimated to be lost each year as a result of trypanosomosis and the annual value of lost milk and meat due to trypanosomosis in Africa is estimated at USD 2.75 billion (PAAT 2001). In Nigeria, trypanosomosis is a disease of great economic importance when the mortality, loss in productivity, cost of treatment and other control measures are comprehensively considered (Onyiah 1997; Omotainse et al. 2004; Shaw 2004). Trypanosomosis is rated the most devastating and widespread disease of African livestock (Omotainse et al. 2004).

The control of animal trypanosomosis relies mainly on tsetse and trypanosome elimination and/or eradication, as the antigenic diversity of the trypanosome has made the development of a vaccine against the disease difficult (Doyle 1977; Cross 1990; PAAT 2001). Bush clearing to destroy tsetse fly habitat, elimination of wild animal reservoir hosts and the use of insecticide sprays targeted at the tsetse fly are currently considered ecologically and environmentally unfriendly, leaving only the options of use of trypanocidal drugs, promotion of trypanotolerant livestock, trapping of tsetse and possible use of the sterile insect technique (SIT) as the only viable control measures (PAAT 2001).

3.6.1. Trypanosomosis prevalence studies

Several studies have shown that *Glossina* spp. that transmit trypanosomes of economic importance are widely distributed in all the states of the Nigerian Federation including the Federal Capital Territory (Onyiah 1985), and even the Jos Plateau that used to be considered tsetse-free is now recognized to be infested with trypanosome-bearing *Glossina* (Kalu 1996a; Kalu 1996b, Dede et al. 1997; Omotainse et al. 2004). The occurrence of animal trypanosomosis follows the pattern of tsetse spread in Nigeria, covering about 80% of the land mass between latitude 4°N and 13°N over the five agroecological zones of the country including the highlands of Jos, Mambilla and Obudu which were earlier considered tsetse and trypanosomosis-free (Onyiah 1997; Omotainse et al. 2004).

Earlier surveys of some parts of the northern states of Nigeria between 1989 and 1991 showed an overall trypanosomosis prevalence of 4.3% in cattle, 1.6% in sheep and 1.0% in goats (Onyiah 1997), while studies on cattle in some of the derived savannah and Southern Guinea savannah regions of the southwest and Bendel States of Nigeria showed a prevalence of 2.7% to 6.7% in Ogun and Bendel States, 28.2% in Ondo State, 17.3% in Kwara State and 28.2% in Oyo State (Ikede et al. 1987; Omotainse et al. 2004). Also, a study by Daniel et al. (1993) showed a prevalence of 7.4% and 5.0% in sheep and goats, respectively, in Alkaeri and Gombe LGAs of the former Bauchi State of Nigeria. A more comprehensive survey across the country's agroecological zones between 1993 and 1996 showed a prevalence of 10% for cattle, 8.6% for sheep and 8.1% for goats (Onyiah 1997). An abattoir-based survey by Isamah and Otesile (1997) at the Ibadan municipal abattoir recorded a prevalence of 19.86% out of 559 samples of cattle blood. A survey by Omotainse et al. (2000) on the peri-domestic animals in Konshisha LGA in Benue State showed a prevalence of 57.1% in sheep, 33.9% in goats and 36.8% in pigs, while prevalence rates of 10.04% and 8.85% were recorded for cattle and sheep, respectively, in Yamaltu-Deba LGA of Gombe State (Omotainse et al. 2001). A country report on Nigeria documented an average trypanosome infection rate during 1999-2001 of 10.9% in cattle, 1.9% in sheep and 4.5% in goats from various ecological zones (Pollock 2001). A prevalence of 47.9% was reported at Keffi in Nasarrawa State of Nigeria (Omotainse et al. 2004).

For the Plateau of Jos and Mambilla that were earlier believed to be tsetse- and trypanosomosis-free, following the reported outbreak of trypanosomosis in Bassa LGA of Jos Plateau (Kalu 1996a), infection rates of 38.6% had been reported in cattle in the area, and with reports of other outbreaks in Vom and Barkin Ladi LGA of the Jos Plateau infection rates of 16.4% and 37.6% in cattle in the two respective LGAs were recorded (Kalu 1996b; Kalu and Uzoigwe 1996). A study by Kalejaiye and Omotainse (2001) at Bokkas LGA of Plateau State reported a prevalence of 11.7% in cattle and 17.9% in sheep. Another survey spanning Jos North, Jos South, Bassa and Jos East LGAs of Plateau State reported an overall infection rate of 7.9% in cattle and sheep (Shamaki et al. 2002), while that by Yanan et al. (2003) on the trypanosomosis status of selected herds of trypanotolerant Muturu in the Jos Plateau reported a prevalence of 7.5% out of 107 blood samples screened.

An earlier estimate by Esuruoso (1973) of the economic loss due to animal trypanosomosis in Nigeria was put at NGN 135 million per annum. Estimates by the NITR between 1993 and 1996 in six states showed that losses in cattle alone due to trypanosomosis could amount to NGN 837.2 million annually, and it was postulated that if trypanosomosis were controlled or eradicated, tsetse-infested areas of the country would be able to support an additional 2.5 to 3.2 times the current estimated livestock population (Onyiah 1997).

Table 8: Prevalence of trypanosomosis in the Jos Plateau, Nigeria that was formerly known to be tsetse-free

Study location and animal sampled	Prevalence (%)	Source
Bassa LGA (cattle)	38.6%	Kalu (1996a)
Vom LGA (cattle)	16.4%	Kalu (1996b)
Barkin Ladi LGA (cattle)	37.6%	Kalu and Uzoigwe (1996)
Bokkas LGA (cattle)	11.7%	Kalejaiye and Omotainse (2001)
Bokkas LGA (sheep)	17.9%	Kalejaiye and Omotainse (2001)
Jos North, Jos South, Bassa and Jos East LGAs (cattle and sheep)	7.9%	Shamaki et al. (2002)
Selected trypanotolerant Muturu herds in the Jos Plateau (cattle)	7.5%	Yanan et al. (2003)

3.6.2 Initial conclusions based on review of literature on trypanosomosis

The most significant conclusion of the study on trypanosomosis is that the disease is now widespread all over the country with numerous outbreaks and reports of relatively high infection rate in the Jos Plateau that used to be regarded as being tsetse- and trypanosomosis-free, and even among trypanotolerant Muturu breeds in the Jos Plateau (Table 8).

3.7. PE perspectives on the priority diseases

The presence of diseases from multiple sources and the lack of access to grazing were the two most significant challenges to cattle and small ruminant production in all areas. For swine production, the presence of diseases and lack of access to funds for investing in production were the most important challenges in all areas. For chickens, the most frequently mentioned challenge was the presence of diseases, but there was no significant difference between the various chicken production challenges except in Enugu where presence of disease and predators, as well as lack of access to veterinary services, were significantly more important. In all four species, lack of access to veterinary services was usually the third most frequently mentioned challenge, while lack of access to pharmaceuticals was much less frequently mentioned. These results point to the critical challenge livestock diseases pose to livestock production in all four agroecological zones surveyed. They indicate that inability to access animal health services, because their providers are urban-based, contributes to this situation, while farmers feel that they can usually access the pharmaceuticals necessary for the treatment of disease and would be able to properly apply them should access to veterinary services be improved. Interestingly, lack of access to funding for investment in swine production was mentioned as frequently as the presence of disease. This indicates that farmers would greatly benefit from small credit schemes that would allow them to invest in the sector or improve current backyard practices. The presence of predators ranked as the third most frequent constraint to chicken production in three states, higher in Enugu. This indicates that indigenous chicken producers would benefit from low-cost methods for reducing predation on backyard flocks.

The annual herd/flock level incidence rates of different diseases varied between zones, as would be expected with different host-pathogen-environment interactions. The acute viral diseases (FMD, ASF, PPR and NCD) normally occur as seasonal outbreaks that do not infect all herds/farms in an outbreak zone. This is evident in the wide upper and lower percentiles observed for most incidence ranking and scoring. The bacterial and mycoplasmal diseases, although in some instances highly contagious, will have more patchy distributions with higher herd incidence rates in zones where animal density and housing are higher. Vector-transmitted diseases will be restricted to the distribution of the vector, while parasitic diseases tend to be widespread. However, focusing the study on the five targeted diseases chosen for the Nigeria Integrated Animal and Human Health Management (NIAHHM) project served as a source of bias in the relative incidence scoring exercise.

CBPP, trypanosomosis and FMD were among the frequently mentioned cattle diseases in the study area. CBPP is a highly contagious disease but typically has a patchy distribution in Africa that is believed to be dependent on local risk factors associated with climate, husbandry and control practices (Mariner et al. 2005; Mariner et al. 2006). In Nigeria, it is currently being vaccinated against at different levels of intensity in the different regions and treated by farmers with antibiotics, particularly in Kano. Herd incidence of CBPP would be higher in zones where animals are confined in close proximity such as tightly packed corrals and barns in Enugu and Oyo/Lagos (where it was ranked third). In Kano, CBPP was not reported. This may be due to more frequent

CBPP vaccination and treatment, and because animals are less tightly housed at night. It must also be kept in mind that the seven villages surveyed in Kano are not representative of the state or agroecological zone. Although treatment is widely available for trypanosomosis and CBPP, the high overall case fatality rates of 30% and 23%, respectively, indicate a need to review what drugs are available for these diseases and how to better inform farmers and animal health service providers of their effective use.

The swine diseases with the highest relative annual herd incidences were ASF, mange and helminthosis. Psoroptic mange is highly contagious, leading to hypersensitivity reactions that may contribute to the high livelihood impact ranking reported by farmers. ASF is an acute, highly fatal and contagious disease that occurs in seasonal outbreaks likely to affect many but not all villages in a region. It was reported primarily by respondents in Oyo/Lagos, and by one village each in Enugu and Niger. The overall case fatality rate was 100%, indicating the large impact this disease can have on livelihoods when and where it occurs. However, morbidity and mortality at 15% were surprisingly low, indicating that protective measures, particularly biosecurity, may be part of household and village practice during outbreaks. Helminthosis is a chronic disease of production in all three states (ranked third in Oyo/Lagos), particularly for swine in free-range or cut-and-carry systems.

PPR was the most frequently occurring small ruminant disease, with the relative annual herd incidence of diarrhoea, mange and pneumonia significantly lower than PPR but higher than other diseases. PPR is an acute, highly fatal and contagious disease that occurs in seasonal outbreaks likely to affect many but not all herds in a region, which may explain the unusually low overall morbidity and mortality at 23% and 10%, respectively. The wide range of case fatality rates (36-94%) may indicate the circulation of different strains. Psoroptic mange, particularly in goats, is reported to be highly contagious with a high fatality rate, and it is frequently ranked as having a high impact on livelihoods (Bett et al. 2009). Pneumonia is most often seen in close confinement systems.

NCD was the most frequently occurring chicken disease, with the relative annual flock incidence of ectoparasitosis and pox significantly lower. NCD is an acute to per-acute, moderately to highly fatal and highly contagious disease that occurs in seasonal outbreaks likely to affect many but not all flocks in a region. The relatively low overall morbidity at 51%, mortality at 39% and case fatality at 73% indicate the circulation of less virulent strains of the virus. Pox is also a highly contagious and fatal disease with less seasonality. Ectoparasitosis in chickens is most commonly caused by lice, and most often occurs under conditions of poor housing and sanitation, poor nutrition, or when bird immunity is compromised and ectoparasitosis therefore occurs as a secondary disease.

These results argue for different approaches to disease control depending on the species and zone, with a clear understanding of the epidemiology of each disease in the targeted eco-zones, in most cases targeting control resources to the highest risk areas (Mariner and Roeder 2003; Mariner 2005; Taylor et al. 2006). NCD in chickens has a high annual flock incidence rate throughout the study areas, and points to the need for control programs throughout Nigeria. It is currently argued that highly contagious poultry diseases can most effectively be controlled by identifying critical control points along the value chain rather than adopting blanket vaccination campaigns. In the case of this study, this means identifying high impact points along and at the intersection of the backyard and small-scale commercial value chains (Willyanto et al. 2010). It should be noted, however, that this promising theory has yet to be objectively tested, and that village-level control programs may also contribute to control (Alders et al. 2005). For PPR and mange in small ruminants, a dual approach may be optimal. Disease control options can be identified at the herd level in pastoral systems, targeting PPR vaccination to seasons and geographic locations that bring herds together and supporting access and appropriate use of drugs for mange through private animal health providers at the village level. However, it should be noted that severe mange is nearly impossible to treat, and full recovery for mild to moderate cases often requires two courses of injectable Ivermectin©, emphasizing the need for education of animal health workers and farmers regarding treatment of this disease (Bett et al. 2009). Value chain critical control points should also be identified, particularly in areas where sheep and goats frequently move between herds and markets. Some respondents in this study reported that they do not introduce new animals into their chicken flocks and small ruminant herds to prevent the introduction of NCD and PPR. ASF appears to occur throughout Nigeria in the areas where swine are kept. Like poultry, it appears that most swine are in the backyard sector in Nigeria. ASF control is difficult because of lack of a vaccine and the difficulty to implement sustained biosecurity measures for backyard producers. Recent research has indicated that optimal CBPP control can be achieved by using a herd-level program that combines vaccination of healthy animals with treatment for ill animals (Mariner et al. 2005a). This finding points to the need to ensure access to quality treatment options for CBPP and trypanosomosis at the village level.

The NIAHHM project provides an excellent opportunity to shift the focus of disease control in Nigeria towards effective packages of interventions involving collaboration between the public and private sectors, including in the private sector collaboration between veterinarians and village-level animal health workers, veterinary pharmacists and livestock supply shops, and farmers and farmer associations. Control for each disease should be planned as a package, including training for the private sector (for example, treatment protocols, drug protocols, vaccination protocols and national policies and regulations) as well as support for critical businesses in the private sector. Focus should be on the knowledge, skills and infrastructure necessary to bring veterinary services out of urban centres and closer to the farm level, including business training to established veterinary and pharmaceutical providers to expand their network to village-level workers.

Farmers' perceptions of the importance of different diseases are guided by how a disease impacts their livelihoods. These perceptions will dictate to what extent farmers will invest in the treatment and control of a disease, including payment for veterinary services, vaccination campaign cost recovery and participation in public disease control programs (even free programs require farmers to invest time and resources to participate). For this study NCD, PPR, ASF, CBPP and trypanosomosis were identified as the priority diseases. In all four regions, NCD was perceived to have by far the greatest impact on livelihoods of poultry diseases, likewise ASF in swine. PPR was perceived to have the greatest impact on livelihoods of sheep and goat diseases, but mange was also ranked as highly important in all zones but Niger. This argues for addressing mange as well as PPR in sheep and goats, particularly through reforms that provide greater access to and proper use of pharmaceuticals for ectoparasites through private providers at the village level. The perceived impact of cattle diseases shows more geographic variability. FMD was reported to be the disease with highest impact on livelihoods in Oyo/Lagos and Kano, ranking fourth in the other two zones. This argues for the strengthening of programs for the control of FMD, likely nationwide. CBPP was ranked first or second in terms of livelihoods impact in three zones, with its absence from Kano likely being due to a combination of sampling artifact, established control programs and disease epidemiology. It is known that CBPP is present in the Sudan Savannah, although its perceived impact on livelihoods is unknown. This argues for strengthening of CBPP control programs, including access to both vaccination and treatment options through private providers at the village level. A validated spatially heterogeneous model, taking into account the patchy distribution of CBPP as well as the complex contact structures in pastoral herds, considered the efficacy of mass and elective vaccination programs, treatment and mixed elective vaccination with treatment as control options for the disease. It was found that mass vaccination was unlikely to eradicate CBPP, while a combination of elective vaccination and treatment was most promising for control and provided the greatest benefits to cattle owners (Mariner et al. 2005; Mariner et al. 2006). Trypanosomosis was ranked as a disease with high livelihoods impact in Enugu, arguing for more targeted strengthening of pharmaceutical supply chains for treating this disease, with potential for other regions as well. The growing prevalence of trypanocide resistance in West African trypanosome species deserves notice, and strengthening of programs to control the spread of resistance should be part of a trypanosomosis control policy. A recent study in the West Africa cotton zone found that community-based vector control programs were most effective in limiting the spread of trypanocide-resistant species, and that rational drug use programs were promising (Clausen et al. 2010).

