ASSESSMENT OF NONBIOLOGICAL DETERMINANTS OF AFRICAN SWINE FEVER AND PORCINE CYSTICERCOSIS IN FREE RANGE PIG VALUE CHAINS IN THE GWEMBE VALLEY OF SOUTHERN ZAMBIA - A SYSTEMS THINKING APPROACH

By

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A Dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the award of the degree of Master of Science in One Health Analytical Epidemiology

The University of Zambia
Lusaka

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DECLARATION

I, CATHERINE BESNART DZOMBE, declare that I have written this dissertation and that the work has not been submitted for any other degree or professional qualification to any other institution. Where assistance was sought, it has been acknowledged accordingly. It has been presented by the guidelines for the Masters of Science dissertation of the University of Zambia.

Signature ……..

Date…….

CERTIFICATE OF APPROVAL

The University of Zambia approves the dissertation submitted by CATHERINE BESNART DZOMBE, as fulfilling the partial requirements for the award of the Master of Science Degree in One Health Analytical Epidemiology by the University of Zambia

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(Board of Examiners)

ABSTRACT

The pig production sector in Zambia, particularly in Southern province, has exhibited consistent growth owing to the substantial pig populations in these regions. However, the industry faces significant challenges primarily arising from diseases such as African Swine Fever (ASF) and porcine cysticercosis (PCC), which hinder its expansion and sustainability. Consequently, the aim of this study was to conduct an assessment of nonbiological determinants of ASF and PCC in free range pig value chains in the Gwembe valley of Southern Zambia. A cross-sectional study that incorporated the Spatial Group Model Building (SGMB) process, using the LayerStack tool, was conducted in October 2023. This participatory method engaged 11 members of the Gwembe pig value chain in a focus group discussion using a semi-structured guide as well as two District Veterinary Officers (DVOs) as key informants. The study revealed that socio-economic factors, traditional farming practices, and market dynamics significantly contribute to the persistence and spread of these diseases. Poor access to veterinary services, especially in remote areas, delayed disease management, while traditional free-range farming practices facilitated disease transmission through unsanitary environments and contact with contaminated human waste. Cultural practices, such as pig movement during ceremonies, and economic pressures, including the sale of infected pigs in informal markets, further exacerbated the situation. The study also identified gaps in biosecurity measures, inadequate disease awareness, and financial constraints as major barriers to effective disease control. A systems thinking approach, using the SGMB, highlighted the spatial and socio-economic dynamics that sustain the prevalence of ASF and PCC, underscoring the need for integrated, multi-dimensional interventions that address both cultural and economic challenges. It is recommended that efforts be focused on improving access to veterinary services in remote areas. To address the delay in disease interventions, veterinary outreach programs should be strengthened, ensuring timely disease prevention and control measures. Based on the findings that traditional free-range farming practices significantly contribute to disease transmission, it is recommended that pig farming practices be modernized through the promotion of confined and semi-confined farming systems. Going forward, exploring the socio-cultural factors that influence farmers' acceptance and adoption of modern biosecurity measures could shed light on ways to bridge the gap between traditional practices and disease control.

Keywords: African Swine Fever, Porcine Cysticercosis, Non-biological factors

DEDICATION

I dedicate this work to my beloved late young sister, Muonga Lukwesa, whose unwavering support and anticipation of my graduation always inspired me.

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ACRONYMS AND ABBREVIATIONS

%	Percentage
˚C	Degree Celsius
$	American dollar
ASF	African Swine Fever
ASFV	African Swine Fever Virus
BOT	Behaviour over time
CDF	Constituency Development Fund
CLD	Causal loop diagrams
DVO	District Veterinary Officer
FAO	Food and Agriculture Organisation
FDG	Focus group discussion
Fig	Figure
GIS	Geographic Information System
LMIC	Low- and middle-income countries
NTD	Neglected Tropical Disease
PCC	Porcine Cysticercosis
SGMB	Spatial group model building
T4	Great-East Road
VA	Veterinary assistant
WHO	World Health Organisation
ZMW	Zambian Kwacha

CHAPTER ONE: INTRODUCTION

1.1 Background

African swine fever (ASF) and porcine cysticercosis (PCC) are critical threats to global pig production, especially in areas where free-range pig farming is prevalent. ASF, a viral disease, has been responsible for significant economic losses worldwide, with recent estimates indicating that outbreaks between 2018 and 2021 led to the culling of over 25% of the global pig population, translating to losses exceeding $55 billion (FAO, 2021). Porcine cysticercosis, caused by the larval stage of Taenia solium, remains a major zoonotic disease with both public health implications and economic burdens. Recent studies show that the global prevalence of porcine cysticercosis varies widely, ranging from 9.8% to 45.6% in endemic regions, leading to an estimated economic loss of over $1 billion annually due to reduced pork quality and marketability (WHO, 2022).

In Africa, ASF and PCC continue to undermine the potential of the pig farming industry, particularly in sub-Saharan Africa, where smallholder and free-range pig farming are vital to rural livelihoods. ASF outbreaks in Africa have been recurrent, with a reported mortality rate of up to 100%, leading to significant income losses for rural farmers (Penrith et al., 2021). The economic impact of ASF in Africa is substantial, with recent data showing that Nigeria, the continent's largest pig producer, lost over $200 million in 2020 due to ASF outbreaks (FAO, 2021). PCC is also prevalent, particularly in Eastern and Southern Africa, where up to 35% of pigs in some communities are infected, contributing to widespread food insecurity and economic instability (Thomas et al., 2022).

In Southern Africa, the burden of ASF and porcine cysticercosis is particularly acute due to the region's reliance on free-range pig farming, which is more susceptible to these diseases. Recent outbreaks of ASF in the region, particularly in South Africa, Zimbabwe, and Zambia, have led to severe economic losses, with the South African pork industry alone losing approximately $50 million in 2022 due to ASF-related culling and trade restrictions (DAFF, 2023). Porcine cysticercosis also remains a significant challenge, with studies showing a prevalence of up to 30% in rural pig populations in Zambia and Zimbabwe, exacerbating the economic challenges faced by smallholder farmers (Phiri et al., 2022).

Pig production in Zambia is steadily growing and projected to reach approximately 279,820 heads by 2026, with Eastern and Southern provinces accounting for a large part of this increase (FAO, 2022; Ministry of Fisheries and Livestock and Central Statistical Office, 2019). In Zambia, the pig farming sector is a crucial part of the agricultural economy, particularly for smallholder farmers in rural areas. However, the sector is severely impacted by ASF and porcine cysticercosis. Recent data indicate that ASF outbreaks in Zambia have resulted in the loss of approximately 40% of the national pig population in affected areas, translating to economic losses of over $10 million in 2023 alone (Zambia Livestock Services Cooperative, 2023). Porcine cysticercosis is also widespread, with a national prevalence rate estimated at 20%, leading to significant public health concerns and economic losses due to reduced pork marketability and the costs associated with controlling the disease (Mwape et al., 2022).

The Gwembe Valley, located in Southern Zambia, is an area where free-range pig farming is a primary livelihood activity. However, the valley's pig farming is increasingly threatened by ASF and porcine cysticercosis. The prevalence of ASF in the Gwembe Valley has been reported to be alarmingly high, with recent outbreaks leading to the culling of up to 50% of the pig population in certain communities, resulting in severe economic hardship for local farmers (Gwembe District Veterinary Office, 2023). Porcine cysticercosis is also prevalent, with a recent study estimating a local prevalence rate of 25%, further complicating the economic and public health landscape in the region (Simuunza et al., 2023). Given the interconnected nature of these challenges, a systems thinking approach is essential to assess and address the nonbiological determinants that contribute to the persistence and spread of these diseases in the Gwembe Valley's pig value chains.

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1.2 Problem Statement

Southern Province harbours the second largest pig population in the country, primarily comprised of traditional farmers practicing free-range husbandry (Abigaba et al., 2022; Ministry of Fisheries and Livestock and Central Statistical Office, 2019). According to the Veterinary Association of Zambia (2023), free-range pig value chains in the Gwembe Valley of Southern Zambia face significant challenges due to non- biological determinants that exacerbate the prevalence of ASF and PCC. Recent findings by the Ministry of Fisheries and Livestock have highlighted the increasing incidence of ASF and PCC in the region, with prevalence rates as high as 20% for ASF

and 30% for PCC (Ministry of Fisheries and Livestock, 2023). While biological factors such as viral transmission and parasite infestation play a role in the spread of these diseases, non-biological determinants, including socio-economic conditions, farming practices, and environmental factors, market dynamics and value chain actors also play a crucial role. This study aimed to assess the interrelationships between these non- biological determinants and the prevalence of ASF and PCC in the swine value chains of the Gwembe Valley, providing a systems thinking approach to identify effective interventions for disease prevention and control.

1.3 General Objective

The general objective of this study was to investigate the non-biological factors that may influence the occurrence of ASF and Porcine cysticercosis in Gwembe district of Southern Province.

1.4 Specific Objectives

1. To identify socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley's free-range pig value chains.
2. To evaluate the role of market dynamics and value chain actors in the transmission of African Swine Fever and Porcine Cysticercosis in Gwembe District.
3. To analyze the effect of pig farming practices on the occurrence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley.

1.5 Research Questions

1. What are the socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley's free-range pig value chains?
2. What is the role of market dynamics and value chain actors in the transmission of African Swine Fever and Porcine Cysticercosis in Gwembe District?
3. How do pig farming practices affect the occurrence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley?

1.6 Significance of Study

The significance of this study is profound as it seeks to unravel the complex web of nonbiological determinants influencing the prevalence and transmission of ASF and Porcine Cysticercosis within free-range pig value chains in the Gwembe Valley of Southern Zambia. By employing a systems thinking approach, the research moves beyond traditional epidemiological methods, integrating an

analysis of socio-economic conditions, cultural practices, environmental factors, and market dynamics that collectively shape disease patterns. This holistic perspective is crucial for identifying the underlying drivers of disease spread that may not be immediately apparent when only biological factors are considered. The study's findings are expected to guide the development of more nuanced, context-specific interventions that address the root causes of disease transmission, rather than merely treating symptoms. Such interventions could lead to more effective and sustainable control measures, improving animal health and productivity, enhancing food security, and supporting the livelihoods of smallholder farmers. Furthermore, this research aligns with the principles of One Health, emphasizing the interconnectedness of human, animal, and environmental health, and contributing to a broader understanding of how to manage zoonotic diseases within complex ecosystems.

CHAPTER TWO: LITERATURE REVIEW

2.1 Background

Porcine cysticercosis (PCC) and African Swine Fever (ASF) remain significant challenges to the rapidly growing pig industry in Zambia, each with unique and compounded threats. ASF is a highly contagious disease that has led to severe outbreaks in the region. Recent statistics indicate that ASF outbreaks have affected approximately 15% of Zambia's pig population, resulting in the loss of over 100,000 pigs between 2020 and 2023 (FAO, 2023). The absence of effective treatments for ASF necessitates the culling of infected and nearby pigs to prevent further spread, which has devastating effects on the livelihoods of farmers and the broader pig industry (Chenais et al., 2022). Porcine cysticercosis, despite the availability of vaccines and treatment, continues to be a prevalent issue in Zambia. It is estimated that up to 30% of pigs in rural areas are infected with cysticercosis, contributing to significant economic losses and posing a substantial public health risk due to its zoonotic potential (Mwape et al., 2021). The disease's persistence underscores the complexity of controlling zoonotic diseases, even with medical interventions (Ministry of Health, 2019).

The combined impact of ASF, porcine cysticercosis, and human activities represents a formidable challenge to the growth and sustainability of Zambia's pig industry. To mitigate these threats, it is essential to implement comprehensive strategies, including disease management, stricter regulatory measures, and public awareness campaigns. These efforts are crucial to safeguard public health, animal health, and the viability of the pig and pork industry in Zambia (Ndebe et al., 2023).

2.2 Transmission Dynamics and Epidemiology of ASF

African swine fever (ASF) is a highly contagious viral hemorrhagic disease affecting domestic pigs, wild boars, and other members of the Suidae family. It is caused by the African swine fever virus (ASFV), a large double-stranded DNA virus belonging to the Asfarviridae family and the Asfivirus genus. ASFV is the sole known member of its genus, making it a unique arbovirus in the field of virology (Gallardo et al., 2021). The hemorrhagic nature of ASF is primarily observed in its acute and hyperacute forms, characterized by extensive hemorrhages in affected animals. However, the chronic and asymptomatic presentations of ASF do not display these hemorrhagic features, complicating clinical diagnosis (Zani et al., 2019). The manifestation of ASF varies

significantly, depending on factors such as the host species, virus strain, infectious dose, and mode of transmission (Penrith & Vosloo, 2021). Clinically, ASF can resemble other hemorrhagic diseases, including classical swine fever and salmonellosis, making laboratory confirmation essential for definitive diagnosis (Sánchez-Cordón et al., 2018).

ASF was first documented in 1909 following the introduction of European pig breeds in Kenya (Montgomery, 1921). Since then, ASF has become endemic in several regions, particularly Sub-Saharan Africa, where it presents significant challenges for pig farming (Simulundu et al., 2018). The transmission and spread of ASFV vary across continents, but four major epidemiological cycles have been identified: the sylvatic, tick-pig, domestic, and wild boar-habitat cycles (Kolbasov et al., 2021). The sylvatic cycle involves ASFV circulation between warthogs (Phacochoerus africanus) and soft ticks of the Ornithodoros moubata complex, which act as natural reservoirs of the virus (Jori & Bastos, 2020). This cycle is particularly significant in Eastern and Southern Africa, where warthogs and ticks sustain the virus, contributing to sporadic spillovers into domestic pig populations (Simulundu et al., 2018).

