FAO Consultancy
Final Report

Job Title:

National Consultant for Conducting Socially and Economically Acceptable Biosecurity Intervention in One Model Community for African Swine Fever

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Executive Summary

The future of African swine fever (ASF) in Bhutan relies on unwavering vigilance in biosecurity, robust international collaboration in disease surveillance, and advancements in vaccine development. Understanding the current state of biosecurity is pivotal for devising adaptive strategies to prevent, control, and eventually eradicate ASF. This highly contagious viral disease affects both domestic and wild pigs, leading to devastating economic losses through high mortality rates and trade restrictions. The recent surge in ASF outbreaks has presented significant challenges to pig farmers in Bhutan, particularly smallholder farmers who often lack the resources and infrastructure to manage such outbreaks effectively. These impacts have compounded the challenges faced by smallholder farmers, threatening both their livelihoods and food security. This situation underscores the urgent need for effective and sustainable biosecurity measures to prevent and control ASF in Bhutan.

While regional studies have addressed animal diseases and control measures in South Asia, comprehensive data and studies specific to ASF in Bhutan are scarce. Existing research often lacks the specificity required to address the unique context of Bhutanese smallholder farms, necessitating a focused, localized approach that takes into account the socio-economic conditions of Bhutan's pig farmers and the practical challenges they face in implementing biosecurity measures.

This study was conducted across three gewogs of Gelegphu, Samtenling, and Gakiling in Sarpang dzongkhag, Bhutan. These areas are significant pig-rearing regions in the country, with Gelegphu and Samtenling reporting ASF outbreaks in 2022-2023, while Gakiling remained unaffected. The study aimed to evaluate the biosecurity measures in place at smallholder pig farms in these areas and to recommend economically viable and socially acceptable interventions for preventing and controlling ASF. Using a mixed-methods research approach, which included quantitative surveys and qualitative interviews with pig farmers, key informants, and livestock officials, the study analyzed data to develop a Biosecurity Index and comprehensive biosecurity intervention packages tailored to the prevention and control of ASF in Sarpang. These interventions could potentially be adapted for use in other regions of Bhutan.

The Biosecurity Index revealed that all three study areas fell into the "Fair" category (0.40 to 0.59), with Gakiling achieving the highest index value of 0.590, followed by Gelegphu (0.491) and Samtenling (0.477). Gakiling's higher score was attributed to the higher index values of Farm Access Control, and Animal Health Management variables. All the three study areas had a "Good" category for the Feed and Water Safety Management variable. However, concerns were identified in the implementation of biosecurity measures such as Disinfection Facilities and Practices (Poor category) in Gelegphu and Samtenling, while record keeping Practices need to be unscaled across all areas. Therefore, the comprehensive analysis of the key biosecurity variables underscores the importance of continuous monitoring and improvement of biosecurity measures. The higher Biosecurity Variable Indices in certain variables reflect well-established practices, while the lower indices highlight areas where additional interventions are required such as training, resources, or stricter enforcement of protocols which could further strengthen the farms' defences against disease.

In terms of awareness of ASF, the key findings indicate that farmers across all areas demonstrated moderate to high awareness of ASF basics. However, there were specific knowledge gaps, particularly regarding transmission modes and clinical signs, especially in Samtenling. The ASF outbreaks in

2022-2023 had profound economic and social impacts on smallholder pig farmers in Sarpang. There was notable decreases in farm income, and increased costs for biosecurity measures, exacerbating financial strain and stress levels. The study also highlighted the psychosocial effects experienced by farmers during these outbreaks, consistent with existing literature on the subject.

To enhance the resilience of smallholder farmers during outbreaks, and to promote the adoption of appropriate biosecurity measures, the study explored factors influencing the adoption of such measures. Economic constraints, limited knowledge, training, and mind set, and perception issues were identified as primary barriers. These factors hinder farmers from effectively implementing necessary biosecurity practices, underscoring the need for targeted interventions.

The study provides recommendations for biosecurity interventions that are targeted, context-specific, economically feasible, and socially acceptable. Such strategies will empower farmers to combat ASF effectively, enhancing the sustainability of pig farming in Bhutan. Additionally, the study emphasizes the need to strengthen livestock regulatory services, as these are critical for enforcing biosecurity measures and preventing ASF outbreaks, such as those linked to prohibited pork imports. The ASF outbreaks during 2022 and 2023 in Sarpnag dzongkhag were reported to have been introduced through illegal pork imports from across the border in India, which then spread via infected kitchen waste from hotels to farms in the affected areas. Therefore, enhanced regulatory oversight and rapid response capabilities are essential components of a successful ASF prevention strategy.

Further, while external funding and government support for certain biosecurity interventions are essential, it is equally important for farmers to take proactive steps to control and prevent ASF on their farms. Farmers should also focus on implementing self-managed, locally manageable, cost-effective, and sustainable practices, reducing their dependency on external assistance.

This study, funded by the Food and Agriculture Organization (FAO) and coordinated by FAO Bhutan and the Department of Livestock, Ministry of Agriculture & Livestock, Bhutan, reflects FAO's commitment to enhancing agricultural productivity, improving rural livelihoods, and ensuring sustainable food systems. By supporting this research, FAO aims to develop effective, economically viable, and socially acceptable biosecurity measures to help prevent and control ASF outbreaks in Bhutan's pig farming sector.

Table of Contents

1. GENERAL INTRODUCTION

1.2 Bhutan: The Country

1.1.1 Demography and Governance

The Kingdom of Bhutan is a small, landlocked country in the Eastern Himalayas bordered by China to the north and India to the south, east, and west. It has an elevation that ranges from 100 meters above sea level in the southern foothills to around 7,500 meters in the northern peaks. Forests encompass about 70 percent of the country; 7 percent with year-round snow and glaciers; nearly 3 percent is cultivated or agricultural areas; and 4 percent as meadows and pastures (NSB, 2023).

Bhutan comprises an area of about 38,394 square kilometres with about 170 km north to south and 300 km east to west (NSB, 2023). It shares 470 kilometres (km) long border with Tibet (China's Xizang Autonomous Region) in the north and northwest, 605 km with the Indian state of Sikkim in the west, West Bengal in the southwest, Assam in the south and southeast, and Arunachal Pradesh in the east. The country is divided into 20 dzongkhags (districts) with Thimphu as the capital. These dzongkhags are further subdivided into 205 gewogs (blocks). Bhutan had a population of about 770,000 in 2023 growing at an annual rate of 0.9 %, and therefore the country has a very small average population density per square kilometer of 19 (NSB, 2023).

1.1.2 Socio-economic Development

Bhutan is known for its development philosophy of Gross National Happiness (GNH), which emphasizes sustainable development, cultural preservation, environmental conservation, and good governance over mere economic growth (Ura et al., 2015). Economically, Bhutan is classified by the World Bank as a lower-middle-income country. In 2021 Bhutan had a Gross Domestic Product (GDP) per capita of USD 3560 with a GDP per capita growth of 3.8% (World Bank, 2023). Further, in terms of its human development, the country had a Human Development Index of 0.681 in 2022 and was ranked 125th out of 193 countries (UNDP, 2024).

In 2022, Bhutan's poverty rate was 12.4%, with poverty more pronounced in rural areas at 17.5%, while in urban areas it was 4.2% (NSB, 2022). Agriculture and livestock employed around 43.5% of the Bhutanese population for their livelihoods, contributing 14.67 % to the GDP in 2022 (NAS, 2023). The overall unemployment rate in 2022 was recorded at 5.9% and for the youth unemployment rate it was 28.6% (LFSR, 2022). Therefore, the agriculture and the livestock sector is a priority during this 13th Five Year Plan, which sets ambitious targets for economic growth through strategic investment in opportunities and untapped potentials (GNHC, 2023).

1.1.3 Agricultural & Livestock Production Systems

The country is divided into three distinct agro-ecological zones (AEZ): alpine, temperate (warm and cool temperate) and subtropical zone (wet, humid and dry sub-tropical). The alpine (3600-7500 m.a.s.l.) zone is composed of snow-capped peaks and alpine meadows with very cold winters and cool summers, covering around 29% of the area. Predominant agricultural activities include yak herding for dairy products (semi-nomadic farmers) and cultivation of barley, buckwheat, mustard, and vegetables (NSB, 2023).The wet subtropical (100-600 m.a.s.l.), humid subtropical (600-1200 m.a.s.l.), and dry subtropical (1200-1800 m.a.s.l.) zones are located in the Himalayan foothills in the southern belt and are characterized by high humidity and heavy rainfall, with temperatures ranging

from 15ºC to 30ºC all year. The dry-subtropical AEZ (13% of the country's area) is dominated by maize, paddy, millet, pulses, fruit trees, wild lemon grass, cattle, pigs, poultry, and vegetables farming. In the humid sub-tropical areas and wet subtropical zones - making up 10% and 6% of the country's area, respectively - farmers most commonly cultivate paddy, mustard, wheat, pulses, tropical fruit trees and vegetables.

Warm temperate (1800-2600 m.a.s.l.) and cool temperate (2600-3600 m.a.s.l.) zones are found in the main central valleys, characterized by cool winters and hot summers with moderate rainfall. Summer temperatures usually range from 15ºC to 26ºC, while winter temperatures range from -4ºC to 15ºC. The warm temperate zone, covering 19% of the area, is suitable for paddy, wheat, mustard, barley, potato, temperate fruits, vegetables and dairy cattle production. In the cool temperate zone, farmers rear yaks, cattle, sheep, and horses, as well as crop production (barley, wheat, potatoes, buckwheat, mustard, temperate fruits and vegetables).

1.1.4 Livestock Population, Production and Imports

For the smallholder farmers in Bhutan, livestock is an integral part of Bhutanese agriculture and rural livelihoods and plays a crucial role in the livelihoods of smallholder farmers in Bhutan (MoAF, 2022). The wide spectrum of benefits includes cash income from the sale of dairy and livestock products, food, manure and draft power and as a source of insurance to their economic needs (Samdup, 2018).

Livestock Population:

Figure 1.1 gives that population of crossbred and local cattle of Bhutan in 2020, 2021 and 2022 which was 292,085, 306,959, and 262,632 respectively (NSB, 2023). The crossbred cattle include all exotic (*Bos taurus)*-local cattle crosses, while local cattle includes the local cattle Thrabum *(Bos indicus)*, Mithun (*Bos frontalis)* and their crosses. During 2022, the proportion of local cattle and exotic crossbred cattle was 63% and 37% respectively. Compared to 2020, the total cattle population declined in 2022 by about 10%. The decline was mainly due to a decrease in the exotic crossbred and local cattle population declined by 17.4% and 5.1% in 2022 compared to the year 2020.

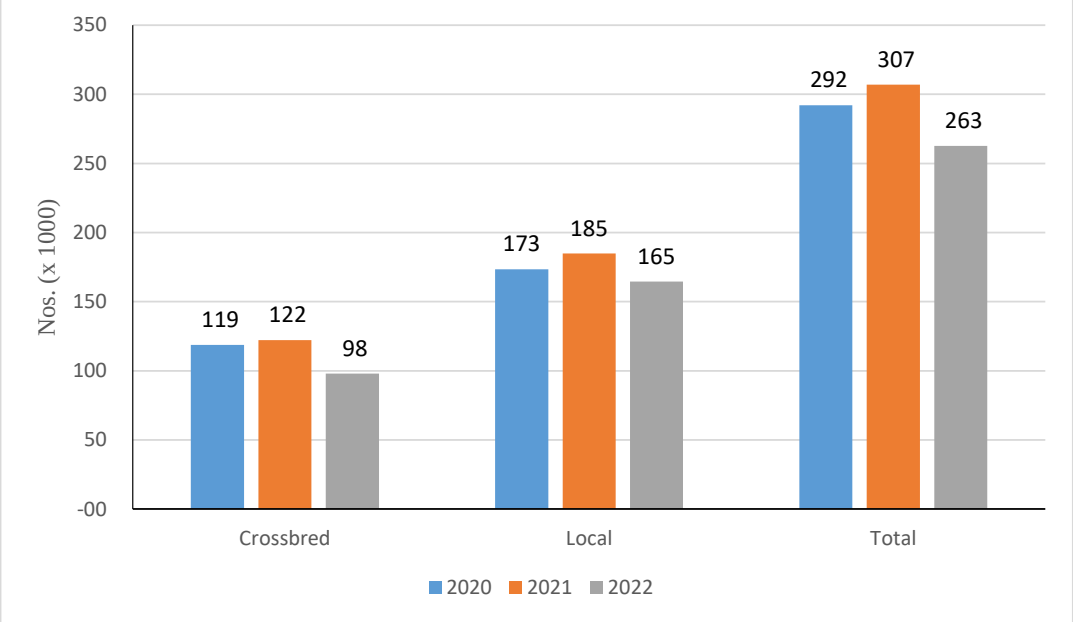

Figure 1.1 Cattle population of Bhutan in 2020, 2021, and 2022 in Bhutan.

The total population of other important livestock in Bhutan during 2000, 2021 and 2022 is given in Table 1.1 (NSB, 2023). The population of large animals like Yaks *(Bos grunniens)* and Equine decreased in 2022 compared to 2020 by about 26% and 20% respectively. While the population of small animals like pigs and goats increased in 2022 compared to 2020 by about 88% and 27% respectively. The sheep population remained stable at about 10,000 over the three years. The poultry population in 2020 was about 1.4 million and declined by 30% in 2022.

Table 1.1 Population (in numbers) of other important livestock in 2020, 2021 and 2022 in Bhutan.

	Year		
	2000	**2021**	**2022**
Yak	40,897	38,642	30,328
Equine	14,649	12,418	11,665
Pig	17,577	22,954	33,082
Goat	44,119	59,577	56,004
Sheep	10,793	10,694	10,024
Poultry	1,383,714	1,384,449	975,152

Livestock Production:

The table 1.2 presents production data for milk, chicken, chevon (goat meat), and eggs in Bhutan over three years (2020 to 2022), highlighting a trend of fluctuating outputs with some notable trends (NSB, 2023). Milk production was relatively high in 2020 at 58,197 metric tonnes but declined by about 6% to 54,654 metric tonnes in 2021, likely due to a decrease in cattle numbers. The lack of data for 2022 may indicate reporting issues.

Chicken production rose slightly in 2021 before falling sharply to 993.6 metric tonnes in 2022. Egg production showed a continuous decline, from 172 million eggs in 2020 to 101 million in 2022. These declines in chicken meat and egg production, by over 40% in 2022 compared to 2020, could be attributed to factors such as avian influenza outbreaks and supply chain disruptions, possibly worsened by the COVID-19 pandemic.

Pork production decreased from 879 metric tonnes in 2020 to 700 tonnes in 2021, likely due to African swine fever (ASF) outbreaks. However, production rebounded significantly to 1,231.8 tonnes in 2022, reflecting an 88% increase in the pig population. This recovery illustrates the livestock sector's resilience despite ongoing ASF cases in some areas. The production of chevon saw a dramatic 45% decline from 296 metric tonnes in 2020 to 162 tonnes in 2021, likely due to a PPR outbreak in 2020, which led to increased mortality and culling. A slight recovery to 173.7 metric tonnes in 2022 indicates efforts to rebuild herds, though production has not returned to pre-outbreak levels, suggesting ongoing challenges in the sector.

