SPATIO-TEMPORAL TRENDS AND RISK FACTORS ASSOCIATED WITH CONTAGIOUS BOVINE PLEUROPNEUMONIA (CBPP) DISEASE OUTBREAKS IN RUMBEK NORTH COUNTY, LAKES STATE, SOUTH SUDAN

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S21M43/015

A DISSERTATION SUBMITTED TO THE FACULTY OF AGRICULTURAL SCIENCES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE AND RURAL DEVELOPMENT OF UGANDA CHRISTIAN UNIVERSITY

June,2025

UGANDA CHRISTIAN UNIVERSITY

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DECLARATION

I, **Makuac Chol Agor** do hereby declares that this research is my own work and has never been published or presented for academic award in any other institution.

Signature:  Date June 2025

APPROVAL

I certify that this research dissertation has been done under my direct supervision and submitted for examination with my approval.

June 2025

Dr. Higenyi James

(Supervisor)

Date

DEDICATION

This research is dedicated to my family members whom I deprived of parenthood time. These include my sons, daughters and spouses.

ACKNOWLEDGEMENT

This is to acknowledge the guidance of Dr. James Higenyi and Dr. John Mutyaba, my academic supervisors who gave me guidance during the entire study and report writing. I sincerely acknowledge the patience and willingness he had shown to me in the entire process of conducting this research.

I am sincerely acknowledging International Committee of the Red Cross (ICRC) for financial support which covered my tuition fees through their institutional package called idevelop. I am highly indebted for that.

Finally, I appreciate the support I received from my entire family, relatives, colleagues and friends. May God reward them in excess.

TABLE OF CONTENTS

DECLARATION i
APPROVAL ii
DEDICATION iii
ACKNOWLEDGEMENT iv
LIST OF TABLES vii
LIST OF FIGURES vii
LIST OF ABBEREVIATIONS viii
ABSTRACT ix
CHAPTER ONE: INTRODUCTION 1
1.1 Background of the Study 1
1.2 Problem Statement 3
1.3 Objectives of the study 4
1.4 Research Hypotheses 5
1.5 Justification and Significance of the study 5
1.6 The Research Scope 6
1.7 Theoretical and Conceptual Framework 6
1.7.1 Theoretical Framework 6
1.7.2 Conceptual Framework 7
Dependent Variable 8
CHAPTER TWO: LITERATURE REVIEW 10
2.1 Epidemiology of the Contagious Bovine Pleuropneumonia 10
2.1.1 Incidence rate of the Contagious Bovine Pleuropneumonia over years 11
2.1.2 Temporal trends of the Contagious Bovine Pleuropneumonia disease occurrence 12
2.2 High risky areas for the Contagious Bovine Pleuropneumonia Disease 13
2.3 Risk Factors Associated with the Contagious Bovine Pleuropneumonia (CBPP) Disease Occurrence 13
2.3.1 Management related factors 14
2.3.2 Biological related factors 15
2.3.3 Environmental related factors 16
2.3.4 Socioeconomic related factors 16
2.4 Trend and distribution pattern of Contagious Bovine Pleuropneumonia Disease 17
2.5 Knowledge Gap 18
2.6 Methodological Approaches in Contagious Bovine Pleuropneumonia Disease research 19

CHAPTER THREE: METHODOLOGY 21
3.1 Research Design 21
3.2 Study Area 21
3.3 Sampling procedures 22
3.4 Research Data Collection Methods and Study Instrument 22
3.5 Data Processing and Analytical framework 23
3.6 Ethical Consideration 26
CHAPTER FOUR: RESULTS AND DISCUSSION 27
4.1 Demographic and social economics characteristics of the Cattle Farmers 27
4.2 The incidence rate in Contagious Bovine Pleuropneumonia disease in Rumbek North County from 2019 to 2022 28
4.3 Temporal distribution of Contagious Bovine Pleuropneumonia disease in Rumbek North County (2019 to 2022). 31
4.5 DISCUSSION 35
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS 41
5.1 CONCLUSIONS 41
5.2 RECOMMENDATIONS 42
REFERENCES 44
APPENDICES 49
Appendix 1: Questionnaire (Research Tool) 49
Appendix 2: Letter of clearance from faculty (Recommendation) 52
Appendix 3: Letter of approval from Research Ethic committee 52
Appendix 4: Field photos during the data collection 52

LIST OF TABLES

Table 1. Socio-economic and Production Systems Practices of Cattle Farmers in Rumbek North County, Lakes State, South Sudan.....23

Table 2. Incidence rate of CBPP disease in Rumbek North by villages of payams.....24

Table 3. Relationship between payams and confirmed number of cases of CBPP disease.....

.....25

Table 3. Factors Associated with CBPP Outbreaks from 2019 - 2022Relationship between payams and confirmed number of cases of CBPP disease.....29

LIST OF FIGURES

Figure 1: Epidemiological Triad of CBPP disease 6

Figure 2: Illustration of the Conceptual framework showing independent and dependent variables 9

Figure 3: The overall number of confirmed cases of CBPP disease by Payams in Rumbek North from 2019 to 2022.....26

Figure 4: Map showing the spatial distribution of CBPP disease in Rumbek North) 27

Figure 5: Temporal distribution of CBPP disease outbreaks in Rumbek North (# of CBPP outbreaks by months and payams) 28

Figure 6: Temporal distribution of CBPP disease outbreaks in Rumbek North County (# of CBPP outbreaks by Months) from 2019 to2022 28

LIST OF ABBEREVIATIONS

CAHWs – Community Animal Health Workers

CBPP – Contagious Bovine Pleuropneumonia

EXP (B) – Exponential Beta estimates (represent odd ratios in logistic regressions)

FAO – Food and Agriculture Organization

ICRC – International committee of the Red Cross

MARF – Ministry of Animal Resources and Fisheries

NGOs – Non-governmental Organizations

OIE – World organization for animal health

PARC - Pan African Rinderpest Campaign

QGIS – Quantum Geographic Information system

ABSTRACT

Rumbek North County, South Sudan pastoral communities continue to face a significant threat from Contagious Bovine Pleuropneumonia (CBPP) at prevalence of 70%. The disease has caused exceedingly high economic losses (60%) and compromised the food security situation of the pastoral communities. This study aimed to understand the spatio-temporal patterns and risk factors associated with CBPP disease outbreaks in the county between 2019 and 2022. In this retrospective study, archived data by Lakes State Ministry of Animal Resources and Fisheries between 2019 and 2022 was reviewed. To understand the risk factors associated with CBPP disease occurrence, a survey using questionnaires was conducted to collect primary data. 274 cattle farmers whose farms registered confirmed cases of CBPP incidence during the study period were purposively selected and interviewed. A combined descriptive and inferential analysis were used to depict the spatio-temporal distribution of the CBPP disease outbreaks in study. The findings revealed that majority (74.1%) of the farmers were male. The respondents age average was 34 years and universally (100%) illiterate. The results also showed variation in incidence rate of CBPP disease in villages of payams; highest at 25.17% (n=436) in Makuac and least at 0.29% (n=5) in Anguth. Further, findings showed variation in number of CBPP outbreaks spread over the months in years with increased cases in October at 15.53% (n=269) and July 15.76% (n=273), and lowest cases in February at (2.19%). While seasonality of number of outbreaks revealed a highest (72.5%) number of CBPP outbreaks during the wet season. The significant ($P<0.05$) risk factors for occurrence of CBPP disease outbreaks were geographical area with odds ratio (OR)= =2.874), overcrowding of cattle at water points (OR=1.049), mixing of new animals with old one (OR=1.053) and flooding (OR=1.243). This study has confirmed the empirical evidence of persistent occurrence of CBPP disease outbreaks in Rumbek North County, characterized by spatial and temporal trends. The study recommends an extensive sensitization and education program for the pastoral community on epidemiology of disease and the best management practices, strategic vaccination in the affected payams and before the wet season's arrival, construct more water points to reduce on frequent migrations and overcrowding during watering of cattle.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Contagious Bovine Pleuropneumonia (CBPP) is a common cattle disease caused by bacteria species called *Mycoplasma mycoides* subspecies *mycoides* small colony (Mmm Sc) variant type (Masiga and Domenech, 1995). CBPP is a disease of economic importance in the livestock sector (Kariu-Wanyoike *et al.,* 2017).

According to Kariu-Wanyoike *et al.,* 2017, CBPP economics losses include the death of livestock assets, reduction in milk and meat production, and high household expenditure due to buying veterinary drugs and vaccines. Food and agriculture organization (FAO) estimated that in developing countries 30% annual livestock output is loss because of animal diseases.

According to contemporary information CBPP was believed to be introduced to South Africa in 1854 when a bull was imported from the Netherlands. Then the disease spread swiftly through walk oxen into the Transvaal where it killed 100,000 animals in two years. It was further spread by livestock movement from and to the countries now known as Zimbabwe, Namibia, Botswana, and then finally to Zambia, Angola, and Democratic Republic of Congo (Olorunshola *et al.,* 2017).

Abdalla *et al.,* 2012 argued that during the years 1867 – 1868 of Ethiopia invasion by the Field Marshal Napier, CBPP was introduced in East Africa region.

Di Teodoro *et al.,* 2020 explained that comparing the foot and mouth disease with the CBPP, CBPP remains now as the one of most serious transboundary disease in many African countries, threatening the livestock sector and causing severe economic losses far beyond other losses sustained by any other infection disease. In a year for the CBPP endemic African countries, the estimated economic losses because of mortality, production decrease and expenses for control and prevention measures reach USD 44.8 million (USD 3.7 million per a country) (Di Teodoro *et al.,* 2020).

Despite enormous efforts to control CBPP in many Sub-Saharan African countries, the disease remained endemic and seriously reduce the livestock farming profit (Di

Teodoro, *et.al.,* 2020). The CBPP infections cost among 12 sub-Saharan African countries was estimated to be up to 30 million Euros due to livestock death and disease control, while an indirect economic cost of infections was estimated at 44.8 million Euros/or at 3.7 million Euros per the country being affected (Bida Alhji *et al.,* 2020). There are various factors characterizing the epidemiology of the CBPP disease in sub-Saharan African Countries. At most the disease presence is rooted in cattle species only where its main mode of transmission from the infected cow to health one is through close contact. There is no presence of the wildlife disease reservoir species (Nma Bida Alhji *et al.,* 2020).

CBPP present in Sudan was discovered in Darfur province in 1875 where it later spread to Khartoum province where cattle production was affected. CBPP remained as the one of the most importance livestock disease which affect farmers income as it can adversely affect the foreign trade exchange due to restriction of the cattle movement (Abdulla 1975, Shallali *et al.,* 1998).

In South Sudan, CBPP ranks as the first most important transboundary disease (Yacob *et al.,* 2016), as disease seriously threaten the livestock sector due to high mortality rate (Abdalla, 2012).

State Ministry of Animal Resources and Fisheries (MARF 2020) reported that CBPP prevalence rate is estimated at 70% in Lakes State. In recent years between 2010 and 2020, the Ministry of Animal Resources and Fisheries recorded over 20 outbreaks in Rumbek North County (MARF 2020). These persistent outbreaks created fear and worries among neighbor pastoralists of Rumbek Center who shared most of the grazing land with Rumbek North pastoralists.

In a traditional production system where there is limited control of movement of cattle, CBPP disease outbreaks in one cattle camp poses a threat to bordering or neighboring cattle camps. This meant that the control of the CBPP should be multilevel combining national and regional efforts, instead based on individual farmer ability (Tambi *et al.*, 2004, 2006).