In the tick-pig cycle, ASFV is transmitted between domestic pigs and soft ticks, primarily in Sub-Saharan Africa, where ticks serve as vectors for viral transmission (Gallardo et al., 2021). The domestic cycle, on the other hand, involves the direct transmission of ASFV between domestic pigs, often facilitated by human activities such as the movement of infected animals and contaminated products (Sánchez-Vizcaíno et al., 2019). This cycle is critical in regions where the virus is maintained within domestic pig populations without involvement from natural reservoirs like warthogs (Gallardo et al., 2021). The wild boar-habitat cycle, newly identified in parts of Europe, involves virus transmission among Eurasian wild boar populations and their environments, often through contact with infected carcasses (Sauter-Louis et al., 2021). This cycle poses a significant challenge to ASF control in Europe, as wild boar populations are difficult to manage and can sustain viral transmission over long periods (Chenais et al., 2019). Despite their susceptibility, wild boars are more resistant to ASFV infection than domestic pigs, yet they exhibit similar pathological and epidemiological patterns (Cwynar et al., 2019). African wild suids, such as warthogs, bush pigs, and giant forest hogs, serve as asymptomatic carriers of ASFV, exhibiting

low viremia levels insufficient for direct transmission, but still playing a crucial role in the virus's persistence in the environment (Jori & Bastos, 2020).

The persistence of ASFV in animal products and the environment is well-documented. ASFV is highly stable under cold and moist conditions, surviving for extended periods in frozen pig tissues and blood—up to two years in contaminated pork products and six years in frozen blood (Beltrán-Alcrudo et al., 2021). Moreover, the virus remains stable across a wide pH range (4 to 11) and can persist in feed ingredients and pig manure, further complicating efforts to eradicate the virus (Mazur-Panasiuk et al., 2020). These characteristics underscore the importance of stringent biosecurity measures in preventing ASF spread and highlight the challenges associated with controlling the disease in endemic areas (Sánchez-Cordón et al., 2018).

ASF was first introduced outside Africa in 1957, when it reached Europe, and later spread to the Caribbean and South America in 1978 (Beltrán-Alcrudo et al., 2021). While ASF was largely eradicated from Europe by the 1990s, it persisted on the Italian island of Sardinia, where it has been endemic since 1978 (Franzoni et al., 2021). A major reintroduction of ASFV occurred in 2007 in Georgia, leading to a rapid spread across the Trans-Caucasian region, the Russian Federation, and the European Union (Olesen et al., 2021). Since this reintroduction, ASF has been sustained by both the domestic pig cycle and the wild boar-habitat cycle, particularly in Eastern and Central Europe (Sauter-Louis et al., 2021). In 2018, ASF reached China, marking the beginning of the largest-known ASFV outbreak, which has since spread to multiple Asian countries (Zhou et al., 2019). By 2021, ASF had spread to 16 Asian countries and two Oceanic nations, marking a significant transcontinental expansion of the virus (OIE WAHID, 2023).

In Africa, ASF remains a persistent threat, with outbreaks reported in 32 countries since 2005 (Penrith & Vosloo, 2021). Despite the large number of outbreaks, the confirmed source of infection has only been identified in a small percentage of cases, with domestic pigs implicated in most instances (Simulundu et al., 2018). The role of wild suids other than warthogs in the transmission of ASFV in Africa appears negligible, highlighting the need for more comprehensive studies on the epidemiology of the virus in different regions (Gallardo et al., 2021). The control of ASF in wild boar populations has proven to be particularly challenging, as wild boar habitats provide

numerous opportunities for indirect viral transmission through contaminated carcasses and environmental persistence (Sauter-Louis et al., 2021).

In Zambia, African Swine Fever (ASF) was first documented in 1912 in Fort Jameson, now known as Chipata District in the Eastern Province. The disease's persistence in the region led to its declaration as an ASF-endemic zone in 1965. Consequently, a permanent ban on the exportation of pigs and pig products from the Eastern Province has been in place since then, aimed at controlling the spread of the virus and mitigating its severe economic impacts (Samui et al., 1996). One key enforcement measure of this ban is the quarantine checkpoint at the Luangwa River Bridge on the Great-East Road (T4), which continues to play a significant role in maintaining biosecurity and preventing the unauthorized movement of pigs from the province. Despite these controls, ASF outbreaks have continued to occur, including a notable event in 1989 in Kabwe, Central Province, an area outside the designated endemic region (Samui et al., 1991).

Since then, sporadic outbreaks have been reported across nearly all regions of Zambia, with a recent case in September 2023 in the Chaminuka area of Chongwe District (Department of Veterinary Services and Animal Health Act, 2010 (Act No. 27 of 2010), 2023). This ongoing pattern of outbreaks underscores the complex epidemiology of ASF in Zambia, which remains only partially understood. While the factors contributing to these outbreaks are still under investigation, molecular epidemiology studies have provided some insights. Chambaro et al. (2020) observed that most ASF outbreaks, aside from the 1989 Kabwe incident, originate outside the Eastern Province. These findings align with previous research by Simulundu et al. (2017), which identified a potential role of the sylvatic cycle in ASF transmission, particularly in the Southern Province. This suggests that the wildlife-livestock interface, especially in regions where wild pigs and other suids interact with domestic livestock, may be a key pathway for ASF spillover events.

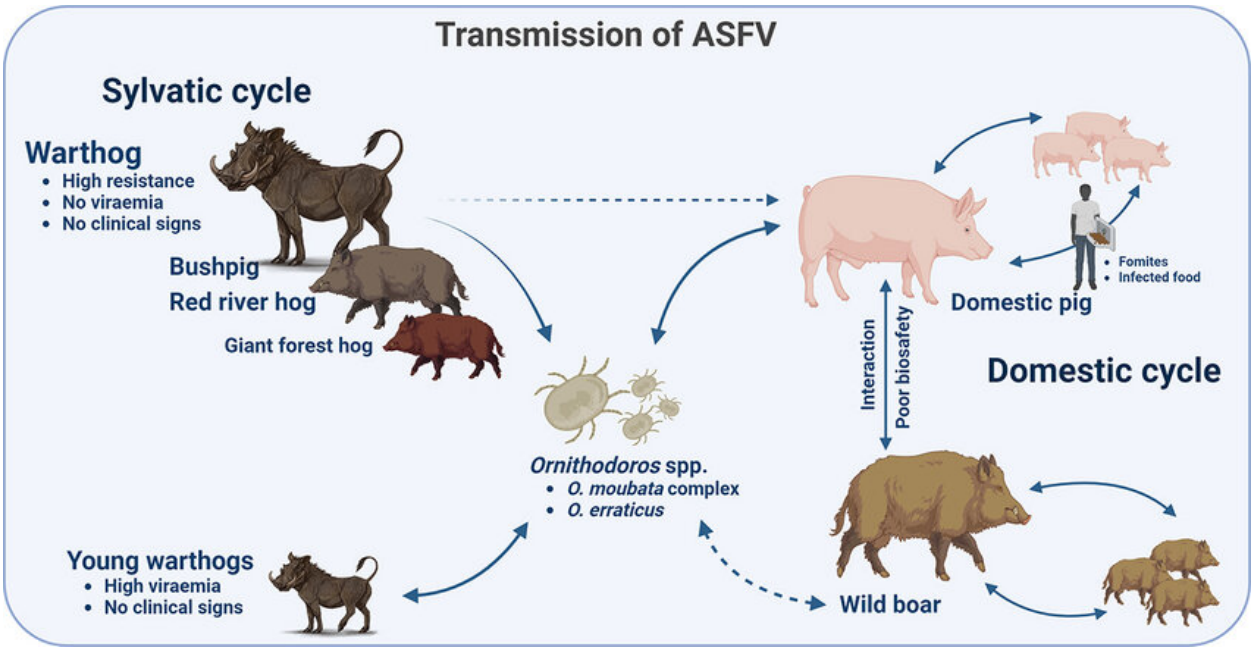

Figure 2.1: The epidemiological cycles maintaining ASFV
Source: (Chenais *et al.*, 2018)

The transmission cycle of African Swine Fever Virus (ASFV), as depicted in the image, highlights both the sylvatic and domestic cycles, with Ornithodoros spp. soft ticks playing a critical role in the virus's maintenance and transmission. In the sylvatic cycle, warthogs, bushpigs, and other wild suids such as the red river hog and giant forest hog, act as reservoirs of the virus. Warthogs, especially juveniles, develop high viraemia without showing clinical signs of disease, allowing ASFV to persist without noticeable outbreaks (Simulundu et al., 2017b). These animals are highly resistant to the virus and do not spread it through viremic blood directly to other species; however, ticks (Ornithodoros spp.) maintain the virus in this environment, transmitting it between wild suids.

When infected ticks or wild suids come into contact with domestic pigs, ASFV can spill over into the domestic cycle. Domestic pigs, unlike their wild counterparts, are highly susceptible to ASFV and can develop severe disease with high mortality rates (Penrith et al., 2019). Transmission in domestic pig populations occurs through direct contact with infected pigs, contaminated fomites (including feed), or by ingestion of infected material, such as meat products. Poor biosecurity measures and human activities, such as the movement of pigs and pig products, amplify the spread of the virus. This cross-contamination and interaction between wild and domestic pigs pose a

significant threat to both commercial and subsistence farming, as shown by the continuing outbreaks in non-endemic regions (Gallardo et al., 2021).

2.3 Transmission Dynamics and Epidemiology of Porcine Cysticercosis

Porcine cysticercosis, caused by the larval stage of the zoonotic tapeworm Taenia solium, continues to be a significant health concern, particularly in endemic regions where it is transmitted between human and porcine populations. In the parasite's lifecycle, pigs serve as the primary intermediate hosts, harboring the larval cysticerci, while humans act as definitive hosts by carrying the adult tapeworm responsible for taeniasis. However, humans can also become accidental intermediate hosts when they ingest T. solium eggs, leading to cysticercosis (Gabriel et al., 2015). Human cysticercosis, particularly neurocysticercosis (NCC), presents severe neurological manifestations, with epilepsy being the most common, constituting a significant public health burden in endemic areas. A recent meta-analysis highlights that neurocysticercosis accounts for nearly 30% of epilepsy cases in these regions, underscoring the connection between NCC and neurological disorders (Carpio et al., 2018).

The geographical distribution of T. solium cysticercosis is extensive, with endemic foci across Latin America, Asia, and Africa. These regions often share environmental and socio-economic conditions conducive to the persistence of the parasite, such as poor sanitation, limited access to clean water, free-range pig farming practices, and insufficient meat inspection protocols (Braae et al., 2015). Infected pork is frequently condemned in local markets, leading to significant economic losses for farmers. A study in Tanzania revealed that porcine cysticercosis can lead to a reduction in the market value of pigs by up to 50%, illustrating the disease's broader socio-economic implications (Thys et al., 2016). In addition to the direct economic burden, T. solium cysticercosis impairs pork productivity, reduces household income, and exacerbates food insecurity in already vulnerable communities (Lightowlers et al., 2016).

The prevalence of T. solium infection is strongly linked to cultural and socio-economic factors, particularly dietary practices and hygiene. In many endemic regions, the consumption of raw or undercooked pork is common, which increases the risk of acquiring taeniasis (Kungu et al., 2017). Furthermore, the practice of free-range pig farming, where pigs scavenge for food, exposes them

to human feces contaminated with T. solium eggs, thus perpetuating the transmission cycle. Areas with limited access to sanitation facilities show a higher prevalence of infection, as demonstrated by a study in Zambia that reported increased transmission in communities practicing open defecation (Mwape et al., 2015). Human cysticercosis, including neurocysticercosis, occurs not only through the ingestion of eggs from contaminated food or water but also via direct contact with individuals harboring the adult tapeworm, which can lead to auto-infection in the absence of pork consumption (Cheesbrough et al., 2019). This highlights the complexity of transmission dynamics, where individuals not involved in pork consumption or pig husbandry remain at risk due to poor hygiene and sanitation.

The public health and economic impact of T. solium cysticercosis is profound. It contributes significantly to the global burden of epilepsy, especially in low- and middle-income countries. Neurocysticercosis, in particular, is associated with severe neurological outcomes, such as hydrocephalus, cognitive impairment, and chronic headaches, which place an immense strain on health systems in endemic areas (Garcia et al., 2020). In economic terms, T. solium cysticercosis reduces productivity in both humans and livestock, thereby exacerbating poverty and reducing economic resilience in affected communities. Moreover, the stigmatisation of epilepsy in many endemic regions leads to social and economic marginalisation of affected individuals (Okello et al., 2017). Addressing this dual health and economic burden requires comprehensive public health interventions, including improved sanitation, education on food safety, and the integration of veterinary and medical health services to break the parasite's transmission cycle (WHO, 2021).