Table 1.2 Dairy and livestock production (x 1000 kg) and eggs (in million) in 2020, 2021 and 2022 in Bhutan.

	Year		
	2020	**2021**	**2022**
Milk	58,197	54,654	No data
Chicken	1,835	1,866	993.6
Pork	879	700	1231.8
Chevon	296	162	173.7
Egg (in million)	172	133	101

1.1.5 Import of Livestock Products

Bhutan is a huge importer of animal and animal products. Table 1.3 gives an overview of animals and animal products imported in Ngultrum (Nu) over the years (DRC, 2020, 2021, 2022, 2023). In 2023, Bhutan imported about Nu. 680 million of meat and 348 million of fish products, an increase of 25% and 56% compared to the import values of 2020. Meat imports were mainly pork, beef, and chicken.

For milk and dairy products, Bhutan has consistently imported these to meet domestic demand, primarily due to limited local production capabilities. These imports of dairy products (mainly) and some eggs and honey products were valued at Nu. 2,243 in 2023, an increase of 27% compared to 2020.

Table 1.3 Bhutan's import of animal and animal products (as per DRC's classification) from 2020 till 2023

Year	**2020**	**2021**	**2022**	**2023**
Products	**Nu in million**			
Animals	39.7	60.2	43.0	52.0
Meat	680.1	1166.4	1220.1	851.6
Fish & crustaceans	348.1	454.9	501.2	543.5
Dairy, eggs & honey	1766.8	1877.2	2005.1	2243.4
Other animal poducts	14.6	7.1	1.8	6.5
Total	2,849.3	3,565.8	3,771.2	3,697.0

[1] Ngultum (1 US$ = 82.25 in 2023, RMA, 2023)

1.1.6 Animal Health Services

Animal health services in Bhutan are designed to enhance livestock health and productivity through a range of support mechanisms. These services encompass regular veterinary check-ups, treatment, vaccination programmes, and advisory services that guide farmers on best practices in animal husbandry (MoAF, 2022).

A key aspect of animal health services is the surveillance of animal diseases. Effective monitoring and early detection systems are vital for managing outbreaks and preventing the spread of diseases. Surveillance helps in identifying potential threats and implementing timely interventions, which are essential for controlling disease outbreaks and mitigating their impact.

Among the various threats, Transboundary Animal Diseases (TADs) pose a particularly significant risk due to their ability to spread rapidly across Bhutan's porous borders. Diseases such as African swine fever (ASF) and Peste des Petits Ruminants (PPR) not only threaten livestock health but also jeopardize food security and the livelihoods of farmers (FAO, 2020). Therefore, controlling these diseases is imperative for safeguarding animal health and ensuring economic stability.

In addition to disease management and surveillance, animal health services in Bhutan also focus on enhancing biosecurity measures, improving livestock management practices, and providing farmers with the necessary resources and training. This comprehensive approach aims to build resilience within the livestock sector, reduce the impact of disease outbreaks, and support sustainable agricultural practices.

1.1.7 African Swine Fever in Bhutan: A Critical Challenge

African swine fever has become a significant concern for the pig industry both globally and locally, with serious implications for the livelihoods of many Bhutanese who depend on pig farming. The pig farming sector in Bhutan is predominantly made up of backyard operations, alongside semi-commercial and commercial farms. The predominance of backyard farming increases the risk of rapid ASF spread, leading to severe socio-economic consequences.

ASF is a highly contagious viral disease of domestic pigs, manifesting itself as hemorrhagic fever with mortalities that can approach 100 percent (Abedin et al., 2020). Bhutan reported its first ASF outbreak in May 2021 in the scavenging pig population of Phuentsholing town, Chukha district near the bordering town of Jaigaon, West Bengal, India, which was effectively controlled by stamping out the susceptible population in the area (Wangdi and Bidha, 2022). The second ASF outbreak occurred in the backyard pig holdings in Sampheling gewog of Chukha district in April 2022 where over 1000 pigs were culled (Wangdi 2022).

The third outbreak occurred in Samtenling and Gelegphu gewogs of Sarpang dzongkhag in November and December 2022 resulting in culling 336 pigs. The total costs incurred by the government was Nu. 1.26 million to contain the outbreak for 3-D operation *(Depopulation, Disposal, and Decontamination*), compensation cost of culled pigs and other associated was Nu 1.64 million for the (Dorji, 2022).

The fourth ASF outbreak was reported in March and April 2023 in four gewogs of Chuzergang, Sompankha, Samentling and Singye, Sarpang dzongkhag and at the government farms of National Development Centre for Aquaculture and National Pig Development Centre, Gelegphu. The total estimated cost incurred to curb this outbreak was about Nu 3.22 million (Lungten, 2023). The most recent ASF outbreaks in Bhutan occurred in Punakha dzongkhag (121 pigs culled), and Wangduephodrang dzongkhag (151 pigs culled) in June 2024 (Kuensel, July 8, 2024).

According to Wangdi and Bidha (2022), comprehensive studies on biosecurity practices of pig holdings in the country are limited. They emphasize the need for effective management of animal health and biosecurity measures, and to address the challenges of TAD which are crucial for sustaining livelihoods, enhancing national food security, and fostering economic development in Bhutan.

1.1.8 Inherent Challenges in the Agricultural and Livestock Sector

While concerted efforts are being implemented by the government in various development activities, some of the inherent challenges are outlined as follows:

Dominance of Backyard Farming:

Agriculture and livestock are major sources of income and employment in Bhutan, with almost 43.5% of the population relying on farming (NSB, 2023). However, a significant portion of farming practices remains at the backyard level. Approximately 37% of farmers produce solely for their consumption, while 53% produce primarily for self-consumption with only a small surplus sold (RNRSD, 2019). This limits the scalability and market integration of agricultural and livestock products.

Dependence on Rain-Fed Agriculture:

Agriculture in Bhutan relies heavily on rain-fed systems, with monsoon rains accounting for 60 to 90% of annual precipitation (MoAF, 2022). This dependency makes the sector vulnerable to water shortages, which can affect feed resources, reduce fodder production, and lead to the degradation of pastures and rangelands. Such conditions diminish livestock productivity and the carrying capacity of rangelands.

Threats from Transboundary Diseases:

The sector faces significant challenges from the emergence and re-emergence of TADs like African swine fever (ASF) and Peste des Petits Ruminants (PPR). Additionally, new plant pests and diseases, along with increasing human-wildlife conflicts, exacerbate the situation. These conflicts include wild animals preying on livestock and damaging crops (MoAF, 2022).

Other critical issues:

Other critical issues include the shortage of irrigation water, insufficient agricultural manpower, and the challenges associated with marginal land holdings. High transportation costs for inputs and marketing, combined with the remote and scattered locations of rural households, further compound these difficulties. Climate change is also impacting the sector, manifesting through glacier lake outbursts, flash floods, windstorms, erratic rainfall, and increased incidences of forest fires (CIAT & World Bank, 2016).Addressing these inherent challenges is essential for enhancing the resilience and productivity of Bhutan's agricultural and livestock sectors.

1.2 Sarpang: The District

1.2.1 Demography and Agriculture Production Systems

Sarpang District, located in the southern part of Bhutan, spans an area of approximately 1,946 square kilometers (NSB, 2023). It is bordered by India to the south and shares internal borders with Tsirang, Zhemgang, and Dagana dzongkhags of Bhutan. The dzongkhag is sub divided into 12 gewogs. In 2023, Sarpang had a projected human population of approximately 50,221 with an average population density per square kilometer of about 24 (NSB, 2023).

1.2.2 Agriculture and Livestock

Sarpang experiences a subtropical climate with hot, humid summers and mild winters. The region receives substantial rainfall during the monsoon season, which is beneficial for agriculture but can

also lead to flooding and landslides. Agriculture and livestock production are major sources of economic activities for farmers in Sarpang. The district's fertile plains and ample water resources support diverse agricultural production with rice, maize, millet, and vegetables being the main crops. Livestock Production oriented activities are significant in Sarpang, with cattle, poultry, and pigs being the primary livestock.

1.2.3 Pig Production Systems

Amongst the various categories of livestock, smallholder pig farmers play a crucial role in sustaining livelihoods, enhancing national food security, and fostering economic development (FAO, WOAH, The World Bank. 2010). According to MoAF (2022), the pig production type can be categorized into: commercial farms wherein pigs are raised in confinement with commercial feeds; semi-commercial farms where pigs have access to outdoor areas and are fed a combination of commercial feeds and household waste and backyard farms where pigs forage for food is the most predominant. The common pig breeds include indigenous breeds known for their hardiness and adaptability to local conditions and exotic breeds and their crossbreds such as Large White, Landrace, Large Black, Saddleback and their which are known for their improved productivity.

Figure 1.2 shows that amongst the 20 dzongkhags, Sarpang had the highest pig population (4347) followed by Tsirang (4011) and Samtse (3891) in 2021. These three dzongkhags accounted for 58% of the pig population in Bhutan. Sarpang also had the highest proportion of exotic crossbred pigs at 95%, followed by Tsirang at 93% (NSB, 2023).

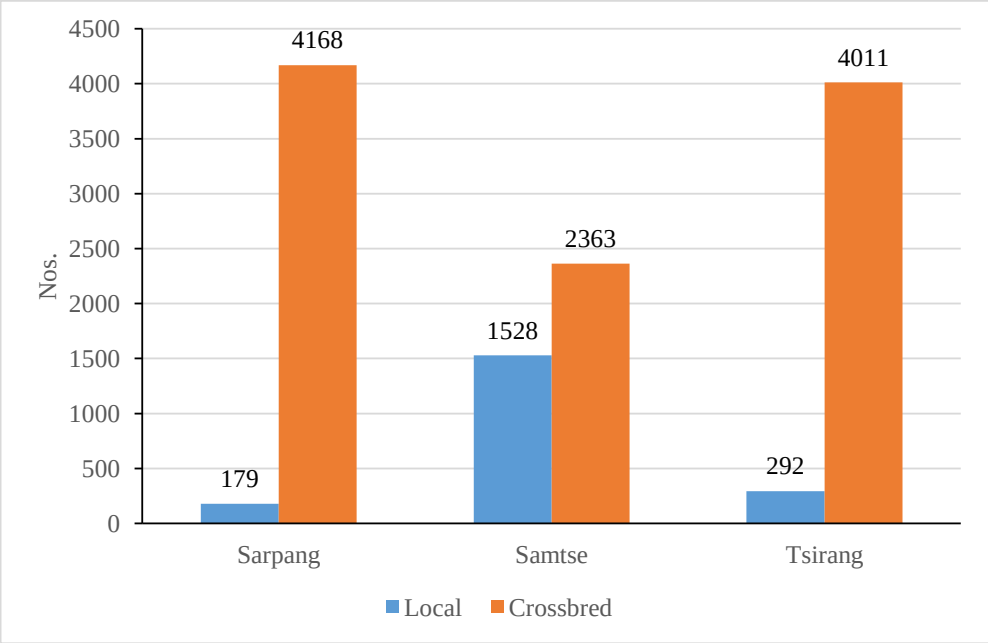

Figure 1.2 Population of pigs in Bhutan's major pig rearing dzongkhags in 2021.

In 2021, in terms of total pork production in Bhutan, Sarpang followed by Tsirang and Samtse dzongkhags accounted for 33.4%, 21.6%, and 14.7% of the country's total pork production respectively (Figure 1.3). Collectively, these three dzongkhags accounted for about 70% of the pork production in Bhutan. The three dzongkhags also sold between 90 to 95% of the pork produced.

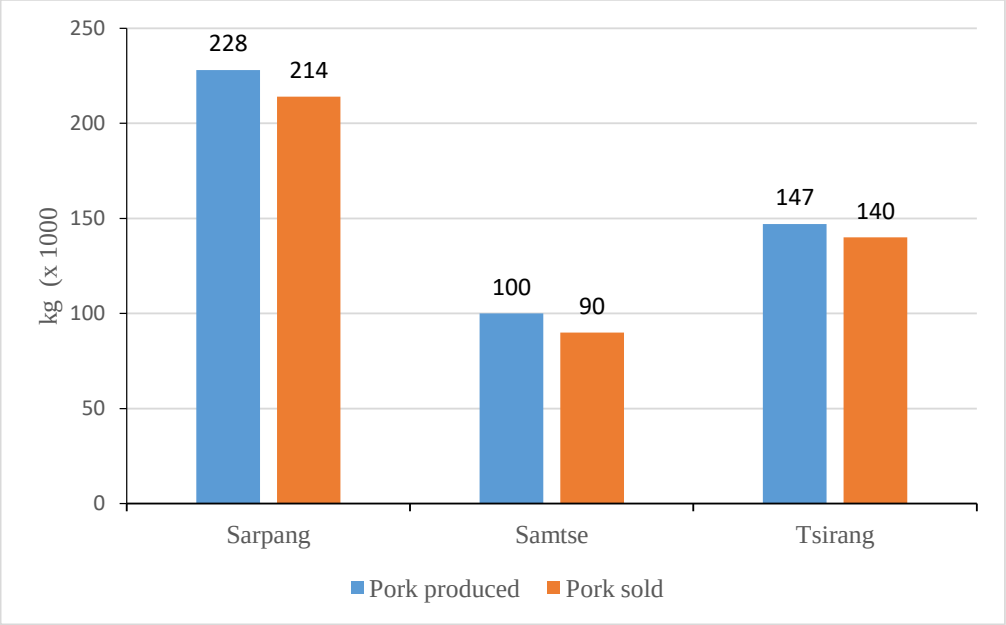

Figure 1.3 Production and sale of pork by the major pig-rearing dzongkhags of Bhutan in 2021

1.3 Study Objectives

Pig farming in Bhutan is pivotal for sustaining livelihoods, enhancing national food security, and fostering economic development. Amongst various pig diseases, ASF is a highly contagious viral disease affecting domestic and wild pigs, causing severe economic losses due to high mortality rates and trade restrictions (FAO, WOAH, The World Bank. 2010). The recent surge in TADs, particularly ASF poses significant challenges, especially to smallholder farms in Bhutan. ASF is associated with losses in production, utility, and income, heavy expenses on outbreak response, creating a compounding effect on the livelihoods and food security of smallholders. This increase is primarily attributed to inadequate farm biosecurity, poor husbandry practices, illegal importation of live pigs, pork, and pork products, as well as the widespread practice of swill feeding.

Therefore, the outlook for ASF in Bhutan depends on continued vigilance in biosecurity measures, international cooperation in disease surveillance, and advancements in vaccine development. Anticipating and preparing for future outbreaks requires a proper understanding of the biosecurity measures in place which would enable us to develop adaptive strategies to prevent, control, and eradicate ASF **(**Bremang et al., 2022). Further, considering that socio-economically disadvantaged communities predominantly undertake small-scale pig farming in Bhutan there is a necessity to devise biosecurity intervention initiatives that are both socially and economically feasible.