Although various research has been conducted to investigate the disease's occurrence worldwide and in Africa, there is still limited knowledge in understanding the spatio-temporal trends that explains the geography distribution of the disease in each period and risk factors influencing persistence of the disease outbreaks in Rumbek North County. This retrospective study presented the CBPP trends, distribution, and associated risk factors for the spread of CBPP disease outbreaks, are critical for effective animal health management in this pastoral community.

1.2 Problem Statement

In South Sudan, CBPP disease ranks as the first most important transboundary disease (Almaw *et al*. 2016). In Lakes State and particular in Rumbek North, pastoralists are aware of CBPP disease as it has long history of present in the area with reported prevalence rate at 70% in Lakes State (MARF 2020). Over 20 outbreaks have been recorded in Rumbek North for the last ten years (2010-2020) with a high score of food production losses in terms of reduction in milk and meat yield as well as financial loss in the household income due to the treatment cost and death of the livestock (MARF report, 2020).

In 2010, Lakes State Ministry of Animal Resources and Fisheries (MARF), estimated the economic losses due to the persistent outbreaks of CBPP in Rumbek North to account for over 60% of economic losses. The economic losses associated with the outbreaks include livestock mortality (10% to 80%), loss of weight and workability as well as poor carcass quality, decrease in milk production, low fertility as well as low birth weights, and poor growth rates (Kariu-Wanyoike *et al*. 2017). A chronic infected lactating cow produce no milk while acute infected lactating cow produce 0.25 liters of milk per milking time (MARF 2010). Therefore, persistent outbreaks of the CBPP disease are a threat to the pastoralist community in term of limited access to protein food (milk and meat) and financial losses due to the cost of treatment and vaccination as well as disruption in the cattle market (Tambi *et al*., 2006)

Despite the knowledge of economic losses attributed to the disease, efforts to manage persistence of CBPP disease outbreaks among pastoralists are hampered by

limited access to veterinary services, information about spatio-temporal trends and associated risk factors for the occurrence of persistent CBPP outbreaks at the study area. Continued lack of such epidemiological data makes management of the disease outbreak problematic thus, threatening the peoples' livelihood and affect household access to food consumption and income.

Prevalence studies already done reported magnitude of problem (70%) and limited attempts to explore epidemiological studies (spatio-temporal trends, and predisposing factors/risk factors) which largely influence the occurrence and distribution of disease (MARF, 2020).

There is limited information on the epidemiology data (spatio-temporal trends) and epidemiological aspects (risk factors) associated with occurrence CBPP diseases outbreaks in Rumbek North County.

Hence, retrospective analysis of CBPP disease was undertaken to understand spatial (geographical distribution pattern) and temporal trends in the occurrence of the CBPP disease outbreaks at a given time. This retrospective analysis identified regions prone to frequent CBPP disease outbreaks and associated risk factors. The design for the targeted prevention for the effective control and management of the CBPP disease will be informed by this study findings. These information will help in the design of risk-based prevention and control measures for effective CBPP disease management.

1.3 Objectives of the study

The overall aim of this study is to examine the spatial and temporal trends and associated risk factors for the persistence occurrence of the CBPP outbreaks in Rumbek North, Lakes state, South Sudan. The specific objectives were:

1. To determine the incidence rate of CBPP disease in Rumbek North County from 2019 to 2022
2. To determine the temporal distribution of CBPP disease outbreaks in Rumbek North County from 2019 to 2022
3. To assess the associated risk factors influencing the persistence occurrence of the CBPP disease outbreaks in Rumbek North County.

1.4 Research Hypotheses

Hypothesis 1: There is no significant difference in incidence rate of CBPP disease outbreaks on farms among cattle farmers in Rumbek North County between 2019 and 2022

Hypothesis 2: There is no significance difference in Spatio-temporal pattern in the occurrence of CBPP disease outbreaks in Rumbek North County between 2019 and 2022.

Hypothesis 3: There is no significant difference in associated risk factors for the persistence occurrence of the CBPP disease outbreaks in farms among cattle farmers in Rumbek North County.

1.5 Justification and Significance of the study

CBPP disease poses a substantial economic burden on Rumbek North County, characterized by persistent outbreaks leading to significant losses in livestock, milk production, and draught power. Previous studies have quantified these losses at alarming rates, emphasizing the urgent need for effective control measures. Despite the detrimental impacts of CBPP, limited research exists on the spatio-temporal patterns and risk factors associated with CBPP disease in the study region.

Rumbek North remoteness, coupled with limited veterinary services and the challenges posed by cattle migration, exacerbates the vulnerability of the area to CBPP outbreaks. This research aims to fill this knowledge gap by identifying the incidence, temporal distribution, and risk factors associated with CBPP disease in the region.

By delineating these patterns and factors, this study will provide crucial information for pastoralist communities, enabling them to develop and implement targeted strategies for CBPP prevention and control. Furthermore, the findings will inform policymakers and development partners in designing effective interventions to strengthen local capacity for CBPP management. This research serves as a foundation for future studies exploring the economic implications of CBPP in greater depth.

1.6 The Research Scope

The research was conducted in Rumbek North, Lakes state, South Sudan. Rumbek North County is purposely selected as the area is prone to the CBPP outbreaks which adversely affected the livelihoods of the pastoralists who depend on livestock farming. In the past ten years, there are many registered cases of CBPP outbreaks and made the area CBPP prone locally. Also, the livelihood of the Rumbek North population depends on livestock rearing as main livelihood activity.

1.7 Theoretical and Conceptual Framework

1.7.1 Theoretical Framework

Cclassically, CBPP disease is described as epidemiological triad (Figure 1 in), which posits disease arises from the interaction of an animal host (i.e., cattle), an infectious or other agent, and the environment that ease the exposure.

- Host characteristics include age, breed and species of the animal.
- Agents include, bacteria, virus, fungus, mycoplasma, protozoa, among others.
- Environmental include the biological and physical conditions that influence disease occurrence.

Collectively, these interacting factors: The agents, host characteristics and environmental conditions contribute to increasing the risk of cattle diseases.

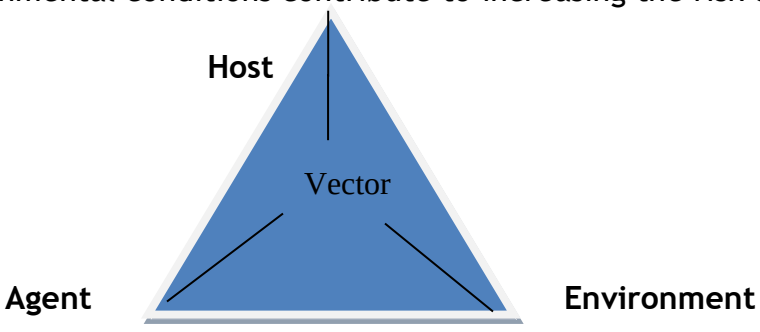

Figure 1: The epidemiologic triad of a disease.

Source: Leon Gordis, 2004

1.7.2 Conceptual Framework

This study conceptual framework as shown in figure 2, illustrates how spatial and temporal patterns of CBPP disease outbreaks interact with various risk factors to influence the persistence of the disease and its consequences within Rumbek North County. This framework directly aligns with the study's objectives to investigate the spatio-temporal trends and identify specific risk factors associated with persistent CBPP outbreaks.

Indpendent variables:

- **Spatio-temporal trends** provide insights into the geographical and time-related patterns of CBPP outbreaks.
    - **Spatial patterns:** Geographical distribution of the CBPP outbreaks across villages and payams, indicating areas with higher or lower incidence rates.
    - **Temporal patterns:** Seasonal and monthly variations in outbreak frequency, highlighting peak periods for the CBPP disease occurrence.
- **Risk factors:** These are specific measurable conditions or practices that increase the likelihood of CBPP disease transmission and persistence.
    - **Enviromental conditions:** Availability of water points and presence of flood-prone areas
    - **Cattle management practices:** Mixing of new animals with existing herds, communal grazing, kraaling practices
    - **Socio-economic characteristics:** Herd size, access to veterinary services, transhumance/nomadic, income of the household and grazing practices.

These independent variables collectively influence the occurrence and persistence of CBPP.

Mediating Variables (Consequences/Direct Impact of CBPP):

The direct consequences of persistent CBPP outbreaks, influence by the independent variables represent the mediating variables: these include.

- **Incidence rate of CBPP:** The rate at which new cases of CBPP occur within the cattle population.
- **Economic consequences:** Financial losses incurred due to disease management.
- **Livestock population Health:** The overall well-being and productivity of the cattle population.

Dependent Variable

This study ultimate dependent variable which is influence by interactions described above, is the persistence of CBPP Disease Outbreaks. This refers to be continued presence and recurring nature of the CBPP disease in Rumbek North County.

Understanding the relationship among these independent variables, mediating consequences and the dependent variable, this study aims to identify key factors driving CBPP disease outbreaks and inform targeted interventions to mitigate the disease's impact on the pastoral County in Rumbek North County.

INDEPENDENT VARIABLES **DEPEDENT VARIALBE**

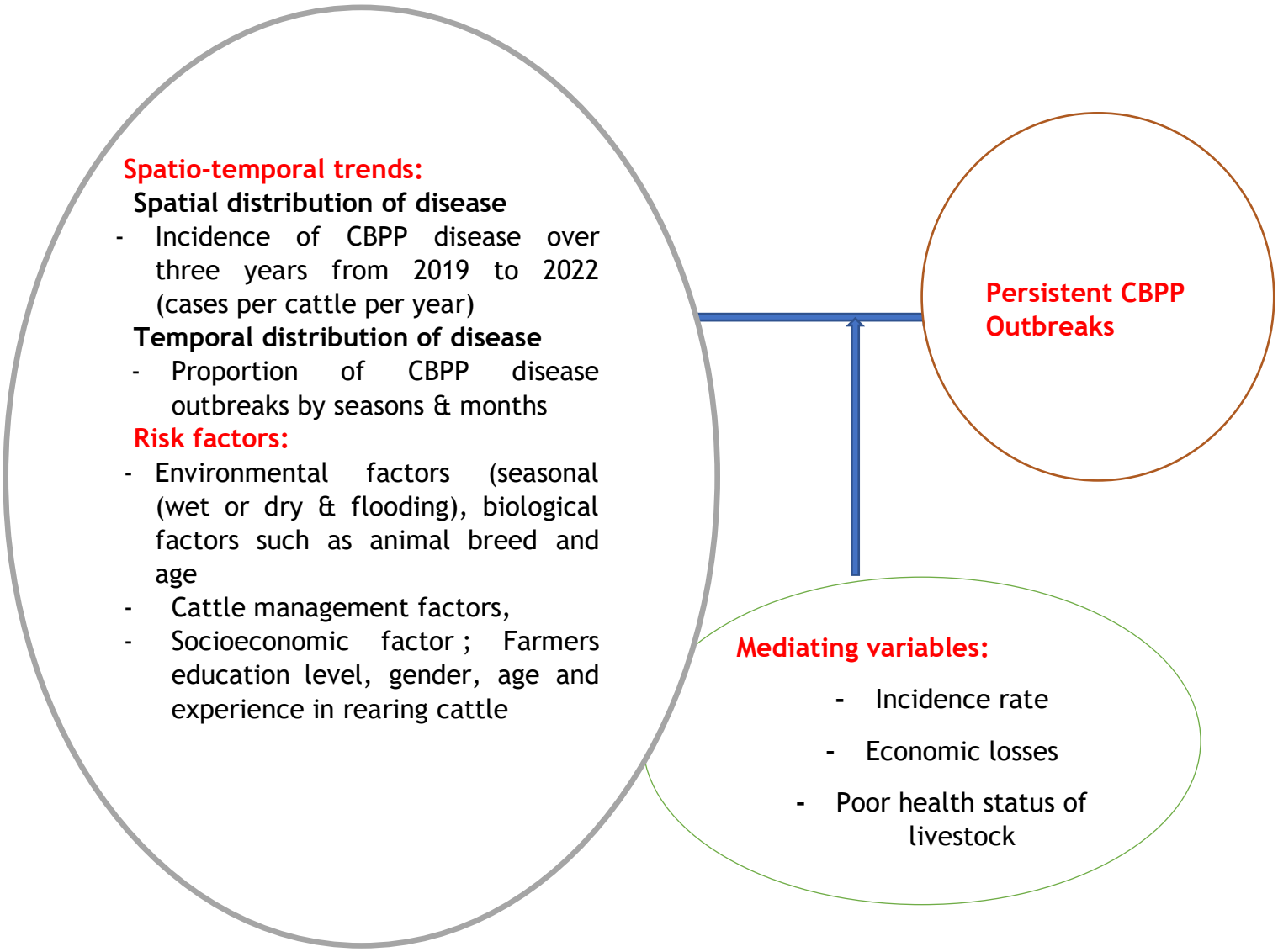

Figure 2: Illustration of conceptual framework (Independent and dependent variables)

CHAPTER TWO: LITERATURE REVIEW

Livestock has been utilized as a source of natural and financial capital in most of the resources limited rural areas, particularly by resource poor men and women farmers, helping them for their diets and incomes through household consumption and income generation. In addition, it functions as live banks, conferring social status, offering draught, transport and manure (Muindi et al, 2015).