Sustainability through the private sector should be emphasized when strengthening treatment and control programs for CBPP, trypanosomosis, ASF, NCD, PPR and mange. Willingness to pay for treatments for CBPP and PPR vaccine, as well as CBPP and trypanosomosis treatment, indicates that strengthening of control programs for these diseases should embrace an element of cost recovery, if not full cost recovery, particularly for provision of vaccination and treatment services by animal health providers at the village level. In addition, farmers' willingness to pay for treatment for ASF and PPR indicates willingness to invest in the control of these diseases. The majority of respondents indicated that the services of private and public veterinarians are difficult to access because these service providers are urban-based; this argues for restructuring of private services so that primary providers and pharmacies are located at the village level with supervision and support through business agreements with urban-based veterinarians (Ly 2003). Devolving responsibility for primary service delivery in terms of treatments and vaccination to the private sector for these key diseases, with evidence from this study indicating that farmers are willing to support the costs of the private sector, will allow the public sector to concentrate on the mandates of coordination, reporting, investigation and regulation of these diseases (Umali et al. 1992).

The frequent occurrence of diseases that could not be clinically diagnosed by the PE practitioners, who are familiar with the clinical presentation of the common diseases in their regions, argues for a more in-depth study, best done by personnel with more experience in the participatory diagnosis of a range of tropical diseases in West Africa paired with laboratory confirmation (Catley 2000). This approach will allow for the development of an exhaustive list of diseases in the project area that includes local names and case definitions, and a better understanding of the epidemiology of these diseases in each agroecological zone.

Chapter 4: Financial burden of priority diseases in Nigeria and cost-benefit analysis of targeted interventions for their control

This section contains results of the economic model (Section 1.3.2) based on primary and secondary data and information on the epidemiology of the diseases discussed in Chapter 3 and cost and price data summarized in Annex 4. Model outputs include the following:

i. direct and indirect financial burden of inaction including costs of death of animals; weight loss; lost milk, eggs and draught power; and treatment during illness;
ii. costs of targeted interventions including treatment, vaccination, surveillance, vector control, and sanitary measures;
iii. additional benefits, additional costs and net benefits associated with baseline interventions;
iv. BCRs of targeted interventions based on sensitivity analysis; and
v. feasibility of the targeted interventions given the underlying uncertainties permeating the various scenarios at the agroecological and national levels.

Following the national level summary below, the above-mentioned outputs of the model are presented according to the priority diseases and for each disease, a disaggregation by agroecological zone is done. This approach hopefully provides the reader with a national overview of the financial costs and benefits as well as feasibility of the full package before delving into the details for the individual diseases.

4.1. National summary

4.1.1. Direct costs, cost of intervention and financial burden of the five priority diseases

The direct costs, the cost of intervention and the financial burden of the five priority diseases are summarized in Table 9.

Table 9: Direct costs, cost of intervention and financial burden of the five priority diseases (million NGN)

	PPR	CBPP	Trypanosomosis	NCD	ASF	Total
Value of dead animals	4320	567	3289	8456	1209	17,841
Direct costs	4320	1307	8651	8925	1209	24,412
Treatment cost	2395	438	477	0	66	3376
Vaccination cost	64	47	528	0	0	639
Surveillance cost	0	414	319	0	0	733
Cost of actual intervention	2459	899	1325	0	66	4749
Disease burden	6779	2206	9976	8925	1274	29,161

Table 9 indicates that the financial burden of PPR, CBPP, trypanosomosis, NCD and ASF amounts to NGN 29.2 billion. This cost of inaction against the diseases is highest for trypanosomosis in cattle and pigs (NGN 10 billion), followed by NCD in rural chicken (NGN 8.9 billion), PPR in sheep and goats (NGN 6.9 billion), CBPP (NGN 2.2 billion) and ASF (NGN 1.3 billion). The highest direct cost of inaction amounting to NGN 8.9 billion is due to NCD while the least is due to ASF (NGN 1.2 billion). The relative population of these species in Nigeria is considered to have influenced this result. Estimated costs of actual intervention indicate that the most attention has been paid to control of PPR relative to the other diseases, which are primarily from carried out treatments despite the availability of vaccine against this disease.

4.1.2. Cost of targeted intervention against the five priority diseases

The cost of targeted interventions against PPR, CBPP, trypanosomosis, NCD and ASF is summarized in Table 10. The financial burden of these diseases amounting to NGN 29.2 billion justifies targeted and elective intervention based on combinations of treatment, vaccination, vector control and surveillance. The model outputs indicate that the cost of targeted intervention is about NGN 15.5 billion with 8.2% of the amount devoted to treatment, 28.4% to vaccination programs, 34% to vector control and 29.4% to surveillance. In terms of allocation of cost of intervention to the priority diseases, targeted interventions against trypanosomosis would take up 43.8% or NGN 6.8 billion of that budget, PPR 28.8%, CBPP 12.4%, NCD 11.5% and ASF 3.5%. Vector control is critical to the success of targeted interventions regarding trypanosomosis and potentially requires 77.7% of the estimated control cost for that disease, which seems to be relatively high but justified if one accounts for the additional benefit of controlling human trypanosomosis.

Table 10: Cost of targeted interventions against the five priority diseases (million NGN)

	PPR	CBPP	Trypanosomosis	NCD	ASF	Total
Treatment	803	109	319	12	34	1277
Vaccination	2572	127	0	1481	228	4408
Vector control	0	0	5284	0	0	5284
Surveillance	1100	1691	1200	296	279	4566
Cost of targeted intervention	4475	1928	6802	1789	541	15,535

4.1.3. BCA of targeted interventions against the five priority diseases

The additional benefits, additional costs, net benefits and BCRs of targeted interventions against the five priority diseases at baseline and with associated uncertainties at 90%, 80%, 70%, 60%, 50%, 25% and 10% level of control are summarized in Table 11.

Table 11: Additional benefits, additional costs, net benefits (million NGN) and BCR of targeted interventions against the five priority diseases

	PPR	CBPP	Trypanosomosis	NCD	ASF	Total
Additional benefits	4320	1307	8651	8925	1209	24,412
Additional costs	2015	1029	5478	1789	475	10,786
Net benefits	2304	278	3173	7137	733	13,625
Baseline BCR	2.14	1.27	1.55	4.99	2.54	2.50
90%	1.93	1.14	1.39	4.49	2.29	2.25
80%	1.32	1.02	1.24	3.99	2.03	1.92
70%	1.50	0.89	1.08	3.49	1.78	1.75
60%	1.29	0.76	0.93	2.99	1.53	1.50
50%	1.07	0.63	0.77	2.50	1.27	1.25
25%	0.54	0.32	0.39	1.25	0.64	0.63
10%	0.21	0.13	0.15	0.50	0.25	0.25

An additional investment of NGN 10.644 billion will be required to eliminate the losses associated with the five priority diseases. This would lead to NGN 24.412 billion worth of additional benefits with 18% or NGN 2.447 billion accruing due to the interventions on PPR, 2% on CBPP, 23% on trypanosomosis, 52% on NCD in rural chicken, and 5% due to the interventions on ASF. The BCR calculated under these circumstances indicated that investments for the targeted interventions would make economic sense for all the priority diseases if the investments eliminated at least 80% of direct costs associated with the diseases. However, additional investments necessary to eliminate the direct costs would be compromised for CBPP and trypanosomosis if such investments eliminated less than 80% and 70% of the direct costs associated with CBPP and trypanosomosis, respectively. For Nigeria, such investments would be 2.29 times beneficial, being most beneficial for action against NCD (4.99), followed by ASF (2.54), PPR (2.31), trypanosomosis (1.55) and CBPP (1.27). The decision about which disease to give priority for targeted actions should not solely be based on the BCA results. These results are influenced by livestock number and the actual cost of interventions. There are additional factors to consider including service delivery, local context, institutional setup and potential spillover benefits. These factors determine the likelihood and magnitude of success.

4.2. PPR in sheep and goats

4.2.1. Costs and financial burden of PPR

The estimated annual physical losses of sheep and goats due to PPR are presented in Table 12. The total numbers of dead sheep and goats are 154,977 in the Sudan Savannah, 325,679 in the Northern Guinea

Savannah, 53,772 in the Subhumid Zone and 74,621 in the Humid Zone. About 3.3% of the total population of sheep and goats is lost each year as a result of PPR.

Table 12: Estimated physical losses (heads) of sheep and goats due to PPR

Agroecological zone	Number of dead sheep and goats
Sudan Savannah	154,977
Northern Guinea Savannah	325,679
Subhumid	53,772
Humid	74,621
National	609,049

The total value of losses caused by PPR amount to NGN 4.3 billion nationwide (Table 13) with the Northern Guinea Savannah Zone accounting for 52%, followed by the Sudan Savannah Zone (28%), the Humid Zone (12%) and the Subhumid Zone (8%). There are additional costs of the disease that pertain to treatment, vaccination, and surveillance. However, secondary data and expert opinions revealed a lack of any credible surveillance program for PPR and despite the absence of any effective treatment against PPR clinical cases, producers still provide various forms of treatment to their stricken flocks. On average, nearly 50% of the flock holders affirmed having carried out treatment against PPR. Moreover, while a vaccine against PPR is available, seldom did producers utilize it as an option to protect their flocks despite its lower cost (NGN 225, on average) compared to the treatment options (NGN 374, on average). Information collected through PE coupled with compiled secondary data, including a 2008 AU-IBAR report and expert opinions, indicated not more than 2% of sheep and goats were vaccinated across all agroecological zones.

Total expenditure on treatment was evaluated at NGN 2.602 billion nationwide of which 16% was incurred in the Subhumid Zone, 50% in the Northern Guinea Savannah Zone, 12% in the Sudan Savannah Zone and 23% in the Humid Zone. Total expenditure on vaccination was evaluated at NGN 64 million of which 44% was incurred in the Northern Guinea Savannah Zone, 25% in the Sudan Savannah Zone, 13% in the Subhumid Zone and 17% in the Humid Zone (Table 13). Total PPR burden amounts to NGN 6.779 billion with the Northern Guinea Savannah accounting for 51%, the Sudan Savannah for 22%, the Subhumid Zone for 11% and the Humid Zone for 16%.

Table 13: Direct costs, cost of intervention and financial burden of PPR (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Value of dead sheep and goats	1213	2228	354	524	4320
Direct costs	1213	2228	354	524	4320
Treatment cost	278	1190	385	542	2395
Vaccination cost	16	28	9	11	64
Surveillance cost	0	0	0	0	0
Cost of actual intervention	294	1219	394	553	2459
Disease burden	1507	3447	748	1077	6779

4.2.2. Cost of targeted PPR interventions

There are credible options to reduce the burden of PPR on Nigeria. Assuming a target rate of vaccination coverage set at 80% of the small ruminant population at risk, followed by widespread surveillance programs (NGN 28 per animal) up to 70% of the small ruminant population to monitor the disease while bringing the level of treatment and sanitary measures down to 15% of all sick animals to cover eventual loss of vaccinal immunity, then the targeted intervention level would cost NGN 4.475 billion with Sudan Savannah Zone accounting for 27%, the Northern Guinea Savannah Zone for 42%, the Subhumid Zone for 13%, and the Humid zone for 16% of the total. The total cost of targeted intervention and its components are presented in Table 14. Nationwide, 18% of the total cost of targeted intervention would be spent on treatment, 57% on vaccination and 25% on surveillance. The distribution across agroecological zones follows a similar pattern.

Table 14: Cost of targeted interventions against PPR (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Treatment	208	357	116	122	803
Vaccination	653	1134	347	439	2572
Surveillance	362	379	110	249	1100
Cost of target intervention	1223	1870	572	810	4475

4.2.3. BCA of targeted PPR interventions

Avoiding the direct costs associated with PPR requires substantial investments to cover additional costs of intervention. Nationally, these additional costs would amount to NGN 1.873 billion with the Sudan Savannah accounting for 48%, followed by the Northern Guinea Savannah (31%), the Humid Zone (12%) and the Subhumid Zone (9%). The derived net benefits are positive across all agroecological zones amounting to NGN 309 million in the Sudan Savannah Zone, NGN 1.655 billion in the Northern Guinea Savannah, NGN 189 million in the Subhumid Zone and NGN 294 million in the Humid Zone (Table 15).

Table 15: Additional benefits, additional costs, net benefits (million NGN) and BCR of targeted interventions against PPR in sheep and goats

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Additional benefits	1213	2228	354	524	4320
Additional costs	929	651	178	257	2015
Net benefits	284	1577	176	267	2304
BCR	1.31	3.42	1.99	2.04	2.14
90%	1.18	3.08	1.79	1.83	1.93
80%	1.03	1.60	1.18	1.20	1.32
70%	0.91	2.39	1.39	1.43	1.50
60%	0.78	2.05	1.19	1.22	1.29
50%	0.65	1.71	0.99	1.02	1.07
25%	0.33	0.86	0.50	0.51	0.54
10%	0.13	0.34	0.20	0.20	0.21

The BCA also confirms that the targeted interventions would be beneficial across all agroecological zones, as their respective BCRs are all greater than one. The Northern Guinea Savannah Zone would post the highest return on investment (3.42), followed by the Humid Zone (2.04), Subhumid Zone (1.99) and Sudan Savannah (1.31). The results of the sensitivity analysis indicate that the additional investments necessary to eliminate the direct costs would be compromised in the Sudan Savannah Zone if such investments eliminated no more than 70% of the direct costs associated with the disease. For the Northern Guinea Savannah Zone, the Subhumid Zone and the Humid Zone, such investments would remain justified, including if they only eliminated 50% of the direct costs associated with PPR.

4.3. NCD in rural chicken

4.3.1. Costs and financial burden of NCD in rural chicken

Significant numbers of Nigeria's rural chickens die as a result of NCD. Table 16 summarizes the physical losses associated with NCD in Nigeria. Total rural chicken deaths attributed to the disease were estimated at 25.5 million nationwide, 8.6 million in the Sudan Savannah, 10.8 million in the Northern Guinea Savannah, 0.692 million in the Subhumid Zone and 5.4 million in the Humid Zone. There is also significant reduction in egg output as a result of these deaths. Total egg output losses amount to 7.3 million in the Sudan Savannah Zone, 8.2 million in the Northern Guinea Savannah Zone, 1.3 million in the Subhumid Zone and 9.6 million in the Humid Zone, totalling 26.5 million nationwide.