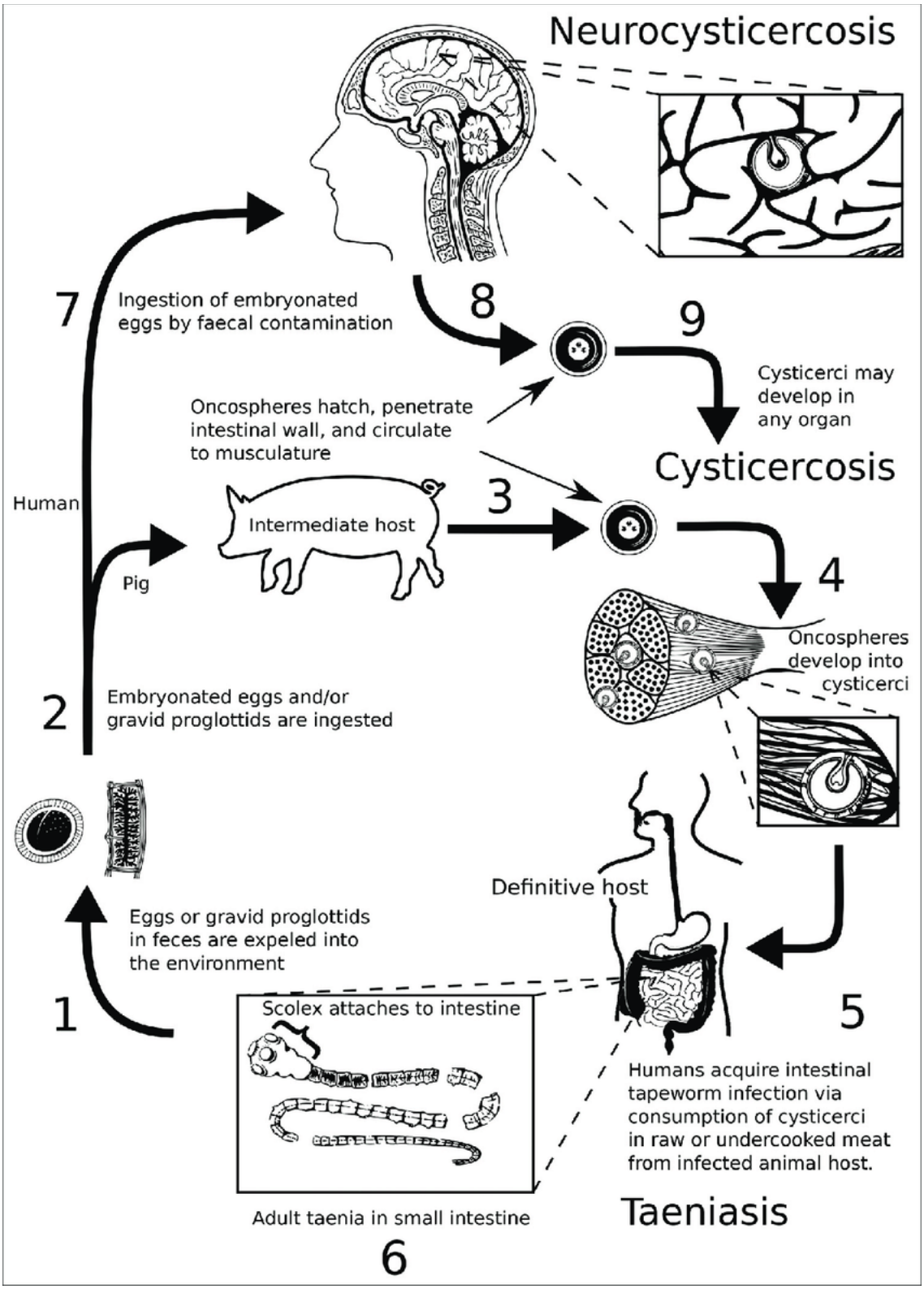

Figure 2.2: Cysticercosis cycle and extensive porcine cysticercosis

Source: (Garcia et al., 2020)

Figure 2.3: Manifestation of porcine cysticercosis

Source: (Garcia et al., 2020)

Figure 2.3 illustrates the transmission cycle of Taenia solium, which leads to taeniasis in humans and cysticercosis in both humans and pigs. The cycle begins when humans excrete eggs or gravid proglottids in their feces, releasing them into the environment (Step 1). Pigs, acting as intermediate hosts, ingest these embryonated eggs or proglottids from contaminated food or water (Step 2). Once ingested, the oncospheres hatch in the pig's intestines, penetrate the intestinal wall, and circulate through the bloodstream to the muscles, where they develop into cysticerci (Step 3-4).

Humans can acquire taeniasis by consuming undercooked pork containing cysticerci (Step 5). The cysticerci then attach to the intestinal wall, developing into adult tapeworms (Step 6). Alternatively, if humans ingest embryonated eggs directly, they can develop cysticercosis (Step 7), where oncospheres hatch, penetrate the intestinal wall, and circulate to various tissues, potentially reaching the brain, causing neurocysticercosis (Step 8-9) (Garcia et al., 2014).

Neurocysticercosis is the most severe form of the disease, often leading to neurological symptoms, including seizures (White, 2021).

2.4 Determinants of Health

There is growing recognition that both biological and non-biological factors interact in the initiation and propagation of diseases (Nikiphorou et al., 2019). Biological determinants constitute individual characteristics with a biological foundation, including genetic makeup, pathological conditions, sex, ethnicity, among others. While some of these factors are non-modifiable, their collective influence remains cardinal in the onset and progression of various diseases (Aleksovska et al., 2019) .

Non-biological determinants of health, on the other hand, encompass non-medical influencers of health outcomes. These include the circumstances surrounding one's birth, upbringing, occupation, living environment, and aging process, as well as broader societal forces and structures. These include economic policies, social norms, political systems, and developmental agendas, as highlighted by the World Health Organization (WHO, 2023). Intriguingly, WHO (2023) reports that non-biological determinants contribute to 30-55% of global health outcomes.

Recognizing the interconnected nature of biological and non-biological determinants, it becomes important to integrate both in addressing persistent health challenges. This integration necessitates active engagement from all stakeholders involved in healthcare delivery and policymaking.

2.5 Systems Thinking

Systems thinking is a problem-solving approach that analyses complex issues by examining the interactions among interconnected elements within a system. A system is a collection of elements working together toward a shared objective. This approach acknowledges that a system's behaviour is frequently emergent, surpassing the cumulative impact of its individual components, highlighting the significance of considering the system holistically (Adam and de Savigny, 2012). Systems thinking is applied in various fields, including business, engineering, ecology, healthcare, and social sciences. Qualitative and quantitative systems thinking are the synergistic approaches employed in systems analysis and problem-solving, each with distinct focuses and methodologies. Both are essential for gaining a comprehensive understanding of complex systems (Nabavi et al., 2017). The quantitative perspective, is a methodically rigorous approach that incorporates data into

simulations, providing a comprehensive representation of system behaviour and operations, while the emphasis of the qualitative approach lies in involving various stakeholders in creating "rich pictures" of a problematic situation (Mumba et al., 2017). These pictures aim to elucidate the mental models held by individuals with differing perspectives. Qualitative tools, such as Causal Loop Diagrams, and Stock and Flow Diagrams, employed in the qualitative approach contribute to an enhanced understanding and illustration of the interactions of actors, linkages and relationships that characterise the whole system (Glenn et al., 2020).

In systems thinking, various qualitative models are employed to analyse systems, these include the Spatial Group Model Building (SGMB) technique, a participatory method for collectively addressing spatial issues using spatial data and models. SGMB involves assembling stakeholders with diverse roles and expertise relevant to the issue at hand using maps and GIS concepts to improve the facilitation and modelling process. It employs a bottom-up approach to policymaking and prioritization, considering local community needs (Rich et al., 2022). Applied to animal health, SGMB facilitates collaboration among stakeholders across the livestock value chain, fostering collective problem-solving. The Layer stack is a tool that can be used to facilitate the SGMB process, it utilizes transparent acetate layers representing different data layers overlaid on a base map, enabling stakeholders to visually explore spatial relationships and interactively analyse data. This hands-on approach enhances stakeholder collaboration, facilitating collective insight and idea generation (Mumba et al., 2017).

2.6 Socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in free-range pig value chains

Costard et al. (2013) investigated the socio-economic factors influencing the prevalence of ASF in the free-range pig farming system in Russia. This study identified poor biosecurity measures, especially among smallholder farmers, as a key factor contributing to the spread of ASF. Many of the farms had limited access to veterinary services, which exacerbated the problem. Furthermore, the socio-economic status of the pig farmers played a significant role in their ability to control and prevent ASF outbreaks. Farmers with limited financial resources could not invest in preventive measures such as vaccination, proper pig housing, and feed, increasing the risk of disease transmission. Additionally, informal markets for pork, where ASF-infected pigs were sold, further contributed to the persistence of the disease in the free-range pig value chain. The study concluded

that socio-economic interventions, including education and financial support for farmers, were essential to mitigating the spread of ASF in Russia (Costard et al., 2013).

Martínez-López et al. (2015) examined the socio-economic determinants of ASF and porcine cysticercosis prevalence in free-range pig farming communities in Spain. Their research focused on the impact of rural poverty, lack of awareness about animal health, and limited access to veterinary care. The study found that farmers in rural areas often had limited knowledge about disease transmission and prevention, which increased the susceptibility of their pigs to ASF. Additionally, poverty was a major barrier to implementing biosecurity measures such as fencing, regular veterinary check-ups, and proper waste disposal, which are critical for controlling both ASF and porcine cysticercosis. The study also highlighted that pigs raised in these low-income rural areas often had access to contaminated feed and water, further exacerbating the risk of disease outbreaks. The authors concluded that socio-economic improvements, including better infrastructure and access to education and veterinary services, were necessary to reduce disease prevalence in Spain's free-range pig farming sector (Martínez-López et al., 2015).

Laddomada et al. (2017) conducted a study in Italy to explore the socio-economic factors influencing the transmission of ASF and porcine cysticercosis in free-range pig farming. The study found that economic constraints on small-scale farmers led to the adoption of low-cost farming practices that increased disease vulnerability. Poor sanitation, inadequate housing for pigs, and the use of contaminated feed were common practices among financially constrained farmers. Additionally, the study revealed that cultural practices, such as the preference for traditional pig farming methods, also contributed to the persistence of these diseases. Farmers were often reluctant to adopt modern farming techniques due to cultural beliefs and financial limitations, which exacerbated the spread of ASF and porcine cysticercosis in the region. The study recommended that socio-economic policies aimed at improving farmer incomes and promoting modern farming practices were crucial to controlling these diseases in Italy (Laddomada et al., 2017).

Jurado et al. (2018) investigated the role of socio-economic factors in the prevalence of ASF and porcine cysticercosis in the Baltic States, specifically Estonia, Latvia, and Lithuania. The study highlighted that low-income pig farmers in rural areas were particularly vulnerable to ASF outbreaks due to their reliance on free-range pig farming, where biosecurity was often compromised. The researchers found that limited access to financial resources prevented these farmers from implementing proper biosecurity measures, such as fencing and separating wild boars from domestic

pigs, which is a key strategy in preventing ASF transmission. Additionally, socio-economic factors like poor infrastructure, lack of government support, and limited access to veterinary services further contributed to the persistence of ASF in these regions. The study concluded that improving the socio-economic conditions of pig farmers through subsidies, education, and infrastructure development could significantly reduce the prevalence of ASF and porcine cysticercosis in the Baltic States (Jurado et al., 2018).

Gogin et al. (2020) focused on the socio-economic factors influencing the prevalence of ASF in Ukraine's free-range pig farming sector. The study found that economic hardships faced by rural pig farmers were a major contributor to the spread of ASF. Due to financial constraints, many farmers were unable to afford proper biosecurity measures, including fencing, vaccination, and regular veterinary care. Additionally, informal pig markets, where biosecurity regulations were rarely enforced, were common in rural areas, further facilitating the spread of the disease. The study also highlighted that the lack of government support for rural farmers exacerbated the situation, as many farmers were left to manage disease outbreaks on their own. The study recommended that socio-economic interventions, including government subsidies, improved veterinary services, and stricter enforcement of biosecurity regulations, were necessary to control the spread of ASF and porcine cysticercosis in Ukraine's free-range pig value chains (Gogin et al., 2020).

Penrith et al. (2013) conducted a study in South Africa to assess the socio-economic factors influencing the prevalence of African Swine Fever (ASF) in the country’s free-range pig farming systems. The study highlighted that the movement of pigs between villages, driven by cultural practices such as communal grazing and the sale of pigs in informal markets, was a major contributor to ASF outbreaks. Additionally, the study found that low-income pig farmers had limited access to veterinary services and faced significant economic barriers to adopting proper biosecurity measures. Poor infrastructure, especially in rural areas, also exacerbated the situation, as it hindered the proper containment and treatment of infected pigs. Furthermore, ASF outbreaks were often financially devastating for smallholder farmers who relied heavily on pig farming for their livelihoods. The study recommended the implementation of targeted socio-economic interventions, including veterinary support, awareness campaigns, and improved infrastructure, to mitigate ASF transmission in South Africa (Penrith et al., 2013).

Fasina et al. (2015) explored the socio-economic drivers of ASF and porcine cysticercosis in Nigeria's free-range pig farming communities. The study found that economic constraints faced by smallholder pig farmers, particularly in rural areas, played a significant role in disease transmission. Limited financial resources meant that farmers could not afford to build secure enclosures for their pigs, leading to free-range systems where pigs roamed freely and interacted with wild animals, which increased the risk of ASF transmission. Furthermore, the lack of awareness and education regarding animal health among the farmers was identified as a key factor in the spread of both ASF and porcine cysticercosis. The informal nature of pig farming in Nigeria, where pigs were sold at informal markets with little to no disease control measures, further facilitated the spread of these diseases. Fasina et al. (2015) concluded that improving the socio-economic conditions of pig farmers through financial support, education, and market regulation would be essential to controlling ASF and porcine cysticercosis in Nigeria (Fasina et al., 2015).

Phiri et al. (2019) focused on the socio-economic factors influencing the prevalence of porcine cysticercosis and ASF in Zambia, particularly in rural free-range pig farming areas. The study found that poverty, lack of access to veterinary services, and poor infrastructure were key contributors to the high prevalence of these diseases. Many pig farmers in Zambia were unable to afford veterinary care or proper housing for their pigs, resulting in frequent disease outbreaks. Additionally, the cultural practice of allowing pigs to roam freely in search of food increased their exposure to contaminated environments and wild animals, which heightened the risk of ASF and porcine cysticercosis. Phiri et al. (2019) also noted that the socio-economic reliance on pig farming for income made it difficult for farmers to control the spread of these diseases, as many were reluctant to cull infected animals due to the financial losses it would entail. The study recommended that the Zambian government and international organizations provide targeted financial and educational support to rural pig farmers to improve their biosecurity practices and reduce the prevalence of ASF and porcine cysticercosis (Phiri et al., 2019).

2.7 The role of market dynamics and value chain actors in the transmission of African Swine Fever and Porcine Cysticercosis

Smith et al. (2014) conducted a detailed study on the role of market dynamics and value chain actors in the transmission of ASF in the Russian Federation. The study focused on understanding

the pathways through which ASF spread, particularly through informal market channels. The researchers employed a combination of epidemiological modeling and qualitative data collection to assess how swine movements within value chains contributed to the disease's persistence and spread. Their findings highlighted that informal and unregulated markets played a critical role in ASF transmission due to the lack of sanitary measures during transportation and trade. In particular, the study found that traders often bypassed veterinary checks to reduce costs, which increased the risk of ASF outbreaks (Smith et al., 2014). Furthermore, the movement of live pigs and pork products through rural markets was identified as a significant factor in maintaining the virus in domestic pig populations.