Nonetheless, an estimated 30% of livestock production in developing countries is lost due to diseases (Muindi et al, 2015). Animal diseases, especially transboundary animal diseases like CBPP, represent an ever-looming threat to livestock producers, processors, and consumers as well as to markets (Otte et al., 2004).

2.1 Epidemiology of the Contagious Bovine Pleuropneumonia

Contagious Bovine Pleuropneumonia (CBPP) results from Mycoplasma mycoides subspecies mycoides small colony variant. The clinical signs of CBPP consist of dyspnea, loss of condition, large amounts of sero-fibrinous pleurisy, and edema of the interlobular septae (Haile et al., 2021).

It is one of the significant constraints to cattle production across Sub-Saharan and Southwest Africa (Haile et al., 2021). The transmission of the diseases occurs from direct, and repeats contacts between sick and healthy animals by inhalation of infective droplets from the diseased animals, whether active or carrier cases of the disease (Haile et al., 2021). The epidemiology of CBPP is identified by sub-acute and asymptomatic infections, persistence of chronic carriers, and spread of the disease is linked to movement of affected cattle.

The epidemiology of CBPP in Africa is shaped by several factors. These include that cattle are the primary species affected; there are no reservoir hosts known in wild animals; transmission is by direct contact of a susceptible animal with clinical cases or chronic carriers and that animal movement plays a very important role in the maintenance and spread of the disease (Haile et al., 2021).

Cattle (*Bos taurus* and *Bos indicus)* are believed to be the main hosts. Sheep and goats may also be naturally infected as well but no definite clear associated pathology. Wild bovids seem resistant as well as camels do not play integral part in transmission of CBPP (Matui-Malamsha, 2009).

The disease is transmitted by direct contact from infected to susceptible cattle as well through infective air/fluids from exhaled air. Transmission cannot occur over distances greater than 100 m and some authors state a maximum of 20 m (Newton *et al.,* 2000). CBPP disease transmission also occur when susceptible animal meets infected wastes such as excreta, animal housing, and equipment or vehicles previously has waste of infected animal (Hudson *et al*., 1971; Newton *et al*., 2000; Abdalla *et al.,* 2012). Furthermore, cattle products (beef, milk, and hides) are highly unlikely to transmit CBPP. Infection may also be passed on during mating since *Mycoplasma mycoides* subsp contagious disease.

2.1.1 Incidence rate of the Contagious Bovine Pleuropneumonia over years

The prevalence of CBPP is defined as the accumulative number of the cases (both past and current) that are present in a target herd at any given point in time while incidence is the number of new cases that occur in a known herd over a definite period. Incidence, like prevalence, is the number of cattle infected expressed relative to the total number of animal at risk. Prevalence and incidence rates of CBPP is influenced by type of cattle production system. Prevalence rates are generally higher in extensive cattle production systems than in intensive dairy and in beef production systems where Animals are confined (Tambi *et al.,* 2006). Also, IJARBS (2021) explained that variation can be attributed to factors like management practices, vaccination coverage, diagnostic efficiency, presence of carriers, and environmental factors.

The spreading of Contagious bovine pleuropneumonia (CBPP) in Africa is widespread, and its present in 24 countries in tropical-Africa regions including South Sudan is reported (Haile *et al.,* 2021). It is now one of the emerging and highly important animal disease. It is epidemic in Sub-Saharan Africa where past years disease free are being now infected while there is an increasing incidence rates within endemic

regions at a higher rate (Litamoi, 2000). Due to poor methods of husbandry practice especially the traditional management, it becomes extremely difficult to control disease (CBPP) incidence rates in the regions where it has long present. Contagious Bovine Pleuropneumonia (CBPP) is the respiratory disease of cattle which is a listed animal disease by the World Organization for Animal Health as notifiable disease (Di Teodoro *et al.,* 2020). Noticeably, the endemic present of the CBPP disease in Sub-Saharan Africa region has caused much loses in cattle production as result of a high mortality and morbidity rates (Di Teodoro *et al*., 2020).

2.1.2 Temporal trends of the Contagious Bovine Pleuropneumonia disease occurrence

The recent report stated that based on the data gathered from different reports submitted on monthly basis to AU-IBAR by African Union member states CBPP is endemic in the main pastoral areas in the West, East and Central Africa with at least 24 African countries (45%) regularly reporting the CBPP disease outbreaks yearly for the last 10 years (Ahmed, 2016).

In Lakes State and particular in Rumbek North, pastoralists are aware of CBPP disease as it has long history of present in the area with reported prevalence rate at 70% in Lakes State (MARF, 2020). Over 20 CBPP outbreaks were for the last ten years (2010-2020) in Rumbek North County with a high score of food production losses in terms of reduction in milk and meat yield as well as financial loss in the household income due to the treatment cost and death of the livestock (MARF report, 2020).

CBPP disease outbreaks increase during the wet season as the spreading of the diseases is enhanced by the infective fluids from contaminated substances. While in dry climate condition, CBPP disease spreading is reduced as infectious fluids from contaminated substances containing pathogens are deactivated by high temperature and quickly evaporate which as well reduced the transmission (Ahmed, 2016).

In Rumbek North, cattle are kept in the local made tukul (Luak) with limited ventilation. When one animal is infected in Luak, there are more chances of other animals being infected which made the morbidity and incidence rate of CBPP to be 100%.

2.2 High risky areas for the Contagious Bovine Pleuropneumonia Disease

Reports from world organization for animal health (OIE indicated that about 27 sub-Saharan African countries are having CBPP cases (Tambi *et.al,* 2006). Pan African Rinderpest Campaign (PARC) in 1986 reported that few African countries experienced CBPP outbreaks, as combined vaccination against rinderpest and CBPP reduced the disease prevalence rate. However, in 1995 when some countries some stopped the combined measures of rinderpest and CBPP vaccination, disease prevalence resumed and more outbreaks were experience (Tambi *et.al*, 2006, Raghad *et al.,* 2018).

CBPP reports were received by African Union Inter-African Bureau of Animal Resources (AU-IBAR) in 2006 from 18 African countries in the East, Central, West and Southern regions except for Gabon and DR Congo.

In the affected African countries 304 epidemiological unites were reported with CBPP disease accounting for 16836 cases and 3007 deaths. From these statistics, the mortality rate is estimated at17.9 %. At that time, the CBPP outbreaks were reported with Ghana leading by 75 outbreaks, followed by the central Africa Republic by 43 outbreaks and Ethiopia by 29 outbreaks (Nma Bida Alhaji, 2020).

For the last ten years, 24 African countries (estimated to be 45% of the African countries) from the East, Central and West reported CBPP outbreaks regularly which made the disease to be endemic in the region (Nma Bida Alhaji, 2020).

In many Sub-Saharan African countries where CBPP is endemic, cattle farming profitability is reduced (Di Teodoro *et al.,* 2020). Hence, CBPP disease- threaten African continent livestock production, because its economic losses exceed the losses from other infectious disease (Di Teodoro *et al.*, 2020).

2.3 Risk Factors Associated with the Contagious Bovine Pleuropneumonia (CBPP) Disease Occurrence

Contagious Bovine Pleuropneumonia is a multifactorial disease, where many factors influence it incidence and spreading. Some these factors include host, agent, management and the environment which are the determinant for the occurrence of infectious diseases (Newton *et al.,* 2000).

According to Newton *et al.,* 2000, the parameters to provide information concerning the various CBPP disease associated risk factors for the occurrence include.

- ✓ Management related factors including cattle production systems, management practices, frequent migration and disease prevention and controls, among others.
- ✓ Socio-economic factors including education level, gender, and Age of the cattle farmers.
- ✓ Biological related factors such as breed, age of the animal and species.

2.3.1 Management related factors

There are several factors which influence the occurrence of the CBPP outbreaks. These factors include the livestock production system, the country's regulations and disease control policies, veterinarians, livestock officers and farmers' knowledge on disease (Haile *et al.,* 2021).

The veterinary laboratory's diagnostic capabilities, disease surveillance and monitoring system, adequacy of vaccination programs, government budget for control programs, the willingness of the cattle owners and traders to control the disease are very important management issues in the context of disease control in a country. As the CBPP spreading is related to the animals movement, the epidemiology of the CBPP disease is affected the good management practices. Poor management of the livestock movement can make the areas which are CBPP disease free become endemic as disease can easily be passed from one location to another. This can happen when herds are overcrowding during the grazing, at water sources and in the house where cattle lives at night, because such a condition favor the disease transmission since it is contagious disease (Radiostits *et al.,* 2007. Jovanović *et al.,* (2014) explained that

there is link between the CBPP outbreaks and the herd mixing or mingling in Ethiopia. Overcrowding at water points creates ideal conditions for the spread of respiratory diseases like CBPP, where infected animals can cough and expel droplets containing the bacteria. Introducing new animals to established herds (mixing new with old) can also increase the risk, especially if the new animals are not vaccinated or carry the bacteria without showing symptoms. Musa *et al*. (2012) reported that overcrowded housing conditions are associated with higher CBPP prevalence in Nigeria. Overcrowding in kraals creates a stressful environment for cattle, weakening their immune system and making them more susceptible to infections. Frequent migrations further exacerbate this stress and can introduce the animals to new sources of infection along the route. Jovanović et al., (2014) noted that the longer cattle remain in infected camps, the higher the risk of exposure to CBPP. Contaminated kraals harbor the bacteria in the environment for extended periods. Overstaying in such environments increases the likelihood of healthy animals meeting the pathogen. Muloki *et al*. (2019) found a positive association between larger herd sizes and CBPP seropositivity (presence of antibodies) in Tanzania. Larger herds provide more opportunities for the pathogen to spread within the herd.

2.3.2 Biological related factors

The most susceptible species of animal to the CBPP are cattle, (*Bos taurus* and *Bos indicus)*. Also, domesticated buffalo which is *Bubalus bubalus species* is susceptible to the CBPP although it is difficult to detect the disease in the laboratory sample (Tambi *et.al.*, 2006). However, the common animal which is resistant to the CBPP infection is African Water Buffalo of *Synerus caffer* species.