Table 16: Estimated physical losses in rural chickens (thousand head) and egg output (thousand units) caused by NCD

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Poultry death	8608	10,803	692	5454	25,556
Reduction in egg output	7321	8219	1309	9677	26,527

The total value of losses as a result of chicken deaths and the subsequent drop in egg output amount to NGN 8.9 billion nationwide (Table 17) with the Northern Guinea Savannah Zone accounting for 40%, followed by the Sudan Savannah Zone (29%), the Humid Zone (27%) and the Subhumid Zone (4%). There is no treatment for the disease and no credible surveillance program focusing on rural chickens has been implemented for NCD in Nigeria. In addition, the PE indicated no vaccination was carried by flock holders. The actual costs to curb NCD in rural chickens are basically nil. Thus, total disease burden is the same as direct costs of the disease.

There are credible means that can help curb NCD. Some of the available options, including sanitary measures and vaccination, are cheap and could be implemented by flock holders themselves. The unit cost of sanitary measures and vaccination were set at NGN 1.25 and NGN 25, respectively. These rates were based on a study by Musa et al. (2009) and were adjusted to reflect their true market values. Assuming a target vaccination covering 90% of the chicken population at risk is implemented and complemented with a credible NCD surveillance program (NGN 2.8 per chicken) with a 75% target coverage rate, it is reasonable to expect significant reduction of costs associated with chicken deaths due to NCD.

Table 17: Direct costs, costs of interventions and financial burden (million NGN) of NCD in rural chickens

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Chicken death	2435	3472	328	2221	8456
Egg loss	110	140	26	194	469
Direct costs	2545	3611	354	2415	8925
Treatment	0	0	0	0	0
Vaccination	0	0	0	0	0
Surveillance	0	0	0	0	0
Cost of actual intervention	0	0	0	0	0
Disease burden	2545	3611	354	2415	8925

4.3.2. Cost of targeted NCD interventions

Table 18 summarizes the cost of these targeted interventions based on the assumed target rates of vaccination, treatment and surveillance program. The nationwide cost would amount to NGN 1.789 billion. About 83% of the total amount would be spent on vaccination with the Sudan Savannah accounting for 33% followed by the Northern Guinea Savannah (32%), Subhumid Zone (10%) and Humid Zone (24%). Nationwide, 83% of the targeted cost would be spent on vaccination, 16% on surveillance and 1% on sanitary measures.

Table 18: Costs of targeted interventions against NCD in rural chickens (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Sanitary measures	4	4	1	3	12
Vaccination	497	493	127	364	1481
Surveillance	88	81	57	69	296
Cost of targeted intervention	589	578	185	436	1789

4.3.3. *BCA of targeted NCD interventions*

An additional investment of NGN 1.789 billion nationally would be required to eliminate the losses associated with the disease. This would lead to NGN 8.925 billion worth of additional benefits with 20% accruing to the Sudan Savannah, 40% to the Northern Guinea Savannah, 4% to the Subhumid Zone and 24% to the Humid Zone (Table 19). The BCR calculated under these circumstances indicated that investments for the target intervention would make economic sense across all agroecological zones. Such investments would be more profitable in the Northern Guinea Savannah (6.25), followed by the Humid Zone (5.53), Sudan Savannah (4.32) and the Subhumid Zone (1.91).

Table 19: Additional benefits, additional costs, net benefits (million NGN) and BCR of targeted interventions against NCD in local chickens

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Additional benefits	2545	3611	354	2415	8925
Additional costs	589	578	185	436	1789
Net benefits	1956	3033	169	1978	7137
BCR	4.32	6.25	1.91	5.53	4.99
90%	3.89	5.62	1.72	4.98	4.49
80%	3.46	5.00	1.53	4.43	3.99
70%	3.03	4.37	1.34	3.87	3.49
60%	2.59	3.75	1.15	3.32	2.99
50%	2.16	3.12	0.96	2.77	2.50
25%	1.08	1.56	0.48	1.38	1.25
10%	0.43	0.62	0.19	0.55	0.50

The additional investments to eliminate the direct costs associated with NCD in rural chickens would remain justifiable under all scenarios across all agroecological zones, except in the Humid Zone in the event that such investments eliminated 50% or less of direct costs associated to NCD and for all agroecological zones when no more than 10% of the direct costs associated with NCD were eliminated.

4.4. *CBPP*

4.4.1. *Costs and financial burden of CBPP*

CBPP infections cause 1563 cattle deaths in the Sudan Savannah Zone, 7316 in the Northern Guinea Savannah Zone, 609 in the Subhumid Zone, and 901 in the Humid Zone (Table 20).

Table 20: Estimated physical losses in cattle (head), beef (tonnes), meat (tonnes) and draught power (thousand ox-days) caused by CBPP

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Cattle deaths	1563	7318	609	901	10,391
Loss of beef	111	265	5	10	391
Loss of milk	694	1474	25	70	2263
Loss of draught power	61	165	0	0	226

The disease also causes output losses because of its effects on livestock productivity. Total losses in meat output amount to 111 tonnes in the Sudan Savannah Zone, 265 tonnes in the Northern Guinea Savannah Zone, five tonnes in the Subhumid Zone, and 10 tonnes in the Humid Zone. Milk production is adversely impacted by CBPP. The estimated milk loss amounts to 2263 tonnes of milk nationwide with the Northern Guinea Savannah accounting for 65%, followed by the Sudan Savannah for 31%. Working oxen are also affected. The loss in draught power was derived as the sum of draught power loss due to dead oxen and draught power loss due to sick oxen. The latter is the product of the number of chronically affected oxen in each agroecological zone, the number of ox-days worked in a year, and the disease transition rate. On average, 61,000 and 165,000 ox-days were lost in the Sudan Savannah Zone and the Northern Guinea Savannah, respectively.

Table 21: Direct costs, costs of interventions and financial burden of CBPP (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Value of cattle death	99	386	41	41	567
Value of beef loss	78	212	4	7	301
Value of milk loss	104	206	3	13	326
Value of draught power loss	31	82	0	0	113
Direct costs	311	887	47	61	1307
Treatment cost	125	293	8	12	438
Vaccination cost	14	32	1	1	47
Surveillance cost	112	300	1	1	414
Cost of actual intervention	250	624	10	14	899
Disease burden	561	1512	57	75	2206

The monetary value of these losses was assessed nationally and across the four agroecological zones (Table 21). CBPP causes NGN 1.307 billion loss to Nigeria as a whole with the Sudan Savannah Zone accounting for 24% of all losses, the Northern Guinea Savannah for 68%, the Subhumid Zone for 4% and the Humid Zone for 5%. Although lower in magnitude, the output losses are particularly heavy for the Humid and Subhumid Zones, considering their cattle stock levels, which are considerably lower than those of the Sudan Savannah and the Northern Guinea Savannah. While the effectiveness of CBPP treatment has been found dubious by most accounts, treatments are still widely sought out by livestock keepers (80% of surveyed livestock keepers, on average). Moreover, while a vaccine against CBPP is available, coverage rates remain very low across all agroecological zones (25% of surveyed livestock keepers, on average). The average unit vaccination cost is relatively modest (NGN 147) compared to treatment (NGN 411 per animal). Livestock keepers spend close to NGN 438 million nationwide to treat symptoms related to CBPP while a little less than NGN 47 million were spent on vaccination. The disease surveillance program is also limited in scope. The total actual cost of treatment, vaccination and monitoring was evaluated at NGN 899 million of which the Sudan Savannah accounted for 28% and the Northern Guinea Savannah for 68%. CBPP burden on Nigeria was estimated at NGN 561 million in the Sudan Savannah Zone, NGN 1.5 billion in the Northern Guinea Savannah Zone, NGN 57 million in the Subhumid Zone and NGN 75 million in the Humid Zone.

4.4.2. Cost of targeted CBPP interventions

If vaccination coverage against CBPP were raised to cover 80% of animals at risk, treatment rates confined to 10% of infected animals and surveillance program widened to cover 70% of total stock, losses due to CBPP could be avoided. Consequently, the previously calculated direct costs would translate to additional benefits to Nigeria. The total costs of the targeted intervention level are summarized in Table 22. They amount to NGN 1.928 billion nationwide with the Sudan Savannah Zone accounting for 45%, the Northern Guinea Savannah for 52%, the Subhumid Zone for 2%, and the Humid Zone for 1% of the total. Under this strategy, most of the expenditures will be devoted to surveillance. This is because of the relatively low cost of vaccination.

Table 22: Costs of targeted interventions against CBPP in cattle (million NGN)

	Sudan Savannah	Northern Guinea savannah	Subhumid	Humid	National
Treatment	31	73	2	3	109
Vaccination	36	85	2	4	127
Surveillance	804	837	30	21	1691
Cost of targeted intervention	872	995	34	27	1928

4.4.3. BCA of targeted CBPP interventions

The calculated additional benefits amount to NGN 1.307 billion of which 68% will be accrued in the Northern Guinea Savannah, 24% in the Sudan Savannah, 3% in the Subhumid Zone and 5% in the Humid Zone (Table 23).

Table 23: Additional benefits, additional costs, net benefits (million NGN) and BCR of targeted interventions against CBPP in cattle

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Additional benefits	311	887	47	61	1,307
Additional cost	621	370	24	13	1,029
Net benefits	-310	517	23	48	278
BCR	0.50	2.40	1.95	4.59	1.27
90%	0.45	2.16	1.76	4.13	1.14
80%	0.40	1.92	1.56	3.67	1.02
70%	0.35	1.68	1.37	3.21	0.89
60%	0.30	1.44	1.17	2.75	0.76
50%	0.25	1.20	0.98	2.30	0.63
25%	0.13	0.60	0.49	1.15	0.32
10%	0.05	0.24	0.20	0.46	0.13

The additional costs amount to NGN 1.029 billion with the Sudan Savannah accounting for 60% of the total, followed by the Northern Guinea Savannah (36%), the Subhumid Zone (2%) and the Humid Zone (1%). The calculated BCR and net benefits are presented in Table 23. The results indicate that the targeted level of intervention would not be beneficial in the Sudan Savannah as the calculated net losses amount to NGN 310 million. This could be remedied by reducing the targeted surveillance rate as the disease is less prevalent in this zone compared to the others. The same targeted level of intervention would be beneficial in the Northern Guinea Savannah, Subhumid and Humid Zones. The derived BCRs are as follows: 0.64 for Sudan Savannah, 1.52 for the Northern Guinea Savannah, 1.67 for the Subhumid Zone and 2.76 for the Humid Zone. Therefore, these targeted options make economic sense in all agroecological zones except the Sudan Savannah for which the BCR is less than 1. The derived additional investments would remain justifiable in the Northern Guinea Savannah, Subhumid and Humid Zones under all scenarios, except in the Subhumid Zone for the scenario under which these targeted interventions would only eliminate less than 50% of the direct costs associated with CBPP.

4.5. ASF

4.5.1. Costs and financial burden of ASF

ASF causes 60,193 deaths in the pig population in the Northern Guinea Savannah, 39,327 in the Subhumid Zone and 48,658 in the Humid Zone (Table 24). The disease has a high fatality rate across all agroecological zones based on PE and secondary sources of data (98% on average). Thus, all monetary values of losses are solely based on pig mortality because of the acute evolution of the disease.

Table 24: Estimated physical losses in pigs (head) caused by ASF

Agroecological zone	Number of dead pigs
Sudan Savannah	-
Northern Guinea Savannah	60,193
Subhumid	39,325
Humid	48,568
National	148,086

Total financial losses due to pig deaths amount to NGN 1.209 billion with the Humid Zone accounting for 37% of the total, followed by the Northern Guinea Savannah Zone (32%) and the Subhumid Zone (31%) (Table 25). The PE survey reveals that treatments are carried by pig producers but were not found to be effective against the disease by most scientific accounts. On average, 25% of the surveyed pig producers affirmed having carried out treatments against ASF at an average cost of NGN 350 per animal. The results indicate that pig producers nationwide are spending NGN 66 million on treating ASF. There is no vaccination against ASF and while sanitary measures such as tick control, disinfection, carcass disposal and control of pig movements in case of an outbreak could reduce piggery's vulnerability to ASF, the PE survey indicated that very few pig producers implement these measures. The sanitary measures would amount to NGN 35 per animal which is much cheaper than attempted treatments (NGN 350). ASF burden was evaluated at NGN 425 million in the Northern Guinea Savannah, NGN 380 million in the Subhumid Zone and NGN 469 million in the Humid Zone.

Table 25: Direct costs, cost of intervention and financial burden of ASF (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Pig death	-	386	370	453	1209
Total losses	-	386	370	453	1209
Treatment	-	39	10	16	66
Sanitary measure	-	0	0	0	0
Surveillance	-	0	0	0	0
Cost of actual intervention	-	39	10	16	66
Disease burden	-	425	380	469	1274

4.5.2. Cost of targeted ASF interventions

ASF burden on Nigeria pig producers calls for preventive measures. With a target level of ASF surveillance covering about 75% of the livestock population, a full implementation of sanitary measures, including tick, insect and rodent control, and a limited treatment option set at 10%, ASF burden could be significantly reduced or avoided. These targeted interventions would cost NGN 541 million with 58% spent in the Northern Guinea Savannah Zone, 16% in the Subhumid Zone and 25% in the Humid Zone (Table 26). Nationwide, 52% of the expenditure will be on surveillance, 42% on sanitary measures and 6% on treatment. The distribution of expenditure by category follows a similar pattern across all agroecological zones.

Table 26: Costs of targeted interventions against ASF (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Treatment	-	17	7	10	34
Sanitary measure	-	135	36	57	228
Surveillance	-	165	44	70	279
Cost of targeted intervention	-	316	88	137	541

4.5.3. BCA of targeted ASF interventions

Nationally, the additional benefits amount to NGN 1.209 billion for NGN 475 million worth of additional costs, yielding net benefits amounting to NGN 733 million (Table 27).

Table 27: Additional benefits, additional costs, net benefits (million NGN) and BCR of targeted interventions against ASF

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Additional benefits	-	386	370	453	1,209
Additional costs	-	278	77	121	475
Net benefits	-	108	293	332	733
BCR	-	1.39	4.79	3.76	2.54
90%	-	1.25	4.31	3.38	2.29
80%	-	1.11	3.83	3.01	2.03
70%	-	0.97	3.35	2.63	1.78
60%	-	0.83	2.87	2.26	1.53
50%	-	0.70	2.39	1.88	1.27
25%	-	0.35	1.20	0.94	0.64
10%	-	0.14	0.48	0.38	0.25

The distribution of the net benefits across agroecological zones is as follows: 15% for the Guinea Savannah, 40% for the Subhumid Zone and 45% for the Humid Zone. Hence, increased investment to finance these targeted interventions makes economic sense in the three agroecological zones considered, as their respective BCRs are all greater than 1. The Subhumid Zone would significantly benefit from these options as the BCR is about 4.79, followed by the Humid Zone (3.76) and the Guinea savannah (1.39). For the Subhumid and Humid Zones, such investments would remain justifiable, including circumstances under which only 50% of direct costs associated with ASF were eliminated. In the Northern Guinea Savannah, however, the needed additional investments would remain justifiable if at least 70% or more of the direct costs associated with the disease were eliminated.

4.6. Trypanosomosis in cattle and pigs

4.6.1. Costs and financial burden of trypanosomosis in cattle and pigs

Trypanosomosis causes 56,104 cattle deaths in the Northern Guinea Savannah, 1044 in the Subhumid Zone and 2523 in the Humid Zone (Table28).