In a study conducted by García et al. (2015), the researchers explored how value chain actors influenced the transmission of porcine cysticercosis in rural Mexico. The study used a mixed-methods approach to analyze the role of intermediaries, such as traders, transporters, and slaughterhouse workers, in the spread of the disease. Through extensive field surveys and interviews with market participants, García et al. found that value chain actors, especially small-scale pig farmers and traders, often lacked the knowledge and resources to implement biosecurity measures, which facilitated the spread of cysticercosis. Additionally, the researchers discovered that many pigs were sold through informal networks where there was little regulation, further exacerbating the transmission of the disease. Their findings underscored the need for greater oversight of market dynamics and value chains in controlling the disease (García et al., 2015).

Ivanov and colleagues (2016) focused on the impact of swine movement networks on the transmission of African Swine Fever in Latvia. Using network analysis and data from government veterinary services, the study mapped the movement of pigs between farms, markets, and slaughterhouses to identify critical points of ASF transmission. The findings revealed that value chain actors, particularly traders and transporters, played a central role in spreading ASF, as they facilitated the movement of infected animals across regions. The study also highlighted that small-scale farmers who relied on intermediaries for transporting pigs to markets were especially vulnerable to ASF outbreaks due to the lack of biosecurity measures during transportation (Ivanov et al., 2016). This study suggested that strengthening biosecurity protocols within the swine value chain could significantly reduce the risk of ASF spread.

In 2017, Reyes et al. conducted a study in the Philippines to examine how slaughterhouses and related market actors contributed to the transmission of porcine cysticercosis. The researchers used

a cross-sectional design, collecting data from slaughterhouse records, interviews with slaughterhouse workers, and observations of slaughtering practices. Their findings indicated that the lack of proper inspection and sanitary measures at slaughterhouses was a major contributor to the spread of cysticercosis. Many pigs, infected with cysticercosis, were slaughtered without adequate veterinary inspection, leading to the contamination of pork products. Additionally, the study highlighted that value chain actors, including butchers and pork vendors, were unaware of the importance of biosecurity, which allowed the disease to persist in the market system (Reyes et al., 2017). This study emphasized the need for improved regulation and training for value chain actors in disease prevention.

Johnson et al. (2019) explored the market dynamics that facilitated the transmission of African Swine Fever in Eastern Europe, focusing specifically on Poland and Ukraine. The study utilized a combination of market surveys, spatial analysis, and epidemiological modeling to assess the role of market actors in ASF outbreaks. The findings revealed that informal pig trade networks were a significant driver of ASF spread, as pigs were often moved across borders without proper health checks. Additionally, value chain actors such as traders and small-scale processors were found to prioritize economic gain over biosecurity, contributing to the persistence of ASF in domestic pig populations. Johnson et al. (2019) concluded that a lack of coordination between different market actors and weak regulatory oversight were key factors in the spread of ASF in Eastern Europe. Their study recommended stronger regional cooperation and the implementation of stricter biosecurity measures throughout the value chain.

Muwonge et al. (2015) conducted a study in Uganda to investigate the role of market dynamics and value chain actors in the transmission of African Swine Fever (ASF). The research focused on identifying the key stakeholders involved in the swine value chain, including farmers, traders, transporters, and butchers, and how their activities contributed to the spread of ASF. The study used a combination of field surveys and interviews with market actors to assess the risk factors associated with ASF transmission. Findings revealed that the movement of live pigs between farms and markets was the most critical factor in the disease's spread. Many value chain actors, particularly small-scale farmers and traders, operated without implementing biosecurity measures, leading to frequent outbreaks. Muwonge et al. (2015) also discovered that informal markets, where pigs were traded without veterinary oversight, served as hotspots for ASF transmission. The study

concluded that improving the biosecurity practices of these actors and enhancing veterinary control at market points were crucial to reducing the disease's prevalence.

A study by Assana et al. (2016) focused on porcine cysticercosis in Cameroon, examining how market dynamics and value chain actors influenced the disease's transmission. The researchers utilized both quantitative and qualitative data collection methods, including field observations, interviews with stakeholders in the pig trade, and laboratory analysis of cysticercosis prevalence in slaughtered pigs. The findings indicated that small-scale pig farmers and intermediaries, such as traders and transporters, played a significant role in perpetuating the disease due to the lack of awareness and knowledge about cysticercosis transmission. Pigs were often sold in local markets without undergoing proper health inspections, and traders prioritized economic returns over disease control measures. Moreover, the study highlighted that many butchers and pork vendors did not properly inspect meat for cysts, leading to the consumption of infected pork by consumers. Assana et al. (2016) emphasized the need for better training for value chain actors and the implementation of rigorous veterinary inspection protocols to curb the spread of porcine cysticercosis in Cameroon.

Jori et al. (2018) explored the role of market systems and value chain actors in the transmission of African Swine Fever ASF in South Africa. The study utilized a mixed-methods approach, combining epidemiological data with interviews and observations of the swine value chain to understand how ASF spread within domestic pig populations. The findings revealed that informal and smallholder pig farms, which formed a significant part of the swine value chain, were particularly vulnerable to ASF outbreaks. The lack of biosecurity measures, coupled with the movement of pigs between farms and informal markets, were identified as the primary drivers of ASF transmission. Additionally, Jori et al. (2018) found that many value chain actors, such as traders and transporters, lacked adequate knowledge about ASF prevention, contributing to the spread of the disease. The study called for more stringent biosecurity measures and better coordination among value chain actors to control ASF transmission in South Africa's pig farming industry.

2.8 The effect of pig farming practices on the occurrence of African Swine Fever and Porcine Cysticercosis

Blome et al. (2017) conducted a study in Germany focusing on the epidemiology and control of ASF. The research highlighted how modern intensive pig farming practices in Germany, characterized by high biosecurity standards and controlled environments, significantly reduced the risk of ASF outbreaks. The study found that ASF was less common in commercial farms that implemented rigorous biosecurity measures, including restricted access, strict sanitation protocols, and controlled animal movement. However, the study also noted that outbreaks occasionally occurred in smaller, less regulated farms where biosecurity was not as rigorously enforced. Blome and colleagues emphasized the need for continuous surveillance and enforcement of biosecurity practices to prevent ASF introduction and spread. They recommended that small-scale and backyard pig farmers adopt similar biosecurity measures to mitigate the risk of ASF (Blome et al., 2017).

D'Antuono et al. (2015) investigated the prevalence and risk factors of porcine cysticercosis in Italy, particularly in the rural regions where traditional pig farming is common. The study found that porcine cysticercosis was prevalent in areas with limited veterinary oversight and poor sanitation practices. The primary risk factors identified included the practice of free-range pig farming, inadequate disposal of human feces, and a lack of awareness among farmers about the disease. The researchers noted that pigs were often exposed to Taenia solium eggs through contact with contaminated environments, exacerbating the risk of infection. D'Antuono and colleagues suggested that improved education for farmers, better sanitation practices, and regular veterinary inspections were essential for controlling cysticercosis in Italy. They also highlighted the need for community-level health interventions to reduce the prevalence of the disease (D'Antuono et al., 2015).

Hansen et al. (2016) conducted a study in Brazil to assess the impact of pig farming practices on the occurrence of porcine cysticercosis. The study revealed that the prevalence of cysticercosis was high in regions where pigs were allowed to roam freely and scavenge for food in environments contaminated with human feces. The researchers found that traditional farming practices, including the lack of proper fencing and sanitary facilities, significantly contributed to the spread of Taenia solium. Additionally, the study highlighted that there was limited access to veterinary services in some rural areas, which further exacerbated the problem. Hansen and colleagues recommended

that targeted interventions, including improvements in sanitation, pig confinement, and increased access to veterinary care, were necessary to reduce the prevalence of porcine cysticercosis in Brazil. Their findings underscored the importance of integrating health education and community engagement into disease control strategies (Hansen et al., 2016).

Etter et al. (2011) conducted a detailed study in Cameroon on the factors influencing the spread of African Swine Fever (ASF) in pig farming communities. The study focused on smallholder farmers who engaged in traditional pig farming, often with low biosecurity standards. The researchers identified that the primary mode of ASF transmission was through contact between domestic pigs and wild suids, which roamed freely near farms in rural areas. This contact was facilitated by the lack of controlled environments and proper fencing on most small-scale farms. The study also found that many farmers lacked knowledge about ASF symptoms and control measures, leading to delayed detection and reporting of the disease. Another critical factor was the movement of infected pigs to markets, which accelerated the spread of the disease. Etter et al. (2011) concluded that the most effective way to reduce ASF outbreaks was to enhance farmers' awareness of biosecurity measures, restrict the movement of pigs, and improve veterinary services to detect and respond to outbreaks more quickly (Etter et al., 2011).

Pondja et al. (2010) conducted a cross-sectional study in Mozambique to assess the prevalence and risk factors associated with porcine cysticercosis in smallholder farming systems. The study found that 34% of pigs in the sampled areas were infected with cysticercosis, making it a significant public health issue in the region. The primary factor contributing to this high prevalence was the practice of allowing pigs to scavenge freely in villages, where they were exposed to feces contaminated with Taenia solium eggs due to open defecation. Another contributing factor was the poor health management practices among farmers, including a lack of veterinary services and regular deworming programs. Pondja and colleagues recommended the implementation of community-led sanitation programs, improved access to veterinary care, and the promotion of pig confinement to reduce the spread of cysticercosis in Mozambique. Their findings emphasized that a multi-pronged approach, combining sanitation, health education, and veterinary interventions, would be the most effective strategy for controlling cysticercosis (Pondja et al., 2010).

2.9 Literature Gap

The literature review on the determinants of African Swine Fever (ASF) and Porcine Cysticercosis in pig farming practices highlights several important studies conducted across different regions. Research has extensively covered biological determinants of these diseases, such as the roles of pathogens and vectors, and has identified various contributing factors within specific farming systems. However, significant gaps in the literature have emerged that motivate the need for a study titled "An Assessment of Nonbiological Determinants of African Swine Fever and Porcine Cysticercosis in Free-Range Pig Value Chains in the Gwembe Valley of Southern Zambia: A Systems Thinking Approach."

Firstly, while much of the existing research, such as that by Blome et al. (2017) in Germany and D'Antuono et al. (2015) in Italy, focuses on the impact of biosecurity measures and veterinary practices on the incidence of ASF and porcine cysticercosis, there is limited exploration of the nonbiological determinants influencing these diseases in the Zambian context. For instance, studies by Olugasa et al. (2014) and Dione et al. (2015) emphasize the role of biosecurity and farmer practices but do not sufficiently address the socio-economic and infrastructural factors that affect disease prevalence in Zambia. The specific socio-economic conditions, cultural practices, and local infrastructure in the Gwembe Valley, where free-range pig farming is prevalent, require a dedicated examination to understand how these factors contribute to disease dynamics. The literature thus shows a gap in integrating nonbiological determinants within the context of Zambia's unique farming environment.

Secondly, while research like that by Phiri et al. (2003) and Pondja et al. (2010) has explored the prevalence of porcine cysticercosis in Zambia and Mozambique, respectively, there is a scarcity of comprehensive studies that adopt a systems thinking approach to assess the entire pig value chain. Most existing studies focus on isolated aspects of pig farming practices or specific disease determinants but fail to consider the interconnected nature of these factors across the value chain. A systems thinking approach can provide a holistic view of how various nonbiological factors—such as market access, local governance, economic pressures, and community practices—interact and influence the incidence of ASF and porcine cysticercosis. This gap in the literature underscores the need for research that examines the broader systemic influences on disease prevalence.

Moreover, the studies reviewed often concentrate on specific regions or diseases in isolation, with limited attention to how combined nonbiological factors might affect disease transmission in a free-range farming context. For example, while Hansen et al. (2016) addressed the impact of pig management practices in Brazil, similar research integrating both ASF and porcine cysticercosis in the context of free-range farming in Zambia is lacking. Understanding how nonbiological determinants such as economic factors, community practices, and local infrastructure collectively impact disease outcomes can provide valuable insights for developing effective control measures tailored to the specific needs of the Gwembe Valley.

Given these gaps, this study aims to address the need for a comprehensive assessment of nonbiological determinants affecting ASF and porcine cysticercosis within the free-range pig value chains in the Gwembe Valley. By employing a systems thinking approach, the study seeks to provide a nuanced understanding of the interplay between various nonbiological factors and disease prevalence. This research will offer insights for policymakers, veterinary professionals, and local stakeholders to develop more effective and context-specific interventions for controlling ASF and porcine cysticercosis in Zambia's unique farming systems.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Overview

This chapter delineates the methodology employed to assess the nonbiological determinants of ASF and PCC within free-range pig value chains in the Gwembe Valley of Southern Zambia, using a systems thinking approach. It commences with an overview of the research design and proceeds to a comprehensive description of the research procedures. This includes the identification and acquisition of study materials, the population and sampling methods, sample size determination, and the criteria for selecting study materials. Furthermore, the chapter elaborates on the strategies for data management, emphasizing the protocols for ensuring data quality, validity, and reliability. It also details the data analysis techniques to be applied and concludes with a discussion on the ethical considerations guiding the research.

3.2 Study Design

A cross-sectional design was chosen for this study on the nonbiological determinants of ASF and PCC in free-range pig value chains in the Gwembe Valley of Southern Zambia due to its suitability for capturing a snapshot of the current state of these diseases and their determinants. This design allows for the simultaneous assessment of the prevalence of ASF and PCC and the associated nonbiological factors within the study population at a single point in time (Setia, 2016). Such a design is effective for understanding the relationships between exposure and outcome variables in a given population, which is crucial for identifying patterns and associations relevant to disease control (Levin, 2006). Furthermore, cross-sectional studies are cost-effective and logistically simpler compared to longitudinal designs, making them practical for large-scale investigations in resource-limited settings like the Gwembe Valley (Flegal et al., 2010). By using this design, the study can provide valuable insights into the current epidemiological landscape and inform targeted interventions for ASF and PCC.