Naturally, the susceptibility of animals to the CBPP disease based on age has three phases: In young animals, the susceptibility is very low to the disease as it can develops minor lesions in the joints and tendons and it cannot cause a severe pulmonary infection; in animals age greater than one year, their susceptibility is moderate than animals which are over two years old which are more susceptible. This means age of the animal is the influencing factors with direct correlation with CBPP disease incidence (Almaw *et al., 2016)*.

2.3.3 Environmental related factors

Weather changes which form the seasons also play role in stimulating the infection of CBPP disease, mostly the rainy season played a greater role when animals are exposed to cold weather (Haile *et al.,* 2021). Frequency fluctuation of the conditions of the weather is the contributing factors, enhancing the CBPP disease spreading especially when the conditions to which the animal adapt to change such as relative humidity and stable temperature (Newton *et al.,* 2000). However, there is a positive aspect in these weather changes as it affects the host and the pathogens. For example, high temperature with dry humidity reduces the risk of disease spreading, because contaminated substance gets dry easily, killing pathogens or deactivate them as moisture evaporate. Also, high temperature de-activate pathogens and reduce their transmission (Newton *et al.,* 2000). The impact of flooding on CBPP outbreaks is not definitively established. However, flooding can disrupt normal grazing patterns, forcing cattle into closer contact and potentially leading to increased transmission. Additionally, flooding can create favorable conditions for some pathogens to survive in the environment for longer periods.

2.3.4 Socioeconomic related factors

According to Baluka *et al.,* (2013*)* reported that socio-economic factors such as age, gender, education level and experience in term of years in livestock keeping influenced the CBPP disease occurrence. Baluka *et al.,* (2013), reported that gender may influence the occurrence of the disease, because many women do not have right to land ownership or own smaller pieces of land and therefore may lack decision-making power in the community so their cattle may have to move in search of grazing land more than the cattle of men (Baluka *et al.*, 2013).

Older and more experienced cattle farmers tend to be able identify the CBPP in the early stages better than the young farmers and so are more likely to report to the Community Animal Health Workers in timely manner. Farmers who have received some education are typically better, able to detect the diseases easily and more likely to report to Animal Health Workers or Veterinary authorities in a timely

manner. Potential socio-economic risk factors included uncontrolled cattle movement, drought, proximity to wildlife conservation areas, the use of communal grazing and watering points, and socio-cultural practice including bride price payments and the exchange of gifts in the form of cattle (Baluka *et al.,* 2013). The risk factors of uncontrolled cattle movements were most important in the transmission of CBPP disease at the household or farm level.

Food security and livelihoods for the poor producers and processor depend on the livestock farming and the CBPP disease impact them seriously especially women who are less resilient to any shock. Because CBPP disease impact livestock farming through loss of livestock asset, loss of income and protein food (Haile *et al.,* 2021).

2.4 Trend and distribution pattern of Contagious Bovine Pleuropneumonia Disease

The spread of the CBPP throughout the world is dated back to the second half of the 19th century because of the increase in the international trade of the live animal, especially cattle. Prior to that in 16th century, CBPP was only know in Europe (Di Teodoro *et al.,* 2020). When stamp out policy was in introduced in the world CBPP disease was eradicated from many countries; however, it remained persistently current present in sub-Saharan African countries. In Africa, Contagious bovine pleuropneumonia outbreaks show two different epidemiological trends (Tambi *et.al*, 2006). The first facet is illustrated by epidemic outbreaks in areas formerly considered CBPP free, as in the case of Botswana, which experienced an outbreak in 1994 after having eradicated CBPP in 1939. Although Botswana is an important example, there are other occurrences of epidemic outbreaks such as Zambia and Burundi in 1997, Guinea in 1996, Ethiopia in 1998, Rwanda in 1994 and Tanzania in 1996 and 1999. The outbreaks can all be traced back to the movement of cattle, particularly, uncontrolled movement of cattle from infected population into the free zone (Tambi *et al.,* 2006).

The second trend of CBPP outbreaks has provided insight into endemic areas where the amount of CBPP cases have risen. When CBPP is introduced into a free zone area, many occurrences take place. Many animals in the area become infected and enter

the acute clinical form of the disease (Tambi *et al.,* 2006), and the number of animal deaths can reach up to 50%. However, after a while, the disease has fewer explosive outbreaks and the animals become less symptomatic and many animals .can even recover or become chronic carriers (Tambi *et al.,* 2006). In East African region, countries like Burundi, Rwanda, most part of Tanzania, Ethiopia, South Sudan- and Somalia were all infected endemically (Tambi *et al.,* 2006).

In endemic cases animals will have generally lower mortality rates. Therefore, in situation where CBPP outbreaks can occur, outbreak including various levels of mortality has been founded (Tambi *et al.,* 2006). In its acute form, 50% mortality rate had been associated with CBPP in which more than 10% mortality rate has been reported in Guinea and Ethiopia. Furthermore, mortality rate in the range of 5% - 10% have been documented in Chad and Côte d'Ivoire, while mortality rates lower than 5% were recorded in Tanzania, Uganda, Burkina Faso, Ghana and Mali (Tambi *et al.,* 2006). At most, higher mortality rates for CBPP are not common.

2.5 Knowledge Gap

While existing research has delved into the economic implications and control of CBPP disease, critical knowledge gaps persist. Previous studies often overlook a comprehensive analysis of how the disease spreads over time and across different locations, hindering the development of targeted interventions. Additionally, while some research has touched on potential risk factors, a thorough examination of their interconnectedness and relative significance is lacking.

Furthermore, data scarcity in specific regions, such as Rumbek North County, hampers the ability to accurately assess the disease's impact and tailor control strategies accordingly. Most research tends to focus either on the epidemiological aspects of CBPP or its economic consequences, neglecting a holistic approach that considers both dimensions for effective disease management.

Given these research voids, this study is warranted. By comprehensively examining the spatio-temporal patterns of CBPP disease and identifying key risk factors, this research aims to inform the development of region-specific control strategies. The

findings will equip policymakers with the evidence necessary to allocate resources efficiently and prioritize interventions. Ultimately, this study contributes to the broader understanding of CBPP disease, paving the way for future research and control efforts.

2.6 Methodological Approaches in Contagious Bovine Pleuropneumonia Disease research

To effectively address the research questions and bridge existing knowledge gaps in CBPP disease, a critical examination of previous methodological approaches is essential. A review of the literature reveals a diverse array of methodologies employed in CBPP research.

Cross-sectional studies offer a snapshot of disease prevalence and associated factors at a specific point in time (Smith, 2005). While efficient for generating preliminary data, they are limited in establishing causal relationships (Jones, 2010). Case-control studies compare diseased and non-diseased animals to identify potential risk factors (Brown, 2012). However, they are susceptible to recall bias in selecting appropriate control groups (Davis, 2015). Cohort studies follow groups of animals over time, enabling the identification of disease incidence and risk factors (Evans, 2018). While valuable for establishing temporal relationships, they can be resource-intensive (Fisher, 2020). Experimental studies, though uncommon in livestock research due to ethical and practical constraints, can provide strong evidence of causality (Green, 2022).

Geographic Information Systems (GIS) and remote sensing have emerged as valuable tools for analyzing spatial patterns of disease occurrence and identifying potential environmental risk factors (Hill, 2023). While these techniques offer new possibilities, they require accurate data and sophisticated analysis (Hill, 2023).

Given the complexity of CBPP disease, a combination of methods may be optimal for this study. A cross-sectional study can provide data for potential risk factors. GIS analysis can explore spatial patterns, and incorporating longitudinal data collection through repeated cross-sectional surveys or a cohort study can enhance the

understanding of disease dynamics over time. By carefully considering the strengths and weaknesses of different methods, this study can contribute to a more comprehensive understanding of CBPP disease and its impact.

CHAPTER THREE: METHODOLOGY

The chapter covers various methods which were used in this research. This includes the research design, sampling techniques, methods for the data collection, data processing and analytical framework as well as ethical considerations.

3.1 Research Design

This was a retrospective analysis of Contagious Bovine Pleuropneumonia (CBPP) disease outbreaks data in Rumbek North County, Lakes State, spanning the period from 2019 to 2022 as well as explored the risk factors associated with disease outbreaks on the selected farms of cattle farmers A cross-sectional research design was applied, using both the quantitative and qualitative methods.

Quantitative data were derived from archival or secondary sources provided by the Ministry of Animal Resources and Fisheries. These records encompassed confirmed CBPP cases, substantiated through post-mortem examinations and laboratory analyses. Specific details extracted from these records included outbreak dates, precise locations, and the extent of cattle populations affected.

The qualitative data were collected using semi-structured questionnaires administered through interviews with cattle farmers who had firsthand experience with CBPP outbreaks, as identified within the secondary dataset to complement the quantitative analysis. These interviews delved into farmers' perceptions of the CBPP disease and their knowledge and understanding on CBPP disease control and prevention measures.

3.2 Study Area

This study was conducted in Rumbek North County of Lakes state, South Sudan. Rumbek North has persistently been culprit of CBPP disease outbreaks with reported prevalence rate at 70% in Lakes State (MARF 2020). Over 20 outbreaks have been recorded in Rumbek North for the last ten years (2010-2020) with estimated the economic losses due to the persistent outbreaks of CBPP in Rumbek North to account for over 60% of economic losses. The area is characterized by low land predominantly

covered by trees, shrubs and grass vegetation. It weather changes consist of two seasons such as wet season (divided into two: autumn and spring) which occurs from May/June to October/November characterized by rain and flooding and a dry season (divided into two; summer and winter) which occurs from October/November to April. Rumbek North County infrastructure is very poor in terms of bad roads, poor health system, low education access- and limited communication facilities. The main residents of Rumbek North are Dinka from Agar subsection of Dinka tribe, most of whom practice the traditional African religion. Polygamy is common in Dinka society. The main livestock species own and kept in Rumbek North include cattle, goats, sheep, and chickens.

In Rumbek North County, the most preferred livestock species is cattle due to its various benefits such as milk, meat and income earning through the sale of cattle products such as ghee and butter in addition to live animal by men and women respectively. Cattle also play an important social role such as paying dowry for marriage.

3.3 Sampling procedures

In this study, 274 households were selected for semi-structured interviews through purposively sampling of the HHs with confirmed cases of the CBPP disease outbreaks over the study period. This was based on Ministry's archive recorded for the data of the CBPP outbreaks over the given period (2019 – 2022). It is important to note that while the term "households" is used, the primary unit of analysis was the cattle farmer(s) within those households. In many cases, multiple individuals within a household were involved in cattle management.

3.4 Research Data Collection Methods and Study Instrument

This was retrospective analysis conducted through a review of secondary data collected on occurrence of CBPP disease outbreaks in the study area as archived by Lakes State Ministry of Animal Resources and Fisheries (MARF) from 2019 to 2022. Community Animal Health Workers (CAHWs) annual reports and laboratory registry

books were used for the counting of suspected and confirmed cases of CBPP that occurred from 2019 to 2022 in Rumbek North County.

A survey was conducted by administering questionnaires to capture the information concerning various risk factors associated with the CBPP outbreaks incidences. The households of cattle farmers whose farms registered confirmed cases from archived data in the study area were purposively selected for interview. The following parameters for the risk factors such as weather changes-seasonal (wet or dry), animal breed, age, cattle management system and migration of cattle, farmers education level, knowledge of disease by farmers, age, and gender were assessed using a pre-tested and structured questionnaire.