Table 28: Estimated physical loss caused by trypanosomosis in cattle and pigs

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Cattle death	-	56,104	1044	2523	59,671
Pig death	-	11,075	2975	4694	18,744
Beef	-	2513	22	34	2569
Milk	-	18,632	189	468	19,288
Draught power	-	589	0	0	589
Pig live weight loss	-	2053	251	208	2513

Note: Cattle and pig deaths are in head; beef, milk, and pig live weight losses are in tonnes; draught power losses are in thousand ox-days

The numbers of pig deaths due to trypanosomosis are 11,075 in the Northern Guinea Savannah, 2975 in the Subhumid Zone and 4694 in the Humid Zone (Table 28). The disease causes significant productivity losses. On average, trypanosomosis causes 13% reduction in milk production, 11% reduction in meat off-take and 21% loss in animal traction days (Swallow 2000). These rates were applied to the spreadsheet model to calculate the effects of trypanosomosis morbidity on cattle production. There are additional losses in milk, beef and draught power as a result of cattle mortality. Total losses in beef output amount to 2513 tonnes in the Northern Guinea Savannah Zone, 22 tonnes in the Subhumid Zone and 34 tons in the Humid Zone. Milk losses amount to 18,632 tonnes in the Northern Guinea Savannah, 189 tonnes in the Subhumid Zone and 468 tonnes in the Humid Zone. Draught power losses are confined to the Northern Guinea Savannah and amount to 589,000 ox-days.

For pigs, trypanosomosis causes weight losses (13%) and compromises piggery financial operation by extending their slaughter ages. Total live weight losses were calculated based on pig daily live weight gains (233 grams/day) according to Madubuike et al. (2006) and their slaughter ages, which vary slightly across agroecological zones. Daily live weight gains and slaughter ages were used to compute the average slaughter weight of pigs across agroecological zones. The calculated national average pig slaughter weight is 84 kg. The rate of live weight losses was applied to the normal live weight at slaughter and the number of pigs affected by trypanosomosis that did not die was used to calculate the total live weight losses. The results indicate pig live weight losses as a result of trypanosomosis amount to 2053 tonnes in the Northern Guinea Savannah Zone, 251 tonnes in the Subhumid Zone and 208 tonnes in the Humid Zone.

The monetary values of output losses due to trypanosomosis are significant. Nationwide, they amount to almost NGN 8.651 billion with the Northern Guinea Savannah bearing 94% of the costs, followed by the Humid Zone (4%) and the Subhumid Zone (2%) (Table 29). The monetary value of pig deaths and live weight losses amounts to NGN 442 million nationwide of which 63% is borne by producers in the Northern Guinea Savannah zone, 18% by those in the Subhumid Zone and 19% by those in the Humid Zone. Nationwide, pig producers bear 5% of total losses due to trypanosomosis. Losses due to morbidity are almost two times (three times in the Sudan Savannah Zone) higher than losses due to mortality. For cattle, however, while losses due to morbidity are comparable to those due to mortality in the Humid Zone, they are more than one and a half times higher in the Sudan Savannah and two times lower in the Subhumid Zone.

Table 29: Estimated value of physical loss in pigs and cattle caused by trypanosomosis (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Cattle death	-	2962	70	114	3146
Pig death	-	71	28	44	143
Beef	-	2010	17	26	2053
Milk	-	2608	19	87	2715
Draught power	-	294	0	0	294
Live weight loss	-	208	51	40	299
Total losses	-	8155	185	311	8651

Numerous options are utilized to control trypanosomosis. The PE survey indicated that 80% of surveyed livestock keepers have used trypanocide for treatment and prophylactic purposes. Vector control through use of traps to catch tsetse flies, SIT, aerial spraying technique (AST), ground spraying technique (GST) and pour-on insecticide are possible options to curb the disease. The costs of these techniques vary by country. On average, AST costs USD 400/km^2, GST USD 300/km^2, traps USD 45/km^2 and SIT USD 800/km^2 (Cattand et al. 2006). Additionally, animals can also be treated with insecticide on a limited basis. The cost amounts to USD 1.3/head of cattle per year (RIU undated) which translates to USD 0.65/livestock unit. These techniques have been used over the years and in various degrees in Nigeria. However, the current rate is very limited, about 5% on average based on the information gathered from various sources and expert assessments. There is also a surveillance program of the disease albeit small in varying scales across agroecological zones. This surveillance covers about 25% of the Northern Guinea Savannah, 27% of the Subhumid Zone and 16% of the Humid Zone. Pig producers' use of trypanocide varies by agroecological zone. The PE survey revealed 75% of pig producers in the Northern Guinea Savannah, 40% in the Subhumid and 20% in the Humid Zone have used trypanocide for treatment. Limited vector control through use of pour-on insecticide on pigs and very limited surveillance program of trypanosomosis on pigs are currently practised, and in our estimation at a rate of no more than 5% of the population across all agroecological zones. The information was used to compute the actual cost of treatment, monitoring and vector control. The results are summarized in Table 30.

Table 30: Direct costs, cost of intervention and financial burden of trypanosomosis in cattle and pigs (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Treatment	-	437	16	24	477
Vector control	-	494	19	15	528
Surveillance	-	296	14	9	319
Cost of actual intervention	-	1227	49	48	1325
Disease burden	-	9382	234	359	9976

Note: The Sudan Savannah was not considered as the incidence of trypanosomosis there was considered minimal

The total cost of actual intervention amounts to NGN 1.325 billion with 92% spent in the Northern Guinea Savannah, followed by the Subhumid and Humid Zones with 4% each. The calculated disease burden is evaluated at NGN 9.976 billion nationwide with 94% borne by the Northern Guinea Savannah, 2% by the Subhumid Zone and 4% by the Humid Zone.

4.6.2. Cost of targeted trypanosomosis interventions

The disease burden is heavy but it could be alleviated by sustained targeted intervention that seeks to increase vector control programs up to 50% of the livestock population at risk, using a combination of methods that include SIT (10%), traps (20%), AST (20%) and GST (50%). The surface area needed to be cleared from tsetse was found by assuming 40 head of cattle per square kilometre, which translates to 215,530 km^2 nationwide with 94% in the Northern Guinea Savannah, 4% in the Subhumid Zone and 2% in the Humid Zone. This represents about 24% of Nigeria's total land mass which is a reasonable target, considering that tsetse flies are not present in the Sudan Savannah Zone and areas with human settlements are not suitable for the tsetse fly. Moreover, livestock populations in the Humid and Subhumid Zones are trypanotolerant and too low to warrant implementing widespread vector control programs. The Pour-on® insecticide was restricted to pigs because of the nature of the production system. The use of trypanocide will be reduced to 50% and disease monitoring increased to 75%. Based on these target rates, total costs of targeted interventions would amount to NGN 6.8 billion with 93% spent in the Northern Guinea Savannah Zone, 2% in the Subhumid Zone and 3% in the Humid Zone (Table 31).

Table 31: Cost of targeted interventions against trypanosomosis in cattle and pigs (million NGN)

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Treatment	-	276	14	28	319
Vector control	-	4938	194	152	5284
Surveillance	-	1034	75	91	1200
Cost of targeted intervention	-	6248	283	271	6802

4.6.3. BCA of targeted trypanosomosis interventions

Additional costs to control trypanosomosis and its effects on cattle and pigs yield additional benefits that amount to NGN 8.651 billion nationwide (Table 32). While the targeted interventions yield NGN 3.173 billion of net benefits at the national level, they may not be justified across all agroecological zones. The calculated net benefits would amount to NGN 3.134 billion in the Northern Guinea Savannah Zone and N88 million in the Humid Zone. However, in the Subhumid Zone such interventions would incur net losses amounting to NGN 49 million. A BCA was carried out and the described options would be economically justifiable in the Northern Guinea Savannah and Humid Zones, as their respective BCRs are greater than 1. This is not the case in the Subhumid Zone, perhaps indicating alternative strategies such as the introduction of trypanotolerant breeds would be more appropriate. A sensitivity analysis was conducted and the results indicate that for trypanosomosis in cattle and pigs, additional investments would remain justifiable in the Northern Guinea Savannah and Humid Zones, provided they eliminated at least 70% of direct costs associated with the disease.

Table 32: Additional benefits, additional costs, net benefits (thousand NGN) and BCR of targeted interventions against trypanosomosis in pigs and cattle

	Sudan Savannah	Northern Guinea Savannah	Subhumid	Humid	National
Additional Benefits	-	8155	185	311	8651
Additional Cost	-	5021	234	223	5478
Net Benefits	-	3134	-49	88	3173
BCR	-	1.62	0.79	1.40	1.58
90%	-	1.46	0.71	1.26	1.39
80%	-	1.30	0.63	1.12	1.24
70%	-	1.14	0.55	0.98	1.08
60%	-	0.97	0.48	0.84	0.93
50%	-	0.81	0.40	0.70	0.77
25%	-	0.41	0.20	0.35	0.39
10%	-	0.16	0.08	0.14	0.15

Chapter 5: Summary, conclusions and recommendations

The wide disparity between the estimated livestock population and the vaccination figures as reported by FDL is worthy of note (Table 33). The very low calculated percentage vaccination coverage is also critically worthy of being worried about especially in a country that relies on vaccination as the major control tool. It should be noted that none of the three priority livestock diseases that can be vaccinated against gets up to 1% vaccination coverage. With only less than 1% vaccination coverage, waves of disease outbreaks and high prevalence rates of these diseases should not be a surprise.

Table 33: Livestock population and vaccination figures, and calculated percentage vaccination coverage for three of the priority livestock diseases in Nigeria

Name of priority diseases	2008 population estimate for animals involved(1)	2008 vaccination figures(1)	Calculated percentage vaccination coverage for 2008
CBPP (cattle)	15,967,361(2)	54,492	0.34%
NCD (chicken)	169,200,839(3)	791,934	0.47%
PPR (sheep and goats)	52,93,9621(2)	293,537	0.47%

(1) Each value is the total reported figure for the whole nation. Source: FDL (2010)
(2) Indicates number has been adjusted downward to reflect the latest population data
(3) Includes chickens from commercial operations

Most farmers and livestock owners are not literate and often do not know of the existence and value of these vaccines. In most cases the vaccines are not available in the rural areas where most farms and farmers are located. It is therefore recommended that the government designs and consistently implements a vaccination program tailored to accommodate and reach rural farmers who constitute the majority of livestock owners in Nigeria. The recent development of a thermostable NCD vaccine targeted at local birds is a welcome development that is in line with the concept of 'vaccines and vaccinations tailored to existing local management systems'. What remains is to inform farmers about the value of the vaccines and make them available everywhere. If possible, the vaccines and vaccination should be provided free, at least initially. Vaccine availability and affordability may not be enough to mount an effective vaccination campaign. Experience has taught that devising an effective delivery system is one of the most difficult components to implement in these types of operations. In this regard, special attention should be accorded to this by those involved in project design and implementation.

However, such a vaccination program requires an extensive awareness campaign (equal in intensity to that used in the expanded program on immunization [EPI] for children) to enlighten and educate rural farmers on the need and value of having their livestock vaccinated. If possible, livestock vaccination campaigns and their awareness programs should run concurrently with the EPI which has recorded a very high level of coverage countrywide. Running the two campaigns together will save costs by making use of the cold chain facilities already in place for EPI, and make for general acceptability as the farmers will wish to save their animals just as they save their children from preventable diseases.

Worthy of note also is the very low reported incidence for each of these priority livestock diseases yet outbreaks, mortalities and losses from these diseases are rampant and their seroprevalence rates are very high. It is therefore recommended that the procedures and bottlenecks involved in formal disease reporting be made simpler (e.g. syndrome surveillance/reporting) to accommodate smallholder rural farmers who own most of the livestock. The current procedure of carrying out disease reporting at the state and VTH levels excludes a large majority of outbreaks and cases. National disease reporting should recognize that most of the farmers and livestock owners are rural smallholders, thus disease reporting should go down to the community and local government levels and from there up to the state and federal levels, because in principle even the seemingly small outbreaks that occur in the rural areas are as important as those that occur in big farms (only a few of which often exist in a state). Also the procedure for the assessment of financial and economic costs of disease burden and outbreaks should be made simpler such that even at the community or local government level, as outbreaks are reported, the associated costs are also evaluated and attached to the reports.

As more research into better methods of tackling and controlling animal trypanosomosis is in progress, good quality trypanocides should be made available to treat infected animals. Drug quality and usage should be monitored by the appropriate authorities to minimize sub-therapeutic dosing that may lead to development of resistance to existing trypanocides. Efforts should be strengthened at the local level at the nation's faculties of veterinary medicine and research institutes to develop new trypanocides or at least drug combinations that will be more effective than the existing trypanocides.

The PE component of the study was designed to generate a large body of diverse data from four agroecological zones. However, the study design was limited in that only a small number of non-randomized villages were surveyed in each zone that tended to be geographically clustered. Therefore, the study results can only be taken to be representative of the villages surveyed, not of the states or zones in which they were carried out. Comparisons between zones should be made with caution, as surveys in each zone were carried out by different teams and team effect cannot therefore be ruled out for any difference seen. When similar rapid assessments are designed in the future this limitation can be overcome in a variety of ways: (i) villages to be surveyed can be chosen following a randomized and representative sample framework, (ii) villages surveyed can be geographically diverse rather than clustered, (iii) all survey teams can work in all areas, (iv) the variety of topics and data to be covered can be limited to allow for more villages to be surveyed per unit time and (v) the topics to be covered can be limited to those for which no other data are available through secondary sources. The first three suggestions would require a greater dedication of resources to the fieldwork component of a study; the final two would require a better understanding of the type and quality of secondary data available prior to finalization of the fieldwork design.

The PE component of the study was designed to meet the needs of a static and structured spreadsheet modelling approach to quantify the economic impacts of not controlling ASF, CBPP, NCD, PPR and trypanosomosis. However, the diversity of the data requested was unrealistic in terms of the time and resources available for the study, leading to sample sizes for individual parameters that were non-representative. In the future, this limitation can be overcome by limiting the rapid assessment to a smaller set of checklist topics that have been shown to drive impact in preliminary model sensitivity analysis, allowing for more comprehensive and representative data for a limited set of key model parameters. This can be achieved by parameterizing the model first with data available through government statistics, literature and reports, running the model, and identifying those key parameters that are driving the model. PE can then be used to gather in-depth data on those parameters in one agroecological zone, and used to determine the mean and variance that can be expected in the data available for those parameters in that agroecological zone. These levels of variability can then be used to calibrate the model in each of the agroecological zones. If the estimated level of uncertainty or variance is expected to differ between zones, field data on the driving parameters should be collected in each zone.