The Objectives of the study are:

- Assess existing biosecurity practices in pig farms within a major pig-rearing community in Bhutan.
- Provide feasible recommendations to enhance disease prevention and control of ASF.
- Develop a socially and economically acceptable biosecurity intervention package for prevention and control of ASF.

2. MATERIALS AND METHODS

2.1 Selection of Study Areas

The study was conducted in the three gewogs of Gelegphu, Samtenling, and Gakiling gewogs under Sarpang dzongkhag, Bhutan (Figure 2.1). The study area under these gewogs comprises of several villages and therefore overall study areas are termed as Gelegphu, Samtenling and Gakiling in this study.

The following criteria were used for selecting the three study areas:

- Prevalence of pig farming: These areas had a high concentration of pig farms, making them ideal for studying biosecurity measures and ASF control strategies.
- Location and incidence of ASF outbreak: All three areas have a porous border with India with both formal and informal entry and exit routes. The gewogs of Gelegphug and Samteling had historical outbreaks of ASF while the Gakiling gewog did not have any reports of an ASF outbreak.
- Geographical representation: The three gewogs represent different geographic conditions and diversity in farming practices within the Sarpang dzongkhag, providing a comprehensive understanding of biosecurity challenges across diverse settings.
- Accessibility: The areas that were accessible for field visits were targeted to ensure efficient data collection and stakeholder engagement. Some of the more interior areas in Sarpang dzongkhag could not be visited due to incessant rains and roadblocks during the period of the field visits.

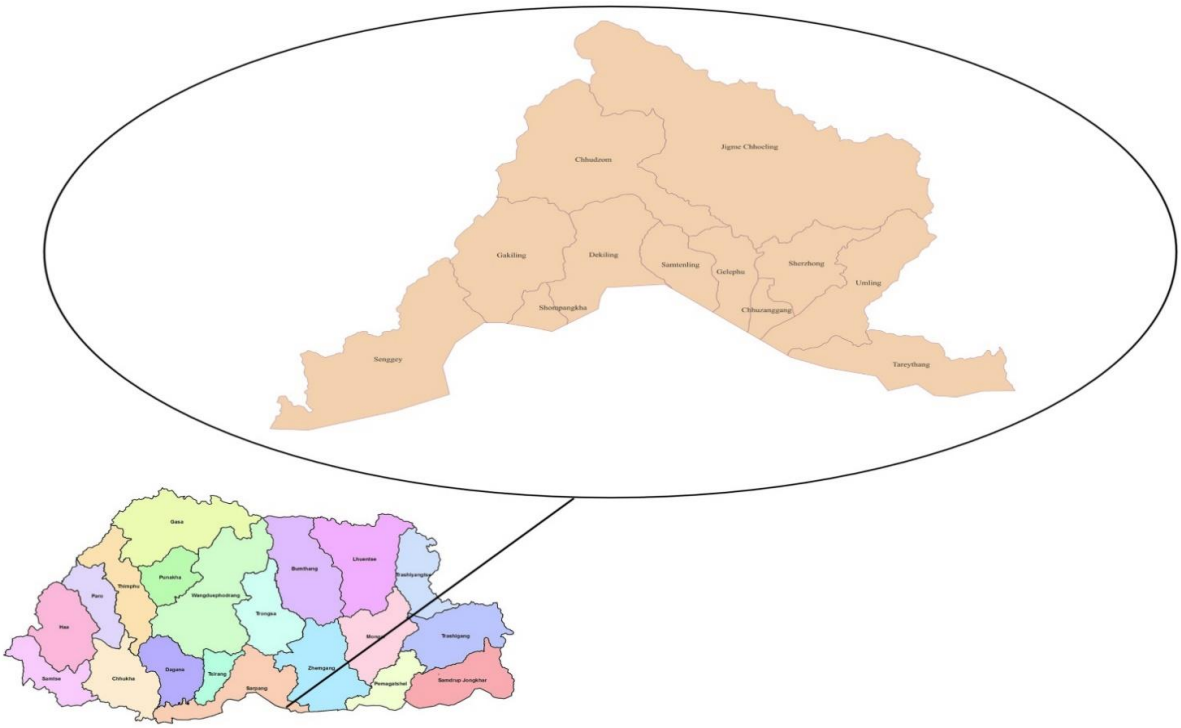

Figure 2.1: The study areas of Gelegphu, Samteling and Gakiling at Sarpang dzongkhag, Bhutan (RGOB, 2022).

2.2 Stakeholders

When conducting field surveys, identifying primary and secondary stakeholders is crucial for ensuring the survey's success and relevance (Reed et al., 2009). The primary stakeholders are those that are directly affected by the project or survey. It usually included beneficiaries, project participants, local communities, and direct users of the survey results. The secondary stakeholders are indirectly affected or have an intermediary role. It usually includes government agencies, NGOs, donors, and other organizations that influence or support the primary stakeholders.

In this study, the stakeholders included are:

- Primary stakeholders: They include smallholder pig farmers, veterinarians, district livestock officers, livestock extension officers, epidemiological officers, and food regulators.
- Secondary stakeholders: These are the local government authorities, National Focal Point for ASF, Department of Livestock, Bhutan; FAO-Thimphu-Focal Officer, and consumers

2.3 Population and Sampling

The target population for the study comprised smallholder pig farmers in the gewogs of Gelegphu, Samtenling, and Gakiling. A stratified random sampling technique was employed to select the farms. This method ensured that the sample was representative of different farming practices, farm sizes, and geographic locations within the gewogs. Due to the heavy rains and constant roadblocks, we could visit only a limited number of farmers during the period of field visits in the three gewogs. A total of 76 smallholder farms were selected for the study, with 21 farms from Gelegphu, 23 from Samtenling, and 32 from Gakiling gewog.

2.4 Data Collection

Data were collected by way of triangulation through farmer interviews, field observations, surveys of key informants, and focus group discussions to gather detailed information on current biosecurity measures and practices in place on smallholder pig farms. The following data collection tools and techniques were employed and carried out from June 14 to 27, 2024.

2.4.1 Survey

A set of structured and semi-structured questionnaires consisting of both closed-ended and open-ended questions was designed to collect information on various aspects of farm management including farm characteristics, farmers' biosecurity knowledge and practices, and farmers' awareness of ASF (Table 2.1).

Pilot testing of the questionnaire was conducted with two pig farmers in Gelegphu before the actual survey and was modified to improve clarity. Feedback from FAO officials in Thimphu and Bangkok was also obtained and their views were incorporated in the final questionnaires The questionnaire was written in English and translated into local dialects by the enumerators for ease and convenience during a one-on-one interview at the residence of the farmer respondents with prior verbal consent. With the support of a few experienced enumerators, the questionnaires were administered and the information obtained was noted on the same questionnaire and later on compiled and consolidated.

Table 2.1 Overview of data types collected in this study

Particulars	Details
Respondent's details	Name, location, contact number, occupation, income
Demographic data	Gender, education level, and experience of farmers.
Farm characteristics:	Farm size, pig herd size, breed types, and farming systems.
Farm management practices,	Feeding practices, record keeping
Farm access and infrastructure	Types of pig housing, fencing, biosecurity signage
Animal health management	Veterinary services, disease incidence and mortality, disease monitoring, quarentine
Hygiene & sanitation practices	Waste management practices, sanitation & disinfection practices
Economic aspects	Impact on farm income, biosecurity costs
Social aspects	Impact on daily work life, stress and anxiety

Purposive samples were used to identify the villages for survey within the gewogs. Subsequently, the structured survey questionnaire was administered to 76 randomly selected smallholder pig farmers across the three gewogs of Gelegphu (21), Samtenling (23), and Gakiling (32). Semi-structured interviews were conducted with key informants such as farmers, livestock officials, veterinarians, livestock regulators, local authorities, and other stakeholders to gather qualitative and quantitative data on biosecurity practices and insights into the challenges and effectiveness of current ASF control strategies. The experiences and perspectives of veterinary professionals and livestock regulators regarding ASF outbreaks, response strategies, and perceived barriers to effective biosecurity implementation were explored.

2.4.2 Direct/Farm Observations

Upon screening the data obtained through the questionnaires, the consent of the farmers was obtained to conduct an on-site visit to some of the pig farms (using a checklist) to assess the infrastructure, hygiene practices physically, and biosecurity measures in place. This method also helped to validate the information collected through questionnaires and enabled further interaction with the farmers to clarify doubts and identify practical suggestions to improve biosecurity practices.

2.4.3 Key Informant Interviews (KIIs)

KII were conducted with key stakeholders including veterinary/livestock officers, district livestock officers, food regulatory officials, farmer representatives, and representatives from the Department of Livestock, Ministry of Agriculture and Livestock, Thimphu. These interviews provided insights into the existing livestock policies, biosecurity protocols, challenges in implementation, and potential areas for improvement.

2.4.4 Focus Group Discussions (FGDs)

FGDs were held with groups of stakeholders who had exposure to the ASF outbreaks. There were the smallholder pig farmers (6), representatives from local communities (3), District livestock officer & Gewog Livestock Officials (6), representatives from the Bhutan Food & Drug Authority Officials (3),

National Pig Development Centre (4), Regional Veterinary Hospital & Epidemiology Centre (4), Gelegphu and Department of Livestock (1).

This FGD provided a platform to discuss and identify major issues and challenges faced in implementing effective biosecurity measures; to develop actionable recommendations to improve biosecurity and provide views on biosecurity measures/ indicators to develop a Biosecurity index. The challenges and perceptions related to biosecurity and ASF prevention were noted. The discussions also facilitated the exchange of ideas and highlighted community-level issues that might affect biosecurity measures.

2.5. Data Analysis

For this study, data was captured through the questionnaire form developed and later compiled and entered into the database of Microsoft Excel. A mixed-methods approach was employed, by integrating both quantitative and qualitative data collection and analytical techniques (Creswell & Plano Clark., 2011) to comprehensively assess and enhance biosecurity practices. Statistical analyses were carried out using the STATISTIX 9 program.

2.5.1 Descriptive Statistics

Quantitative data from the questionnaires were analyzed using descriptive statistics to summarize the demographic characteristics, farm management practices, and biosecurity measures. Data was analyzed for means and standard deviations for numerical data (e.g., number of pigs, frequency of cleaning, farm income) and proportions and percentages for categorical data (e.g., presence of quarantine area, use of disinfectants). This would provide an overview of the current state of biosecurity practices and socio-economic conditions among pig farmers

2.5.2 Analysis of Variance (ANOVA)

Least square methods (Harvey, 1977) were used to explain variation in farm characteristics and other variables between the three study areas (Gelegphu, Samtenling, and Gakiling) e.g. analyze the effect of education background and farming experience on the Biosecurity index; effect of biosecurity measure on the disease incidence.

An ANOVA was done to study the effect of area (the 3 study areas) on several dependent variables of Biosecurity.
A record will be described by the model:
$Y_{ijk} = \mu + \alpha + \varepsilon$

Where:
Y_{ijk} are dependent variable of farm $_j$ of area $_i$
μ is overall mean
α is area effect (Gelegphu, Samtenling, Gakiling)
ε is error

2.5.3 Chi-square Tests

Data was used to assess associations or relationships between categorical variables (e.g., level of knowledge, awareness between the three study areas, and the economic and social impacts between the three study areas (Creswell & Plano Clark., 2011).

2.5.4 Kurskal-Wallis Tests

The KruskaWallis test is similar to ANOVA but used for non-parametric data for categorical variables with 3 or more levels such as ranks and uses the Tukey HSD all-pairwise comparisons test (e.g. the rankings of the various biosecurity measures between the three study areas (Creswell & Plano Clark., 2011).

2.6 Assessment of Biosecurity Measures

Biosecurity assessment can be used to prioritize which biosecurity measures should be improved or implemented first to reduce the likelihood of disease introduction and spread. In addition, it might enable to monitoring of farm biosecurity over time and to compare it with that of other farms (Alcarcon et al., 2021).

Some of the statistical models for Biosecurity assessments that provide probability estimates are the multivariate statistical models, Bayesian belief networks, and machine-learning algorithms (Alarcón et al., 2021). These are, however, complex and time-consuming, and, on the other hand, they require many data that are not always available. Several authors (Pinto & Urcelay, 2003, and Ekakoro et al., 2023) describe biosecurity scoring approaches to produce a Biosecurity score for farms. This study adapted and applied such Biosecurity scoring approaches to develop the Biosecurity ranking system and Biosecurity index to assess the Biosecurity measure of the smallholder pig farms in the three study areas.

The following methodology was employed:

i) Defined the Biosecurity Measures

Before the meeting with key informant interviews, and focus group discussions, an extensive literature review was done to identify important and relevant biosecurity measures for developing countries like Bhutan. Based on the literature review (FAO/WOAH/The World Bank, 2010; Bremang et al. 2022) some of the guidelines to evaluate the effectiveness of existing biosecurity measures of smallholder farms are listed as follows:

- Farm access controls Measures to control the movement of people, animals, and equipment in and out of the farm to prevent the introduction and spread of pathogens
- Waste management: Proper disposal of animal waste and carcasses to reduce the risk of disease outbreaks
- Animal health management: Practices related to animal health monitoring, vaccination, and disease reporting to maintain a healthy livestock population
- Feed and water Management: Ensuring the safety and quality of feed and water to prevent contamination and disease transmission
- Hygiene and Sanitation: Implementation of hygiene and sanitation practices, including regular cleaning and disinfection of animal housing, equipment, and farm premises

ii) Developed a Scoring System for the Biosecurity Measures

To evaluate the different Biosecurity measures, a Likert scales scoring system (Table 2.2) was developed (Joshi et al., 2015). The scales were divided into five categories as Non-compliance/Poor; Low compliance/Fair; Moderate compliance/ OK; High compliance/Good and Full compliance/Excellent.

The enumerators were trained and provided guidelines on scoring each of the seven biosecurity measures for every farm based on the data collected for the identified variables. Some of these data were crosschecked during the direct/field observation visits. Based on these analyses the enumerator assigned scores to each of the identified Biosecurity measures.

Table 2.2 Description of the Scoring scales

Categories	**Scale**
Non-compliance (Poor)	1
Never implement biosecurity measures	
Low compliance (Fair)	2
Occasionally implement some biosecurity measures, but not regularly or thoroughly	
Moderate compliance (OK)	3
Implement biosecurity measures, but there are some measures not followed consistently	
High compliance (Good)	4
Consistently follow most biosecurity measures, though occasionally miss minor details	
Full compliance (Excellent)	5
Rigorously implement all biosecurity measures in the farm with exceptions	

iii) Transforming the Biosecurity Measure score to a Normalized Scores

The raw score of the biosecurity measures were normalized by transforming them to a common scale between 0 to 1 using the formula:

$$\text{Normalized score} = \frac{\text{Score} - \text{Min}}{\text{Max} - \text{Min}}$$

Where:

The score is the actual score obtained; Min is the minimum possible score; Max is the maximum possible score.

iv) Assigned Weights to Each Biosecurity Measures

The focus group participants were divided into three groups representing the three study areas. Each group had a mix of participants from different professional backgrounds such as the livestock officer and extension staff from the study area, farmers representatives, officials of the Bhutan Food and

Drug Authority (BFDA) in each group, piggery experts from the National Pig Research and Development Centre (NPRDC), Gelegphu and officials from the Regional Veterinary Hospital and Epidemiology Centre (RVH & EC), Gelegphu. Thorough discussions ensued within the focus groups on the importance of the seven biosecurity measures to the overall biosecurity in preventing ASF. They then ranked and assigned weights as a proportion of 1 (0 to 1) based on their collective views for the seven biosecurity measures.

v) Computing the Biosecurity Variable Indices and the Overall Biosecurity Index

The Biosecurity Variable Index for the i-th variable is calculated as:

BV Index i = Normalized Score i x Weight i

where:

Normalized Score i = Normalized score of the i-th variable

Weight i = Weight of the i-th variable

The Overall Biosecurity Index was calculated as :

$$Biosecurity\ Index = \sum_{i=1}^{n} (\text{Normalized Score x Weight})$$

Where:

n is the total number of Biosecurity Variables; Normalized Score is the score of the i-th indicator and Weight i is the weight of the i-th indicator.