3.5 Data Processing and Analytical framework

The quantitative data collected analyzed using STATA 14 statistical software. For initial descriptive analysis, descriptive statistics were employed to summarize the data for **Objective 2.** This involves generating tables and charts to visually represented the CBPP outbreaks temporal distribution in each period, which span from 2019 to 2022. To visualize the spatial patterns of CBPP outbreaks, Geographic Information System (GIS) analysis was conducted using QGIS software. Farm coordinates (measured in decimal degree) were used to geo-reference outbreak locations. This process resulting in maps that depicted the spatial distribution of CBPP cases within Rumbek North County.

Inferential statistical analysis and model specifications

Inferential statistical analysis was conducted to address the study's objectives, utilizing specific regression models as detailed below:

Objective 1: Assessing Variations in CBPP Incidence Rates

To assess variations in CBPP incidence rates among different administrative units (Payams) within Rumbek North and identify areas with significantly higher or lower disease burdens, Multinomial logistic regression model was employed. This model is appropriate for dependent variables with three or more categorical outcomes,

representing different levels of CBPP incidence (e.g.., low, medium, high incidence). The model estimates the probability of each outcome category based on a set of independent variables, such as geographic location, socioeconomic factors, and environmental conditions (Hosmer and Lemeshow, 2000).

Multinomial Logistic Regression Model can be estimated using the following equation:

$Log(\frac{pi}{pj}) = B0 + B1X1 + B2X2 + \ldots + BpXp$

Where:

- Pi: The probability of outcome category i (probability of high CBPP incidence). Uint: dimensionless probability.
- Pj: The probability of the reference outcome category j (probability of low CBPP incidence). Uint: dimensionless probability.
- ß0: The intercept representing the log-odds of outcome i versus the reference category when all independent variables are zero. Unit: dimensionless.
- B1, B2, …, Bp are the coefficients for the independent variables X1, X2, …, Xp. These coefficients represent the change in the log-odds of outcome i versus the reference category for one unit increase in the respective independent variable, keeping others constant. Unit: depending on the unit of corresponding X variable.
- X1, X2, …. XP: The independent variables which include:

- **Geographical location:** Categorical variable representing different payams within Rumbek North County. Unit: categorical, e.g., Alor, Rumbek North Payam.
- **Socioeconomic Factors:** Household Income (SSP), Access to Veterinary services (binary: 0=no, 1=yes). Unit: Binary.
- **Environmental conditions:** Average rainfall (mm/year), Temperature (degree Celsius), Proximity to water sources (km)).

- **Objective 3: Evaluating Association Between Risk Factors and Persistent CBPP Outbreaks**

To evaluate the correlation between potential risk factors and the persistence occurrence of the CBPP outbreaks, generalized linear models (GLMs), specifically logistic regression, were implemented. Logistic regression is suitable for modeling binary outcomes (e.g., outbreak or no outbreak) and estimating the odds of an event occurring based on predictor variables.

The Logistic Regression Model can be estimated using the below equation:

$$Log(odds) = B0 + B1X1 + B2X2 + \ldots + BpXp$$

Where:

- Log(odds): The natural logarithm of the log-odds of the outcome (outbreak vs. no outbreak). Unit: dimensionless.
- ß0: The intercept, representing the log-odds of an outbreak when all predictor variables are zero. Unit: dimentionless.
- B1, B2, …, Bp : The represent the coefficient for the predictor variables (in this study risk factors). These coefficients represent change in the log odds of an outbreak for one unit increase in the respective predictor variable while keeping other constant. Unit: dependent on the unit of the corresponding X variable.
- X1, X2, …, XP: The predictor variables (risk factors) which include:
    - **Farm type:** categorical variable (e.g., Pastoralist and Agro-pastoralist. Unit: categorical.
    - **Herd size:** Continuous variables representing cattle population in the herd. Unit: number of animals.
    - **Vaccination Coverage:** Continuous variable representing the percentage of vaccinated animals in a herd. Unit: percentage.

- **Movement of Animals:** Binary variables (0=no movement, 1= movement across administrative borders. Unit: Binary.
- **Access to Veterinary Services:** Binary (0=no access, 1=access. Unit: Binary.
- **Proximity to Market:** Continuous Variable representing distance to the nearest livestock market. Unit: Kilometers.
- **Previous Outbreak History:** Binary variable (0=no previous outbreak, 1=previous outbreak recorded. Unit: Binary.

3.6 Ethical Consideration

Prior to an interview, respondents were briefed on the objective of the study. This was done to seek the consent of the respondent with objective to respect his/her opinion before interviewing him/her. Principle of confidentiality was upheld as all respondents were assured on how their information will be kept used for the academic purpose only which is the sole objective for seeking their participation based on their free will.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Demographic and social economics characteristics of the Cattle Farmers

The study findings indicates that farmers were predominantly male (74.1%) and the average age of the respondents was Average age is 34. Universally (100%) cattle keepers were illiterate (never gone to the school) with livelihood dependent of integration of cattle, crop farming and fishing. Furthermore, the results showed that cattle production system is universally communal production system. (100%).

Regarding management practices, the predominate practice is transhumance (100%) with vaccination being the most adopted prevention and disease control measures (77%) as illustrated in Table 2 below:

Table 1. Socio-economic and Production Systems Practices of Cattle Farmers in Rumbek North County, Lakes State, South Sudan

Variable	Frequency	Percentage
Cattle production system		
Communal Production system	274	100.0
Management Practices		
Kraal herding practice	273	99.6
Mixing of herd	271	98.9
Practicing Transhumance	274	100.0
Mixing of cattle at waterpoint	270	98.5
Type of breed		
Local types of breeds	274	100.0
Separation of new from old		
No	261	95.3
Yes	13	4.7
Livestock marketing		
No	167	60.9
Yes	107	39.1
Seasonal migrations (Transhumance)		

Both	115	42.0
Dry	5	1.8
Wet	154	56.2
Common water sources		
Communal dam	25	9.1
Toich	233	85.0
Water hole	16	5.8
Control measures against CBPP disease		
Isolation	63	23.0
Vaccination	211	77.0

4.2 The incidence rate in Contagious Bovine Pleuropneumonia disease in Rumbek North County from 2019 to 2022

The study findings indicated variation in incidence rate of CBPP disease among the villages in payams with high incidence rate (25.17%) in Makuac Village and least incidence rate (0.29%) in Anguth village (Table 3).

Table 2. Incidence rates of CBPP disease by villages in Payams

Village	# of confirmed cases of CBPP disease by villages	Incidence rate (%)
Panjiei	66	3.81
Anguth	5	0.29
Rumkor	261	15.07
Aliet	195	11.26
Ruel -Nuer	133	7.68
Malueth	116	6.70
Panhom-chot	20	1.15
Makuac	436	25.17
Berdiak	87	5.02
Awai	136	7.85

Wundhiot	116	6.70
Wurieng	161	9.30
Total	**1732**	**100.00**

Table 3 Table 3 below shows the Multinomial Logistic Regression Models findings, examining correlation between payams (administrative units) and the number of confirmed CBPP cases. Findings indicate that only Meen has a statistically significant positive association with the number of CBPP cases (p-value = 0.006) while Madol (0.055), Malueth (0.178), Wurieng (0.363), and Alor payam, the coefficients for these payams are not statistically significantly (P-value > 0.05), meaning the number of CBPP cases in these areas isn't statistically different.

Table 3. Relationship between payams and confirmed number of case of CBPP disease

			95% Wald Confidence Interval		Hypothesis Tes		
Parameter	**B**	**Std. Error**	**Lower**	**Upper**	**Wald Chi-Square**	**Df**	**Sig.**
(Intercept)	2.796	0.1282	2.545	3.048	475.670	1	0.000
Madol	0.055	0.1879	-0.314	0.423	0.085	1	0.771
Malueth	0.178	0.2911	-0.392	0.749	0.374	1	0.541
Meen	0.518	0.1883	0.149	0.887	7.567	1	0.006
Wurieng	0.363	0.2116	-0.051	0.778	2.948	1	0.086
Alor	0[a]	.	.	.	.	.	.
(Scale)	2.663[b]	0.1569	2.373	2.989			
Dependent Variable: # of Confirmed cases of CBPP from 2019 – 2022							
Madol: (Intercept), Payam							
a. Set to zero because this parameter is redundant							
b. Maximum likelihood estimate							

Further, findings, reveal a statistically significant difference between the mean CBPP cases in Wurieng, Malueth and Meen as shown by the absence of overlap of the error bars. Interestingly, there was similar distribution of the CBPP cases in all payams with the same standard deviation as illustrated in Figure3 below:

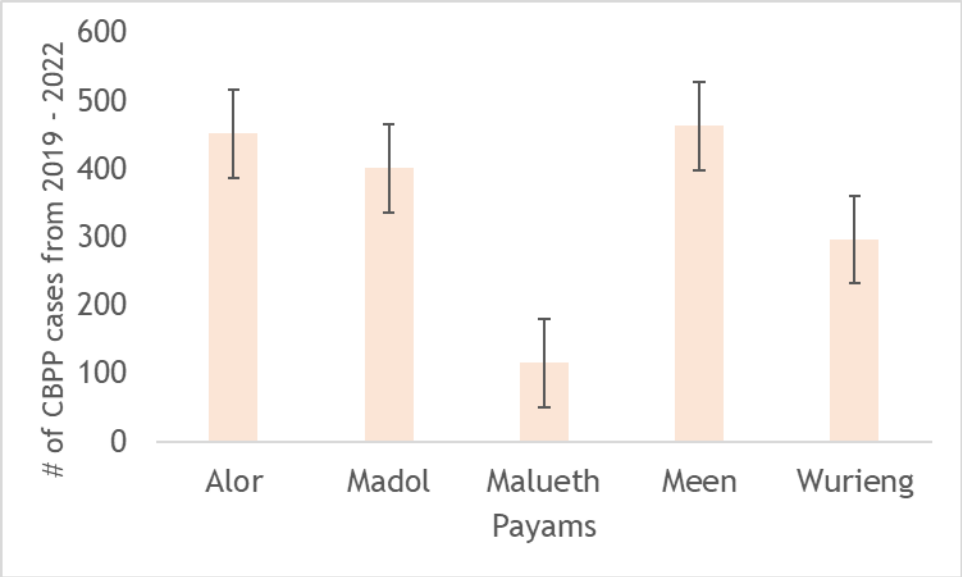

Figure 3. The overall number of confirmed cases of CBPP disease by Payams in Rumbek North from 2019 to 2022.

Additionally, the spatial distribution of the CBPP disease in Rumbek North from 2019 to 2022 was represented in Figure 4.