Outputs of the economic spreadsheet model indicate that financial burden of ASF, CBPP, NCD, PPR and trypanosomosis amounts to NGN 29.2 billion. This cost of inaction against the diseases is highest for trypanosomosis in cattle and pigs (NGN 10 billion), followed by NCD in rural chicken (NGN 8.9 billion), PPR in sheep and goats (NGN 6.8 billion), CBPP (NGN 2.2 billion) and ASF (NGN 1.3 billion). The highest direct cost of inaction amounting to NGN 8.9 billion is due to NCD while the lowest is due to ASF (NGN 1.2 billion). *This justifies targeted and elective interventions based on combinations of treatment, vaccination, vector control and surveillance. The model outputs indicate that the cost of targeted interventions is about NGN 15.5 billion with 8.2% of the amount devoted to treatment, 28.4% to vaccination programs, 34% to vector control and 29.4% to surveillance. In terms of allocation of cost of intervention to the priority diseases, targeted interventions against trypanosomosis would take up 43.8% or NGN 6.8 billion of that budget, PPR 28.8%, CBPP 12.4%, NCD 11.5% and ASF 3.5%. Vector control is critical to the success of targeted interventions regarding trypanosomosis and potentially requires 77.7% of the estimated control cost for that disease. The importance share of vector control may be problematic to some but it is reasonable if one accounts for the added spillover benefits such as control of human trypanosomosis.*

An additional investment of NGN 10.8 billion will be required to eliminate the losses associated with the five diseases. This would lead to NGN 24.4 billion worth of additional benefits with 18% or NGN 2.4 billion accruing due to intervention against PPR, 2% against CBPP, 23% against trypanosomosis, 52% against NCD in rural chicken and 5% against ASF. The BCRs calculated under these circumstances indicated that investments for the target intervention would make economic sense for all the priority diseases if the investments eliminated at least 80% of direct costs associated with the diseases. *Additional investments necessary to eliminate the direct costs would be compromised for CBPP and trypanosomosis if such investments eliminated less than 80% and 70% of the direct costs associated with CBPP and trypanosomosis, respectively. For Nigeria, such investments* *would be 2.29 times profitable, being most profitable for action against NCD (4.99), followed by ASF (2.54), PPR (2.31), trypanosomosis (1.55) and CBPP (1.27).*

At the individual disease level, avoiding the direct costs associated with PPR requires substantial investments to cover additional costs of intervention. Nationally, these additional costs would amount to NGN 1.9 billion with the Sudan Savannah accounting for 48% of the amount, followed by the Northern Guinea Savannah (31%), the Humid Zone (12%) and the Subhumid Zone (9%). *The derived net benefits are all positive across all agroecological zones amounting to NGN 309 million in the Sudan Savannah, NGN 1.7 billion in the Northern Guinea Savannah, NGN 189 million in the Subhumid Zone and NGN 294 million in the Humid Zone.*

An additional investment of NGN 1.8 billion will be required to eliminate the direct costs associated with NCD in rural chicken. This would lead to NGN 8.9 billion worth of additional benefits with 20% accruing to the Sudan Savannah, 40% to the Northern Guinea Savannah, 4% to the Subhumid Zone and 24% to the Humid Zone. The BCRs calculated under these circumstances indicated that investments for the target intervention would make economic sense across all agroecological zones. Such investments would be more profitable in the Northern Guinea Savannah (6.25), followed by the Humid Zone (5.53), Sudan Savannah (4.32) and Subhumid Zone (1.91). *The additional investments to eliminate the direct costs associated with NCD in rural chicken would remain justifiable under all scenarios across all agroecological zones, except in the Humid Zone in the event that such investments eliminated 50% or less of direct costs associated with NCD.*

For CBPP, the calculated additional benefits amount to NGN 1.3 billion of which 68% will be accrued in the Northern Guinea Savannah, 24% in the Sudan Savannah, 3% in the Subhumid Zone and 5% in the Humid Zone. The additional costs amount to NGN 1 billion with the Sudan Savannah accounting for 60% of the total, followed by the Northern Guinea Savannah (36%), the Subhumid Zone (2%) and the Humid Zone (1%). The results indicate that the targeted level of intervention would not be beneficial in the Sudan Savannah as the calculated net losses amount to NGN 310 million. This could be remedied by reducing the targeted surveillance rate as the disease is less prevalent in this zone compared to the others. The same targeted interventions would be beneficial in the Northern Guinea Savannah, the Subhumid and the Humid Zone. The derived BCRs are as follows: 0.64 for the Sudan Savannah, 1.52 for the Northern Guinea Savannah, 1.67 for the Subhumid Zone and 2.76 for the Humid Zone. Therefore, these targeted options make economic sense in all agroecological zones except the Sudan Savannah for which the BCR is less than 1. *The derived additional investments would remain justifiable in the Northern Guinea Savannah, Subhumid and Humid Zones under all scenarios, except in the Subhumid Zone for the scenario under which these targeted interventions would only result in 50% elimination of the direct costs associated with CBPP.*

The additional benefits of eliminating ASF amount to NGN 1.209 billion for NGN 475 million worth of additional costs, yielding net benefits amounting to NGN 733 million. The distribution of the net benefits across agroecological zones is as follows: 15% for the Northern Guinea Savannah, 40% for the Subhumid Zone and 45% for the Humid Zone. Hence, increased investment to finance these targeted interventions makes economic sense in the three agroecological zones considered, as their respective BCRs are all greater than 1. The Subhumid Zone will significantly benefit from these options as the BCR is about 4.79, followed by the Humid Zone (3.76) and the Guinea savannah (1.39). *For the Subhumid and Humid Zones, such investments would remain justifiable, including circumstances under which only 50% of direct costs associated with ASF were eliminated. In the Northern Guinea Savannah, however, the needed additional investments would remain justifiable as long as 70% or more of the direct costs associated with the disease were eliminated.*

Additional costs to control trypanosomosis and its effects on cattle and pigs yield additional benefits that amount to NGN 8.651 billion nationwide. While the targeted interventions yield NGN 3.173 billion worth of net benefits at the national level, they may not be justified across all agroecological zones. The calculated net benefits amount to NGN 3.134 billion in the Northern Guinea Savannah Zone and NGN 88 million in the Humid Zone. However, in the Subhumid Zone such interventions would incur net losses amounting to NGN 49 million. A BCA was carried out and the described options would be economically justifiable in the Northern Guinea Savannah Zone and the Humid Zone as their respective BCRs are greater than 1. This is not the case in the Subhumid Zone, perhaps indicating a need for alternative strategies to deal with trypanosomosis. *For trypanosomosis in cattle and pigs, additional investments remain justifiable in the Northern Guinea Savannah and the Humid Zone provided they would eliminate at least 70% of direct costs associated with the disease.*

Chapter 6: References

Abdu PA, George JB and Umoh JU. 1985. A study of poultry diseases diagnosed at Zaria from 1981 to 1984. *Nigerian Veterinary Journal* 14: 63-65.

Abegunde A, Nawathe DR, Okeke ANC and Opasina BA 1980. Aetiology of Kata in dwarf goats. *Nigerian Veterinary Journal* 9: 48-52.

Adene DF. 1991. Poultry health: The growing limitation and emerging remedy for development in the poultry industry. Inaugural lecture, University of Ibadan, Ibadan University Press, Nigeria.

Adu FD, Edo U and Sokale B. 1986. Newcastle disease: The immunological status of Nigerian chickens. *Tropical Veterinarian* 24: 149-152.

African Union Interafrican Bureau for Animal Resources (AU-IBAR). 2008. Pan African Animal Health Yearbook 2008. Nairobi, Kenya, available online at http://www.au-ibar.org

Ajala OO, Daneji AI, Kumshe HA and Oyeyemi MO. 1997. Treatment of *peste des petits ruminants* (PPR) in pre-weaned West African dwarf goat kids. *Tropical Veterinarian* 15: 39-42.

Alders RG, Bagnol B and Young MP. 2007. *Technically sound and sustainable Newcastle disease control in village chickens: lessons learnt over fifteen years.* Proceedings of the World's Poultry Science Association Asian Pacific Federation Working Group on Small-Scale Family Poultry Farming Symposium. Bangkok, Thailand, 5-6 March 2007. pp. 26-33.

Alexander AJ. 1996. Newcastle disease and others. In: Jordan FTN and Pattison M (eds.), *Paramyoviridae*. 4th edition. Saunders, London, pp. 139 -155.

Aliyu MM and Kyari Z. 2005. Prevalence of contagious bovine pleuropneumonia and bovine tuberculosis-like lesions in slaughtered cattle in Plateau State, Nigeria. *Sahel Journal of Veterinary Science* 4: 25 – 31.

Aliyu MM. 2002. Contagious bovine pleuropneumonia (CBPP) in some states of Northern Nigeria: status, immunological techniques and polymerase chain reaction in the diagnosis of the disease. Thesis.

Aliyu MM, Egwu GO and Ameh JA. 2003. Comparison of two immune diagnostic techniques for detection of *Mycoplasma mycoides* subspecies *mycoides* SC in cattle. *Tropical Veterinarian* 21: 23 – 29.

Aliyu MM, Obi TU and Egwu GO. 2000. Prevalence of contagious bovine pleuropneumonia (CBPP) in northern Nigeria. *Preventive Veterinary Medicine* 47: 263-269.

Aliyu MM, Obi TU, Oladusi LA, Egwu GO and Ameh JA. 2003. The use of competitive ELISA in combination with abattoir survey for CBPP surveillance in Nigeria. *Tropical Veterinarian* 21: 35-41.

Alleweldt F, Upton M, Kara S, Pflug S, Cuc NTK, Béteille R, Doré M-P and von Gall P. 2009. *Cost of national prevention systems for animal diseases and zoonoses in developing and transition countries.* World Organization for Animal Health (OIE), 381p.

Ambali AG, Abubakar WB and James TE. 2003. An assessment of poultry health problems in Maiduguri, Borno State, Nigeria. *Tropical Veterinarian* 21: 138-145.

Amos TT. 2006. Analysis of backyard poultry production in Ondo State, Nigeria. *International Journal of Poultry Science* 5: 247-250.

Annaette IA and Ogundipe GAT. 2003. Prevalence of *peste des petits ruminants* (PPR) in goats in Lagos, Nigeria. *Nigerian Veterinary Journal* 24: 123-125.

Arowolo ROA. 1996. *Protecting our livestock resources.* 1995-96 Inaugural Lecture. University of Ibadan, Ibadan University Press, Nigeria.

Atinmo O and Akinyele O. 1983. *Nutrition and food policy for Nigeria.* National Institute for Policy and Strategic Studies, Kuru, Jos pp. 3-10.

Baba SS, El-Yuguda AD and Baba MM. 1998. Serological evidence of mixed infections with Newcastle disease and egg drop syndrome 1976 viruses in village chickens in Borno State, Nigeria. *Tropical Veterinarian* 16: 137-141.

Babalobi OO, Olugosa BO, Oluwayolu DO, Ijagbone IF, Ayoade GO and Agbede SA. 2007. Analysis and evaluation of mortality losses of the 2001 African swine fever outbreak, Ibadan, Nigeria. *Tropical Animal Health and Production* 39: 533-542.

Bala A, Daneji AI, Luther NJ, Chafe U, Fasina FO, Ifende VI, Emenna P, Bolajoko MP and Ubandawaki S. 2009. Survey of antibody to African swine fever virus (ASFV) in free rabge domestic pigs, Zuru Kebbi State. Vom *Journal of Veterinary Science* 6: 58-60.

Bennett R, Christiansen K and Clifton-Hadley R. 1999. Estimating the costs associated with endemic diseases of dairy cattle. *Journal of Dairy Research* 66:455-459.

Berepabo NA, Wekhe SN and Akori W. 1991. A survey of some major livestock and poultry diseases in Rivers State. *Journal of Animal Production Research* 11: 35-44.

Bett B, Jost C, Allport R and Mariner J, 2009. Using participatory epidemiological techniques to estimate the relative incidence and impact on livelihoods of livestock diseases amongst nomadic pastoralists in Turkana South District, Kenya. *Preventive Veterinary Medicine* 90(3-4): 194-203.

Blanch R. 1994. The expansion and adaptation of Fulbe pastoralism to sub-humid and humid conditions in Nigeria. *Cahiers d'Études Africaines* 34: 197-212.

Blood DC and Radostits OM. 1989. *Veterinary Medicine: a textbook of the diseases of cattle, sheep, pigs, goats and horses.* Bailiere Tindall Ltd., London.

Brandenburg B. 2008. *The animal health surveillance system and avian influenza in Nigeria.* Consultancy report produced for the International Livestock Research Centre. Ibadan, Nigeria.

Cameron A. 1997. *Active surveillance and GIS as components of an animal health information system for developing countries – Thailand and Laos as examples* (Unpublished doctoral dissertation). University of Queensland, Australia.

Cassel GH, Clyde Jr WA and Daves JK. 1985. Mycoplasma respiratory infections. In: Razin S and Barile MF (eds.), *Mycoplasmas*. Academic Press Inc., Orlando, USA. pp. 65-106.

Catley A. 2000. *Learning about* liei*: Participatory diagnosis of the chronic wasting problem in cattle in southern Sudan.* International Institute for Environment and Development, London.

Cattand P, Desjeux P, Guzmán MG, Jannin J, Kroeger A, Médici A, Musgrove P, Nathan MB, Shaw A and Schofield CJ. 2006. Tropical diseases lacking adequate control measures: Dengue, leishmaniasis, and african trypanosomiasis. In: Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, Jha P, Mills A and Musgrove P (eds), *Disease control priorities in developing countries*. 2nd edition, Oxford University Press and the World Bank, pp. 451–466.

CBN. 2008. *Central Bank of Nigeria (CBN) draft annual report and financial statements for the year ended 31st December 2008.* Central Bank of Nigeria.

Chilonda P and Otte J. 2006. Indicators to monitor trends in livestock production at national, regional and international levels. *Livestock Research for Rural Development*, 18, Article #117. Last retrieved 20 September 2010 from http://www.lrrd.org/lrrd18/8/chil18117.htm.

Clausen PH, Bauer B, Zessin KH, Diall O, Bocoum Z, Sidibe I, Affognon H, Waibel H, Grace D and Randolph T. 2010. Preventing and containing trypanocide resistance in the cotton zone of West Africa. *Transboundary and Emerging Diseases* 57: 28-32.

Couacy-Hymann E, Bodjo C, Danho T, Libeau G and Diallo A. 2005. Surveillance of wildlife as a tool for monitoring rinderpest and *peste des petits ruminants* in West Africa. *Revue Scientifique et Technique* 24(3): 869-877.

Cross GAM. 1990. Cellular and genetic aspects of antigenic variation in trypanosomes. *Annual Review of Immunology* 8: 83-89.

Daniel AD, Joshua RA and Kalejaiye JO. 1993. Prevalence of trypanosomosis in sheep and goat in a region of Northern Nigeria. *Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux* 47: 295–297.

Dede PM, Omoogu GA, Uzoigwe NR, Njoku CI, Daniel AD, Dadah AJ and Ajagbona BO. 1997. *Evaluation of tsetse and trypanosomosis situation on the Jos Plateau, a tsetse free zone in Central Nigeria.* Proceedings of the 28th Annual Conference of Entomological Society of Nigeria, Maiduguri, Nigeria, 6-9 October 1997.

Diallo A, Minet C, Le Goff C, Berhe G, Albina E, Libeau G and Barrett T. 2007. The threat of *peste des petits ruminants*: Progress in vaccine development for disease control. *Vaccine* 25: 5591–5597.

Doyle JJ. 1977. Antigenic variation in the salivarian trypanosomes. *Advances in Experimental Medicine and Biology* 93: 31 – 63.

Durojaiye OA, Obi TU and Ojo MO. 1983. Virological and serological diagnosis of *peste des petits ruminants*. *Tropical Veterinarian* 1: 13-17.

Durtnell R and Eid FIA. 1973. Preliminary note on a disease of goats resembling *peste des petits ruminants* (PPR) in Sokoto province , North Western Nigeria. *Nigerian Veterinary Journal* 2: 18 – 21.

Duru S, Saidu L, Akpan GN, Jonathan GE, Kabir M, Olugbemi TS, Abdu SB, Yashim SM and Hamman I. 2008. *Prevalent disease in local poultry: a case study of Zaria area of Kaduna State.* Proceedings of the 13th Annual Conference of the Animal Science Association of Nigeria (ASAN), Zaria, Nigeria, 15-19 September 2008, pp. 683–685.