3.2 Description of study regions

The research was carried out in Gwembe district, approximately 93.5 km east of Choma, the capital city of Southern Province as shown in Figure 4 and 5. Siavonga, Monze, Pemba districts and Lake Kariba border Gwembe district to the east, north, west, and south, respectively. Gwembe district

is made up of a valley and a plateau area. The district's northern part is made up of flat regions due to the region's hilly natural topography and heavily worn limestone rock. The majority of Gwembe's terrain is made of stones, with a limited amount of land utilised for farming (Ministry of Fisheries and Livestock, 2020). Its population is around 79,273 with a human population density of 19.9 persons per km^2 (Zambia Statistics Agency, 2022). The topographical features of the region render it unsuitable for the husbandry of large ruminant species such as cattle, thereby contributing to the district's status as having the lowest cattle population within the province (Ministry of Agriculture and Livestock, 2011). Nevertheless, the area sustains a stable population of smaller livestock, namely pigs and goats, as evidenced by a pig population of 11188 recorded in 2023 (Ministry of Fisheries and Livestock, 2023).

Gwembe communities are mostly made up of rural and peri-urban townships where most households live in rather impoverished conditions with no access to basic sanitation or water supplies (Ministry of Fisheries and Livestock, 2020). Generally speaking, trade and agriculture are Gwembe District's two primary economic sectors. The three main food crops grown in the region are millet, sorghum, and maize. Groundnuts are planted with various vegetables such as cucumbers, pumpkins, tomatoes, melons, rape, and cowpeas, cotton is the main cash crop. In recent years, fishing has emerged as a significant economic activity in the region due to the installation of fishing cages by the Ministry of Livestock (Ministry of Agriculture, 2019).

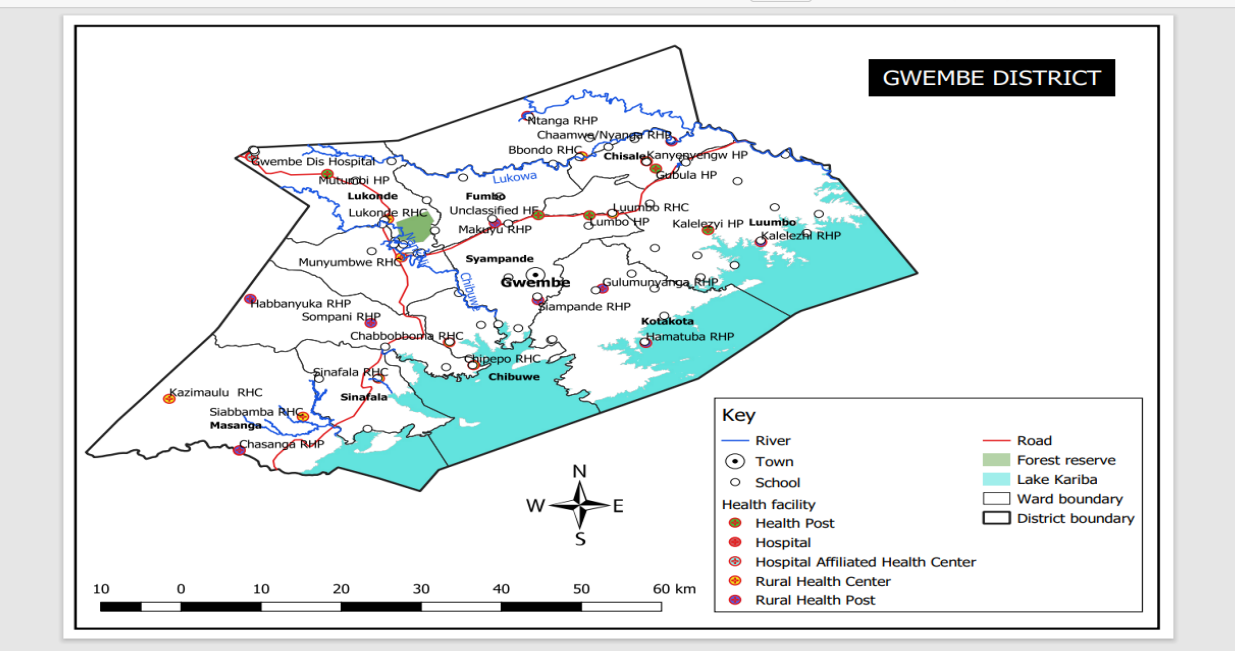

Figure 3.1: Map of Gwembe district
Source: Generated using Arc GIS Software

3.3 Research Approach

A qualitative approach was employed in this study on ASF and PCC in the Gwembe Valley to gain a deep understanding of the complex and context-specific factors influencing these diseases within free-range pig value chains. The use of the Spatial Group Model Building (SGMB) technique, a qualitative method, facilitated the exploration of stakeholders' perspectives and the intricate interactions among various determinants. This approach was particularly advantageous for capturing the nuanced and dynamic nature of the nonbiological factors affecting ASF and PCC, as it allowed for the integration of diverse viewpoints and the identification of underlying patterns and relationships (Richardson and Pugh, 2009). Qualitative methods are essential in revealing the contextual and subjective elements that quantitative approaches might overlook, thereby providing a more comprehensive understanding of the systems at play (Checkland and Scholes, 2019). By employing SGMB, the study effectively mapped out the complex interactions and developed more targeted and contextually appropriate interventions.

3.4 Study Population

Pig farmers were the target population for this study because they are directly involved in the management of free-range pigs and are thus at the forefront of both the impacts and challenges

associated with African Swine Fever and Porcine Cysticercosis. Their first-hand experiences and practices provide critical insights into the nonbiological determinants of these diseases, making them essential for understanding and addressing the factors influencing disease prevalence and control within the Gwembe Valley.

3.5 Sample size and Sampling

A sample of 13 members of the Gwembe pig value chain, representing one of the four regions in the district with the highest pig populations was chosen for this study to allow for in-depth exploration and detailed understanding of their experiences and perspectives. In qualitative research, smaller samples are often preferred as they enable more comprehensive and nuanced data collection and analysis, facilitating rich, detailed insights into complex issues such as the nonbiological determinants of African Swine Fever and Porcine Cysticercosis (Crouch and McKenzie, 2006). Besides, two Veterinary officers were interviewed in the study as key informants.

Purposive sampling was used to select 11 pig value chain actors and two veterinary personnel as key informants to ensure that participants with relevant and specific knowledge about African Swine Fever and Porcine Cysticercosis were included. This method allowed for the deliberate selection of individuals who could provide valuable insights into the nonbiological determinants of these diseases based on their direct involvement and expertise (Palinkas et al., 2015). By targeting knowledgeable and experienced individuals, the study aimed to gather in-depth and contextually relevant information essential for understanding and addressing the complexities of disease management in the Gwembe Valley

Table 1: Demographics of study participants

Variable	Frequency
Age	
< 30	1
30-50	10
>50	2
Years lived in Gwembe	
< 20	3
20-30	3
>30	7
Years in Pig business	
< 10	6
10-20	6
>20	1
Sex	
Male	9
Female	4

Variable	Frequency
Education	
Primary	2
Secondary	8
Tertiary	3
Region	
Chipepo	1
Bboondo	3
Munyumbwe	3
Gwembe central	6
Role in Pig-Value chain	
Veterinary doctor	1
Veterinary assistant	1
Farmer	9
Transporter	2

3.6 Data Collection

The disease prevalence, distribution, control measures, livestock movement, and other relevant epidemiological and surveillance data about ASF and Porcine Cysticercosis in Gwembe was be obtained from the District Veterinary Office through a document review. Spatial group model building was used to understand the dynamics of these diseases facilitated by LasyerStack as described by Mumba et al (2017) and Lie and Rich (2016). This approach involved involving stakeholders in the Gwembe pig value chain via focus group discussions (FGD) utilizing the Layer

Stack tool. A semi-structured guide was used to lead 3 FGDs each consisting of 5 pig farmers the while in-depth structured interviews were also conducted with the two District Veterinary Officers.

3.6 Data Analysis

Thematic analysis was utilized in this study to systematically identify and analyze patterns within the qualitative data generated through the Spatial Group Model Building (SGMB) technique. This method was selected due to its ability to provide a detailed and nuanced understanding of the nonbiological determinants of ASF and PCC in the Gwembe Valley. Thematic analysis is particularly effective for organizing and interpreting complex data sets by identifying recurring themes and patterns (Braun and Clarke, 2006). Information generated from the SGMB process was incorporated into the predetermined scripts of the LayerStack, a tool that facilitated the extraction of key themes and insights (Checkland and Scholes, 1990). By coding and categorizing the qualitative data, thematic analysis allowed for a structured exploration of how various nonbiological factors interact and influence the prevalence of ASF and PCC (Guest et al., 2012). This approach enabled a comprehensive understanding of the contextual and systemic factors affecting disease dynamics, ultimately informing more effective interventions tailored to the local context.

3.7 Procedure of spatial group model building in Gwembe

3.7.1 Planning of meetings: The planning of meetings for Focus Group Discussions (FGDs) and in-depth interviews with key informants involved a methodical approach to ensure thorough and effective data collection. For the FGDs, sessions were scheduled to fit participants' availability, with sessions held at central, accessible locations such as local community centers to maximize attendance and convenience (Krueger and Casey, 2015). Each FGD comprised of 5 participants, a number deemed optimal for facilitating dynamic and in-depth discussions while ensuring each participant could contribute meaningfully (Morgan, 1997). The FGDs lasted approximately 30 to 45 minutes, during which a semi-structured format was used to guide the discussion on specific topics related to nonbiological determinants of ASF and PCC. A local facilitator was engaged to assist with interpreting questions and ensuring clarity, particularly given the local dialect and cultural nuances. This approach helped bridge any communication gaps and ensured that questions were understood and responded to accurately (Flick, 2014). In-depth interviews were scheduled

individually with key informants, including two veterinary officers, in private settings to foster a comfortable and confidential environment for detailed responses (Cohen and Crabtree, 2006). A pilot study was conducted with a small group from the target population to refine the FGDs and interview protocols. Feedback from the pilot enabled adjustments to improve question clarity and procedural effectiveness, thereby enhancing the overall quality and reliability of the data collection process for the main study (Yegidis and Moffatt, 2004).

3.7.2 Script 1: Introductions, Hopes and Fears: In handling the Introductions, Hopes, and Fears for the FGDs and in-depth interviews, a careful and empathetic approach was employed to build rapport and ensure a comfortable atmosphere for participants. During the introductions, participants were welcomed and briefed on the purpose of the study, the structure of the discussions, and the expected outcomes. This was done to establish a clear understanding of the study's aims and to foster a sense of trust and transparency (Smith et al., 2009). The "Hope and Fears" GMB script developed by (Luna-Reyes et al., 2006) was utilized to assess stakeholders' expectations and concerns regarding the Spatial Group Model Building (SGMB) meeting. Participants were then invited to express their hopes for the study, allowing them to articulate what they hoped to achieve or gain from their involvement, which helped to align their expectations with the study objectives and foster engagement (Meyer and Lunn, 2015). Addressing fears was also crucial; participants were encouraged to voice any concerns or apprehensions they might have about the study, and assurances were provided regarding confidentiality and the voluntary nature of their participation (Creswell, 2014).

3.7.3 Script 2: Understanding the pig value chain in Gwembe district using Layer stack: The Spatial Group Model Building (SGMB) technique was executed through a structured approach designed to enhance stakeholder engagement and model development. Initially, the LayerStack tool was central to the session, providing a comprehensive visualization platform. The study region map, enclosed in a transparent sleeve of the LayerStack, was layered with six distinct transparencies representing various elements such as settlements, pig production, pig/pork markets, disease distribution, and agrovet stores. Stakeholders utilized stickers of different colors and shapes to depict the actors and processes within the pig value chain. This facilitated a collective exploration of spatial relationships and interactions. To capture and analyze the dynamic behavior of these elements, behavior over time (BOT) graphs were generated. These graphs allowed for the

examination of variable patterns over time, assisting in the identification of causal relationships and trends rather than focusing solely on discrete events (Luna-Reyes et al., 2013). This method promotes a collaborative and iterative approach to model building, integrating diverse stakeholder perspectives to enhance the accuracy and relevance of the spatial model.

3.8 Ethical Considerations

Ethical clearance was obtained from the Excellence in Research Ethics and Science (ERES) Coverage, reference number "2023-May-009". The Gwembe District Veterinary Office's office granted permission to engage with the Gwembe district pig value chain actors. All research participants gave informed consent, were at least eighteen years old, and knew they could withdraw from the study at any time if they felt uncomfortable or thought that their rights were not being respected. The study participants were treated with dignity, respect, and confidentiality.

CHAPTER FOUR: RESULTS

4.1 Overview

This chapter presents a comprehensive analysis of the data collected to assess the non-biological determinants of African Swine Fever and Porcine Cysticercosis within the free-range pig value chains in the Gwembe Valley of Southern Zambia. Employing a systems thinking approach, this chapter delves into the intricate interplay of socio-economic, environmental, and management factors that influence the prevalence of these diseases. The results are systematically organized and illustrated through various thematic representations, allowing for an in-depth understanding of the critical determinants affecting pig production in this region.

4.2 Socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley's free-range pig value chains

According to the focus group discussion (FGD), Sinafala has the highest pig population (marked by pink rectangle with plus signs in fig 4.1) in the district, which is explained by the area's proximity to Lake Kariba and its water supply. In terms of the pig population, Bbondo ranked second, followed by Munyumbwe and Gwembe Central in third. Most of the pigs in the district are allowed to roam freely. Several socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley's free-range pig value chains were revealed by both farmers and key informants.