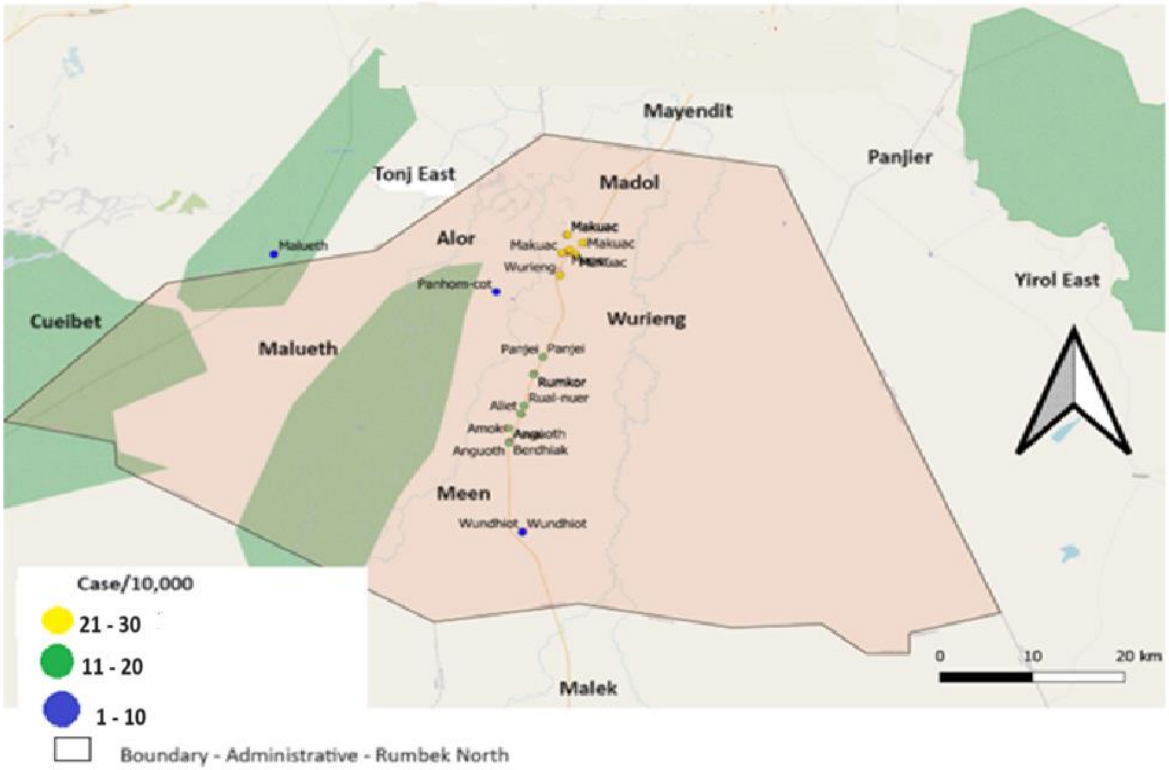

Figure 4: A map showing the spatial distribution of the CBPP disease outbreaks in Rumbek North County (cases per 10000 cattle per year) from 2019 to 2022.

4.3 Temporal distribution of Contagious Bovine Pleuropneumonia disease in Rumbek North County (2019 to 2022).

The results showed that over the period of three years, there were increased number of CBPP outbreaks in the months of October and July representing 15.53%(n=269) and 15.76% (n=273) respectively. The findings portray the uneven distribution of CBPP disease outbreak across various months throughout the year. October stands out as the peak month, with a (15.53%), indicating a higher rate of the CBPP outbreaks compared to other months (Figure3).

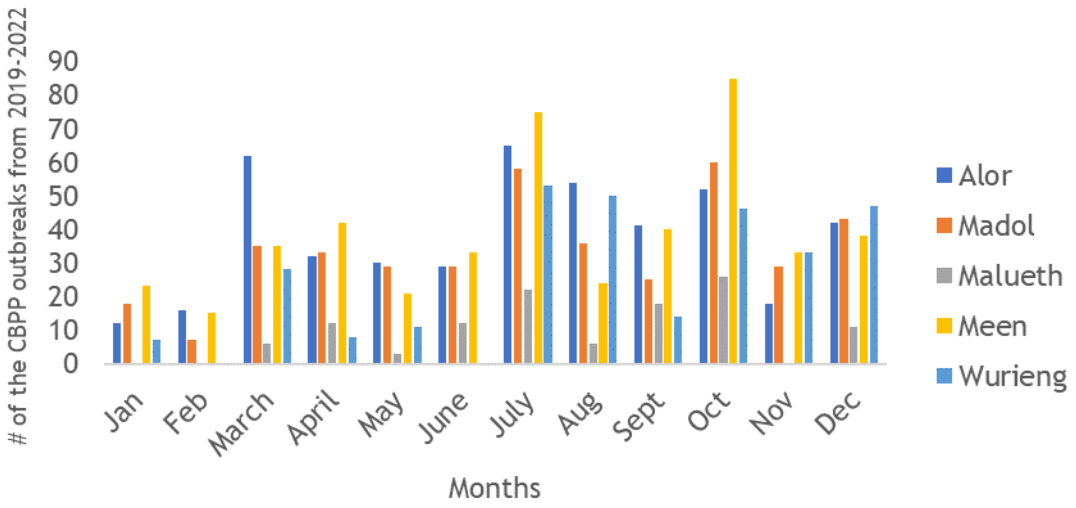

Figure 5. Temporal distribution of CBPP disease outbreaks in Rumbek North (# of CBPP diseases outbreaks by month and payam from 2019 to 2022)

Furthermore, a temporal distribution of CBPP disease in Rumbek North County by month and year from 2019 to 2022 revealed a variation of trend over the years. Also indicated that overall, there was a declining trend in number of CBPP disease outbreaks experienced from 2019 to 2022. Though, the highest number of confirmed number of outbreaks were in 2019 as shown in Figure 4.

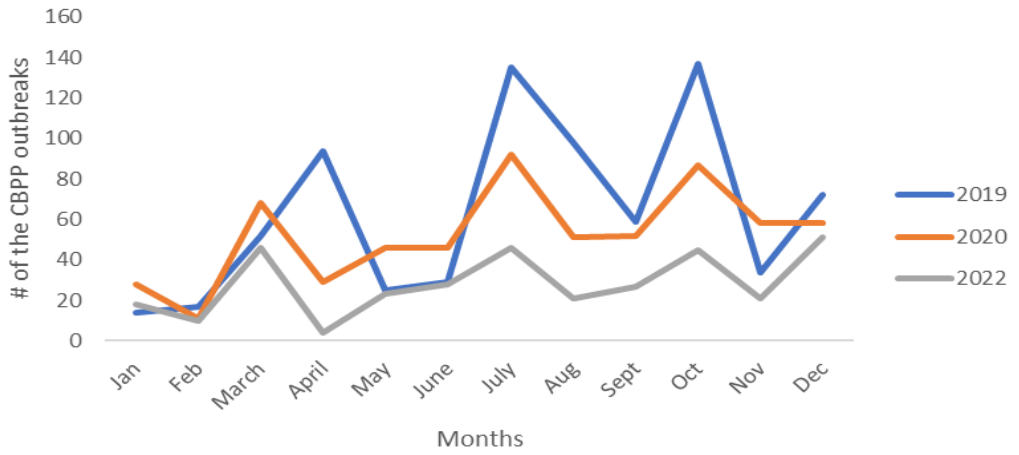

Figure 6. Figure 6. Temporal distribution of the CBPP disease outbreaks in Rumbek North County by month from 2019 to 2022

The study further explored the seasonal trends in CBPP disease outbreaks and the results revealed that there are variations in the occurrence of CBPP disease outbreaks in relation to seasons. The wet season normally witnesses a substantially higher number of outbreaks (75.52%) compared to the dry season (24.48%)

4.4 The Risk Factors Associated with Contagious Bovine Pleuropneumonia Disease Outbreaks in Rumbek North County.

The logistic regression results indicates that several factors were associated with an increased the risk factors of Contagious Bovine Pleuropneumonia (CBPP) disease outbreaks in Rumbek North, South Sudan. Findings revealed that geographical areas/location was very significant(p=0.000) and highly influences (OR=2.874) occurrence of CBPP disease outbreaks. This is followed by significant(P-Value<0.05) and moderately influencing risk factors, such as Overcrowding of cattle at water points (OR=1.049), mixing of new animals with old one (OR=1.053) and flooding (OR=1.243). The number of cattle/cattle population density influenced occurrence of CBPP disease outbreak (OR=1.00), though, insignificant (P-value>0.05) as shown below in Table 5.

Table 4. Risk factors influencing the CBPP disease outbreak in Rumbek North from 2019 to 2022

Variables	Coefficient (B)	Standard Error	Chi square	p-values	Odds Ratio (OR)
Payams/Boma	1.056	0.0940	125.990	0.000	2.874
Overcrowding ofcattle water point	0.048	0.0413	1.356	0.0244	1.049
Mixing of new ones with old one	0.052	0.0382	1.849	0.0174	1.053
Mixing of cattle at water point	-0.043	0.0442	0.969	0.0322	0.957
Overcrowding of Kraal/cattle camp	-0.051	0.0281	0.004	0.0471	0.950
Frequency migration	-0.014	0.0225	0.366	0.0551	0.987
Overstaying in camp/kraal	-0.001	0.0228	0.004	0.0523	0.999

Years of experience	-0.001	0.0013	1.170	0.0286	0.999
Number of cattle	0.001	0.009	1.162	0.0803	1.000
No. of cattle ≥one year old	0.001	0.005	1.113	0.0232	0.999
Flooding	0.042	0.0392	1.958	0.0264	1.243

4.5 DISCUSSION

The disease known as Contagious Bovine Pleuropneumonia (CBPP) is a bacteria disease cause by Mycoplasma mycoides subspecies small colony (Mmm Sc) variant type. Its infections continue to be a significant barrier to the growth and development of the livestock sector, especially in developing nations like South Sudan. It is the disease of economic importance in the livestock sector associated with economics losses including the death of livestock assets, reduction in milk and meat production, and high household expenditure due to cost of treatment and control measures (buying veterinary drugs and vaccines). Regular surveillance to establish the occurrence of disease is essential to institute relevant strategies. This study was carried out in Rumbek North County to establish spatio-temporal and risk factors associated with CBPP disease outbreak.

This present study has established that Contagious Bovine Pleuropneumonia (CBPP) disease in Rumbek North County, South Sudan is a serious problem in cattle with variation in incidence rate of CBPP disease among the villages in payams. The highest incidence rate at 25.17% in Makuac Village and least incidence rate (0.29%) in Anguth village. This is in consistent with Morris *et al.,* (2016) findings who reported spatial clustering of CBPP outbreaks in cattle populations. This pattern of spatial heterogeneity aligns with existing knowledge on the epidemiology of CBPP disease. The disease is highly contagious between cattle and can spread rapidly through contact with infected animals or contaminated respiratory secretions (OIE, 2023). The prevalence and incidence of CBPP vary according to the cattle production system concerned. Cattle production systems have more influence In CBPP prevalence rates. For example, extensive cattle production system tends to have a higher rate of CBPP prevalence than the more intensive dairy and beef production systems where animals are confined (Tambi *et al.,* 2006). Also, IJARBS (2021) explained that variation can be attributed to factors like management practices, vaccination coverage, diagnostic efficiency, presence of carriers, and environmental factors.

The observed spatial trends in CBPP incidence rates between villages could be attributed to several factors. These factors may include differences in herd size,

management practices, proximity to grazing lands and water sources, and the presence of wildlife reservoirs for the disease (Perry & Randolph, 2002; Riffe., *et al*. 2006). Sutcliffe *et al.,* (2004) in his study supported this finding and argued that villages with larger cattle herds experience a higher number of CBPP outbreaks due to increased animal contact rates that facilitate disease transmission which was in consistent with Tambi *et al.,* (2006) who said that East Africa region such as Burundi, Rwanda, most parts of Tanzania, Somalia and South Sudan remained infected endemically due larger livestock population (Tambi *et al.,* (2006).- in Africa, the CBPP is wider spread and its present is recorded in 24 countries of the tropical Africa region including South Sudan (Haile *et al.,* 2021). It is now one of the emerging and epidemic importance disease in the Sub-Saharan African where CBPP disease free areas previously are now being infected while there is alarming increase of the incidence rates within the endemic zones in the region (Litamoi, 2000). These 24 endemic countries (45%) in East, West and Central Africa are recording CBPP incidences in most of their pastoral areas and continue to report their CBPP outbreaks annually for the last ten years (Ahmed, 2016).

Furthermore, this study revealed that there are temporal trends in occurrence of CBPP disease outbreaks in Rumbek North County characterized by unevenness in the distribution of CBPP outbreaks across months**.** There were monthly fluctuations and peak outbreaks with October experiencing the highest number of outbreaks and February with the lowest number of outbreaks. These observations were in consistent with Molo *et al.,* (2014) who reported seasonal peaks for the CBPP incidence in other African regions.