El-Yuguda AD, Chabiri LM, Adamu F and Baba SS. 2009. *Peste des petits ruminants* virus (PPRV) infection among small ruminants slaughtered at the Central abattoir, Maiduguri, Nigeria. *Sahel Journal of Veterinary Science* 8: 90 – 96.

Esuruoso GO. 1973. *The epizootiology, prevalence and economic aspects of bovine trypanosomosis in Nigeria.* Proceedings of the USA Animal Health Association, Missouri, 13-19 October 1973. pp. 160–174.

Ezeibe MCO and Wosu LO. 1997. Clinical signs of *peste des petits ruminants* in natural field outbreaks. *Nigerian Veterinary Journal* 18: 249–252.

Ezeibe MCO. 2000. Recurrence of *peste des petits ruminants* (PPR) in kids. *Nigerian Veterinary Journal* 21: 27–29.

Ezeokoli CD, Umoh JU, Adesiyun AA and Abdu PA. 1984. Prevalence of Newcastle disease virus antibodies in local and exotic chickens under different management systems in Nigeria. *Bulletin of Animal Health and Production in Africa* 32: 253–257.

FAO (Food and Agriculture Organization of the United Nations). 1994. Opening address of Y. Chaneau. In: *A systematic approach to tsetse and trypanosomiasis control*. Proceedings of the FAO Panel of Experts, Rome, 1-3 December 1993. FAO Animal Production and Health Paper No. 121. pp. 1–3.

FAO (Food and Agriculture Organization of the United Nations). 1996. *World livestock production systems: Current status, issues and trends.* FAO Animal Production & Health Paper No. 127. FAO, Rome.

Fatumbi OO and Adene DF. 1979. Susceptibility of the Nigerian local chickens to a fulminating Newcastle disease outbreak. *Nigerian Veterinary Journal* 8: 30–32.

Fayomi A and Aliyu ID. 1997. *A retrospective study of the incidence of contagious bovine pleuropneumonia in Kano and environs.* Proceedings of the Nigerian Veterinary Medical Association (NVMA) Annual Congress, Oshogbo.

FDL (Federal Department of Livestock). 2010. *National livestock estimates. Livestock sector – disaggregated data on key development indicators*. FDL, Ministry of Agriculture and Natural Resources, Nigeria.

FDLPCS (Federal Department of Livestock and Pest Control Services). 1992. *Nigerian livestock resources survey.* Abuja, Nigeria.

Fernandez-Rivera S, Okike I, Manyong V, Williams TO, Kruska RL and Tarawali SA. 2004. Classification and description of the major farming systems incorporating ruminant livestock in West Africa. In: Williams TO, Tarawali SA, Hiernaux P and Fernández-Rivera S. (eds), *Sustainable crop–livestock production for improved livelihoods and natural resource management in West Africa.* Proceedings of an international conference held at the International Institute of Tropical Agriculture, Ibadan, Nigeria, 19–22 November 2001. CTA (Technical Centre for Agricultural and Rural Cooperation) ACP-EC, Wageningen, the Netherlands and ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 89–122.

Fraser CM, Bergeron JA, Mays A and Aiello SE. 1991. *The Merck Veterinary Manual.* Merck and Co. Inc., Rahway, NJ.

Furo NA and Ambali AG. 2008. Prevalence of poultry diseases and their control by farmers in some parts of Adamawa State. *Sahel Journal of Veterinary Science* 7: 46–50.

George BDJ, Sackey AK and Lawal AP. 2001. Recurrent outbreaks of *peste des petits ruminants* (PPR) in flocks of Sokoto Red and Kano Brown goats in Zaria and environs. *Tropical Veterinarian* 19: 243–247.

Gomwalk NE, Adesiyun JT, Bishu G and Adesiyun AA. 1985. A serological survey of Newcastle disease virus in domestic poultry around Zaria. *Nigerian Veterinary Journal* 14: 70-74.

Gray AR. 1972. Variable agglutinogenic antigens of *Trypanosoma gambiense* and their distribution among isolates of the trypanosome collected in different places in Nigeria. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 66(2): 263–284.

Halle PD, Ajogi ID, Muzong B and Zafi MD. 1998. A retrospective study on the incidence of contagious bovine pleuropneumonia (CBPP) in Mubi Adamawa State, Nigeria. *Tropical Veterinarian* 16: 143–147.

Halle PD, Umoh JU, Saidu L and Abdu PA. 1999. Prevalence and seasonality of Newcastle disease in Zaria, Nigeria. *Tropical Veterinarian* 17: 53–62.

Hanson RP. 1978. Newcastle disease. In: Hofstad MS, Calnek BW, Helmboldt CF, Reid MW and Yoder HF (eds), *Diseases of poultry*. 7th edition. Iowa State University Press, USA. pp. 513–535.

Harun ES, Shamaki AD, Echeonwu GON, Majiyagbe KA, Shuaibu Y and Du DR. 1993. A natural outbreak of Newcastle disease in guinea-fowl (*Numida meleagris galeata*) in Nigeria. *Revue Scientifique et Technique* 12(3): 887-893.

Hill OH, Olive SO and Wilde JKH. 1953. Newcastle disease in Nigeria. *British Veterinary Journal* 9: 11–13.

Ikede BO. 1987. *The Nigerian livestock industry: Assets, liabilities and potentials.* 1987 University lectures, University of Ibadan, Ibadan University Press, Nigeria.

Ikede BO, Reynolds L, Ogunsanmi AO, Fawumi MK, Ekwuruke JO and Taiwo VO. 1987. *The epizootiology of bovine trypanosomosis in the derived savannah zones of Nigeria. A preliminary report*. Paper presented at the 19th meeting of the ISCTRC, Lomé, Togo, 30 March–3 April 1987.

ILRI (International Livestock Research Institute). 2005. *The current status of livestock diseases in Nigeria: Establishing animal health priorities and strengthening capacity in disease diagnosis and control*. Consultancy report produced for the International Livestock Research Centre, Ibadan, Nigeria.

ILRI (International Livestock Research Institute). 2010. *Terms of reference for a pre-project study: Nigeria integrated animal and human health management project.* Finalized 9 February 2010.

Isamah CI and Otesile EBO. 1997. *Prevalence of African trypanosomosis among cattle of different age groups, breed and sex.* Proceedings of the NVMA Congress, Oshogbo, Nigeria. pp. 108–111.

Johnston J. 1990. *Health and productivity of village poultry in Southeast Asia.* ACIAR Working Paper No. 31. ACIAR, Canberra, Australia.

Jones TC, Hunt D and King NW. 1996. Diseases due to protozoa – Trypanosomiasis. In: *Veterinary Pathology*. 6th edition. Williams & Wilkins, Baltimore, MD. pp. 583–589.

Kalejaiye JO and Omotainse SO. 2001. *Prevalence and distribution of ruminant trypanosomosis in Bokkas LGA of Plateau State.* Proceedings of the NVMA 38th Annual Congress. pp. 197–199.

Kalu AU and Uzoigwe RN. 1996. Tsetse fly and trypanosomosis on the Jos Plateau: observations on outbreaks in Barkin-Ladi Local Government Area. *Tropical Veterinarian* 14: 114–126.

Kalu AU, 1995. Prevalence of trypanosomosis among Trypanotolerant cattle at the lower Benue River area of Nigeria. Preventive Veterinary Medicine 24, 97-103.

Kalu AU. 1996a. An outbreak of trypanosomosis in Jos Plateau, Nigeria. *Tropical Animal Health and Production* 23: 215–216.

Kalu AU. 1996b. Acute trypanosomosis in a sedentary herd on the tsetse free Jos Plateau, Nigeria. *British Veterinary Journal* 152: 477.

Kane M. 2002. *Etude historique sur la péripneumonie contagieuse bovine au Burkina Faso, Côte d'Ivoire, Guinée, Mali, Mauritanie, Niger et Sénégal.* Consultancy report produced for the African Union Interafrican Bureau for Animal Resources – Pan African Programme for the Control of Epizootics. AU-IBAR – PACE, Nairobi.

Kazeem HM, Umoh JU, Majiyagbe KA and Adekeye JO. 2002. *Vaccination of savannah brown goats against Peste des petits ruminants using a homologous vaccine. A clinical assessment*. Proceedings of the 39th NVMA Congress, Sokoto, Nigeria. pp. 112–113.

Luther NJ, Umoh JI, Majiyagbe KA, Shamaki D and Udeani TKC. 2002. *Incidence of antibody to African swine fever virus (ASFV) in pigs from Plateau State correlated with signs of African swine fever-like illness.* Proceedings of the 39th NVMA Annual Conference, Sokoto, Nigeria. pp. 144–146.

Ly C. 2003. The economics of community based animal health workers. In: The IDL Group (ed), *Community based animal health workers – Threat or opportunity?* The IDL Group, Crewkerne, UK. pp 91-106.

Madubuike F, Ekenyem B and Obih T. 2006. Performance and cost evaluation of substituting rubber seed cake for groundnut cake in diet of growing pigs. *Pakistan Journal of Nutrition* 5: 59-61.

Mailafa S and Iliya JB. 2009. African swine fever outbreak in Kumo, Nigeria. A case report. *Nigerian Veterinary Journal* 29: 53–57.

Mailafa S. 2008. *Assessment of financial losses incurred during an outbreak of African swine fever in Kumo, Akko LGA, Gombe state, Nigeria.* Proceedings of the 45th Annual Congress of the NVMA, Imo, Nigeria. pp. 147–150.

Majiyagbe KA. 1999. *African swine fever.* Paper presented at an FAO/FGN Training Workshop on control and eradication of African swine fever in Nigeria, 16–17 November 1999. National Veterinary Research Institute Vom, Nigeria.

Majiyagbe KA, Shamaki D, Luther NJ and Udeani TKC. 2004. African swine fever epidemics. The Nigerian experience, 1997–2004. *Vom Journal of Veterinary Science* 1: 138 –147.

Mariner JC. 2005. *Participatory approaches to the mathematical modelling of rinderpest and contagious bovine pleuropneumonia* (Unpublished doctoral dissertation). University of Guelph, Canada.

Mariner JC and Paskin R. 2000. *Participatory epidemiology: Methods for the collection of action-oriented epidemiological intelligence.* FAO Manual No. 10. FAO, Rome. 81 pp.

Mariner JC and Roeder PL. 2003. Use of participatory epidemiology in studies of the persistence of lineage 2 rinderpest virus in East Africa. *Veterinary Record* 152: 641-647.

Mariner JC, McDermott J, Heesterbeek JAP, Thomson G, Roeder PL and Martin SW. 2005. A heterogeneous population model for contagious bovine pleuropneumonia transmission and control in pastoral communities of East Africa. *Preventive Veterinary Medicine* 73(1): 75-91.

Masiga WN and Domenech J. 1995. Overview and epidemiology of contagious bovine pleuropneumonia in Africa. *Revue Scientifique et Technique* 14(3): 611-620.

Masiga WN, Domenech J and Windsor RS. 1996. Manifestation and epidemiology of contagious bovine pleuropneumonia in Africa. *Revue Scientifique et Technique* 15 (4): 1283-1308.

Mebus CA. 1988. African swine fever. *Advances in Virus Research* 35: 251–269.

Montgomery RE. 1921. On a form of swine fever occurring in British East Africa (Kenya colony). *Journal of Comparative Pathology* 34: 159–191.

Musa U, Abdu P A, Dafwang I I, Sa'idu L, Edache JA, Ahmed MS and Karsin PD. 2009. Cost implications and benefits of intraocular vaccination of rural chickens with Newcastle disease vaccine strain I_2. *Livestock Research for Rural Development* Volume 21, Article #113. Retrieved 23 December 2010, from http://www.lrrd.org/lrrd21/7/musa21113.htm

Nduaka O and Ihemelandu EC. 1973. Observation of pneumoenteritis complex in dwarf goats in Eastern states of Nigeria – preliminary report. *Bulletin of Epizootic Diseases of Africa* 21: 87.

Odo BI. 2003. Comparative study of some prevalent diseases of ecotype goats reared in southeastern Nigeria. *Small Ruminant Research* 50: 203–207.

OIE (World Organization for Animal Health). 2010a. *Contagious bovine pleuropneumonia technical disease card.* http://www.oie.int/eng/maladies/Technical%20disease%20cards/CONTAGIOUS%20BOVINE%20PLEUROPNEUMONIA_FINAL.pdf. Downloaded 6 September 2010.

OIE (World Organization for Animal Health). 2010b. *World Animal Health Information Database, Nigeria Animal Health Situation 2009.* http://www.oie.int/wahis/public.php?page=country_status&year=2009. Downloaded 6 September 2010.

OIE (World Organization for Animal Health). 2010c. *Trypanosomosis (tsetse-transmitted) technical disease card.* http://www.oie.int/eng/maladies/Technical%20disease%20cards/TRYPANO_TSETSE_FINAL.pdf. Downloaded 6 September 2010.

OIE (World Organization for Animal Health). 2010d. African swine fever technical disease card. http://www.oie.int/eng/maladies/Technical%20disease%20cards/AFRICAN%20SWINE%20FEVER_FINAL.pdf. Downloaded 6 September 2010.

OIE (World Organization for Animal Health). 2010e. Peste des petits ruminants *technical disease card.* http://www.oie.int/eng/maladies/Technical%20disease%20cards/PESTE%20DES%20PETITS%20RUMINANTS_FINAL.pdf. Downloaded 6 September 2010.

OIE (World Organization for Animal Health). 2010f. *Newcastle disease technical disease card.* http://www.oie.int/eng/maladies/Technical%20disease%20cards/NEWCASTLE%20DISEASE_%20FINAL.pdf. Downloaded 6 September 2010.

Ojo SO. 2003. Productivity and technical efficiency of poultry egg production in Nigeria. *International Journal of Poultry Science* 2: 459–464.

Omotainse SO, Edeghere H, Omoogu GA, Alhassan EO, Thomson G, Igweh CA, Ukah JAC, Ikenga MA and Halid I. 2000. The prevalence of animal trypanosomosis in Konshisha local government area of Benue state, Nigeria. *Israel Journal of Veterinary Medicine* 55: 142–144.

Omotainse SO, Kalejaiye JO, Dede P and Dada AJ. 2004. The current status of tsetse and animal trypanosomosis in Nigeria. *Vom Journal of Veterinary Science* 1: 1–7.

Omotainse SO, Kalejaiye JO, Eche T and Halid I. 2001. The prevalence of animal trypanosomosis in Yamaltu-deba LGA of Gombe State of Nigeria. *African Journal of Clinical and Experimental Microbiology* 2: 10–12.

Onu JE. 2004. Contagious bovine pleuropneumonia and lung condemnation in Sokoto metropolitan abattoir in Nigeria. *Bulletin of Animal Health and Production in Africa* 52: 123–126.

Onyiah JA. 1985. *Tsetse distribution in Nigeria.* In: National Institute for Trypanosomosis Research (NITR) Annual Report, 1980–1983. NITR, Nigeria. pp. 28–32.

Onyiah JA. 1997. African animal trypanosomiasis: an overview of current status in Nigeria. *Tropical Veterinarian* 15: 111–116.

Opasina BA. 1985. Health problems of market purchased sheep and goats in the south west area of Nigeria. *Nigerian Veterinarian Journal* 14: 45–48.