4.2.1 Poor Veterinary Services and Disease Surveillance

One of the dominant themes that emerged from both the FGDs and key informant interviews was the inadequate provision of veterinary services in the Gwembe Valley. Pig farmers consistently expressed concern over the limited access to professional veterinary services, particularly during disease outbreaks like ASF and PCC. The DVOs confirmed that the district's capacity for timely disease surveillance and response was hindered by logistical challenges, such as the vast geographical area, understaffing, and a lack of resources. This theme highlighted how socio-economic constraints, like limited infrastructure and government support, exacerbate the prevalence of these diseases.

Through SGMB, the spatial aspect of this challenge was examined, revealing that remote areas with poor road access were more likely to experience delayed disease control measures, which contributed to the widespread nature of ASF and PCC. The FGDs reflected that local farmers often relied on traditional, and sometimes ineffective, treatments due to the absence of veterinary support. This lack of medical intervention allowed diseases to become endemic in certain regions, as highlighted by the DVOs during their interviews.

4.2.2 Traditional Farming Practices and Biosecurity Risks

A second theme that emerged was the role of traditional farming practices in influencing the prevalence of ASF and PCC. Members of the Gwembe Pig value chain described their free-range system as a long-standing tradition that was economically sustainable due to the minimal input costs. However, these systems were identified as significant risk factors for disease transmission. Farmers in the FGDs recognized that free-ranging pigs often scavenged for food, coming into contact with contaminated waste, human feces (a major cause of PCC), and other infected animals.

The SGMB analysis revealed that the spatial distribution of these practices, particularly in communal areas with high pig densities, created disease hotspots. The free-range systems lacked adequate fencing or biosecurity measures, increasing the interaction between healthy and infected pigs. Moreover, the lack of awareness about improved farming methods and the costs associated with upgrading these systems acted as significant socio-economic barriers. Farmers viewed biosecurity measures, such as quarantine zones, as impractical and too costly to implement, a sentiment corroborated by the DVOs during interviews.

4.2.3 Economic Dependency on Pigs and Limited Market Access

Another major theme was the economic dependency on pigs for livelihoods, which influenced farmer decisions in disease management and control. Pigs were identified as a critical source of income for many households, especially given the region's harsh climatic conditions that made crop farming unreliable. In the FGDs, farmers discussed how the high demand for pork in local markets led them to prioritize quick sales over proper disease control, often selling pigs that were infected or exposed to ASF and PCC to avoid financial losses.

The SGMB technique was instrumental in visualizing the geographic distribution of markets and their relation to disease prevalence. Markets with limited oversight, often in rural areas, were linked to higher disease transmission rates as pigs were sold with little to no veterinary inspection. Farmers' economic imperatives led to resistance against government-imposed culling or movement restrictions, as they feared significant financial losses.

This economic pressure also intersected with a lack of access to formal markets where stricter health regulations were enforced. Farmers reported that the distance to formal markets was prohibitive, making it difficult for them to sell their pigs legally. Instead, they relied on informal markets where health checks were minimal, a factor that the DVOs recognized as contributing to the unchecked spread of diseases.

4.2.4 Knowledge Gaps and Communication Barriers

The thematic analysis further revealed that a significant knowledge gap among farmers contributed to the persistence of ASF and PCC. While some farmers were aware of the general symptoms of ASF, few understood the transmission mechanisms or preventive measures. For PCC, the FGDs revealed that the disease was poorly understood, with many farmers unaware that it was linked to pigs consuming human feces contaminated with tapeworm eggs. Farmers attributed outbreaks to superstition or environmental factors rather than identifying specific behavioral risks.

Key informants pointed out that communication barriers, both linguistic and cultural, hindered the dissemination of accurate information. The SGMB technique facilitated the mapping of these barriers, revealing that areas with limited exposure to government extension services had higher incidences of misinformation. Farmers in remote villages received minimal education on ASF and PCC prevention, and even when information was provided, it was often not culturally adapted or delivered in local dialects.

4.2.5 Limited Access to Credit and Financial Resources

Another significant socio-economic factor influencing ASF and PCC prevalence is the limited access to credit and financial resources among pig farmers. During the FGDs, farmers consistently mentioned that they lacked the financial means to invest in improved pig housing, veterinary services, and disease prevention measures such as vaccination. This theme was echoed by the

DVOs, who noted that many farmers were operating at subsistence levels, with barely enough income to feed their families, let alone purchase veterinary drugs or build secure pig pens.

The SGMB analysis illuminated how access to financial services was geographically uneven, with more remote areas having fewer options for loans or credit facilities tailored to small-scale farmers. The lack of financial empowerment contributed to the persistence of traditional free-range pig farming methods, as farmers were unable to transition to more biosecure, intensive pig production systems. Furthermore, the absence of insurance schemes for livestock meant that farmers bore the full economic burden of disease outbreaks, making them less likely to report cases or comply with culling orders.

The DVOs suggested that the absence of formal financial support systems aggravated the socio-economic vulnerability of farmers, leading to a cycle where low incomes and poor farming practices perpetuated disease outbreaks. This was especially problematic during ASF outbreaks, where entire herds were lost, leaving farmers without the financial capacity to restock or implement preventive measures.

4.2.6 Inefficient Market Structures and Price Volatility

Farmers in the FGDs highlighted the theme of inefficient market structures and price volatility as another socio-economic factor exacerbating disease prevalence. The pig market in the Gwembe Valley is highly informal, with most pigs sold at local markets or through middlemen who often offered prices far below market value. This market inefficiency discouraged investment in disease prevention, as farmers struggled to see any financial gain from improving the health and productivity of their herds.

Moreover, during periods of ASF or PCC outbreaks, prices for pigs dropped significantly due to the fear of infected meat, leaving farmers with little incentive to report sick animals or comply with disease control measures. Instead, as noted by the DVOs, many farmers sought to sell infected pigs quickly at discounted prices before outbreaks were officially declared, further contributing to the spread of ASF and PCC.

The SGMB technique revealed spatial patterns of market access and price instability, showing that farmers closer to formal markets or larger urban areas tended to adopt better farming practices due to more stable prices and higher demand for healthy pigs. In contrast, those in more remote areas with limited market access were more likely to engage in risky behaviors such as selling sick pigs.

4.2.7 Education and Knowledge Deficits

Another critical socio-economic factor identified through the thematic analysis was the general lack of education and knowledge about pig diseases, especially ASF and PCC. In the FGDs, farmers often expressed confusion over the symptoms of ASF and PCC and were unaware of the preventive measures that could be taken to mitigate outbreaks. There was also a significant knowledge gap regarding the connection between pig health and human health, particularly with respect to PCC, which is a zoonotic disease.

The DVOs emphasized that educational outreach and training programs were insufficient and underfunded, with very few resources dedicated to informing farmers about disease management, biosecurity, or pig health. This lack of knowledge extended beyond farmers to local pig traders and consumers, who often contributed to the spread of ASF and PCC by purchasing and distributing infected pigs.

Through the SGMB process, it became evident that areas with greater access to extension services and veterinary education had lower rates of disease prevalence. The spatial distribution of knowledge and information access was a critical factor, as regions with regular veterinary outreach programs showed better disease management practices, while more remote areas were disease hotspots due to a lack of training and awareness campaigns.

4.2.8 Public Health Infrastructure and Sanitation

Public health infrastructure and sanitation were also identified as socio-economic factors impacting disease prevalence, particularly in relation to PCC. The FGDs revealed that poor sanitation in the Gwembe Valley was a significant driver of PCC, with many households lacking access to proper toilet facilities. Farmers reported that pigs often roamed freely in areas where human defecation occurred, leading to ingestion of human feces and subsequent transmission of the Taenia solium tapeworm.

Key informants from the veterinary sector highlighted that the absence of public health infrastructure, such as latrines, exacerbated the risk of PCC. Poor coordination between public health and veterinary services meant that efforts to reduce human fecal contamination were not integrated with pig disease control programs.

The SGMB technique added a valuable spatial dimension to the thematic analysis by integrating farmers' experiences with the geographical realities of the Gwembe Valley. It allowed for a visualization of disease hotspots, market access routes, and areas with limited veterinary services, offering a clearer picture of where interventions could be most effective. The model also highlighted the spatial dynamics of pig movement across the region, identifying how informal trade routes facilitated the spread of ASF and PCC. By involving farmers in the mapping process, SGMB provided a participatory platform for them to express their knowledge of local disease transmission patterns. This approach fostered greater understanding and ownership of the problem among the farmers, who could now see how their practices, combined with spatial factors, contributed to disease spread. It also allowed key informants, like the DVOs, to contextualize their efforts within the broader socio-economic landscape of the region.

4.3 The role of market dynamics and value chain actors in the transmission of African Swine Fever and Porcine Cysticercosis in Gwembe District

Although there is no formal market in the district where pigs or pork products are sold, there is a small location in Gwembe Central where this is done on a very limited scale. The 11 engaged in focus group discussions (FGDs) claimed that Kasumbalesa in the Copperbelt Province is the second-largest market for pigs, after Lusaka. They disclosed that in Lusaka, every pig from Gwembe is transported to one of the four slaughter slabs in Chibolya township: New Dawn, Dundumwezi, New Kabesha, and Old Kabesha. Additionally, the members noted that sand and water are placed inside trucks to serve as a floor for the pigs to lie on during transit, creating a cooling system that helps keep them alive and reduces stress during the journey. They also mentioned that keeping the pigs not too crowded might assist in preventing stress. Interestingly, the farmers disclosed that pig sales to these regions begin to increase in August and peak from October to February (as marked by the blue and red graph in Fig. 4.1). Following that, they claimed that sales begin to decline due to the rainy season and a lack of disposable income from potential

purchasers, as most funds are allocated to school fees during this time. It was also noted that the Bottom Road was the preferred route since it was faster for transporting pigs to Lusaka. Despite the distance from Gwembe, the transporters revealed that they would also bring pigs to Kasumbalesa because they would receive a commission of 2,000 ZMW ($81.14) for every 150 pigs transported. Furthermore, the price of pigs is higher in Kasumbalesa; for example, a pig sold for 1,500 ZMW ($60.86) in Lusaka could fetch 2,500 ZMW ($101.43) in Kasumbalesa. However, they observed that the Lusaka market was more stable than the Kasumbalesa market. The indicated that they courier between 150 to 200 pigs to Lusaka three times a week and about 250 to 350 pigs to Kasumbalesa three times a week from Gwembe. Surprisingly, these figures differ from the statistics provided by the two District Veterinary Officers (key informants), which may indicate a thriving illegal movement of livestock, a risk factor for ASF. According to the district's report, Kasumbalesa recorded 235 pigs in the second quarter and 240 pigs in the first quarter from Gwembe. The DVO's report did not account for the pigs transported out of the district in the third quarter due to the outbreak of ASF in the neighboring Siavonga during the study period. Furthermore, there were no records kept by the DVO of the pigs that were transported to Lusaka in the first or second quarter. This discrepancy between the DVO's report and the assertions made by the transporters could point to a flaw in the actual number of pigs transported from the district for trade.

The data analysis employed a thematic approach, and the findings were synthesized using the Spatial Group Model Building (SGMB) technique, which helped to map out key relationships between market dynamics, value chain actors, and the spread of ASF and PCC.

4.3.1 Market Dynamics and Pig Farming Practices

One of the emerging themes from the FGDs was the intricate link between market demand for pigs and farming practices in the region. Farmers frequently discussed how market forces shaped their decisions regarding pig-rearing practices, including feeding, sanitation, and pig transport.

4.3.2 Market Demand as a Driver of Pig Movement

Farmers expressed that during periods of high demand for pork, particularly around festive seasons and local ceremonies, they were compelled to transport pigs across long distances. This movement of pigs across districts, often without proper veterinary checks, was highlighted as a significant

risk factor in the spread of ASF and PCC. The SGMB technique allowed for a visual representation of this movement and its correlation with disease outbreaks, showing increased cases of ASF following high-traffic periods.

4.3.3 Unsanitary Market Environments

Another theme that emerged was the role of market environments in disease transmission. Participants in the FGDs noted that markets were often unsanitary, with inadequate facilities for proper cleaning and disinfection. This lack of hygiene was identified as a major contributor to the spread of PCC, as pigs were often exposed to contaminated water sources or came into contact with infected animals during transportation and at the market itself.

In addition, the SGMB model indicated that farmers had little control over the sanitary conditions in markets, which were often managed by local authorities or third-party intermediaries. The model showed a direct link between unsanitary markets and clusters of PCC cases.

4.3.4 Middlemen as Disease Vectors

According to both the FGDs and interviews with the DVOs, middlemen often acted as key players in moving pigs from farms to markets. However, these intermediaries were not regulated and often failed to adhere to biosecurity measures. The FGDs revealed that middlemen typically transported pigs in open trucks, often mixing animals from multiple farms, which increased the risk of cross-infection. The SGMB mapping highlighted middlemen as a central node in the transmission chain, showing how their activities created multiple contact points between infected and healthy pigs.

4.3.5 Transporters' Role in Disease Spread

Transporters also emerged as critical actors in the transmission of ASF and PCC. The discussions with Gwembe pig value chain actors highlighted the fact that transport vehicles were rarely disinfected between trips, and pigs from different regions were often transported together. The thematic analysis indicated that transporters were not always aware of the risks they posed in spreading these diseases. Moreover, the spatial mapping in the SGMB model showed that transport routes often overlapped with high-risk zones, such as areas with known outbreaks of ASF, further facilitating the spread of the disease.

4.3.6 Veterinary Oversight and Gap

The in-depth interviews with the DVOs provided valuable insights into the regulatory and oversight gaps that contributed to disease transmission. While veterinary officers were responsible for enforcing biosecurity measures and inspecting pigs before they were transported, limited resources and staff shortages meant that many pigs moved through the value chain without adequate inspection.

The DVOs also discussed the challenges of enforcing quarantine measures during ASF outbreaks. The SGMB model identified weak points in the enforcement process, showing that despite quarantine zones being established, pigs were still being moved through informal routes, often facilitated by intermediaries and transporters who were more concerned with profit than biosecurity.

4.3.7 Knowledge and Perception of Disease Among Farmers

A significant theme that arose from the FGDs was the general lack of knowledge among farmers about ASF and PCC. Most farmers were familiar with the symptoms of the diseases but did not fully understand the mechanisms of transmission or the necessary biosecurity measures to prevent outbreaks.