The granular Likert scales used to interpret the Biosecurity Index and Biosecurity Variable Indices are given in Table 2.3.

Table 2.3 Description of the Biosecurity Index and Biosecurity Variable Indices Scale

	Biosecurity Index	**Biosecurity Variables Indices**
Categories	**Scale (value 0-1)**	**Scale (percentage 0-100)**
VERY POOR	0 - 0.190	0-19
Indicates a critical lack of biosecurity measures, posing a high risk for disease outbreaks.		
POOR	0.200 - 0.390	20-39
Shows inadequate biosecurity measures, with significant risks remaining.		
FAIR	0.400 - 0.590	40-59
Reflects moderate biosecurity measures that are somewhat effective but need substantial improvement.		
GOOD	0.600 -0.790	60-79
Represents effective biosecurity measures with minor gaps.		
VERY GOOD	0.800 - 0.990	80-99
Indicates highly effective biosecurity measures with very few areas needing improvement.		
EXCELLENT	1	100
Exemplifies optimal biosecurity measures with no identifiable gaps.		

3. RESULTS

3.1 Characteristics of the Study Areas

An overview of some of the major physical characteristics of the three study areas under Gelegphu, Samtenling and Gakiling gewogs, Sarpang dzongkhag, Bhutan is given in Table 3.1 (RGOB, 2023). Amongst the three study areas Gakiling gewog is the largest in terms of area, experienced more of a cool temperate type of climate, however, it had the least human population which was about 23% of Gelegphu gewog. The types of livestock reared in the study areas were mainly pigs, poultry and cattle.

Table 3.1 Major characteristics distinguishing the three study areas of Gelegphu, Samtenling and Gakiling, Sarpang, Bhutan

Gewog	**Gelegphu**	**Samtenling**	**Gakiling**
Area (sq. km)	54	55	785
Altitude (masl)	200-800	190-380	250-2700
Agro-ecological zone	humid sub-tropical	wet sub-tropical	wet sub-tropical/cool temperate
Demography			
households (nos.)	1027	467	53
human population	4461	3068	
Cropping systems			
rain-fed	.+++	.+++	
irrigated	.++	.++	
Agriculture land			
wetland (acre)	621		
dryland (acre)	1114		
Major crops	rice, maize, vegetables	rice, maize, vegetables, citrus	rice, maize, millet, vegetables
Pig population			
local	.-	17	9
crossbred	253	971	582
ASF outbreaks	Yes	Yes	No
.+++ high frequency; .++ moderate; +low			

Table 3.1 gives the pig population in the three study areas. The pig population was the highest in Samtenling gewog followed by Gakiling and Gelegphu gewogs respectively. All the three study areas had a porous border with India. While Gelegphu and Samtenling geowgs experienced outbreaks of ASF, there was no reported ASF outbreaks in Gakiling gewog.

3.2 The Household Sub-system

In this study the household sub-system, the pig sub-system and crop sub-system are considered as the main components of the farm system. Table 3.2 gives the least square means of selected parameters of household size and farm income in 2023.

3.2.1 Household Size and Composition

The average household size (Hh size) ranged from 3.8 to 4.6 across the study areas, with no statistically significant differences observed. This suggests similar demographic profiles in terms of family members contributing to farm activities. Distribution by gender within households showed no significant differences across the study areas, with 0.8 to 1.3 households under 18 years old.

3.2.2 Farm Income

The farm income consist of both on-farm activities such as pig production and others (dairy, poultry and crop production) and off-farm income (day workers). Gelegphu and Samtenling had the highest on-farm income from pig production, about Nu. 192,000 to Nu. 195,000 per average farm in 2023 and was significantly higher ($p < 0.05$) by about 2.8 times Gakiling. This is due to the larger numbers of commercial and semi-commercial pig farms in Gelegphu and Samtenling.

Table 3.2 Farm household sub-system: household (Hh) members and farm income, averages (least square means, lsm) and standard errors (s.e) in three study areas of Sarpang, Bhutan, in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**		
Variables	**lsm**	**s.e**	**lsm**	**s.e**	**lsm**	**s.e**	**P value**
Number of farms (n)	21		23		32		
Hh size (n)	4.6	0.47	3.8	0.44	4.5	0.34	0.925
female	2.5		1.9		2.4		
male	2.1		1.9		2.1		
under 18 years	1.0		1.3		0.8		
Farm income (Nu [1] x 1000)							
pig production	192[a]	32.2	195[a]	30.8	69[b]	26.1	0.002
others[2]	47[a]	12.6	24[ab]	23.5	6[b]	23.5	0.046
Total	239[a]	32.7	219[a]	31.3	75[b]	26.7	0.002
[a,b] lsm with different superscripts between study areas are significantly different ($p<0.05$)							
[1] Ngultum (1 US$ = 82.25 in 2023, RMA, 2023)							
[2] others (dairy, poultry, agriculture, off-farm)							

Off-farm income was also significantly higher ($p < 0.05$) in Gelegphu and Samtenling compared to Gakiling. The total farm income, combining pig production and other sources, showed significant differences among the areas. Gelegphu had an average total income of Nu. 239,000 Nu; Samtenling had 219,000 and Gakiling had significantly lower ($p < 0.050$) total income at 75,000.

3.2.3 Education and Farming Experience

Table 3.3 presents the distribution of education levels and farming experience among smallholder pig farmers across three study areas in Sarpang, Bhutan, in 2023. This would enable us to do a more in-depth study of the impact of educational background and framing experience on the overall farm

management and biosecurity aspect of the farm. According to Roche et al., (2020) educational attainment and farming experience, are critical factors influencing biosecurity practices and ASF prevention efforts.

Table 3.3 Farm household sub-system: education, and farming experience, frequency (Freq.) and proportions (%) in three study areas of Sarpang, Bhutan, in 2023

Area	**Gelegphu (n-21)**		**Samtenling (n-23)**		**Gakiling (n-32)**	
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Number of farms (n)	21		23		32	
Education				0.0		
no formal education	11	52.4	10	43.5	10	31.2
primary	5	23.8	6	26.1	12	37.5
secondary/tertiary	5	23.8	7	30.4	10	31.3
Farming experience				0.0		
< 1 year	0	0	2	8.7	7	21.9
1 to 3 years	5	23.8	3	13.0	13	40.6
> 3 years	16	76.2	18	78.3	12	37.5

Approximately 31% of farmers in Gakiling reported having no formal education, which is notably lower compared to Gelegphu (52.4%) Interestingly the proportion of farmers without formal education was the highest in Gelegphu. and Samtenling (43.5%). Pig farms in Gelegphu are in the periphery of the Gelegphu urban area, and Gelegphu, though several family members were educated, the educated family members did not work full time on the farm. Gakiling had the highest number of

With regards to farming experience, Gakiling had the highest proportion (21.9%) of farmers with less than one year of farming experience, compared to Gelegphu (0%) and Samtenling (8.7%). Farmers with limited experience may face challenges in biosecurity due to unfamiliarity with disease management and prevention strategies. Farmers with 1 to 3 years of experience varied between Gelegphu (23.8%), Samtenling (13.0% to 23.8%. This group represents a transitional phase where farmers may begin to implement biosecurity measures but may require additional training and support. The majority of farmers in Gelegphu (76.2%) and Samtenling (78.3%) reported more than 3 years of farming experience, compared to 37.5% in Gakiling. Experienced farmers are likely more adept at implementing and adapting biosecurity protocols, contributing to disease prevention and control efforts.

3.3 The Pig Sub-system

The pig sub-system is an integral component of the farm system and provided livelihood opportunities and valuable sources of income for all the households in this study. Table 3.4 provides an overview of pig production characteristics across three study areas in Sarpang, Bhutan, in 2023. This includes the categorization of pig farms, purposes of pig rearing, and sources of breeding and fattening pigs, highlighting variations and trends among smallholder pig farmers.

3.3.1 Pig Farm Categories

In line with MoAF (2021), the pig farms in this study were classified based on the number of pigs owned such as as backyard pig farms (< 10 pigs), semi-commercial (10-50 pigs), and commercial farms (>50 pigs). Pig farming was largely backyard-oriented in all the study areas. The backyard pig farms in the study areas were characterized by small-scale, family-run operations.

Pigs were usually kept in simple enclosures and fed a combination of kitchen waste, agricultural by-products, and sometimes commercial feed. The backyard farm category was predominant and comprised 56.3%, 47.8%, and 34.8% of the total pig farm categories at Gakiling, Gelegphu, and Samtlenling respectively. Backyard farms typically have a lower adoption of biosecurity measures (Lapar et al., 2018). This is because, backyard farms often have a lower adoption of biosecurity measures due to limited resources since they typically operate on a small scale with limited financial and material resource, and informal management as such farms are often run by families or small groups with limited formal training in animal husbandry or disease prevention.

Table 3.4 Pig farm category, purpose of rearing and sources of pigs in areas of Sarpang, Bhutan, frequency (Freq.) and proportions (%) in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**	
Variable	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Number of farms (n)	21		23		32	
Pig farm category						
backyard farm	10	47.6	8	34.8	18	56.3
semi commercial	8	38.1	11	47.8	12	37.5
commercial	3	14.3	4	17.4	2	6.2
Pig rearing purpose						
breeding	3	14.3	5	22	3	9.4
fattening	13	61.9	14	61	26	81.2
both	5	23.8	4	17	3	9.4
Source of breeding pigs		0.0				
own boars	16	76.2	16	69.6	8	47.1
hired boars	5	23.8	5	21.7	4	23.5
artificial insemination	0	0.0	2	8.7	5	29.4
Source of fattening pigs		0.0				
own	9	42.9	8	34.8	5	16.7
purchased	12	57.1	15	65.2	25	83.5
government farms	*3*		*3*		*5*	
contract farmers	*9*		*11*		*20*	
imported (India)	*0*		*0*		*0*	

Samtenling (47.8%) and Gelegphu (38.1%) showed higher proportions of semi-commercial farms compared to Gakiling (37.5%). Semi-commercial farms often engage in both subsistence and income-generating activities, requiring balanced biosecurity practices to manage disease risks effectively.

The semi-commercial pig farms incorporated improved breeding practices and better feeding regimes, including a mix of commercial feed and locally available feed grains. Biosecurity measures are more robust in semi-commercial farms that in backyard farms mainly due to the larger scale of operations, investment in infrastructure such as housing, and formal management practices.

Higher proportions of commercial farms were reported at Gelegphu (14.3%) and Samtenling (17.4%) compared to Gakiling (6.2%). Commercial farms typically adhere to stricter biosecurity protocols for several reasons such as larger scale of operations, higher investment and regelatory compliace set by the government, and usually benefit from economies of scale in disease management (Kabir, 2020). The feeding regimen was primarily based on commercial feeds formulated for optimal growth and health.

3.3.2 Pig Rearing Purposes

The primary purpose of pig rearing was for fattening and Gakiling was the highest with 81% of the farms engaged in fattening followed by Samtenling and Gelegphu at around 61%. Fattening operations are critical for income generation but require robust biosecurity measures to prevent ASF transmission, especially in regions prone to disease outbreaks (FAO, 2020). Gelegphu (14.3%) and Samtenling (22%) had higher proportions of farmers involved in pig breeding compared to Gakiling (9.4%).

3.3.3 Breeding and Fattening Pigs: Sources

Most farmers across all areas preferred using their own boars for breeding (Gelegphu 76.2%, Samtenling 69.6%, Gakiling 47.1%). However, there were variations in the use of hired boars and artificial insemination, reflecting different levels of access to breeding technologies and services (FAO, 2020).

For fattening Pigs, farmers largely relied on purchasing pigs for fattening, with Gakiling (83.5%), Samtenling (65.2%), and Gelegphu (57.1%) sourcing pigs from various suppliers including government farms, contract farmers, and imports from India. The reliance on external sources underscores the importance of quarantine and biosecurity measures to prevent disease introduction (Lapar et al., 2018). There was no report of any imported pigs in 2023.

3.3.4 Pig Numbers and Pig Farm Types

Table 3.5 presents the average number of pigs and their distribution across different categories in three study areas of Sarpang, Bhutan, in 2023. The average number of pigs per farm did not statistically differ significantly across the three study areas, although there were noticeable differences. Samtenling reported the highest average number of pigs at 17.3, followed by Gelegphu with 11.9 pigs, and Gakiling with the lowest average at 9.4 pigs.

Table 3.5 Pig sub-system: pig numbers and pig farm categories averages (least-square means, lsm) and standard errors (s.e), in three study areas of Sarpang, Bhutan in 2023

Area	Gelegphu		Samtenling		Gakiling		
Variables	**lsm**	**s.e**	**lsm**	**s.e**	**lsm**	**s.e**	**P value**
Number of farms (n)	21		23		32		
Pigs numbers (n)	11.9	2.8	17.3	2.7	9.4	2.3	0.092
boar	0.7		2.3		0.7		
bow	2		3.2		2.8		
gilts	4		3.5		2.6		
barrow	3.4		2.5		2.4		
piglets	1.7		5.9		0.9		
[a,b] lsm with different superscripts between study areas are significantly different ($p<0.05$)							

The average number of boars per farm was similar in Gelegphu and Gakiling, both reporting 0.7 boars, whereas Samtenling reported a higher average of 2.3 boars. Samtenling had the highest average number of sows and gilts piglets at 3.2, 3.5, and 5.9 respectively, Gakiling had the lowest number of gilts, barrow, and piglets at 2.6, 2.4, and 0.9 pigs respectively. In this survey, there were no local pig breeds; all the pigs were mainly exotic crossbreds of Large white, Landrace, and Duroc breeds. The initial sources of these exotic breeds were from the government farm; the National Pig Research Development Centre in Gelegphu, Sarpang.