Opasina BA and Ekwuruke JO. 1988. Trypanosomosis in Nigerian trade cattle. *Tropical Animal Health and Production* 19(4): 251-252.

Oranusi NA and Onyekaba CO. 1986. Serological study of Newcastle disease in commercial poultry farms in Niger Delta, Nigeria. *Bulletin of Animal Health and Production in Africa* 34: 290–292.

Owolodun OA, Yakubu B, Haruna ES, Antiabong JF and Shamaki D. 2005. Detection of African swine fever virus in apparently healthy pigs by polymerase chain reaction. *Vom Journal of Veterinary Science* 2: 80–86.

Oyejide A, Adu FD, Olaleye OD and Ikede BO. 1988. Prevalence of neutralizing antibodies to *peste des petits ruminants* in Nigerian sheep and goats. *Zariya Veterinarian* 3: 32–35.

Oyewola KA, Ogundipe GAT and Durojaiye OA. 1996. Seroprevalence of Gumboro and Newcastle disease in local chickens (*Gallus gallus domesticus*) in Ibadan, Nigeria. *Bulletin of Animal Health and Production in Africa* 44: 57–59.

PAAT (Programme Against African Trypanosomosis). 2001. Facts and Figures on African Trypanosomosis. *PAA Newsletter* 10: 5–7.

PACE (Pan-African Programme for the Control of Epizootics). 2003. PACE Newsletter No. 4.

Pollock J. 2001. Trypanosomosis: Country Report – Nigeria. *Tsetse and Trypanosomiasis Information Quarterly* 24(3): 80-83. FAO, Rome, Italy.

RIU. [no date]. *Tsetse control through restricted application of insecticide to cattle.* Last Retrieved 20 September 2010 from http://www.researchintouse.com/nrk/RIUinfo/PF/LPP14.htm.

Saidu L, Abdu PA, Tekdek LB and Umoh JU. 1998. Retrospective study of Newcastle disease cases in Zaria, Nigeria. *Nigerian Veterinary Journal* 27: 53–62.

Saidu L, Abdu PA, Tekdek LB, Umoh JU, Usman M and Oladele SB. 2006. Newcastle disease in Nigeria. *Nigerian Veterinary Journal* 27: 23–32.

Shamaki BU, Yanan EG, Omotainse SO, Balak CG and Halid I. 2002. *Ruminant trypanosomosis in Plateau state of Nigeria: Current status.* Book of abstracts of the 39th NVMA Annual Congress, Sokoto, 27– 31 October 2002. p. 21.

Shaw APM. 2004. The economics of African trypanosomiasis. In: Maudlin I, Holmes PH and Miles MA (eds), *The Trypanosomiases*. CAB International, Wallingford, pp. 369–402.

Sonaiya EB. 1990. *The context and prospects for development of smallholder rural poultry production in Africa.* In: Proceedings of a Technical Centre for Agricultural and Rural Cooperation (CTA) seminar on smallholder rural poultry productivity. Vol. 1: Results and technical papers. Thessaloniki, Greece, 9–13 October 1990. pp. 35–52.

Swallow BM. 2000. *Impacts of trypanosomiasis on African agriculture.* PAAT Technical and Scientific Series No. 2. FAO, Rome, Italy. 52 pp.

Tambi NE, Maina WO and Ndi C. 2006. An estimation of the economic impact of contagious bovine pleuropneumonia in Africa. *Revue Scientifique et Technique* 25(3): 999-1012.

Taylor WP. 1979. Serological studies with the virus of *peste des petits ruminants* in Nigeria. *Research in Veterinary Science* 26: 236–242.

Taylor WP and Abegunde A. 1979. The isolation of *peste des petits ruminants* virus from Nigerian sheep and goats. *Research in Veterinary Science* 26: 94–96.

Taylor WP, Roeder PL and Rweyemamu MM. 2006. Use of rinderpest vaccination in international programs for the control and eradication of rinderpest. In: Barrett T, Pastoret P and Taylor W. (eds), *Rinderpest and peste des petits ruminants*. Elsevier, London. pp. 260-282.

Terlaak EA. 1992. Contagious bovine pleuropneumonia: A review. *Veterinary Quarterly* 15: 104–110.

Tewari SC, Aloba EA and Nawathe DR. 1992. Detection of haemagglutination inhibition antibodies against Newcastle disease virus in unvaccinated indigenous chickens in Maiduguri, Borno State, Nigeria. *Revue Scientifique et Technique* 11(3): 813-817.

Umali DL, Feder G and de Haan C. 1992. *The balance between public and private sector activities in the delivery of livestock services.* World Bank Discussion Paper No. 163.The World Bank, Washington DC.

Willyanto I, Bett B, Unger F and Randolph T. 2010. *Alignment of poultry sector actors with avian influenza control measures in Indonesia.* Africa/Indonesia Team Working Paper. ILRI (International Livestock Research Institute) Nairobi, Kenya. pp. 52.

Wosu LO. 1989. Management of clinical cases of *peste des petits ruminants* (PPR) disease in goats. *Beiträge zur tropischen Landwirtschaft und Veterinärmedizin* 27: 357–361.

Wosu LO and Okeke SO. 1989. The role of local chicken in the spread of Newcastle disease in Nigeria. *Zariya Veterinarian* 4: 25–29.

Yanan GE, Dede PM and Uzoigwe NR. 2003. A survey of animal trypanosomosis in selected Muturu herds on the Jos Plateau, Plateau State, Nigeria. *Nigerian Veterinary Journal* 24: 39–41.

Annex 1: Spreadsheet model data requirements

Data required for cattle

Livestock population
- Total population
- Proportion of cows
- Proportion of calves
- Proportion of lactating cows
- Proportion of heifers
- Proportion of steers
- Proportion of bulls
- Proportion of oxen

Livestock population growth parameters
- Fertility rate
- Prolificacy
- Calf mortality risk
- Age at first calving
- Calving rate
- Female breeder mortality rate
- Male breeder mortality rate
- Female replacement mortality rate
- Male replacement mortality rate
- Young mortality rate
- Other stock mortality rate
- Female replacement mortality risk
- Male replacement mortality risk
- Cow mortality risk

Dairy production parameters
- Milk off-take per year
- Fraction of females milked
- Milk yield per lactation
- Milk fat content

Meat and draught production parameters
- Carcass dressing of culled cow
- Carcass dressing of mature bull
- Carcass dressing of culled ox
- Ox number of working days per year
- Off-take rate
- Live weight of female breeders
- Live weight of male breeders
- Live weight of draught animals
- Live weight of other stock
- Years from young to slaughter

Livestock breeding parameters
- Breeder males per breeder females
- Years in breeding herd
- Years in replacement herd
- Years as young
- Retention ratio for young females

- Average live weight of breeder female
- Average live weight of breeder male
- Average live weight of replacement female
- Average live weight of replacement male
- Average live weight of other stock
- Average live weight of young female
- Average live weight of young male

Livestock and livestock product price/cost

- Price of milk
- Price of beef
- Cost of draught power
- Price of mature bull
- Price of mature cow
- Price of draught animal
- Cost of replacement male
- Cost of replacement female
- Cost of dead calf

Animal health and prophylactic measures against CBPP

- Cost of vaccination per animal
- Cost of treatment per clinical case
- Cost of veterinary service per animal

Animal health and prophylactic measures against trypanosomosis

- Cost of drugs per animal
- Cost of veterinary service per animal
- Cost of control of the disease per animal

Data Required for Pigs

Livestock populations at risk

- Pig population
- Proportion of boars
- Proportion of sows
- Proportion of gilts
- Proportion of piglets
- Proportion of weaners
- Proportion of growers
- Proportion of finishers

Pig population growth parameters

- Fertility rate
- Prolificacy
- Piglet mortality risk
- Female breeder mortality rate
- Male breeder mortality rate
- Female replacement mortality rate
- Male replacement mortality rate
- Young mortality rate
- Female replacement mortality risk
- Male replacement mortality risk
- Sow mortality risk

Pig production parameters

- Weaners per litter per sow
- Pigs per sow per year
- Live weight gain per day
- Slaughter weight
- Feed conversion rate
- Carcass dressing

Market prices

- Price of pig meat
- Value of average weaner
- Average carcass value of finished pig
- Cost of piglet mortality
- Cost of sow mortality
- Cost of feed input
- Piglet value
- Value of culled sow
- Gilt purchase price

Animal health and prophylactic measures against ASF

- Cost of testing per animal
- Cost of veterinary service per animal
- Cost of carcass disposal
- Cost of quarantine

Animal health and prophylactic measures against trypanosomosis

- Cost of drugs per animal
- Cost of veterinary service per animal
- Cost of control of the disease per animal

Data required for small ruminants

Livestock populations at risk

- Total sheep and goat population
- Proportion of breeding ewes and does
- Proportion of all sheep and goats two years of age or older
- Proportion of sheep and goat aged one year and older
- Proportion of suckling and growing lambs and kids

Small ruminant population growth parameters

- Ewe and doe fertility rate
- Ewe and doe prolificacy
- Lamb and kid mortality risk
- Age at first lambing and kidding
- Lambing and kidding rate
- Female breeder mortality rate
- Male breeder mortality rate
- Female replacement mortality rate
- Male replacement mortality rate
- Young mortality rate
- Female replacement mortality risk
- Male replacement mortality risk
- Ewe mortality risk
- Doe mortality risk

Quantities

- Live weight of female breeders
- Live weight of male breeders
- Live weight of other stock
- Years from young to slaughter
- Replacement rate of ewes
- Average number of lambs per ewe
- Replacement rate of does
- Average number of kids per doe
- Carcass dressing of mature rams
- Carcass dressing of mature bucks
- Carcass dressing culled ewe
- Carcass dressing culled doe
- Sheep off-take rate
- Goat off-take rate

Sheep meat and goat production parameters

- Carcass dressing of mature sheep
- Carcass dressing of mature goat
- Sheep off-take rate
- Goat off-take rate
- Live weight of mature male goat
- Live weight of mature male sheep
- Live weight of other sheep stock
- Live weight of other goat stock
- Years from young to slaughter

Market prices

- Value of breeding ewe
- Value of breeding doe
- Value of sheep aged one year and older
- Value of lambs under one year of age
- Value of goat aged one year and older
- Value of kids under one year of age
- Cost of ewe abortion
- Cost of doe abortion
- Goat price per unit live weight
- Sheep price per unit live weight
- Price of a kilogram of sheep meat
- Price of a kilogram of goat meat

Animal health and prophylactic measures against PPR

- Cost of testing per animal
- Cost of veterinary service per animal
- Cost of vaccination
- Cost of disinfectant
- Cost of medicines used

Data Requirement for Poultry

Livestock populations at risk

- Chicken population
- Proportion of hens
- Proportion of cocks
- Proportion of chicks

- Proportion of growers

Poultry Production Parameters

- Egg output per hen per year
- Average number of chicks per hatch
- Average number of eggs per clutch
- Average egg output per layer per year

Prices/values used

- Price of laying hen
- Price of cock
- Price of grower
- Price of chick
- Price of egg

Animal health and prophylactic measures against NCD

- Cost of vaccination per dose
- Cost of veterinary service

Annex 2: Pre-project study — PE checklist

1. Introductions
2. Descriptive (state, village, number of informants, ethnicities, genders)
3. Sources of livelihoods - list
4. Types of livestock in village
    a. Species kept by number – simple ranking
    b. Species importance to livelihoods – simple ranking
    c. Livestock population proportions – proportional piling
        i. Cattle (< 1 year, lactating cows, dry cows, heifers, steers, bulls, oxen)
        ii. Pigs (piglets, weaners, gilts, castrated growers, breeding females, boards, culled females, castrated finishers)
        iii. Small ruminants (<3 months, 3 months to 1 year, > 1 year)
        iv. Chickens (chicks, growers, adults)
5. Production
    a. Growth parameters over past year – proportional piling
        i. Mortality rates
            1. Cattle (lactating cows, dry cows, heifers, steers, bulls, oxen)
            2. Pigs (weaners, gilts, castrated growers, breeding females, boards, culled females, castrated finishers)
            3. Small ruminants (3 months to 1 year, > 1 year)
            4. Chickens (growers, adults)
        ii. Breeding animals entries and exits (breeding males/females)
    b. Breeding parameters over past year
        i. Breeding males to females – proportional piling
        ii. Age at first mating
        iii. Years in breeding herd
        iv. Female fertility rates (conceived, aborted, birthed, newborn mortality) – proportional piling
        v. Number of young per parturition (poultry eggs per clutch and chicks per hatch)
        vi. Pigs (piglets per sow per year)
    c. Production parameters
        i. Live weights in kilograms – weight bands cattle/pigs, scales small ruminants
            1. Cattle (breeder cows, heifers, steers, bulls, oxen)
            2. Pigs (weaners, gilts, castrated growers, breeding females, boars, culled females, castrated finishers)
            3. Small ruminants (3 months to 1 year, > 1 year)
            4. Chickens (growers, adult males, adult females)
        ii. Years from young to slaughter
        iii. Dairy production parameters (milk off-take/day per cow during dry season and rainy season, fraction of females milked during dry and rainy season)
        iv. Ox number of working days per year
6. Product price/cost
    a. Price of milk per litre
    b. Cost of draught power per hectare
    c. Pigs (average weaner, finished pig carcass, piglet, culled sow, gilt, feed/adult/day)
    d. Small ruminants (adults, breeders, young)
    e. Chickens (egg, hen, rooster)
7. Livestock challenges
    a. Challenges to production
    b. Diseases that occurred over past year
        i. Disease priorities according to numbers affected – proportional piling
        ii. Livelihoods impacts – proportional piling
        iii. Relative incidence scoring over last year of CBPP, ASF, PPR, NCD, trypanosomosis
8. Disease control services (CBPP, trypanosomosis, ASF, PPR, NCD)

a. Availability
    i. Prevention
        1. Vaccine – proportional piling
        2. Biosecurity
    ii. Treatment
b. Costs
    i. Prevention
    ii. Treatment
    iii. Testing
    iv. Veterinary services

Annex 3: Small ruminant disease case definitions

PPR
At the herd level, outbreaks with all of the following symptoms:

- Profuse watery diarrhoea with foul odour
- Vesicular mouth lesions
- High fever dropping to low temperature near death

together with any two of the following:

- Respiratory distress including cough
- Clear to muco-purulent ocular and nasal discharge
- Dehydration
- Anorexia

are likely to be PPR. The outbreak affects all ages of sheep and goats, spreading rapidly, causing very high morbidity and high mortality in the majority of the susceptible population.

FMD
At the herd level, outbreaks with both of the following symptoms:

- Vesicular mouth lesions
- Inter-digital ulcers and coronet swelling

together with any two of the following:

- Foamy salivation
- Gnashing of teeth
- Anorexia
- Fever

are likely to be FMD. The outbreak affects all ages of cloven-hoofed animals (cattle, sheep, goats and swine), spreading very rapidly, causing very high morbidity but very low mortality, mostly in calves of the susceptible population.