4.3.8 Perceived Low Risk of PCC

Farmers generally perceived the risk of PCC to be lower than ASF, partly because the symptoms of PCC were less dramatic and did not always result in immediate pig deaths. The thematic analysis revealed that many farmers did not see PCC as a pressing concern and were thus less likely to adopt preventive measures, such as improving sanitation or controlling pig movement. The SGMB model illustrated this gap in awareness, showing a weak correlation between farmer behavior and PCC control, particularly in comparison to ASF.

4.3.9 Limited Access to Veterinary Services

Farmers consistently reported that access to veterinary services in Gwembe District was limited, both in terms of the physical distance to veterinary clinics and the cost of services. Many farmers only sought veterinary assistance when pigs were already showing signs of illness, by which point the diseases had often spread to other animals.

4.4 The effect of pig farming practices on the occurrence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley

The discussion revealed that the most densely human populated area (marked by yellow stars in fig 4.1) in the district is Chipepo which is situated along the shores of Lake Kariba. In Chipepo, the presence of fish camps appears to be a significant factor attracting both local and external migrants. The economic opportunities associated with the fish business seem to be a driving force behind the population increase in this region. It's also interesting to note the cross-border migration from neighbouring Zimbabwe to Chipepo, indicating that economic opportunities can transcend national boundaries.

The district's second and third most populous regions were found to be Munyumbwe and Gwembe Central respectively. In these regions, the availability of livestock like goats, chicken, and pigs might be a key factor in attracting people. Economic activities related to animal farming and trade could be contributing to the population growth in these areas. Additionally, the district's plateau region, where Gwembe Central is located, has some fertile land, suggesting the possibility for agriculture. However, the challenge of water scarcity in the region poses a significant obstacle to successful farming. This highlights the delicate balance between geographical advantages and limitations that influence settlement patterns and economic activities. The stakeholders claimed that the district's population has been gradually growing over the past few years, which is consistent with the results of the 2022 national census. According to the stakeholders this can also be attributed to the polygamous nature of the locals.

Additionally, it was noted that the majority of residents with a good socioeconomic standing (marked by pink star in fig 4.1) lived in Chipepo; this may be primarily due to the lucrative fish trade in the area. Munyumbwe and Gwembe Central placed second and third, respectively, which is probably due to the availability of the aforementioned livestock. Gwembe Central has a large

population of government employees, which may possibly account for the region's socioeconomic status citizens' third place ranking in the district.

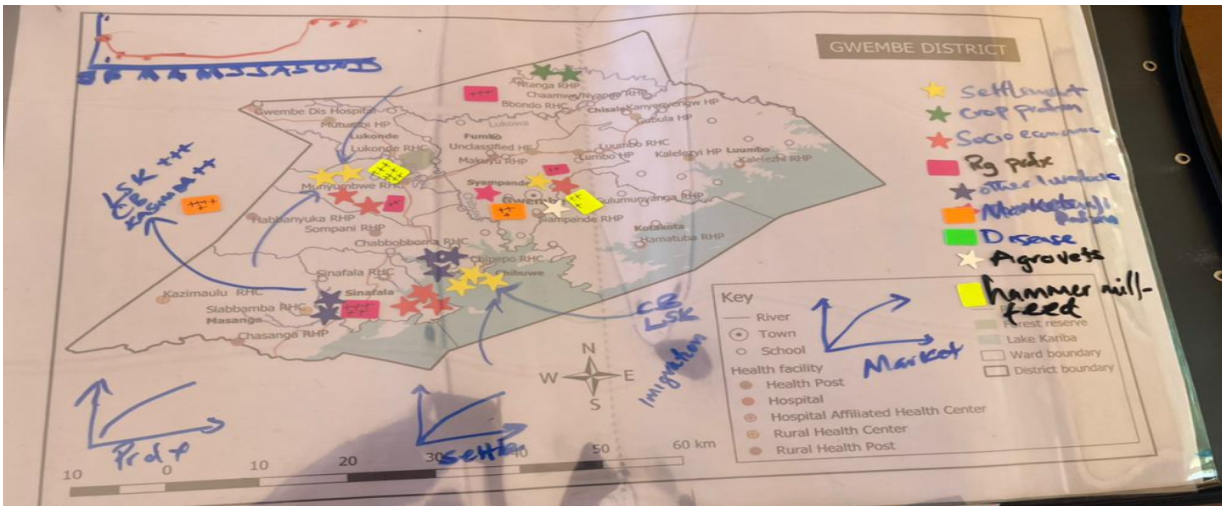

Figure 4.1: LayerStack after SGMB process

The data were analysed using thematic analysis, with the SGMB technique applied to explore interactions between various factors, identify patterns, and examine the complex relationship between pig farming practices and disease occurrences. Below is the thematic breakdown of the findings:

4.4.1 Free-Ranging Pig Rearing and Disease Prevalence

A significant theme that emerged from the focus groups was the widespread use of free-ranging pig farming practices in the Gwembe Valley. Pig farmers explained that pigs were often left to roam freely, feeding on household waste, communal pastures, or open fields. The FGDs revealed that this practice, though economically favorable to the farmers, exposed pigs to potential sources of infection for ASF and Porcine Cysticercosis.

Free-ranging pigs frequently interacted with other domestic and wild animals, increasing the risk of exposure to ASF, a highly contagious viral disease spread through direct contact with infected animals or contaminated environments. The FGDs highlighted that farmers had minimal control over the movements of their pigs, which made it difficult to implement biosecurity measures, such as isolating infected animals or preventing contact with wild pigs—known carriers of ASF.

The DVOs echoed these concerns, identifying free-ranging practices as a major contributor to the persistence of ASF outbreaks. According to the DVOs, efforts to enforce confinement and improve sanitation had met resistance from farmers, primarily due to cultural and economic factors.

SGMB Application: Mapping of Free-Ranging Practices and Disease Transmission

Using the SGMB technique, free-ranging practices were mapped as key nodes in the disease transmission pathways. These nodes highlighted the connection between uncontrolled pig movement, exposure to ASF vectors, and the contamination of communal grazing areas with Porcine Cysticercosis. The model illustrated how any attempt to reduce ASF would require systematic interventions that alter farmers' pig-rearing habits, especially in terms of encouraging enclosed farming practices.

4.4.2 Knowledge Gaps in Biosecurity and Disease Prevention

Many farmers participating in the FGDs admitted limited knowledge about ASF and Porcine Cysticercosis transmission pathways. They noted that while some informal information was available through community members, veterinary officers seldom provided educational resources or conducted awareness campaigns. This lack of knowledge contributed to delayed detection and response to outbreaks. Farmers often only became aware of infections when symptoms manifested in pigs, by which point the diseases had already spread within herds. For Porcine Cysticercosis, farmers were unaware of the role of Taenia solium (the tapeworm responsible for the infection) and the need for sanitary practices such as latrine usage or pig enclosures to reduce exposure to human feces, which serves as a medium for infection. The DVOs confirmed these findings, acknowledging that budgetary and logistical constraints had limited outreach activities in rural areas, making it difficult to disseminate critical information on disease control.

SGMB Application: Visualizing Knowledge Transfer Barriers

The SGMB approach helped visualize the structural barriers in knowledge transfer between veterinary authorities and pig farmers. The model illustrated a feedback loop where poor veterinary outreach and limited farmer education contributed to recurrent ASF and Porcine Cysticercosis outbreaks, as uneducated farmers were less likely to adopt biosecurity measures. The SGMB

model suggested that strengthening veterinary extension services could break this feedback loop, reducing disease occurrence over time.

4.4.3 Cultural Attachment to Traditional Pig Farming

Cultural factors also emerged as a theme contributing to the persistence of disease outbreaks. FGDs indicated that many farmers in the Gwembe Valley were deeply attached to traditional free-range pig farming, which they associated with their cultural identity and practices. Farmers explained that keeping pigs in confinement was seen as unnatural and was viewed with skepticism by older generations, who had practiced free-ranging for decades. This cultural attachment, combined with limited education on the benefits of confinement for disease prevention, resulted in resistance to adopting new pig farming practices. Farmers mentioned that even when aware of the risks, they were hesitant to confine their pigs due to social pressure from peers and elders. The DVOs pointed out that efforts to change traditional farming practices had to be approached carefully, as overtly opposing cultural norms could lead to non-compliance with disease control programs.

SGMB Application: Cultural Factors in Disease Management

The SGMB approach was used to incorporate cultural factors into the disease management model. This layer demonstrated how cultural resistance reinforced free-ranging practices and weakened attempts to implement biosecurity measures. The model suggested that disease control efforts would benefit from community engagement initiatives that respect cultural practices while gradually introducing new farming methods. The SGMB highlighted that such a community-centered approach could foster greater compliance and reduce disease spread.

CHAPTER FIVE: DISCUSSION

5.1 Overview

This chapter presents the discussion of the findings from the survey conducted by the researcher to assess the non- biological determinants of ASF and PCC in free-range pig value chains in the Gwembe Valley of Southern Zambia, utilizing a systems thinking approach. The findings are interpreted in light of the research objectives and relevant literature, providing a comprehensive analysis of the key factors influencing the spread of these diseases. This section also explores the implications of the results for pig production and disease management in the region.

5.2 Socio-economic factors influencing the prevalence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley's free-range pig value chains.

The first objecrive of this study sought to identify socio-economic factors influencing the prevalence of ASF and PCC in the Gwembe Valley's free-range pig value chains. The study revealed several socio-economic and farming practices contributing to ASF and PCC prevalence. First, poor access to veterinary services, particularly in remote areas, delayed disease interventions and allowed outbreaks to spread. Traditional free-range farming practices, characterized by pigs scavenging for food in unsanitary conditions, facilitated the transmission of diseases, particularly PCC, as pigs often ingested contaminated human waste. The SGMB analysis further highlighted spatial dynamics where densely populated, free-range farming regions acted as disease hotspots due to poor biosecurity measures. Economic dependency on pigs for livelihoods led farmers to sell infected animals to avoid financial losses, perpetuating the spread of diseases in informal markets with limited veterinary oversight. Cultural beliefs and traditional practices, such as the movement of pigs during ceremonies, compounded these challenges, with some farmers attributing disease outbreaks to superstition rather than biosecurity lapses. Additionally, limited access to financial resources prevented farmers from investing in better farming practices or veterinary care, while environmental degradation forced pigs into high-risk areas for disease exposure. These factors, combined with a lack of awareness and knowledge about disease transmission and prevention, underpinned the persistence of ASF and PCC in the region. SGMB provided a visual framework to identify these spatial patterns and socio-economic disparities, showing how inadequate

infrastructure, market volatility, and cultural practices interacted to sustain high disease prevalence.

Furthermore, similar findings regarding the impact of farming practices and socio-economic factors on the prevalence of animal diseases have been documented by various researchers in different regions. A study by Mutua et al. (2017) in Kenya found that traditional free-range pig farming practices contributed to the spread of ASF and PCC, particularly in areas with poor biosecurity and sanitation. Like the findings in the Gwembe Valley, Mutua's study emphasized that pigs scavenging in contaminated environments facilitated disease transmission. Additionally, Carrique-Mas and Bryant (2015) in Vietnam highlighted that limited access to veterinary services in remote areas delayed disease interventions, allowing outbreaks to escalate. Their study, similar to the Gwembe findings, also pointed to the economic dependency of farmers on pigs, leading to the sale of infected animals in informal markets, which perpetuated the spread of diseases. Both studies underscored the role of cultural practices and financial constraints in limiting disease prevention efforts, reflecting similar challenges faced by pig farmers in the Gwembe Valley.

5.3 The role of market dynamics and value chain actors in the transmission of African Swine Fever and Porcine Cysticercosis in Gwembe District.

Secondly, the study sought to evaluate the role of market dynamics and value chain actors in the transmission of ASF and PCC in Gwembe District. The study revealed that market dynamics and value chain actors play a critical role in the transmission of ASF and PCC in Gwembe District. High market demand for pigs, especially during festive seasons, drives increased pig movement across districts, often without adequate veterinary checks, significantly contributing to the spread of ASF and PCC. Unsanitary market environments and a lack of biosecurity measures were identified as major risk factors, with middlemen and transporters acting as unregulated disease vectors. Additionally, a general lack of disease awareness among farmers, coupled with limited access to veterinary services and oversight, further exacerbates the transmission of these diseases. The findings highlighted systemic gaps in veterinary interventions and the need for sustained education and biosecurity practices to mitigate disease outbreaks.

These findings are consistent with research by Nantima et al. (2015) in Uganda, where market dynamics and the role of value chain actors were identified as key factors in the transmission of ASF. Their study found that high demand for pigs, especially during peak seasons, led to increased

pig movement across regions, often without veterinary checks, contributing to the spread of ASF, similar to the situation in Gwembe District. Additionally, Fasina et al. (2012) in Nigeria highlighted the role of unregulated middlemen and transporters as critical vectors in the disease transmission chain, due to poor biosecurity measures. Furthermore, a study by Penrith et al. (2013) in South Africa emphasized the lack of disease awareness among farmers and limited access to veterinary services, which exacerbated the transmission of ASF, reflecting the findings observed in Gwembe District. These studies underline the systemic challenges in managing ASF and PCC outbreaks across different African contexts.

5.4 The effect of pig farming practices on the occurrence of African Swine Fever and Porcine Cysticercosis in the Gwembe Valley

Finally, the study sought to analyze the effect of pig farming practices on the occurrence of ASF and PCC in the Gwembe Valley. The study revealed that traditional free-ranging pig farming practices in the Gwembe Valley played a significant role in the spread of ASF and PCC. Pigs left to roam freely had increased exposure to infected wild animals and contaminated environments, heightening the risk of disease transmission. Farmers demonstrated limited awareness of disease prevention measures, with knowledge gaps surrounding biosecurity practices such as proper sanitation, pen construction, and quarantine protocols. Economic barriers, including the high costs of confined pig farming and lack of financial support, further hindered farmers' ability to implement these protective measures. Additionally, strong cultural attachment to traditional free-ranging methods, rooted in the community's identity, fuelled resistance to adopting modern biosecurity approaches. The inadequacy of veterinary services, characterized by insufficient staffing, outreach, and resources, compounded the issue, as timely interventions and education were rarely available to farmers. Addressing these challenges requires a multi-faceted approach, including targeted financial assistance, culturally sensitive community engagement, and increased veterinary support to improve disease control and enhance biosecurity practices.