3.3.5 Pig Morbidity and Mortality

Sarpang dzongkhag has been the most severely affected district in Bhutan in terms of ASF outbreaks in recent years. Between November and December 2022, four gewogs in Sarpang dzongkhag, including Gelegphu and Samtenling - both of which are part of this study, experienced significant ASF outbreaks. Investigations across 40 pig farms revealed that 91 pigs were suspected of being infected, leading to 25 deaths (Dorji, 2022). A subsequent ASF outbreak occurred in March and April 2023, affecting four gewogs—Chuzergang, Sompankha, Samtenling, and Singye, and the government farms at the National Development Centre for Aquaculture and the National Research & Pig Development Centre in Gelegphu (Lungten, 2023). This study also covers the events of 2023. In both the ASF outbreaks, the virus was believed to have been introduced through illegal pork imports from across the border in India, which then spread via infected kitchen waste from hotels to farms in the affected areas.

Table 3.6 provides details on pig morbidity, mortality, and the number of pigs culled in the three study areas of Sarpang, Bhutan. The proportion of households reporting sick pigs varied significantly between the study areas. In Gelegphu, 47.6% (n = 10) of households reported sick pigs, while in Samtenling, the proportion was 39.13% (n = 9). Gakiling had the lowest proportion at 12.5% (n = 4), with a significant Chi-square value of 8.64 (p = 0.033), indicating a significant difference in morbidity rates between the areas.

Pig mortalities were in Samtenling and Gelegphu and by 30% and 28.6% of households respectively. Samtenling reported the highest number of dead pigs at 26, followed by Gelegphu with 18 pigs due to ASF, while Gakiling reported 2 dead pigs due to causes other than ASF. Due to the ASF outbreak in 2022 - 2023 the total number of pigs culled was notably higher in Samtenling at 104, compared to 16 in Gelegphu and none in Gakiling,

Table 3.6 Pig morbidity & mortality in three study areas of Sarpang, Bhutan frequency (Freq.), proportions (%), and Chi-square value (χ^2) in 2023.

Area	Gelegphu		Samtenling		Gakiling		χ^2	P value
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Number of farms (n)	21		23		32			
hh that reported-sick pigs	10[a]	47.6	9[a]	39.13	4[b]	12.5	8.64	0.033
total sick pigs (n)	24		30		5			
Pig mortality								
hh that reported-dead pigs	6	28.6	7	30.00	3	9	4.56	0.1024
total dead pigs (n)	18		26	30.00	2			
Total pigs culled	16		104		0			

[a,b] Freq. with different superscripts between study areas are significantly different ($p<0.05$)

3.4 Farm Biosecurity Measures

3.4.1 Farm Access Control

Biosecurity measures such as farm access control and their facilities are crucial for preventing and controlling ASF outbreaks by managing the entry of potential disease vectors onto pig farms (Costard et al. (2009). Table 3.7 provides insights into farm access control measures and facilities in the three study areas, Sarpang dzongkhag, Bhutan in 2023.

Visitor and Vehicle Entry Recording:

The proportion of farms recording visitor and vehicle entry varied significantly across the study areas. In Gelegphu, only 14.3% (n=3) of farms recorded entries, compared to 34.8% (n=8) in Samtenling and 53.1% (n=17) in Gakiling. The Chi-square value indicates a significant difference in entry recording practices among the areas (χ^2=13.18, P=0.014).

Foot Dips at Farm Entrance:

The use of foot dips at farm entrances was relatively low across all areas, with Gelegphu at 14.3% (n = 3), Samtenling at 21.7% (n =5), and Gakiling at 25% (n = 8). The differences were not statistically significant, as indicated by a Chi-square value (χ^2=6.32, P=0.425)

Foot Baths at Pig Pen's Entrance:

The presence of foot baths at the entrance of pig pens was more common, with 71.4% (n =15) of farms in Gelegphu, 73.9% (n=7) in Samtenling, and 62.5% (n=20) in Gakiling reporting this measure. These differences were not statistically significant (χ^2=0.93, P=0.629).

Biosecurity Signage:

The use of biosecurity signage was relatively similar across the areas, with 38.1% (n = 8) of farms in Gelegphu, 47.8% (n =11) in Samtenling, and 34.4% (n =11) in Gakiling. These differences were also not statistically significant (χ^2=1.04, P=0.596).

Table 3.7 Farm access control and facilities in three study areas of Sarpang, Bhutan, frequency (Freq.), proportions (%) and Chi-square value (χ^2) in 2023.

Area	**Gelegphu**		**Samtenling**		**Gakiling**			
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**χ^2**	**P value**
Number of farms (n)	21		23		32			
Visitor & vehicles entry recorded								
Yes	3[a]	14.3	8[a]	34.8	17[b]	53.1	13.18	0.014
No	18	85.7	15	65.2	15	46.9		
Foot dips at farm entrance								
Yes	3	14.3	5	21.7	8	25	6.32	0.425
No	18	85.7	18	78.3	24	75		
Foots bath at entrance of pig sty								
Yes[1]	15	71.4	17	73.9	20	62.5	0.93	0.629
No	6	28.6	6	26.1	22	37.5		
Biosecurity signage								
Yes	8	38.1	11	47.8	11	34.4	1.04	0.596
No	13	61.9	12	52.2	21	65.6		

[a,b] Freq. with different superscripts between study areas are significantly different ($p<0.05$)

3.4.2 Farm Infrastructure

Table 3.8 presents data on biosecurity infrastructure facilities in smallholder pig farms in the three study areas, Sarpang dzongkhag, Bhutan in 2023.

Housing:

The majority of pig farms in all three regions used confined housing for their pigs. In Gelegphu, 85.7% of farms had confined housing, compared to 74% in Samtenling and 78.1% in Gakiling. Semi-confined housing was less common, with 14.3% in Gelegphu, 26% in Samtenling, and 21.9% in Gakiling. None of the farms in the study used free-range housing.

Perimeter Fencing:

The type of perimeter fencing varied significantly between the regions. In Gelegphu, 52.4% of farms had no fencing, while in Samtenling and Gakiling, this figure was 52% and 25%, respectively. Wooden fencing was rare, with only 9% of farms in Samtenling and 12.5% in Gakiling using it. Wire mesh fencing was used by 19% of farms in Gelegphu, 4% in Samtenling, and 9.4% in Gakiling. Green net fencing was the most common type, with 28.6% in Gelegphu, 35% in Samtenling, and 53.1% in Gakiling.

Rodent and Pest Control Facilities:

Rodent and pest control facilities were present in a significant proportion of farms in Samtenling and Gakiling, with 69.6% and 53.1% of farms, respectively, having these facilities. In contrast, only 14.3% of farms in Gelegphu had rodent and pest control facilities. The absence of such facilities was most notable in Gelegphu, where 85.7% of farms lacked them, compared to 30.4% in Samtenling and 46.9% in Gakiling.

Table 3.8 Infrastructure facilities in three study areas of Sarpang, Bhutan in 2023 and proportions (%) in 2023.

Area	**Gelegphu**		**Samtenling**		**Gakiling**	
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Number of farms (n)	21		23		32	
Housing						
confined	18	85.7	17	74	25	78.1
semi-confined	3	14.3	6	26	7	21.9
free range	0	0.0	0	0	0	0
Perimeter fencing						
wooden	0	0.0	2	9	4	12.5
wire mesh	4	19.0	1	4	3	9.4
green net	6	28.6	8	35	17	53.1
No fencing	11	52.4	12	52	8	25
Rodents & pest control facility						
Yes	3	14.3	16	69.6	17	53.1
No	18	85.7	7	30.4	15	49.9

3.4.3 Feed & Water Safety Management Practices

Table 3.9 presents the data on feed and water safety management practices in smallholder pig farms across three study areas in Sarpang, Bhutan, in 2023.

Feed Types:

The distribution of feed types varied across the three regions. In Gelegphu, 33.3% of farmers used commercial feed, while 66.7% used a mix of commercial and local feed ingredients. In Samtenling, 44.0% of farmers relied on commercial feed, and 56% used mixed feed. In Gakiling, feeding commercial feed was higher at 56.3%, with the remaining 43.8% using mixed feed. The chi-square test indicated no significant differences in the use of feed types between the regions (χ^2=2.77, P=0.2505).

Swill feed consisted exclusively of household kitchen waste, and its usage also showed variation between the study areas. Gelegphu had the highest percentage of farmers using swill feed (57.1%), followed by Gakiling (46.9%), and Samtenling (26.1%). The chi-square test did not show significant differences between regions (χ^2=4.4, P=0.1014).

Feeding Practices:

Cooking or boiling swill feed was relatively common across all regions, with 58.3% of farmers in Gelegphu, 66.7% in Samtenling, and 80% in Gakiling adhering to this practice. The chi-square test showed no significant differences (χ^2=1.52, P=0.454). Feeding pigs by designated persons was practiced by 66.7% of farmers in Gelegphu, 78% in Samtenling, and 81.2% in Gakiling, with no significant differences noted (χ^2=1.9, P=0.387).

Table 3.9 Feed & water safety management practices in three study areas of Sarpang, Bhutan, frequency (Freq.), proportions (%) and Chi-square value (χ^2)in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**			
Variables[a]	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**χ^2**	**P value**
Number of farms (n)	21		23		32			
Feed types								
Concentrate feed type							2.77	0.2505
Commercial feed	7	33.3	10	44.0	18	56.3		
Mixed[2]	14	66.7	13	56.0	14	43.8		
Swill feed							4.4	0.1014
Yes[3]	12	57.1	6	26.1	15	46.9		
No	9	42.9	17	73.9	17	53.1		
Feeding practices								
Swill feed is cooked/boiled							1.52	0.454
Yes	7	58.3	4	66.7	12	80		
No	3	41.7	2	33.3	3	20		
Feeding by designated persons								
Yes	14	66.7	18	78	26	81.2	1.9	0.387
No	7	33.3	5	22	6	18.8		
Feed safety practices								
Cleanliness of feed & feeding troughs							1.85	0.396
Yes	17	81.0	20	87.0	30	93.7		
No	4	19.0	3	13.0	2	6.3		
Facility for safe feed storage							3.66	0.160
Yes	21	100.0	20	87.0	27	84.4		
No	0	0.0	3	13.0	5	15.6		
Borrow animal feed and equipments								
Yes	3	14.3	4	17.4	6	18.8	0.19	0.908
No	18	85.7	18	82.6	26	81.2		

[1] all p values (>0.05), so no significantl differences of variables between study areas

[2] mixed: mix of commercial and local feed ingredients

[3] swill feed: only hh kitchen waste (no hotel waste)

Feed Safety Practices:

Maintaining cleanliness of feed and feeding troughs was observed in 81.0% of farms in Gelegphu, 87.0% in Samtenling, and 93.7% in Gakiling. Again, no significant differences were found (χ^2=1.85, P=0.396). All farmers in Gelegphu reported having facilities for safe feed storage, compared to 87.0% in Samtenling and 84.4% in Gakiling (χ^2 =3.66, P=0.160).

The practice of borrowing animal feed and equipment was done by a few households with 14.3% of farmers in Gelegphu, 17.4% in Samtenling, and 18.8% in Gakiling engaging in this practice. No significant differences were noted (χ^2=0.19, P=0.908).

3.4.4 Animal Health Management and Disease Monitoring Protocols

Table 3.10 provides insights into animal health management practices and disease monitoring protocols in smallholder pig farms across three study areas in Sarpang, Bhutan, in 2023.

3.4.4.1 Animal Health Management

Regular Veterinary Services by Livestock Officials:
The majority of farmers in all three regions reported receiving regular veterinary services from livestock officials. In Gelegphu, 90.5% of farmers had access to these services, slightly higher than Samtenling (91.3%) and Gakiling (87.5%). The differences were not statistically significant.

Vaccination of Pigs:
The vaccination of pigs was reported by 52.4% of farmers in Gelegphu, 60.9% in Samtenling, and 62.5% in Gakiling. No significant differences were found across the regions.

Isolation of Sick Pigs
Isolation of sick pigs from healthy ones is a crucial biosecurity practice. In Gelegphu, 66.7% of farmers isolated sick pigs, compared to 61% in Samtenling and 75% in Gakiling. Again, no significant differences were observed.

3.4.4.2 Disease Monitoring Protocols

Regular Health Checks by Livestock Officials:
Regular health checks by livestock officials were reported by 71.4% of farmers in Gelegphu, 56.5% in Samtenling, and 43.8% in Gakiling. The percentage of farmers reporting irregular checks (sometimes) was 14.3% in Gelegphu, 34.8% in Samtenling, and 40.6% in Gakiling, with no significant differences between regions.

Regular Health Checks by Farmers:
Farmers conducting their own regular health checks were 66.7% in Gelegphu, 56.5% in Samtenling, and 78.1% in Gakiling. A smaller proportion of farmers conducted health checks irregularly or never did so, with no significant differences noted.

Quarantine of New Pigs:
Quarantining new pigs was practiced by 52.4% of farmers in Gelegphu, but only by 26% in Samtenling and 28.1% in Gakiling. The differences were not statistically significant.

Table 3.10. Animal health management and disease monitoring protocols in three study areas of Sarpang, Bhutan, frequency (Freq.), proportion`s (%) in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**			
Variables[a]	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	χ^2	**P value**
Number of farms (n)	21		23		32			
Regular veterinary services by livestock officials								
Yes	19	90.5	21	91.3	28	87.5	0.44	0.804
No	2	9.5	1	4.3	4	12.5		
Vaccination of pigs								
Yes	11	52.4	14	60.9	20	62.5	0.26	0.8762
No	7	33.3	9	39.1	12	37.5		
Isolate sick pigs from healthy ones								
Yes	14	66.7	14	61	24	75	2.09	0.352
No	7	33.3	9	39	8	25		
Disease monitoring								
Regular health checks by livestock officials								
Yes	15	71.4	13	56.5	14	43.8		
No	3	14.3	2	8.7	5	15.6		
Sometimes	3	14.3	8	34.8	13	40.6		
Regular health checks by farmer								
Yes	14	66.7	13	56.5	25	78.1		
No	2	9.5	6	26.1	4	12.5		
Sometimes	5	23.8	4	17.4	3	9.4		
Quarantine new pigs								
Yes	11	52.4	6	26	9	28.1	4.09	0.129
No	10	47.6	17	74	23	71.9		

[a] all p values (>0.05), so no significantl differences of variables between study areas

3.4.5 Waste Management & Hygiene Practices

Effective waste management is crucial for preventing the transmission of diseases like ASF and maintaining overall farm hygiene. Table 3.11 presents waste management and hygiene practices in smallholder pig farms across three study areas in Sarpang, Bhutan, in 2023.

Manure Management:

The methods of manure management varied significantly across the three regions. In Gelegphu, composting was practiced by 23.8% of farmers, while a higher percentage (43.5%) in Samtenling and 50% in Gakiling used this method. Biogas production was noted in only one farm in Samtenling (4.3%), with no instances in Gelegphu or Gakiling.

Direct disposal of manure was practiced by 19.0% of farmers in Gelegphu, a higher 52.2% in Samtenling, and 40.6% in Gakiling. The use of septic tanks for manure management was significantly higher in Gelegphu (57.1%) compared to 0% in Samtenling and 9.4% in Gakiling.