Annex 4: Data used in the spreadsheet models

Annex 4A: Data Used in PPR the spreadsheet model

Parameters	Sudan Savannah	Guinea Savannah	Subhumid	Humid	National
Population	18,130	19,012	5,501	12,503	55,145
As % of total	32.88%	34.48%	9.97%	22.67%	100.00%
Herd structure					
<3 month male	13%	13.0%	10.3%	12.9%	12.2%
<3 month female	18%	19.6%	18.8%	15.5%	17.9%
Male 3m - 1yr	15%	9.0%	10.3%	11.0%	11.3%
Female 3m - 1yr	18%	15.8%	23.0%	13.7%	17.5%
Male >1yr	12%	13.1%	11.3%	12.9%	12.2%
Female >1yr	26%	29.5%	26.2%	34.0%	28.9%
Breeding parameters					
Breeding male/female (%)	16.8%	46.4%	33.8%	39.1%	34.0%
Age at 1st breeding (months)	7.2	7.3	7.7	8.9	7.8
Years breeding	7.8	7.0	6.2	7.9	7.2
Age at 1st parturition (years)	1.3	1.0	2.0	1.5	1.5
Kids/lambs per parturition	2.0	2.0	2.0	2.0	2.0
Breeding females pregnant	88.0%	88.1%	86.2%	89.1%	87.9%
Breeding females aborted	24.7%	12.5%	15.1%	14.2%	16.6%
Breeding females farrowed	75.3%	87.5%	82.5%	85.8%	82.8%
Production parameters					
Years to slaughter	1.0	1.0	2.8	3.6	2.1
Replacement /off-take rates (%)					
Females removed	10.3%	4.9%	5.3%	3.5%	6.0%
Males removed	17.2%	15.9%	11.2%	21.5%	16.4%
Females introduced	7.8%	5.9%	1.7%	9.0%	6.1%
Males introduced	5.7%	3.4%	0.5%	6.0%	3.9%
Product price/cost (NGN)					
Adult male	14,667	8375	8200	12,375	10,904
Adult female	8333	8188	7333	9429	8321
Male breeder	8638	8438	8333	5833	7810
Female breeder	8288	8188	7000	5500	7244
Young	4117	3917	4340	2938	3828
Relative disease scoring					
Proportion sick in herd (%)	39.0%	45.5%	35.8%	38.6%	39.7%
PPR Morbidity (%)	20.0%	33.1%	35.0%	19.5%	26.9%
PPR Mortality (%)	13.0%	15.0%	28.0%	13.5%	17.4%
PPR Case fatality (%)	65.0%	37.9%	80.0%	68.7%	62.9%
Disease monitoring					
Actual Surveillance rate	0.0%	0.0%	0.0%	0.0%	0.0%
Targeted Surveillance Rate	70.0%	70.0%	70.0%	70.0%	70.0%
Treatment and vaccination rate					

Actual Vaccination Rate (%)	2.0%	2.0%	2.0%	2.0%	2.0%
PPR Vaccination cost (NGN)	225	225	225	225	225
Actual Treatment Rate (%)	20.0%	50.0%	50.0%	66.7%	46.7%
PPR treatment cost (NGN)	383	378	400	333.3	374
Targeted Vaccination Rate (%)	80.0%	80.0%	80.0%	80.0%	80.0%
Targeted Treatment Rate (%)	15.0%	15.0%	15.0%	15.0%	15.0%

Annex 4B: Data used in NCD spreadsheet model

Parameters	Sudan Savannah	Guinea Savannah	Subhumid	Humid	National
Population	40,131	36,706	25,956	31,354	134,147
As % of total	30%	27%	19%	23%	100%
Flock structure					
Chicks	39%	41.9%	31.8%	34.1%	36.7%
Growers	32%	30.6%	32.5%	30.4%	31.4%
Hens	20%	18.7%	20.3%	20.2%	19.9%
Cocks	9%	8.9%	15.3%	15.2%	12.0%
Breeding parameters					
Breeding male/female (%)	18.2%	52.8%	34.9%	50.0%	39.0%
Age at 1st breeding (months)	4.2	6.4	6.7	6.8	6.0
Years breeding	2.5	1.7	3.7	1.9	2.4
Age at 1st laying (months)	5.0	6.4	6.7	6.8	6.2
% flock that laid	34.3%	34.3%	74.5%	77.3%	55.1%
Eggs per clutch	12.2	11.9	12.5	11.3	12.0
Chicks per clutch	10.0	10.3	10.0	9.7	10.0
Production parameters					
Years to slaughter	0.8	0.8	1.2	1.4	1.1
Replacement /off-take rates (%)					
Females removed	11.4%	11.4%	3.7%	13.3%	10.0%
Males removed	18.0%	18.0%	6.2%	16.7%	14.7%
Females introduced	10.4%	10.4%	0.0%	13.0%	8.5%
Males introduced	5.6%	5.6%	0.0%	26.0%	9.3%
Product price/cost (NGN)					
Egg	15	17	20	20	18
Hen	567	586	917	656	681
Rooster	783	1,279	1,233	1,189	1,121
Chicks	50	50	50	50	50
Grower	254	254	254	254	254
Relative disease scoring					
Proportion sick in herd (%)	69.0%	71.7%	37.8%	57.3%	59.0%
NCD Morbidity (%)	55.0%	59.7%	21.8%	51.7%	47.0%
NCD Mortality (%)	39.0%	49.3%	12.3%	33.7%	33.6%
NCD Case fatality (%)	71.2%	81.4%	54.0%	63.1%	67.4%
Actual Surveillance Rate (%)	0.0%	0.0%	0.0%	0.0%	0.0%
Targeted Surveillance Rate (%)	75.0%	75.0%	75.0%	75.0%	75.0%
Treatment and vaccination					
Actual vaccination rate (%)	0.0%	0.0%	0.0%	0.0%	0.0%
Cost of NCD Vaccination	25	25	25	25	25
Actual Treatment Rate (%)	0.0%	0.0%	0.0%	0.0%	0.0%
Cost of Sanitary Measures (NGN)	1.75	1.75	1.75	1.75	1.75
Targeted Vaccination Rate (%)	90.0%	90.0%	90.0%	90.0%	90.0%
Target Sanitary Measures (%)	10.0%	10.0%	10.0%	10.0%	10.0%
Targeted Treatment Rate (%)	0.0%	0.0%	0.0%	0.0%	0.0%
Cost of Treatment (NGN)	395	395	395	395	395

Annex 4C: Data Used in the ASF and Trypanosomosis in Pigs Spreadsheet Model

Parameters	Sudan Savannah	Guinea Savannah	Subhumid	Humid	National
Population	665	3852	1035	1633	7184
As % of total	9%	54%	14%	23%	100%
Herd structure					
Piglets	NA	21%	21%	20%	21%
Weaners	NA	20%	21%	19%	20%
Gilts	NA	10%	11%	11%	10%
Castrated growers	NA	12%	12%	13%	12%
Boars	NA	9%	6%	7%	7%
Female breeders	NA	8%	12%	11%	10%
Castrated finishers	NA	14%	12%	12%	12%
Culled female finishers	NA	7%	7%	8%	7%
Production parameters					
Breeding male/female (%)	NA	37%	19%	43%	33%
Age at 1st breeding (years)	NA	9.0	7.5	8.4	8.2
Years breeding	NA	3.4	3.6	1.6	2.8
Age at 1st parturition (years)	NA	12.3	11.5	5.2	9.6
Piglets per parturition	NA	6.3	9.2	8.0	8.0
Piglets per sow per year	NA	12.5	18.3	16.0	16.0
Breeding females pregnant	NA	89%	85%	86%	87%
Breeding females aborted	NA	12%	5%	11%	9%
Breeding females farrowed	NA	88%	95%	89%	91%
Years to slaughter	NA	0.9	1.0	1.1	1.0
Average daily weight gain	NA	0.2	0.2	0.2	0.2
Average Slaughter Weight (kg)	NA	85.0	83.9	83.9	83.9
Replacement / off-take rates (%)					
Females removed	NA	9%	10%	15%	11%
Males removed	NA	21%	18%	34%	24%
Females introduced	NA	19%	4%	14%	12%
Males introduced	NA	9%	4%	11%	8%
Product price/cost (Naira)					
Cost of feed/adult/day	NA	82	82	82	82
Weaner price	NA	2667	3357	3500	3175
Piglet price	NA	2000	3000	3000	2667
Gilt price	NA	6500	9250	8875	8208
Finished carcass price	NA	8625	17018	16188	13943
Sow price	NA	11375	16019	15250	14215
Culled sow price	NA	14000	17911	16938	16283
Trypanosomosis					
Relative disease scoring (%)					
Proportion sick in herd (%)	NA	33%	33%	32%	32%
Tryps Morbidity (%)	NA	12%	12%	12%	12%
Tryps Mortality (%)	NA	3%	3%	3%	3%
Tryps Case fatality (%)	NA	13%	13%	13%	13%

Treatment and Vaccination					
Tryps treatment available (%)	NA	75%	40%	20%	45%
Target Tryps Treatment	NA	50%	50%	50%	50%
Tryps treatment cost (NGN)	NA	200	150	190	180
Surveillance rate	NA	5%	5%	5%	5%
Target surveillance rate	NA	75%	75%	75%	75%
Vector control	NA	5%	5%	5%	5%
Target vector control	NA	50%	50%	50%	50%
Output Loss					
Live Loss of weight	NA	13%	13%	13%	13%
ASF					
Relative disease scoring (%)					
ASF Morbidity (%)	NA	13%	20%	18%	17%
ASF Mortality (%)	NA	13%	19%	17%	16%
ASF Case fatality (%)	NA	100%	95%	99%	98%
Treatment and Vaccination					
Actual sanitary measure rate	NA	0%	0%	0%	0%
Target sanitary measure rate	NA	100%	100%	100%	100%
Cost of sanitary measure	NA	35	35	35	35
ASF treatment available (%)	NA	25%	25%	25%	25%
ASF treatment cost (NGN)	NA	350	350	350	350
Target treatment rate	NA	10%	10%	10%	10%
Actual surveillance rate	NA	0%	0%	0%	0%
Target surveillance rate	NA	75%	75%	75%	75%

Annex 4D: Data Used in the CBPP and trypanosomosis in cattle spreadsheet model

Parameters	Sudan Savannah	Guinea Savannah	Subhumid	Humid	National
Population	7814	8131	290	200	16,435
As % of total	48%	49%	2%	1%	100%
Herd structure					
Calves	31.00%	32.00%	32.00%	32.00%	31.75%
Steers	0.00%	3.00%	12.00%	0.00%	3.75%
Heifers	15.00%	14.00%	11.00%	16.00%	14.00%
Bulls	11.00%	15.00%	16.00%	16.00%	14.50%
Lactating cows	23.00%	20.00%	20.00%	20.00%	20.75%
Dry cows	14.00%	10.00%	9.00%	16.00%	12.25%
Oxen	6.00%	6.00%	0.00%	0.00%	3.00%
Production Parameters					
Breeding male/female (%)	20.00%	35.40%	39.10%	26.90%	30.35%
Age at 1st breeding (years)	3.2	3.4	2	3	2.9
Age at 1st calving (years)	4.2	3.8	3.3	3.5	3.7
Calves per parturition	1	1	1	1	1
Length of time breeding (yrs)	13.8	13.8	10	12.5	12.7
Breeding females pregnant (%)	86.10%	90.30%	60.00%	79.30%	78.93%
Breeding females aborted (%)	16.80%	7.40%	27.30%	17.50%	17.25%
Breeding females calved (%)	83.20%	92.60%	72.70%	82.50%	82.75%
Years to slaughter	6.5	4	6.8	6.3	5.9
Milk yield dry season (l/day)	1	0.7	1.7	1.4	1.1
Milk yield wet season (l/day)	2.5	3	1.3	3	2.9
Females milked dry season (%)	76.00%	76.00%	40.00%	70.00%	65.50%
Females milked wet season (%)	100.00%	100.00%	40.00%	100.00%	85.00%
Calving rate (%)	60.00%	60.00%	60.00%	60.00%	60.0%
Milk yield (litre/day)	1.6	1.7	1.5	2.1	1.7
Lactation length (day/year)	210	210	210	210	210.0
Beef production calves (kg/head)	68	68	54	54	61.0
Beef production adults (kg/head)	135	135	108	108	121.5
Weight gain calves (kg/day)	0.11	0.11	0.11	0.11	0.11
Weight gain adults (kg/day)	0.063	0.063	0.063	0.063	0.063
Oxen work (days/year)	90	90	90	90	90
Market prices & costs					
Price of beef (NGN/kg)	700	800	780	750	758
Price of raw milk (NGN/litre)	150	140	100	187	144
Price of processed milk (NGN/litre)	220	220	220	220	220
Cost of Draft Power (NGN/day)	500	500			
Heifer purchase price (NGN)	65,000	40,000	80,000	60,000	61,250
Value of finished cattle (NGN)	115,000	80,000	180,000	80,000	113,750
Cost of calf mortality (NGN)	22,000	20,000	20,000	15,000	19,250
Cost of cow mortality (NGN)	73,000	80,000	80,000	50,000	70,750
Relative disease scoring (%)					
Proportion sick in herd (%)	NA	46.00%	48.00%	55.00%	49.7%
Trypanosomosis					
Prevalence	NA	43.00%	29.50%	19.86%	30.8%

Infection rate	NA	19.90%	6.60%	6.60%	11.0%
Morbidity (%)	NA	23.00%	9.00%	18.00%	16.7%
Mortality (%)	NA	3.00%	4.00%	7.00%	4.7%
Case fatality (%)	NA	14.00%	46.00%	40.00%	33.3%
Treatment and vaccination					
Treatment available (%)	NA	80.00%	80.00%	80.00%	80.0%
Target Treatment Rate (%)	NA	50.00%	50.00%	50.00%	50.0%
Treatment cost (NGN)	NA	248	411	575	411
Actual Vector Control (rate)	NA	5.00%	5.00%	5.00%	5.0%
Target Vector control (%)	NA	50.00%	50.00%	50.00%	50.0%
Surveillance (%)	NA	24.60%	26.47%	16.40%	18.2%
Target surveillance rate (%)	NA	75.00%	75.00%	75.00%	58.8%
Output Loss					
Percentage of milk loss	NA	13.00%	13.00%	13.00%	13.0%
Loss of weight	NA	11.00%	11.00%	11.00%	11.0%
Loss of traction	NA	21.00%	21.00%	21.00%	21.0%
CBPP					
Prevalence	29.00%	29.00%	29.00%	29.00%	29.0%
Disease transition rate	0.0357	0.0357	0.0357	0.0357	0.0357
Morbidity (%)	4.00%	9.00%	7.00%	15.00%	8.8%
Mortality (%)	0.50%	1.00%	3.00%	3.00%	1.9%
Case fatality (%)	12.50%	11.00%	43.00%	19.00%	21.4%
Treatment and Vaccination					
Vaccination available (%)	30.00%	30.00%	20.00%	20.00%	25.0%
Vaccination cost (NGN)	145.00	145.00	150.00	150.00	147.50
Treatment available (%)	80.00%	80.00%	80.00%	80.00%	80.0%
Treatment cost (NGN)	500	500	500	500	500
Target Vaccination Rate (%)	80.00%	80.00%	80.00%	80.00%	80.0%
Target Treatment Rate (%)	20.00%	20.00%	20.00%	20.00%	20.0%
Surveillance (%)	10.04%	25.88%	3.44%	3.44%	10.7%
Target surveillance rate (%)	70.00%	70.00%	70.00%	70.00%	70.0%
Output Loss Relative to Clinical Cases					
Milk Loss	0.8	0.8	0.8	0.8	0.8
Percentage of milk loss	90.00%	90.00%	90.00%	90.00%	90.0%
Loss of weight	0.8	0.8	0.8	0.8	0.8
Loss of traction	0.8	0.8	0.8	0.8	0.8