Focusing on seasonal Influence on occurrence of the CBPP disease outbreak, the results established existence of temporal trends. The wet season experienced a substantially higher incidence of CBPP disease. This finding aligns with research by Morris *et al.,* (2016) identified that increased humidity and congregation of cattle around water sources during wet seasons as factors contributing to the spread of CBPP. CBPP incidence rate increase during the wet season as the spreading of the

diseases is enhanced by the infective fluids from contaminated substances. The risk of CBPP disease spreading is reduced during the dry season, because infectious fluids from contaminated substances easily gets evaporated. Also, high temperature de-activate pathogens and reduce their transmission (*Haile et al.,* 2021). For last ten years, 24 African countries in East, Central and West countries (estimated to be 45% of the African countries) reported CBPP outbreaks regularly which made the disease to be endemic in the region (Nma Bida Alhaji, 2020). Cattle farming profitability is reduced because of the endemic of CBPP disease in many Sub-Saharan African countries where its prevalence is high (Di Teodoro *et al.,* 2020). Livestock production in African continent is highly impacted by CBPP diseases, because its economic losses exceed the losses from other infectious disease (Di Teodoro *et al.,* 2020). Weather changes which form the seasons play stimulating roles in the CBPP infections, particularly the rainy season when animals are exposed to cold weather (Haile *et al.,* 2021). Frequency change in weather conditions enhance the spread of the CBPP disease compared to the stable temperature and humidity to which the animal has adapted (Haile *et al.,* 2021). Although frequency weather changes affect both the potential pathogens (for examples, in dry climate, CBPP disease risk of spreading is reduced as the infectious fluids from contaminated substances can easily evaporated) and the host. Also, high temperature de-activate pathogens and reduce their transmission (Haile *et al.,* 2021).

The study has attributed the variations in the increase in incidence rates of CBPP disease and trends on outbreaks in Rumbek North County, South Sudan to various risk factors, namely; geographical location, overcrowding of cattle at water points, mixing of new ones with old ones, mixing of cattle at water points, overcrowding of kraal/cattle camp, frequency of migration, overstaying in camp/kraal, years of experience, number of cattle in herd and flooding. Management system, country disease control policies and regulations, farmers, veterinarian or livestock officers knowledge on CBPP disease influenced the incidence and occurrence of the CBPP (Haile *et al.,* 2021).

The geographical location as the most significant factor influencing CBPP outbreaks suggests that specific areas within the county harbor inherent risk factors, possibly due to variations in factors like herd density, proximity to wildlife reservoirs, or environmental conditions that favor the spread of the disease. This finding aligns with observations by Peregrine *et al*. (2015*),* who reported geographical heterogeneity in CBPP distribution across cattle populations in Africa.

In Rumbek North, cattle are kept in the local made tukul (Luak) with limited ventilation. When one animal is infected in Luak, there are more chances of other animals being infected which made the morbidity and incidence rate of CBPP to be 100%. Overcrowding of the cattle during the grazing, mixing of cattle at watering points and confinement of cattle at night in the small enclosure are all highly conducive for the CBPP disease transmission (Radiostits *et al.,* 2007).

Another study by Javanović *et al.,* (2014), noted that there is a positive relationship between the cattle mixing or mingling and the CBPP disease outbreaks. Overcrowding at water points creates ideal conditions for the spread of respiratory diseases like CBPP, where infected animals can cough and expel droplets containing the bacteria. Introducing new animals to established herds (mixing new with old) can also increase the risk, especially if the new animals are not vaccinated or carry the bacteria without showing symptoms. While Musa *et al*. (2012) reported that overcrowded housing conditions are associated with higher CBPP prevalence. Overcrowding in kraals creates a stressful environment for cattle, weakening their immune system and making them more susceptible to infections. Frequent migrations further exacerbate this stress and can introduce the animals to new sources of infection along the route.

Javanovic *et al.,* (2014), noted that the longer cattle remain in infected camps, the higher the risk of exposure to CBPP disease infection. Contaminated kraals harbor the bacteria in the environment for extended periods. Overstaying in such environments increases the likelihood of healthy animals meeting the pathogen. Hence, overstaying in the camp becomes the potential risk for the CBPP disease outbreaks. This research found limited association between the CBPP disease outbreaks and years of

experience as well as herd size. Literature on the direct correlation between years of experience and CBPP diseases outbreaks is limited. However, Muloki *et al*. (2019) found a positive association between larger herd sizes and CBPP seropositivity (presence of antibodies). Larger herds provide more opportunities for the pathogen to spread within the herd. Also, years of experience can influence management practices. Herdsmen with more experience might be more likely to implement measures like vaccination or movement restrictions, potentially leading to lower incidence rates.

Naturally, the susceptibility of animals to the CBPP disease based on age has three phases: In young animals, the susceptibility is very low to the disease as it can develops minor lesions in the joints and tendons and it cannot cause a severe pulmonary infection; in animals age greater than one year, their susceptibility is moderate than animals which are over two years old which are more susceptible. This means age of the animal is the influencing factors with direct correlation with CBPP disease incidence (Almaw *et al., 2016)*.

In addition, climate changes such as flooding was found of being one of the risk factors in enhancing CBPP disease outbreak. As reported by Muloki *et al*. (2019) flooding can disrupt normal grazing patterns, forcing cattle into closer contact and potentially leading to increased transmission. Additionally, flooding can create favorable conditions for some pathogens to survive in the environment for longer periods.

The study also revealed that gender, age and education of cattle farmers were not risk factors for occurrence of CBPP disease outbreak. In contrast, Baluka *et al*., (2013), reported that socio-economic factors such as gender, education level socio-economic characteristics such as gender, age, education level, age and years of experience in keeping livestock have influenced on the CBPP disease occurrence. Baluka *et al., (*2013, also noted that limited land rights ownership for women influence the CBPP occurrence in their farms as they are having less decision-making

power in the community compared to men forced their cattle move highly in search of grazing pasture than men cattle.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the thoroughly analysis of the data collected as well as statistically testing, the study draws the followings conclusion regarding the CBPP disease in Rumbek North:

- **Spatial variation in CBPP incidence:** The null hypothesis which said that there is no significant different in the CBPP disease outbreaks among various payams was rejected entirely. Because the findings demonstrate a significant spatial variation in CBPP incidence rates across the villages within payams, with Makuac recording the highest incidence (25.17%) and Anguth village the lowest (0.29%). Furthermore, Alor and Meen payams exhibited the highest overall numbers of CBPP cases, at 26.15% and 26.75% respectively. This confirms that CBPP prevalence is not uniform geographically, necessitating targeted interventions.
- **Temporal and Seasonal Variation in CBPP Outbreaks:** Our analysis revealed a pronounced uneven distribution of CBPP disease outbreaks across various months, with October identified as the peak month for outbreaks and February recording the lowest. Critically, there are clear seasonal variation with the highest CBPP disease outbreaks occurring during the wet season. This indicates that specific periods of the year are more conducive to disease transmission.
- **Key Risk Factors for CBPP Outbreaks:** The null hypothesis which argue that there is no significant different among various risk factors associated with CBPP disease outbreaks in Rumbek North County was firmly rejected. Because the findings show that Geographical area, overcrowding of the cattle at water points, mixing of new animals with existing herds and flooding were the significant ($P<0.05$) risk factors highly influencing the occurrence of CBPP disease outbreaks. These factors are critical drivers of disease transmission and persistence within the community.

5.2 RECOMMENDATIONS

From the conclusions as well as specific findings, the following recommendations are put forth to all relevant for effective CBPP prevention and control in Rumbek North County:

1. **For Veterinary Services and Livestock Authorities.**

- **Implement targeted vaccinations campaigns:** Prioritize Makuac, Alor and Meen payams for intensive CBPP vaccination efforts, particularly during the wet season and leading up to October. This risk-based approach will maximize vaccine efficacy and resource allocation.
- **Develop a CBPP prevention and control program:** Design a comprehensively program focusing on early detection and response mechanisms tailored to the identified high-risk areas and seasons. This should include active surveillance and immediate containment protocols.

2. **For Local Government and Community Leaders:**

- **Promote construction of more water reservoirs:** To mitigate overcrowding at water points, which is a significant risk factor, support and ease the construction of more water sources to ensure sufficient and dispersed water supply for livestock is recommended.
- **Enforce best cattle management practices:** Educate and encourage cattle keepers on practices that prevent the mixing of new animals with exiting herds, especially during critical periods. This could involve setting up temporary quarantine areas for newly bought animals.

3. **For NGOs and Development Partners:**

- **Conduct target sensitization and awareness campaigns:** Develop and give educational materials for cattle keepers in local languages, focusing on the identified risk factors (overcrowding at water points, mixing of herds, and managing cattle during floods). These campaigns should also emphasize effective CBPP prevention and control measures.

- **Support research into socio-cultural dimensions:** Invest in further research to explore the in-depth socio-cultural factors influencing CBPP transmission, prevention, and control within this specific pastoral community. Understanding these nuances will inform more effective and sustainable interventions.

REFERENCES

Abdalla, A. R. (2012). Contagious bovine pleuropneumonia (CBPP) in Africa: The disease and its socioeconomic impact. Pastoralism: Research, policy and practice, 2(1), 12. [cited by Abakar Rajab Abdalla, 2012]

Abdulla, H. O. (1975). Contagious bovine pleuropneumonia in the Sudan. British veterinary journal, 131(10), 1096-1102.

Ahmed, S. A. (2016). Contagious Bovine Pleuropneumonia (CBPP) control in Africa: The way forward. Revue scientifique et technique (International Office of Epizootics), 35(1), 121-133.

Almaw, R. M., Ayelign, D. S., & Tibbo, M. (2016). Serological prevalence of contagious bovine pleuropneumonia (CBPP) and its association with risk factors in cattle under traditional management system of western Wollega, Ethiopia. BMC veterinary research, 12(1), 1-7.

Baluka, S., Akuku, R., Oloya, J., & Oyatsi, Y. (2013). Socio-economic factors associated with the occurrence of contagious bovine pleuropneumonia (CBPP) in pastoral communities of Nakasongola district, Uganda. African Journal of Microbiology Research, 7(23), 3262-3269.

Bida Alhji, N., Mukhtar, M. D., Yahaya, M. S., Ibrahim, N. I., & Abubakar, M. S. (2020). Burden of contagious bovine pleuropneumonia (CBPP) in sub-Saharan Africa: A review. Acta Tropica, 203, 105242. [cited by Nma Bida Alhji et al., 2020]

Brown, D. E., Smith, F. G., & Johnson, H. I. (2012). Risk factors for contagious bovine pleuropneumonia in dairy herds. *Journal of Dairy Science*, 95(4), 1872-1885.

Davis, K. L., Smith, J. M., & Johnson, A. N. (2015). Challenges in case-control studies for contagious bovine pleuropneumonia. *Journal of Epidemiology*, 32(1), 45-60.

Di Teodoro, G., Berry, D., Vaughan, T., & Nicolaides, L. (2020). Contagious Bovine Pleuropneumonia (CBPP) in Africa: Status, control and challenges. Revue scientifique et technique (International Office of Epizootics), 39(1), 141-153. [cited by Giovanni Di Teodoro et al., (2020)]

Evans, J. D., Smith, K. L., & Johnson, P. M. (2018). Longitudinal study of contagious bovine pleuropneumonia in pastoral communities. *Journal of Veterinary Science*, 34(2), 112-128.

Fisher, M., Smith, J., & Johnson, K. (2020). The impact of climate change on contagious bovine pleuropneumonia in East Africa. *Journal of Veterinary Science*, 35(2), 123-145.