Table 3.11 Waste management & hygiene in three study areas of Sarpang, Bhutan in 2023 frequency (Freq.) and proportions (%) in 2023

Area	Gelegphu		Samtenling		Gakiling	
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Number of farms (n)	21		23		32	
composting	5	23.8	10	43.5	16	50
biogas	0	0.0	1	4.3	0	0
direct disposal	4	19.0	12	52.2	13	40.6
septic tanks	12	57.1	0	0.0	3	9.4
Carcass disposal						
deep burial	19	90.5	23	100.0	29	90.6
dispose (open area/bushes)	2	9.5	0	0.0	3	9.4
Cleaning pens/equipments						
daily	18	85.7	15	65.2	29	90.6
once (2-3 days)	3	14.3	5	21.7	3	9.4
weekly	0	0.0	3	13.0	0	0

Carcass Disposal:

Deep burial was the predominant method for carcass disposal across all regions, with 90.5% in Gelegphu, 100% in Samtenling, and 90.6% in Gakiling adhering to this practice. Disposal in open areas or bushes was relatively rare, reported by 9.5% in Gelegphu and 9.4% in Gakiling, and not practiced in Samtenling.

Cleaning Pens and Equipment:

Daily cleaning of pens and equipment was reported by 85.7% of farmers in Gelegphu, 65.2% in Samtenling, and 90.6% in Gakiling. Cleaning every 2-3 days was practiced by 14.3% in Gelegphu, 21.7% in Samtenling, and 9.4% in Gakiling. Weekly cleaning was only reported in Samtenling (13.0%)

3.4.6 Footbath and Disinfection Practices

Disinfection practices in the farms are important for preventing the spread of diseases like (ASF) within and between farms. Table 3.12 presents the nu,ber of household with footbath facikities,and the frequency and proportion of household using disinfecttants n the both baith and other practices in smallholder pig farms across three study areas in Sarpang, Bhutan, in 2023.

Farms with Footbath Facilities at Pigsty:

Foot bath facilities at pigsty entrances are a key biosecurity measure to prevent the spread of infectious diseases like ASF. In Samtenling, 73.9% of farms had foot bath facilities (may or may not be using disinfectants), slightly higher than Gelegphu at 71.4%, and Gakiling at 62.5%. The differences were statistically significant (χ^2 =0.93, P=0.035).

Table 3.12 Footbath facilities, use of disinfectants, and hand wash facilities in the three study areas at Sarpang, Bhutan, frequency (Freq.), proportion (%) and Chi-square value (χ^2) in 2023.

Area	Gelegphu		Samtenling		Gakiling			
Variable	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**χ^2**	**P value**
Number of farms (n)	21		23		32			
Farm with footbath facilities								
Yes	15	71.4	17	73.9	22	68.8	0.93	0.035
Farm using disinfectants								
Yes	13	61.9	14	60.9	21	65.6	0.52	0.771
Proper dilution of disinfectants[1]								
Yes	7	33.3	9	39.1	17	53.1	0.30	0.041
Hand wash facility at farm entrance								
Yes	10	47.6	9	39.1	21	65.6	3.90	0.143

[1] as per advise of livestock extension centre in the gewogs/manufacturer's instruction

Farms Using Disinfectants in Footbaths:

When compared to the total number of farms in the study areas, the use of disinfectants in foot baths was reported by 65.6% in Gakiling (highest) followed by 61.9% of farmers in Gelegphu and 60.9% in Samtenling. However, there were no significant differences between the study areas (χ^2 = 0.52, P=0.771).

Proper Dilution of Disinfectants:

Proper dilution of disinfectant is critical to ensure its optimal antimicrobial efficacy. Incorrect dilution can compromise the disinfectant's ability to eliminate pathogens or cause adverse effects on equipment and surfaces. When compared to the total number of farms, proper dilution of disinfectants was practiced by about 53.1% of farmers in Gakiling, 39.1% in Samtenling, and 33.3% in Gelegphu, with significant differences (χ^2 =0.30, P=0.041).

Hand Wash Facility at Farm Entrance:

The presence of hand wash facilities at the farm entrance was the highest by 65.6% in Gakiling. Followed by 47.6% of farmers in Gelegphu and 39.1% in Samtenling. The differences were not statistically significant (χ^2 =3.9, P=0.1426).

3.4.7 Record Keeping Practices

Accurate and comprehensive farm records are vital for effective ASF control and overall farm management. Table 3.13 gives the details of records about animal feed, equipment, and animal health and death records.

Records of Animal Feed/Equipment:

Record-keeping practices regarding animal feed and equipment were found to be minimal across the study areas. In Gelegphu, only 4.8% of farmers kept detailed records, 33.3% kept basic records, and a

significant 61.9% did not keep any records. In Samtenling, 9% of farmers kept detailed records, 30% kept basic records, and 61% did not keep any records. Gakiling showed similar trends, with 6% keeping detailed records, 25% keeping basic records, and 69% not keeping any records.

Records of Pigs Morbidity/Mortality:

The recording of pig morbidity and mortality also showed low adherence across the regions. In Gelegphu, 4.8% of farmers kept detailed records, 19% kept basic records, and 76.2% did not keep any records. Samtenling had 9% keeping detailed records, 22% keeping basic records, and 69% not keeping any records. In Gakiling, 9% of farmers kept detailed records, 28% kept basic records, and 63% did not keep any records.

Table 3.13 Record keeping practices in three study areas of Sarpang, Bhutan in 2023 frequency (Freq.) and proportions (%) in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**	
Variables	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Number of farms (n)	21		23		32	
detailed records kept	1	4.8	2	9.0	2	6.0
basic records	7	33.3	7	30.0	8	25.0
no records	13	61.9	14	61.0	22	19.0
Records of pigs morbidity/mortality						
detailed records kept	1	4.8	2	9	3	9
basic records	4	19.0	5	22	9	28
no records	16	76.2	16	69	20	63

3.5. Farm Biosecurity Ranking

Table 3.14 summarizes the median, minimum, and maximum Likert scale rankings of biosecurity measures across three study areas in Sarpang, Bhutan, in 2023. The Kruskal-Wallis H test statistics are also provided to assess significant differences among the study areas.

Farm Access Control:

Farm access control is a critical measure to prevent the introduction and spread of ASF. The median ranking for Gelegphu and Samtenling was 2.0, with ranges from 1.0 to 4.0. Gakiling exhibited a higher median ranking of 3.0, with a range from 2.0 to 4.0. The Kruskal-Walli's test revealed a statistically significant difference (H=17.85, P=0.001) between the areas, indicating that Gakiling has more stringent access control measures compared to Gelegphu and Samtenling.

Infrastructure:

The infrastructure quality of pig farms in all three areas had a median ranking of 3.0. The ranges were consistent, from 1.0 to 4.0, across Gelegphu, Samtenling, and Gakiling. The Kruskal-Wallis test showed no significant difference (H=1.80, P=0.408) between the areas, suggesting similar infrastructure conditions across the three regions.

Feed and Water Safety Management:

The safety management of feed and water also demonstrated consistent medians of 3.0 across the three areas. The ranges were slightly varied but generally aligned, from 1.0 to 4.0 in Gelegphu, 2.0 to 4.0 in Samtenling, and 2.0 to 4.0 in Gakiling. The statistical analysis did not show significant differences (H=1.13, P=0.345), indicating that feed and water safety practices are uniformly implemented.

Table 3.14 Biosecurity Measures (Likert scale rankings) of the three study areas of Sarpang, Bhutan, median, minimum (min), maximum (max) values and Kruskal-Wallis H test statistics in 2023

Area	**Gelephu (n=21)**			**Samtenling (n=23)**			**Gakiling (32)**				
Biosecurity Measures	**median**	**min**	**max**	**median**	**min**	**max**	**median**	**min**	**max**	**Kruskal-Wallis statistic**	**P value**
Farm Access Control	2.0[a]	1.0	4.0	2.0[a]	1.0	4.0	3.0[b]	2.0	4.0	17.85	0.001
Infrastrucure	3.0	1.0	4.0	3.0	1.0	4.0	3.0	1.0	4.0	1.80	0.408
Feed & Water Safety Management	3.0	1.0	4.0	3.0	2.0	4.0	3.0	2.0	4.0	1.13	0.345
Animal Health Management	3.0	1.0	4.0	3.0	1.0	4.0	3.0	2.0	4.0	1.29	0.525
Waste Management & Hygiene	3.0	2.0	4.0	2.0	1.0	4.0	3.0	3.0	4.0	19.34	0.312
Disinfection Facilities	2.0[a]	1.0	4.0	2.0[a]	1.0	4.0	3.0[b]	1.0	4.0	24.67	0.001
Records of Animals	2.0	1.0	4.0	2.0	1.0	4.0	2.5	1.0	4.0	2.53	0.282
[a,b] medians with different superscripts between study areas are significantly different (p<0.05)											

Animal Health Management:

Animal health management practices were ranked with a median of 3.0 in all areas. The ranges for Gelegphu and Samtenling were from 1.0 to 4.0, while Gakiling had a range from 2.0 to 4.0. The Kruskal-Wallis test did not reveal significant differences (H=1.29, P=0.525), suggesting a similar approach to animal health management in all three areas.

Waste Management and Hygiene:

Waste management and hygiene had a median ranking of 3.0 in Gelegphu and Gakiling, while Samtenling had a median of 2.0. The ranges were from 2.0 to 4.0 in Gelegphu, 1.0 to 4.0 in Samtenling, and 3.0 to 4.0 in Gakiling. Although the Kruskal-Wallis test indicated significant variation (H=19.34, P=0.312), the results suggest that Gakiling adheres more strictly to waste management and hygiene practices.

Disinfection Facilities:

The disinfection facilities showed a median ranking of 2.0 for Gelegphu and Samtenling, ranging from 1.0 to 4.0. Gakiling had a higher median of 3.0, ranging from 1.0 to 4.0. The Kruskal-Wallis test revealed a significant difference (H=24.67, P=0.001), indicating that Gakiling is more rigorous in disinfection practices compared to the other areas.

Records of Animals:

Keeping records of animals had median rankings of 2.0 in Gelegphu and Samtenling, with ranges from 1.0 to 4.0. Gakiling had a slightly higher median of 2.5, with a range from 1.0 to 4.0. The Kruskal-Wallis test did not show significant differences (H=2.53, P=0.282), indicating a generally uniform practice of record-keeping across the study areas.

3.6 Biosecurity Index

3.6.1 Overall Farm Biosecurity Index of the Study Areas

The Farm Biosecurity Index (BI) is the single, aggregate score that represents the overall biosecurity status of the farm. Table 3.15 presents the Overall Biosecurity Index of pig farms across three study areas of Gelegphu, Samtenling, and Gakiling in Sarpang, Bhutan for the year 2023. The data reflects an assessment of biosecurity practices within these areas, with the number of farms evaluated being 21 in Gelegphu, 23 in Samtenling, and 32 in Gakiling.

The BI represents the overall adherence to biosecurity measures on a scale from 0 to 1, with higher values indicating better biosecurity practices. Amongst he three study areas, Gakiling shows the highest BI at 0.590, while Gelegphu and Samtenling exhibited a BI of 0.491 and 0.477 respectively. Although all three study areas are categorized within the "Fair" scale of biosecurity performance, the higher BI for Gakiling indicates that Gakiling implements a more robust set of biosecurity measures compared to the other study areas.

The "Fair" category in general suggests that while basic biosecurity measures are in place, there is considerable room for improvement to reach optimal biosecurity standards. The similar ratings across the three study areas indicate a consistent level of biosecurity implementation, with no area significantly outperforming the others.

The data underscores the need for targeted interventions to enhance biosecurity measures across all the study areas, particularly focusing on the variables that contribute most to the overall BI. By addressing these areas, the farms can elevate their biosecurity standards, thereby reducing the risk of disease outbreaks and enhancing the overall health and productivity of the livestock

Table 3.15 Overall Biosecurity index of farm in three study areas, Sarpang, Bhutan in 2023

Area	**Gelegphu**	**Samtenling**	**Gakiling**
Number of farms (n)	21	23	32
Biosecurity index	0.491	0.477	0.590
Category	Fair	Fair	Fair

3.6.2 Individual Biosecurity Variable Indices

The Biosecurity Variable Indices refers to the individual index scores for each specific biosecurity measure or variable in the three study areas. Tables 3.16, 3.17 and 3.18 presents a detailed analysis of the individual Biosecurity Variable Indices (BV indices) for farms in Gelegphu, Samtenling and Gakiling in Sarpang, Bhutan, as of 2023. This table dissects the biosecurity measures that contribute to the overall biosecurity status of the farms, providing a granular view of each biosecurity variable and its impact on the overall Biosecurity Index. Further, the detailed breakdown of biosecurity varia-

bles not only highlights the strengths and weaknesses in current practices but also provides a roadmap for prioritizing interventions to elevate the biosecurity standards across farms in the three study areas.

The Biosecurity Variable Indices for the three study are detailed as follows:

3.6.2.1 Biosecurity Variable Indices of Gelegphu

Table 3.16 provides a comprehensive analysis of the Individual Biosecurity Variable Indices (BV) indices) for farms in Gelegphu, Sarpang, Bhutan, for the year 2023. Amongst the seven biosecurity variables, Farm Access Control is ranked highest, indicating its critical role in maintaining farm biosecurity. Farm Access Control, with a weight of 0.24, is the most heavily weighted variable, underscoring its significance in protecting the farm from external disease threats. Other variables like Infrastructure and Disinfection Facilities & Practices also carry substantial weight, at 0.15 and 0.18, respectively, indicating their essential roles in biosecurity.

The Feed & Water Safety Management variable has a normalized score of 0.66, indicating relatively high compliance with biosecurity standards in this area. In contrast, Farm Access Control and Disinfection Facilities & Practices have lower normalized scores of 0.45 and 0.35, suggesting these are areas where biosecurity practices could be strengthened. Farm Access Control has a BV index of 0.108, while Infrastructure has a BV index of 0.084, reflecting their respective contributions.

With regards to the Scale (%), the Feed & Water Safety Management variable achieves 66%, categorized as "Good", while Farm Access Control achieves 45%, categorized as "Fair". Overall, the data reveals that while some biosecurity practices, such as Feed & Water Safety Management, are well-implemented (with a "Good" rating), others like Disinfection Facilities and Practices with a “Poor” rating and Farm Access Control and Record Keeping are less robust, with a "Fair" rating. Therefore, a strategic focus on improving these weaker areas, could significantly enhance the overall biosecurity, thereby reducing the risk of disease outbreaks and ensuring better health outcomes for the livesto

Table 3.16 Individual Biosecurity Variable Indices of Gelegphu, Sarpang, Bhutan in 2023

Area	**Gelegphu (n=21)**					
Biosecurity Variables	**Rank**	**Weight**	**Normalised Score**	**BV indices**	**Scale (%)**	**Category**
Farm Access Control	1	0.24	0.45	0.108	45.0	Fair
Infrastructure	3	0.15	0.56	0.084	56.0	Fair
Feed & Water Safety Management	6	0.10	0.66	0.066	66.0	Good
Animal Health Management	4	0.13	0.54	0.070	54.0	Fair
Waste Management & Hygiene	5	0.11	0.56	0.062	56.0	Fair
Disinfection Facilities & Practise	2	0.18	0.35	0.063	35.0	Poor
Record Keeping	7	0.09	0.42	0.038	42.0	Fair
Overall Farm Biosecurity Index		1.00		0.491		

Where:

- Rank: The priority or importance rank of the biosecurity measures/variable among all considered variables.