These findings are consistent with research by Mutua et al. (2019) in Kenya, where traditional free-ranging pig farming practices were also linked to the spread of ASF. The study emphasized that free-roaming pigs had greater contact with infected wildlife and contaminated areas, increasing the risk of ASF transmission, similar to the scenario observed in the Gwembe Valley. Additionally, Garcia et al. (2021) in Mozambique identified limited awareness of biosecurity

measures among pig farmers, with significant knowledge gaps related to proper sanitation and disease prevention, echoing the challenges faced by farmers in the Gwembe Valley. Similarly, Muwonge et al. (2020) in Uganda highlighted the economic barriers and cultural resistance to adopting confined pig farming practices, noting that financial constraints and a strong attachment to traditional farming methods hindered biosecurity improvements. These studies collectively underscore the universal challenges of disease control in traditional pig farming systems, aligning with the findings in Gwembe Valley.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6. 1 Overview

This chapter serves as the final stage of a comprehensive evaluation of the nonbiological determinants of African Swine Fever and Porcine Cysticercosis in free-range pig value chains in the Gwembe Valley of Southern Zambia, using a systems thinking approach. It presents a synthesis of the key findings and insights derived from the study, offering a clear summary of the core discoveries. The conclusion reflects on the significance of these findings within the broader context of animal health and agricultural practices. Additionally, this chapter provides practical recommendations for mitigating the identified risks and outlines potential avenues for future research to further explore the dynamics of disease control in pig farming systems.

6.2 Conclusions

In conclusion, the study on the nonbiological determinants of ASF and PCC in free-range pig value chains in the Gwembe Valley of Southern Zambia revealed that socio-economic factors, traditional farming practices, and market dynamics significantly contribute to the persistence and spread of these diseases. Poor access to veterinary services, especially in remote areas, delayed disease management, while traditional free-range farming practices facilitated disease transmission through unsanitary environments and contact with contaminated human waste. Cultural practices, such as pig movement during ceremonies, and economic pressures, including the sale of infected pigs in informal markets, further exacerbated the situation. The study also identified gaps in biosecurity measures, inadequate disease awareness, and financial constraints as major barriers to effective disease control. A systems thinking approach, using tools like SGMB, highlighted the spatial and socio-economic dynamics that sustain the prevalence of ASF and PCC, underscoring the need for integrated, multi-dimensional interventions that address both cultural and economic challenges.

6.3 Recommendation

This study offers the following recommendations based on the findings of each research objective:

- ✓ It is recommended that efforts be focused on improving access to veterinary services in remote areas. To address the delay in disease interventions, veterinary outreach programs should be strengthened, ensuring timely disease prevention and control measures.
- ✓ Community education programs should be developed to raise awareness of biosecurity practices and disease transmission prevention. This could include workshops and extension services to train farmers on safe pig farming practices, such as pen construction, proper sanitation, and quarantine protocols.
- ✓ Based on the findings that traditional free-range farming practices significantly contribute to disease transmission, it is recommended that pig farming practices be modernized through the promotion of confined and semi-confined farming systems.
- ✓ Financial support, such as subsidies or low-interest loans, should be provided to farmers to enable them to invest in better farming infrastructure, such as pig pens and biosecurity equipment. This will reduce the reliance on free-range farming and decrease disease exposure.
- ✓ To further reduce disease transmission, veterinary authorities should collaborate with local leaders to restrict the movement of pigs, especially during ceremonies and festive seasons when disease outbreaks are more likely due to increased pig movement.
- ✓ Based on the findings that market dynamics play a critical role in disease transmission, it is recommended that regulations be established to ensure proper veterinary checks before the movement of pigs between districts. This can be achieved by implementing a mandatory certification process for livestock transportation and creating disease-free zones.
- ✓ Improving market environments by enforcing hygiene and biosecurity standards in local pig markets should be prioritized. Investment in the sanitation infrastructure of markets, as well as training for market vendors on safe animal handling practices, will reduce the risk of disease transmission.
- ✓ Middlemen and transporters should be formally integrated into disease control strategies. Veterinary authorities can offer them training on biosecurity measures and disease prevention, making them part of the solution rather than contributors to disease spread.

6.4 Suggestions for further research

Further research in the area of assessing the non-biological determinants of African Swine Fever and Porcine Cysticercosis in free-range pig value chains in the Gwembe Valley could explore several avenues to deepen the understanding of disease dynamics and control strategies. Firstly, investigating the long-term impact of improved veterinary services and biosecurity practices on disease prevalence across different regions would offer insights into the sustainability of current interventions. Additionally, exploring the socio-cultural factors that influence farmers' acceptance and adoption of modern biosecurity measures could shed light on ways to bridge the gap between traditional practices and disease control. Further research could also focus on the role of gender dynamics in pig farming practices and how they affect disease transmission and management, as well as the financial decision-making processes of farmers during outbreaks. Moreover, comparative studies across different districts or regions with similar socio-economic conditions could provide valuable benchmarks and identify best practices for managing ASF and PCC in free-range pig farming systems. Finally, integrating advanced spatial analysis tools to model disease transmission patterns under varying environmental and socio-economic conditions could provide more precise data to inform targeted interventions in high-risk areas.

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APPENDICES

Appendix A: Information Sheet

No……

Dear Participant,

You are invited to participate in a study titled "Assessment of nonbiological determinants of African Swine Fever and Porcine Cysticercosis in free range pig value chains in the Gwembe Valley of Southern Zambia - A systems thinking approach". My name is Catherine Besnart Dzombe, the principal investigator in this study from the school of Veterinary Medicine at the University of Zambia. This study is in partial fulfilment of the requirement for a Master degree in One Health Analytical Epidemiology. This study aims to understand the non-biological determinants of pig diseases (African Swine fever and Porcine cysticercosis) in Gwembe.

The study will require your presence at the District Veterinary Office on 04/10/2023 at 8:30 hours to participate in a focus group discussion. The session is supposed to last for not more than 4 hours.

Participation in this survey is voluntary and you have the right to withdraw at any point. All participants will receive a transport refund of 180 ZMW, snacks and water will be provided during the discussion. The participation is anonymous, and no one will be able to link any views or suggestions to you. Any report of this research that is made public will not include your name or any individual information by which you could be identified.

In case you have any questions about this study please do not hesitate to contact the student researcher, Catherine Besnart Dzombe – dzombecatherine@gmail.com or

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Appendix B: Consent Form

By undersigning this consent form, you agree and declare that;

You have been informed about this study's purpose, procedures, possible benefits, and risks.

You have been given the chance to ask questions before you sign.

You have voluntarily agreed to participate in this study.

Please indicate Yes or No

I agree to participate in this study

☐Yes ☐No

Name of participant: _____

_____ _____ _____

Signature of participant or Thumb print

Date

In signing here, I agree that I have read and understood the agreement/consent form and agree to participate in the study.

Name of Witness: _____

_____ _____ _____

Signature of Witness or Thumb print Date

_____ _____

Signature of Investigator Date

Appendix C: Ethical Approval

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Final Decision Certificate

This document certifies that the study:

"University of Zambia"

Principal Investigator: Ms. Dzombe, Catherine Besnart
Reference number: 2023 -May-009

Was reviewed and received the following status:
"done"
Additional Comments: Final decision: **approved**
Comments sent:

Reviewer #1:
'A well written study
'

Appendix D: Agenda of FGD

Time	Public schedule	Detailed scheduled
08:00 - 08:50	Arrival of stakeholders	Scene preparation
09:00 - 09:30	Introductions	Who are the facilitators? Where are they coming from? Why are they in Gwembe district? Why the stakeholders have been summoned? Concept of focus group discussions Concept of layer stack model House rules
09:30 - 12:00	Layer stack definition	Presentation and definition of each acetate theme Each stakeholder to identify their position on the map. Stakeholders to discuss how settlements have changed over time and what they assume could be the influencing that change Stakeholders to identify and discuss areas where pig production, trade, support and disease are mostly
12:00 - 12:30	Registration and lunch	Registration and lunch

Appendix E: Stakeholders in the Gwembe Pig value chain

Pig value chain actors	Number of stakeholders
Farmers	9
Transporters	2
Veterinary assistants	1
Veterinary Officers	1
Note: The District has no formal pig processing plant, however, the traders informally slaughter pigs in their backyards. Gwembe district only has traditional pig farmers.	

Appendix F: SGMB facilitation tool; Layer Stack

Appendix G: Focus Group Discussion Guide

ASSESSMENT OF NONBIOLOGICAL DETERMINANTS OF AFRICAN SWINE FEVER AND PORCINE CYSTICERCOSIS IN FREE RANGE PIG VALUE CHAINS IN THE GWEMBE VALLEY OF SOUTHERN ZAMBIA - A SYSTEMS THINKING APPROACH

Overview of Objectives:

1. Identify socio-economic factors influencing the prevalence of ASF and PCC in the Gwembe Valley's free-range pig value chains.
2. Evaluate the role of market dynamics and value chain actors in the transmission of ASF and PCC in Gwembe District.
3. Analyze the effect of pig farming practices on the occurrence of ASF and PCC in the Gwembe Valley.

Discussion Sections:

Section 1: Socio-Economic Factors

1.Demographic Information:

- What is your age, gender, and level of education?
- How long have you been involved in pig farming?

2. Economic Factors:

- What are the primary economic activities in your household aside from pig farming?
- How does your income from pig farming compare to other income sources?
- What are the costs associated with pig farming (e.g., feed, veterinary care)?

3. Access to Resources:

- What challenges do you face in accessing resources (e.g., feed, veterinary services)?
- How does access to financial support (e.g., loans, grants) influence your farming practices?

4. Cultural Practices:

- Are there any cultural beliefs or practices related to pig farming that you follow? How do these influence your farming practices?

Section 2: Market Dynamics and Value Chain Actors

1. Market Access:

- How do you market your pigs? What channels do you use (e.g., local markets, wholesalers)?
- What challenges do you face in accessing markets for your pigs?

2. Role of Value Chain Actors:

- Who are the main actors involved in the pig value chain (e.g., suppliers, processors, retailers)
- How do these actors influence your farming practices and market access?

3. Transmission of Diseases:

- In your opinion, how do market dynamics (e.g., transportation of pigs, market conditions) contribute to the spread of ASF and PCC?
- Have you noticed any specific practices among value chain actors that may increase the risk of disease transmission?

Section 3: Farming Practices and Disease Occurrence

1. Farming Techniques:

- What farming practices do you employ for raising pigs (e.g., feeding, housing, breeding)?
- How do you manage the health of your pigs, particularly in relation to ASF and PCC?

2. Disease Awareness and Management:

- What is your awareness of ASF and PCC? How do you educate yourself about these diseases?
- Have you implemented any specific measures to prevent ASF and PCC in your pig endeavours? If yes, please describe them.

3. Impact of Practices on Disease Prevalence:

- In your experience, how have your farming practices affected the occurrence of ASF and PCC in your pigs?
- What changes in practices do you believe could help reduce the prevalence of these diseases?

- Final Thoughts:

- Is there anything else you would like to share regarding pig farming and the challenges you face related to ASF and PCC?

- Thank everyone for their valuable contributions and time.

Appendix H: Interview Guide for Key Informants

ASSESSMENT OF NONBIOLOGICAL DETERMINANTS OF AFRICAN SWINE FEVER AND PORCINE CYSTICERCOSIS IN FREE RANGE PIG VALUE CHAINS IN THE GWEMBE VALLEY OF SOUTHERN ZAMBIA - A SYSTEMS THINKING APPROACH

Section 1: Socio-Economic Factors

1. Professional Background:

- Can you provide a brief overview of your experience and role as a District Veterinary Officer in Gwembe District?
- How long have you been working in veterinary services, and what specific responsibilities do you have related to pig farming?

2. Socio-Economic Challenges:

- In your opinion, what socio-economic factors most significantly influence the prevalence of ASF and PCC in the Gwembe Valley?
- How do these socio-economic factors affect the farmers' practices and overall pig farming operations?

3. Resource Access:

- What challenges do farmers face in accessing veterinary services, funding, or other resources essential for managing their pig farms?
- How do these challenges contribute to the risk of disease transmission among pigs?

Section 2: Market Dynamics and Value Chain Actors

1. Market Insights:

- Based on your experience, how do market dynamics (such as pricing, demand, and supply) influence the prevalence of ASF and PCC?
- What are the main market channels that farmers utilize for selling pigs, and how do these channels affect disease transmission?

2. Role of Value Chain Actors:

- Who are the key value chain actors involved in the pig farming industry in Gwembe, and what roles do they play?
- How do these actors influence the practices of pig farmers regarding disease management and prevention?

3. Disease Transmission:

- From your observations, how does the movement of pigs within the value chain contribute to the spread of ASF and PCC?
- Are there any specific market practices that you believe heighten the risk of these diseases?

Section 3: Farming Practices and Disease Occurrence

1. Farming Practices:

- What common pig farming practices have you observed in the Gwembe Valley?
- How do these practices align with best practices for disease prevention, particularly for ASF and PCC?

2. Health Management:

- What health management strategies are most effective in preventing ASF and PCC among free-range pig farms?
- How do farmers typically respond when they suspect a case of ASF or PCC in their herd?

3. Training and Education:

- How effective are the current training and educational programs for farmers regarding pig health and disease management?
- What improvements would you recommend to enhance farmers' awareness and practices related to ASF and PCC?

Final Insights:

- Is there anything else you would like to add regarding the challenges and strategies for managing ASF and PCC in the Gwembe Valley?

Thank You