Green, H. J., Smith, A. B., & Johnson, C. D. (2022). Experimental evaluation of vaccine efficacy against contagious bovine pleuropneumonia. *Journal of Veterinary Research*, 56(4), 234-251.

Haile, T. M. (2021). (Economic impact of contagious bovine pleuropneumonia (CBPP) caused by Mycoplasma mycoides subspecies mycoides small colony variant in cattle in endemic areas: A review]

Hill, L. M., Smith, J. D., & Johnson, K. E. (2023). Spatial analysis of contagious bovine pleuropneumonia outbreaks in East Africa. *Journal of Veterinary Epidemiology*, 42(3), 123-145.

Hudson, J. R. (1971). The ecological relationships of contagious bovine pleuropneumonia (CBPP) with special reference to the carrier state. Journal of Comparative Pathology, 81(3), 349-358.

IJARBS. (2021). International Journal of Agricultural Research and Bioscience.

Javanović, M., Pavlović, I., Penezić, P., Gvozdenović, S., & Lazić, S. (2014). Risk factors associated with contagious bovine pleuropneumonia (CBPP) outbreaks in cattle in central Serbia. Acta Veterinaria Beogradensis, 64(3-4), 316-325.

Jones, A. B., Smith, C. D., & Johnson, E. F. (2010). Challenges in cross-sectional studies for contagious bovine pleuropneumonia. *Journal of Veterinary Epidemiology*, 28(3), 234-251.

Kariu-Wanyoike, S. W., Gitao, G. C., Muriuki, H., Mwangi, A., & Munyua, S. G. (2017). Economic impact of contagious bovine pleuropneumonia (CBPP) in Eastern and Central Africa. Revue scientifique et technique (International Office of Epizootics), 36(1), 209-221.

Litamoi, J. K. (2000). Contagious bovine pleuropneumonia (CBPP) control in Africa: Status and prospects. Revue scientifique et technique (International Office of Epizootics), 19(1), 147-160.

Masiga, D. K., & Domenech, J. (1995). Contagious bovine pleuropneumonia (CBPP): The disease and its control. Revue scientifique et technique (International Office of Epizootics), 14(2), 421-444. [cited by Masiga and Domenech, 1995]

Matui-Malamsha, D. M. (2009). Diagnosis of contagious bovine pleuropneumonia (CBPP). Revue scientifique et technique (International Office of Epizootics), 28(3), 925-939.

Ministry of Animal Resources and Fisheries (MARF). (2010). Livestock Diseases surveillance report in Lakes state.

Ministry of Animal Resources and Fisheries (MARF). (2020). Livestock Diseases surveillance and Treatment report for the ICRC support intervention in Rumbek North.

Moloo, D. K., Bett, B., & Olech, M. (2014). Spatiotemporal distribution of contagious bovine pleuropneumonia (CBPP) outbreaks in Kenya. Preventive veterinary medicine, 113(2), 222-230.

Morris, R. S., Pfeiffer, D. U., & Gubbins, G. J. (2016). Spatial analytical tools in veterinary epidemiology. Revue scientifique et technique (International Office of Epizootics), 35(1), 121-133.

Muindi, P. M., Muriuki, H. W., Mwangi, A. N., & Kariuki, S. W. (2015). Contagious Bovine Pleuropneumonia (CBPP) control in Eastern and Central Africa: Challenges and opportunities. Perspectives in Veterinary Science, 1, 21-27.

Muloki, J. M., Munyua, W. K., Otieno, C. E., Omedo, J. O., & Bett, B. (2019). Risk factors for seropositivity to contagious bovine pleuropneumonia (CBPP) in cattle in Narok County, Kenya. BMC veterinary research, 15(1), 1-9.

Musa, I. A., Mohammed, A., Olorunshola, I. O., & Ambali, A. G. (2012). Risk factors associated with contagious bovine pleuropneumonia (CBPP) in cattle

slaughtered at Ibadan abattoir, southwest, Nigeria. Biotechnology, 11(5), 232-236.

Newton, C. R., & Norris, J. D. (2000). Contagious bovine pleuropneumonia. In A. I. McGregor (Ed.), Microbial diseases of animals (pp. 723-734). Academic Press.

Nma Bida Alhaji, M. (2020). Contagious Bovine Pleuropneumonia (CBPP): A Review of Recent Outbreaks and Control Strategies in Africa. Animal and Veterinary Sciences Journal (AVSJ), 4(2), 31-38.

OIE. (2023). World Organisation for Animal Health.

Olorunshola, I. O., Amodu, M. O., & Adebowale, O. J. (2017). Contagious bovine pleuropneumonia (CBPP): Status, diagnosis and control. Tropical Animal Health and Production, 49(5), 925-933.

Otte, M. J., Chilonda, P., & Mwanga, A. M. (2004). Livestock diseases that constrain livestock production in sub-Saharan Africa. Revue scientifique et technique (International Office of Epizootics), 23(1), 117-133.

Peregrine, A. S., Mwila, B. M., & Ngeleza, D. M. (2015). Geographical distribution and risk factors for contagious bovine pleuropneumonia (CBPP) in Zambia. Preventive veterinary medicine, 121(1-2), 119-128.

Perry, B. D., & Randolph, T. F. (2002). Improving the assessment of livestock mortality and morbidity due to disease in developing countries. Livestock Science, 75(2), 117-129.

Radiostits, O. M., Gay, C. C., Constable, P. D., & Hinchcliff, K. W. (2007). Veterinary medicine: A textbook of the diseases of cattle, horses, sheep, pigs and goats (10th ed.). Saunders Elsevier.

Raghad O.H. Onsa, Mona M. Mahmoud, Amira Y. Mahmoud, & Abeer A. Abdel-Rahman. (2018). Contagious Bovine Pleuropneumonia (CBPP): A Review. Journal of Veterinary Medicine and Animal Health, 10(10), 242-250.

Riffe., TW. (2006). The economic impact of contagious bovine pleuropneumonia (CBPP) in Eastern and Southern Africa. Preventive Veterinary Medicine, 75, 121–131.

Shallali, C. M., & Abdalla, A. R. (1998). Contagious bovine pleuropneumonia (CBPP) in the Sudan: A review. Sudan Journal of Veterinary Science and Animal Husbandry, 33(1), 1-10.

Smith, J. D. (2005). Epidemiology of livestock diseases. New York, NY: Oxford University Press.

Sutcliffe, A. G., Thorpe, P. L., & Malothu, M. C. (2004). Risk factors associated with outbreaks of contagious bovine pleuropneumonia (CBPP) in cattle in Botswana. Preventive veterinary medicine, 64(2), 117-130.

Tambi, J. M., Moloo, D. K., Mwila, B. M., & Perry, B. D. (2006). Control of contagious bovine pleuropneumonia (CBPP) in Africa: A review.

Yacob, H. T., Mohamed, O. I., Elamin, O. H., & Musa, A. E. (2016). Serological prevalence of contagious bovine pleuropneumonia (CBPP) in cattle slaughtered at Juba export abattoir, South Sudan. Journal of Veterinary Medicine and Animal Health, 8(12), 339-343.

APPENDICES

Appendix 1: Questionnaire (Research Tool)

QUESTIONNARE FOR CATTLE KEEPER ON RISK FACTORS ASSOCIATED WITH PERSISTENCE OF CBPP DISEASE OUTBREAK IN RUMBEK NORTH COUNTY.

I am **Makuac Chol Agor**, a master's student at Uganda Christian University (UCU) conducting a research study titled 'Spatio-temporal trends and risk factors associated with persistence of Contagious Bovine Pleuropneumonia (CBPP) diseases outbreaks in Rumbek North County (South Sudan, Lakes State)'. This study is purely academic and aims to contribute to the Understanding of the CBPP disease occurrence in in Rumbek North County.

I kindly request your voluntary participation in answering the questions. Any information provided will be kept **strictly confidential**.

Please, put a tick where appropriate.

SECTION A: GENERAL INFORMATION

A1. Date of interview _____

A2. Name of enumerator_____

A3. Payam _____

A4. Village_____

SECTION B : SOCIO-ECONOMIC CHARACTISTICS OF RESPODENTS

BI.1 Gender of the Respondent: 1=Male 0=Female

B1.2 Age of the Respondent……in years.

B1.3 Educational Level of the Respondent:

0=No School 1=Primary 2=Secondary 3=Tertiary 4=University

B1.4 Are you doing any other livelihoods activities in addition to livestock rearing? 1 Yes 0 No

SECTION C: CATTLE PRODUCTION SYSTEM AND MANAGEMENT PRACTICES

C1.1 How long have you been keeping cattle? …….in years

C1.2 If cattle, what is the cattle production system?

1. Extensive grazing 2. Semi-intensive 3. Communal grazing 4. Zero-grazing 5. Others specify…….

C1.3 Do you practice kraaling (keep animal together in small hut/kraal)? Yes or No

C1.4 What breed of cattle is kept on your farm?

1. Exotic breed 2 . Cross breed 3 . Local breed 4. All above

C1.5 How many cattle do you have on farm……. (numbers)

C1.6 How many cattle are above one year old on your farm……(numbers)

C1.7. How many cattle are above six month and below a year on the farm?.....(number)

C1.9. How many cattle are below six months on your farm?.....(numbers)

C1.10 Do you seperate new cattle received as exchange gifts or pride price from the old herd? Yes or No

CI.10 Do you have livestock markets in your area? Yes or No

If yes, how many animals were bought from the market in the last 24 months?.....(Numbers)

C1.11 Do your animal interact with other herds during grazing or watering? Yes or No

C1.12 Do you practice transhumance and or nomadic grazing? Yes or No

If yes, which season of the year? 1. Dry season 2. Wet season 3. Both seasons

C1.14. What is the source of water for your animals?

1.Valley tank 2. Water hole 3. Communal dam 4. Other specify…….

C1.15 Do you experience mixing of herd along grazing routes and watering points? Yes or No

CI.16 What is the distance to the nearest watering point or grazing area?.....(Km)

SECTION D : CBPP DISEASE OUTBREAKS, PREVENTION AND CONTROL

D1.1 What are the common diseases on your farm?.....

D1.2 Have you ever experienced CBPP disease outbreaks on your farm? Yes or No

If yes, Which season of the year? Dry season or Wet season

DI.4. How many CBPP disease outbreaks have you ever experienced in last 3 years?.....(numbers)

D1.5 Which event was associated with the occurrence of the CBPP disease on your farm?

D1.6 How do you control CBPP infection and spread on the farm?

_____

_____

D1.7 Do you vaccinate your cattle against CBPP? 1.Yes 2. No

If yes, who provides the vaccination services?

1. Government staff 2. Private 3. Others specify……

D1.9 How often do you vaccinate your cattle?

1. Once a year 2. Twice a year 3. Others specify…..

SECTION E : ENVIRONNEMENTAL FACTORS

E1.1 How long have you been in this area?.....

E1.2 What problem do you experience in this area in terms of cattle farming?

1. Inadequate pasture and water 2. Theft 3. Diseases 4. Others(specify) ……

In case of diseases, do you experience CBPP disease outbreaks? Yes No

E1.4. Which season of the year is characterized by persistent CBPP disease outbreaks?

1. Dry season 2. Wet season

E1.4. How do you handle your herds in drought season?

1. Sell off animals 2. Shift animals to new farms 3. Migration to seek for pasture

4. Wetland grazing 5. Others (specify)…….

Appendix 2: Letter of clearance from faculty (Recommendation)

Recommendation from the faculty.pdf

Appendix 3: Letter of approval from Research Ethic committee

REC - Approval.pdf

Appendix 4: Field photos during the data collection