- Weight represents the relative importance of each biosecurity variable (as a proportion of 1).
- Normalized Score represents the actual ranking score of the variable which is normalized between 0 and 1
- BV Indices: The product of Weight and Normalized Score
- Scale (%): The BV Indices as a proportion of its assigned weight and then converting this proportion into a percentage.
- Category: A qualitative assessment based on the Scale (%).

3.6.2.2 Biosecurity Variable Indices of Samtenling

Table 3.17 provides a comprehensive analysis of the Individual Biosecurity Variable Indices (BV indices) for farms in Samtenling, Sarpang, Bhutan, for the year 2023. The variables Farm Access Control and Disinfection Facilities & Practices had higher ranks, reflecting their critical role in preventing disease entry and spread on farms. Farm Access Control (0.21) and Disinfection Facilities & Practices (0.20) were given the most weights, indicating their crucial role in the biosecurity framework. Infrastructure also holds a notable weight of 0.18, emphasizing its importance in supporting biosecurity.

The Feed & Water Safety Management variable has a normalized score of 0.6, indicating a relatively high level of compliance. Conversely, the Disinfection Facilities & Practices variable shows a lower normalized score of 0.339, suggesting that this area is less well-managed and might require improvement. In terms of BV index, the infrastructure variable has a BV index of 0.094, reflecting its substantial contribution, while Record Keeping, with a BV index of 0.019, has a minimal impact on the overall biosecurity score.

The Feed & Water Safety Management has a scale value of 60.0%, indicating that this measure is relatively well implemented. In contrast, Disinfection Facilities & Practices and Record Keeping have a lower scale value of 33.9%, highlighting a potential area for improvement. This suggests that targeted improvements, especially in the lower-scoring areas, could enhance the overall biosecurity of the farms.

Table 3.17 Individual Biosecurity Variable Indices of Samtenling, Sarpang, Bhutan in 2023

Area	**Samtenling (n=23)**					
Biosecurity Variables	**Rank**	**Weight**	**Normalised score**	**BV indices**	**Scale (%)**	**Category**
Farm Access Control	1	0.21	0.44	0.091	43.5	Fair
Infrastructure	3	0.18	0.52	0.094	52.2	Fair
Feed & Water Safety Management	5	0.13	0.60	0.078	60.0	Good
Animal Health Management	4	0.15	0.59	0.089	59.1	Fair
Waste Management & Hygiene	6	0.08	0.47	0.038	47.0	Fair
Disinfection Facilities & Practise	2	0.20	0.34	0.068	33.9	Poor
Record Keeping	7	0.05	0.38	0.019	38.3	Poor
Overall Farm Biosecurity Index		1.00		0.477		

3.6.2.3 Biosecurity Variable Indices of Gakiling

Table 3.18 presents a detailed analysis of the Individual Biosecurity Variable Indices (BV indices) for farms in Gakiling, Sarpang, Bhutan, in 2023. Farm Access Control carries the highest weight of 0.21, underscoring its importance as the first line of defense against potential biosecurity threats. It has a normalized score of 0.61, suggesting that this measure is fairly well implemented across the farms. Similarly, Feed & Water Safety Management and Animal Health Management both have high normalized scores of 0.65 and 0.63 respectively, indicating strong adherence to these practices.

The Farm Access Control, Water Safety Management and Animal Health Management variables with a BV index of 0.129, 0.098 and 0.095 respectively have the most significant impact on the overall biosecurity index, indicating that it is a well-prioritized and effectively managed aspect of farm biosecurity. The Scale (%) for the Farm Access Control and Feed, Water Safety Management, and Animal Health Management variables have scale values exceeding 60% which categorizes them as "Good" practices, indicating a strong level of implementation. In contrast, Record Keeping has a lower scale value of 47.5%, classifying it as "Fair" and suggesting that this area could benefit from targeted improvements.

The results indicate that while Gakiling farms generally maintain a satisfactory level of biosecurity, with strong performance in critical areas such as Farm Access Control and Feed & Water Safety Management, there are still areas like Record Keeping and Disinfection Facilities & Practices that could be enhanced to elevate the overall biosecurity performance.

Table 3.18 Individual Biosecurity Variable Indices of Gakiling, Sarpang, Bhutan in 2023

Area	**Gakiling (number of farms=32)**					
Biosecurity Variables	**Rank**	Weight	Normalised score	**BV indices**	**Scale (%)**	**Category**
Farm Access Control	1	0.21	0.61	0.129	61.3	Good
Infrastructure	5	0.13	0.56	0.073	56.3	Fair
Feed & Water Safety Management	2	0.15	0.65	0.098	65.0	Good
Animal Health Management	2	0.15	0.63	0.095	63.1	Good
Waste Management & Hygiene	4	0.14	0.59	0.083	59.0	Fair
Disinfection Facilities & Practise	6	0.12	0.55	0.066	55.0	Fair
Record Keeping	7	0.10	0.48	0.048	47.5	Fair
Overall Farm Biosecurity Index		1.00		0.590		

3.6.2.4 Comparison of the Biosecurity Variable Indices of the Study Areas

Table 3.19 gives an overview of the Biosecurity Variable (BV) Indices in the three study areas, Sarpang, Bhutan in 2023. Some of the key observations are outlined as follows:

Farm Access Control:
The BV index for farm access control were highest in Gakiling (0.129) (“Good category”), followed by Gelegphu (0.107) and Samtenling (0.091) both in the “Fair” category of the BV index. This may

indicate that Gakiling has the more stringent access control measures, which are crucial in preventing ASF introduction and spread.

Infrastructure:
Samtenling had the highest BV index for infrastructure (0.094), followed by Gelegphu (0.083) and Gakiling (0.073), but all came in the "Fair "category. This suggests that infrastructure quality is relatively better in Samtenling, contributing to overall farm biosecurity.

Feed and Water Safety Management:
Gakiling exhibited the highest biosecurity index for feed and water safety management (0.091), with Samtenling (0.078) and Gelegphu (0.066), and all fell in the "Good "category of the BV index. These indicate that most farms followed relative appropriate management practices in ensuring the safety of feed and water sources.

Animal Health Management:
The biosecurity index for animal health management for all the three study areas came in the: Fair "category. It was highest in Samtenling (0.089) and Gakiling (0.088), with Gelegphu trailing slightly (0.071). This reflects similar practices in Samtenling and Gakiling in terms of managing animal health effectively.

Waste Management and Hygiene:
Gelegphu had a biosecurity index of 0.062 for waste management and hygiene, higher than Samtenling (0.038) but slightly lower than Gakiling (0.083). However, they all came in the "Fair "category", which may indicate similar waste management and hygiene practices.

Disinfection Facilities and Practices:
The biosecurity indices for disinfection facilities and practices were relatively similar across the three areas: Gelegphu (0.062), Samtenling (0.068), and Gakiling (0.0660). This suggests a generally uniform implementation of disinfection measures.

Record Keeping:
Gakiling had the highest biosecurity index for record keeping (0.0475), followed by Gelegphu (0.038) and Samtenling (0.0191). The results indicate that Gakiling maintains better records of animals compared to the other areas.

Table 3.19 Comparison of the Biosecurity Variable Indices between the three study areas, Sarpang, Bhutan in 2023

Area	**Gelegphu**	**Samtenling**	**Gakiling**
Biosecurity Measures	**BV Indices**		
Number of farms (n)	*21*	*23*	*32*
Farm Access Control	0.108	0.091	0.129
Infrastructure	0.084	0.094	0.073
Feed & Water Safety Management	0.066	0.078	0.098
Animal Health Management	0.070	0.089	0.095
Waste Management & Hygiene	0.062	0.038	0.083
Disinfection Facilities & Practise	0.063	0.068	0.066
Record Keeping	0.038	0.019	0.048
Overall Farm Biosecurity Index	0.491	0.477	0.590

3.6.3 Biosecurity Index Based on Farm Category, Education & Experience

The Biosecurity index of farm category, farmer education, and farming experience of farmers in the three areas are given in Table 3.20.

Farm Category:

The Biosecurity Index (BI) of farms in the study areas varied based on farm category, though the differences were not statistically significant (P=0.248). Backyard farms (n=36) had a mean BI of 0.486 while semi-commercial farms (n=31) reported a slightly higher mean BI of 0.498. Commercial farms (n=9) had the highest mean BI at 0.543.

Farmer Education:

Farmer education levels did not show a significant impact on the Biosecurity index (P = 0.611). However, farmers with no formal education (n=27) had the lowest BI of 0.484, while those with primary education (n=26) had a slightly higher BI of 0.494. Farmers with secondary or tertiary education (n=23) had the highest BI at 0.518.

Farming Experience:

In terms of farming experience also, there were significant effect on the Biosecurity index (P=0.313). Farmers with less than 1 year of experience (n=7) had the highest BI of 0.530, while those with 1 to 3 years of experience (n=22) had a BI of 0.513. Interestingly farmers with more than 3 years of experience (n=47) had the lowest BI at 0.489.

Table 3.20 Biosecurity Index of Farm Category, Farmer Education and Farming Experience in three areas of Sarpang, Bhutan, least square means (lsm) and standard errors (s.e) in 2023

Area	**Gelephu, Samteling, Gakiling (n=76)**			
Variables	**n**	**lsm**	**s.e**	**P value**
Farm Category				0.248
back-yard	36	0.486	0.02	
semi commercial	31	0.498	0.02	
commercial	9	0.543	0.03	
Farmer Education				0.611
no formal education	27	0.484	0.0177	
primary	26	0.494	0.018	
secondary /tertiary	23	0.518	0.0196	
Farming Experience				0.313
< 1 year	7	0.530	0.0343	
1 to 3 years	22	0.513	0.0199	
> 3 years	47	0.489	0.0135	

3.7 Knowledge & Awareness of ASF

Farmer knowledge and awareness are pivotal in preventing and controlling the disease (Costard et al., 2013). Well-informed farmers can recognize early symptoms of ASF and respond appropriately to outbreaks and implement biosecurity measures effectively. Though, ASF does not affect humans, but its impact on the pig population can have indirect effects on public health and food security. According to FAO (2010), improved farmer awareness and education can enhance food security by maintaining a healthy pig population and preventing disruptions in the food supply chain.

3.7.1 Knowledge Levels

Table 3.21 presents the proportions of responses to knowledge and awareness questions concerning ASF across the three study areas in Sarpang, Bhutan is given in Table 3.21. They are detailed as follows:

Have You Heard of ASF?

A high proportion of farmers across all areas reported having heard of ASF. Gelegphu had 90.5% (19/21) affirmative responses, Samtenling had 82.6% (19/23), and Gakiling had 93.8% (30/32). The Chi-square test did not indicate a significant difference between the areas (χ^2=1.79, P=0.408), suggesting a widespread awareness of ASF among the farmers (Table 3.21).

Any Idea on Modes of Transmission of ASF?

Knowledge about the modes of transmission of ASF varied more across the areas. In Samtenling, 60.9% (14/23) of farmers knew about the transmission modes, compared to 38.1% (13/21) in Gelegphu and 40.6% (13/32) in Gakiling. The differences were not statistically significant (χ^2=3.20, P=0.202), indicating moderate awareness about transmission modes.

Can You List Some Symptoms of ASF?

The ability to list symptoms of ASF was higher in Gakiling, with 62.5% (20/32) of farmers responding affirmatively, compared to 56.5% (13/23) in Samtenling and 42.9% (9/21) in Gelegphu.

However, the Chi-square test showed no significant difference (χ^2=2.00, P=0.368), suggesting a similar level of symptom awareness across the areas.

Table 3.21 Knowledge and Awareness of ASF by farmers in three study areas at Sarpang, Bhutan, frequency (Freq.), proportion (%), and Chi-square value (χ^2) in 2023

Area	**Gelegphu**		**Samtenling**		**Gakiling**			
Variable	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**χ^2**	**P value**
Number of farms (n)	21		23		32			
Knowledge Level								
Have you heard of ASF?							1.79	0.408
Yes	19	90.5	19	82.6	30	93.8		
No	2	9.5	4	17.4	2	6.2		
Any idea on modes of transmission of ASF ?								
Yes	13	38.1	14	60.9	13	40.6	3.20	0.202
No	8	61.9	9	39.1	19	50.4		
Can you list some symptoms of ASF?								
Yes	9	42.9	13	56.5	20	62.5	2.00	0.368
No	12	55.1	10	43.5	12	37.5		
Awareness Level								
Aware of any recent outbreaks of ASF?							2.47	0.292
Yes	18	85.7	86.9		23	71.9		
No	3	14.3	13.1		9	28.1		
Can wild pigs transmit ASF to your pigs?								
Yes	19	90.5	78.3		25	78.1	1.53	0.466
No	2	9.5	21.7		7	21.9		
Attended any trainings/workshops on biosecurity?								
Yes	10	47.6	30.4		10	31.3	1.86	0.395
No	11	52.4	69.6		22	68.7		

3.7.2 Awareness Aspects

Based on the results of Table 3.21, the key finding are given as follows:

Aware of Any Recent Outbreaks of ASF?

Awareness of recent ASF outbreaks was relatively high in all areas. Gelegphu had 85.7% (18/21) of farmers aware, Samtenling had 86.9% (20/23), and Gakiling had 71.9% (23/32). The Chi-square test did not show significant differences (χ^2=2.47, P=0.292), indicating a general awareness of recent outbreaks (Table 3.21).

Can Wild Pigs Transmit ASF to Your Pigs?

The understanding that wild pigs can transmit ASF was high across the areas. Gelegphu had 90.5% (19/21), Samtenling had 78.3% (18/23), and Gakiling had 78.1% (25/32). The Chi-square test indicated no significant differences (χ^2=1.53, P=0.466), suggesting strong awareness of the role of wild pigs in ASF transmission.

Attended Any Training/Workshops on Biosecurity?

Participation in biosecurity training or workshops varied, with Gelegphu at 47.6% (10/21), Samtenling at 30.4% (7/23), and Gakiling at 31.3% (10/32). The Chi-square test did not reveal

significant differences (χ^2=1.86, P=0.395), indicating generally low participation in biosecurity training across all areas.

3.8 Economic & Social Impact of ASF

Understanding the economic impact of ASF outbreaks is important as ASF outbreaks result in significant financial losses to farmers due to the high mortality rate of infected pigs. This economic strain can lead to reduced household income, increased poverty, and financial instability. According to Costard et al. (2013), the economic burden of ASF on smallholder farmers is profound, as they often lack the financial resilience to absorb such losses.

Further, the impact of social and psychological aspects on farmers dealing with ASF outbreaks can be significant. Otte et al. (2007) mention that the psychological toll on farmers during animal disease outbreaks is often overlooked, yet it is a critical component of the overall impact on rural communities. The loss of livestock can lead to emotional distress, anxiety, and depression among farmers and their families.

3.8.1 Economic Impact

Table 3.22 outlines various economic and social impacts of the ASF outbreak on farmers across the three study areas in Sarpang, Bhutan for the year 2023.

The following key aspects of the economic impacts of ASF are:

Farm Income Decreased:

A high proportion of farmers reported a significant decrease in farm income due to ASF. In Gelegphu, 81.0% (17/21) of farmers experienced this impact, compared to 78.3% (18/23) in Samtenling and 59.4% (19/32) in Gakiling (Table 3.22). The Chi-square test showed no significant differences between the study areas (χ^2=4.8, P=0.091), indicating that income reduction is a widespread economic issue among farmers affected by ASF.

Increased Costs for Farm Biosecurity Measures:

Farmers also reported increased costs for implementing biosecurity measures. In Gakiling, 75.0% (24/32) of farmers experienced increased costs, compared to 60.9% (14/23) in Samtenling and 52.4% (11/21) in Gelegphu. The differences were not statistically significant (χ^2=3.03, P=0.221), suggesting that increased biosecurity costs are a common challenge.

3.8.2 Social Impact

Based on Table 3.22, some of the findings of the social impacts of ASF are :

Significantly Increased Stress and Anxiety Levels:

The ASF outbreak significantly increased stress and anxiety levels among farmers. In Samtenling, 73.9% (17/23) of farmers reported increased stress and anxiety, compared to 47.8% (15/32) in Gakiling and 38.1% (8/21) in Gelegphu (table 3.22). The Chi-square test indicated no significant difference (χ^2 = 1.15, P=0.562), highlighting a general increase in stress and anxiety across all areas.

Felt Isolated Due to the Strict Biosecurity Measures Required:

Farmers also felt isolated due to the strict biosecurity measures. In Samtenling, 60.9% (14/23) of farmers ***felt*** isolated, compared to 52.4% (11/21) in Gelegphu and 56.3% (18/32) in Gakiling. The Chi-square test showed no significant differences (χ^2=0.32, P=0.850), indicating that isolation due to biosecurity measures is a common experience among farmers.

Table 3.22 Economic and Social impact on farmers due to ASF outbreak in the three study areas at Sarpang, Bhutan, frequency (Freq.), proportion (%) and Chi-square value (χ^2) in 2023

Area	**Gelegphu (n=21)**		**Samtenling (n=23)**		**Gakiling (n=32)**			
Variable	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**χ^2**	**P value**
Number of farms (n)	21		23		32			
Economic Impact								
Farm's income significantly decreased							4.8	0.091
Yes	17	81.0	18		78.3	19		
No	14	19.0	5		21.7	13		
Increased costs for farm biosecurity measures							3.03	0.221
Yes	11	52.4	14		60.9	24		
No	10	47.6	9		39.1	8		
Social Impact								
Significantly increased my stress and anxiety levels							1.15	0.562
Yes	8	38.1	17		47.8	15		
No	13	61.9	15		52.2	15		
Felt isolated due to the strict biosecurity measures required							0.32	0.850
Yes	11	52.4	14		60.9	18		
No	10	47.6	19		39.1	14		

4. DISCUSSIONS

4.1 Farm Household Sub-system

4.1.1 Household Size and Farm Income

The household size and composition were similar across Gelegphu, Samtenling, and Gakiling which suggests a commonality in family involvement in farm activities. Therefore, the significant difference in farm income ($p < 0.05$) suggests other underlying factors influencing economic outcomes. Gakiling reported significantly lower income from pig production and other sources compared to Gelegphu and Samtenling (Table 3.2). This disparity may be attributed to several factors, including differences in access to markets and availability of resources. The lower income from pig production in Gakiling could also reflect the impact of ASF outbreaks in Samtenling and Gelegphu.. The economic disparities observed in this study are consistent with findings from other research on smallholder pig farming in developing countries. According to Costard et al. (2013), variations in farm income can be influenced by factors such as disease outbreaks, and market integration.

4.1.2 Education and Farming Experience

The findings from Table 3.3 provide insights into the educational backgrounds and farming experience of smallholder pig farmers in Sarpang, Bhutan, crucial for understanding their capacity to adopt and implement biosecurity measures against ASF.

Education play a pivotal role in shaping farmers' understanding and adoption of biosecurity practices. Studies such as those by Roche et al. (2020) emphasize that higher educational levels correlate with better biosecurity compliance and disease management. Farming experience influences farmers' ability to recognize disease risks and implement preventive measures effectively. Novice farmers, particularly those with less than one year of experience as observed in Gakiling, may benefit significantly from mentorship programs and practical training in biosecurity protocols (Lapar et al., 2018).

4.2 Pig Sub-system

4.2.1 Pig Production Characteristics

Table 3.4 shows significant variations in pig production characteristics among smallholder farmers in Sarpang, Bhutan, influencing biosecurity practices and ASF prevention strategies.

***Biosecurity Challenges Across Farm Categories*:**

The predominance of backyard and semi-commercial farms, particularly in Gakiling, highlights potential challenges in implementing effective biosecurity measures. Studies by Kabir (2020) emphasize that smallholder farms often face resource constraints and may require tailored interventions to improve biosecurity compliance and disease management.

Risk Factors in Pig Rearing Purposes:

The high proportion of farmers engaged in pig fattening across all study areas necessitates targeted biosecurity interventions due to the intensive nature of fattening operations. Biosecurity strategies must address factors such as pig movement, contact with wild animals, and waste management to mitigate ASF transmission risks (FAO, 2020).

Importance of Source Control in Disease Prevention:
The reliance on external sources for breeding and fattening pigs underscores the need for stringent biosecurity protocols during pig procurement and transportation. Importantly, ensuring traceability and health certification of pigs from different sources can mitigate the introduction of ASF and other infectious diseases (Roche et al., 2020).

4.2.2 Pig Population

The results from Table 3.5 reveal notable differences in pig numbers and farm types among the three study areas in Sarpang, Bhutan. Although the overall differences in pig numbers were not statistically significant, the variations in specific categories such as boars, sows, gilts, barrows, and piglets suggest different farming practices and management strategies in each area. Samtenling's higher average number of pigs may be attributed to better resources, infrastructure, or market access, allowing farmers to maintain larger herds. Conversely, Gakiling's lower average suggests potential limitations in these areas, which could impact the ability to scale pig farming operations.

The findings align with previous studies on smallholder pig farming, which highlight the influence of resources, market access, and management practices on pig numbers and farm productivity. According to Halimani et al. (2012), smallholder pig farmers' ability to maintain larger herds is often linked to access to feed, veterinary services, and markets. The significant variations in specific pig categories, such as boars and piglets, are consistent with reports by Nguhiu-Mwangi et al. (2013), who found that the availability of breeding stock and piglet survival rates are critical factors influencing pig farm productivity. Samtenling's higher number of boars and piglets suggests better breeding practices and higher piglet survival rates, which contribute to larger herd sizes.

4.2.3 Pig Morbidity and Mortality

The results reveal significant variations in pig morbidity and mortality across the three study areas (Table 3.6). The higher morbidity and mortality rates in Gelegphu and Samtenling compared to Gakiling highlight disparities in disease management and biosecurity practices among the areas.

Pig Morbidity:
The significantly higher morbidity rate in Gelegphu (47.6%) compared to Gakiling (12.5%) suggests differences in disease prevalence and farm management practices. The higher morbidity in Samtenling (39.13%) also indicates that disease control measures in this area might be less effective. Factors such as farm density, biosecurity measures, and veterinary care likely contribute to these differences.

Pig Mortality:
The mortality rates were not significantly different between the areas, although the higher absolute numbers in Samtenling and Gelegphu indicate a greater impact of disease outbreaks. The high number of pigs culled in Samtenling (104) compared to Gelegphu (16) and none in Gakiling further underscores the severity of disease outbreaks in this area.

The findings are consistent with studies on pig farming in other regions, which highlight the importance of effective biosecurity measures in reducing morbidity and mortality. According to Penrith and Vosloo (2009), inadequate biosecurity is a major risk factor for disease outbreaks in pig farms,

leading to high morbidity and mortality rates. The significant difference in morbidity rates between the areas aligns with reports by Dixon et al. (2020), who found that variations in farm management practices and access to veterinary services significantly influence disease prevalence in pig farms.

4.3 Farm Biosecurity Measures

4.3.1 Farm Access Control

Visitor and Vehicle Entry Recording:
Table 3.7 indicates significant differences in some biosecurity measures among the three study areas. The recording of visitor and vehicle entry showed the most significant variation, while other measures, such as the use of foot dips, foot baths, and biosecurity signage, did not differ significantly.

The significantly higher proportion of farms in Gakiling (53.1%) recording visitor and vehicle entry compared to Gelegphu (14.3%) and Samtenling (34.8%) suggests better adherence to biosecurity protocols in Gakiling. Recording entries is a critical biosecurity measure to trace and control potential sources of infection, as highlighted by Costard et al. (2009). The lower adherence in Gelegphu may indicate a need for increased awareness and training on the importance of this measure.

Foot Dips at Farm Entrance:
The overall low use of foot dips at farm entrances is concerning, given their importance in preventing the introduction of pathogens via footwear. The lack of significant differences among the areas suggests a general need for improvement in this practice across all study locations. This finding is consistent with reports by Alarcón et al. (2013), which emphasize the need for consistent biosecurity practices to control disease spread effectively.

Foot Baths at Pig Pen Entrance:
The relatively high use of foot baths at pig Pen entrances across all areas indicates a good level of awareness and implementation of this measure. However, the slightly lower percentage in Gakiling (62.5%) compared to Gelegphu (71.4%) and Samtenling (73.9%) suggests potential gaps in implementation that need to be addressed.

Biosecurity Signage:
The similar proportions of farms using biosecurity signage across the areas suggest a consistent level of awareness regarding the importance of visible biosecurity measures. However, the overall percentages indicate room for improvement. Signage is a simple yet effective tool to remind farm workers and visitors of biosecurity protocols (Laanen et al., 2014).

The findings align with broader research on biosecurity in pig farming. Studies by Costard et al. (2009) and Alarcón et al. (2013) highlight the critical role of strict biosecurity measures, such as recording entries and using foot dips, in preventing disease outbreaks. The lower adherence to these measures in some areas of Bhutan suggests a need for targeted interventions to improve biosecurity compliance. While signage alone may not prevent ASF, its presence can reinforce biosecurity practices and serve as a visual reminder for personnel and visitors to adhere to farm protocols (Roche et al., 2020).

4.3.2 Biosecurity Infrastructure

Housing:

The predominance of confined housing across all three regions aligns with recommended practices for preventing the spread of ASF, as confined housing can limit pigs' exposure to potential sources of infection. This also aligns with global recommendations for reducing ASF transmission risks (OIE, 2021). However, the presence of semi-confined housing, particularly in Samtenling and Gakiling, indicates a potential area of risk, as semi-confined systems can allow for more contact with external sources of infection (Penrith et al., 2019, Lapar et al., 2018).

Perimeter Fencing:

The variability in the use of perimeter fencing types impacting biosecurity practices may suggest economic constraints (Lapar et al., 2018). A significant proportion of farms in Gelegphu (52.4%) and Samtenling (25%) did not have any perimeter fencing, indicating a gap in biosecurity practices and pose a substantial risk for ASF introduction and spread, as unrestricted access can lead to contamination from various vectors and carriers (Dione et al., 2014). The use of green net fencing was most common, which may provide a moderate level of protection against the entry of wild animals and unauthorized personnel. However, green net fencing may offer limited protection compared to solid barriers like wire mesh or wooden fencing, impacting containment effectiveness.

Rodent and Pest Control Facilities:

The presence of rodent and pest control facilities is critical for ASF prevention, as rodents and pests can act as mechanical vectors for the virus (Gavier-Widen et al., 2015). High variability in pest control facilities underscores the need for standardized practices to mitigate ASF transmission via rodents (Roche et al., 2020). The high percentage of farms lacking such facilities in Gelegphu is concerning and highlights a major biosecurity gap. Samtenling's relatively high percentage of farms with these facilities (69.6%) is a positive finding, though there is still room for improvement. Gakiling's moderate level (53.1%) also indicates a need for enhanced rodent and pest control measures.

Comparative Analysis with Literature:

The findings of this study are consistent with other research on ASF prevention, which emphasizes the importance of housing, perimeter fencing, and pest control in minimizing disease risk (Penrith et al., 2019). The relatively high adoption of confined housing and the moderate use of effective perimeter fencing in some regions align with these best practices. However, the significant gaps in rodent and pest control, particularly in Gelegphu, underline a critical area needing attention, as highlighted by studies such as Dione et al. (2014).

4.3.3 Feed and Water Safety Management

Feed Types and Swill Feed:

The use of commercial and mixed feed types reflects a combination of modern and traditional feeding practices. Mixed feed predominates across study areas, reflecting a blend of economic feasibility and local resource availability (FAO, 2020). The use of commercial feed was higher in Gakiling, but their reliance on mixed feed indicates a preference for cost-effective and locally available resources. The use of swill feed, primarily household kitchen waste, poses a risk of ASF transmission if not properly

managed. The relatively high usage in Gelegphu and Gakiling highlights the need for education on the risks and proper handling of swill feed.

Feeding Practices:
Cooking or boiling swill feed is crucial in mitigating the risk of ASF, as heat can effectively inactivate the virus (Penrith et al., 2019). While some farmers adhere to this practice, with compliance rates ranging from 58.3% to 80%, more widespread adoption is necessary, even if a single farm feeding infected swill can trigger an ASF outbreak. The ASF outbreaks in Sarpang dzongkhag during 2022 and 2023 were primarily attributed to infected kitchen waste from hotels, which was fed as swill feed to some farms. The subsequent movement of farmers facilitated the spread of the disease. Hence, it is imperative to establish standardized protocols to reduce ASF transmission risks associated with improper food waste handling (OIE, 2021).

Role of Designated Feeding Persons:
High compliance with designated feeding practices enhances biosecurity by reducing potential disease (Lapar et al., 2018). The study areas high relatively good compliance with designated feeding persons ranging from 66.7% in Gelegphu to 81.2% in Gakiling. According to Lapar et al., (2018), such practices enhance biosecurity by reducing disease transmission risks from transmission via random persons feeding the animals.

Feed Safety Practices:
Maintaining the cleanliness of feed and feeding troughs and ensuring safe feed storage are critical components of biosecurity. Consistent cleanliness and adequate feed storage facilities are essential for safeguarding feed quality and reducing contamination risks (Roche et al., 2020). The high percentage of farmers (87% to 93%) adhering to these practices indicates an awareness of their importance and is encouraging, but warrants continuous monitoring and education. The low incidence of borrowing animal feed and equipment is a positive finding, as this practice can facilitate the spread of ASF (Fasina et al., 2012).

4.3.4 Animal Health Management
The findings from Table 3.10 underscore essential aspects of animal health management and disease monitoring protocols critical for mitigating ASF risks among smallholder pig farms in Bhutan. This discussion evaluates these practices in comparison with global biosecurity standards and identifies areas for improvement.

Utilization of Veterinary Services:
Ensuring consistent access to veterinary care enhances early disease detection and treatment efficacy. In all the study areas, more than 87% of farmers appreciated the regular veterinary services imparted by the livestock officials. Such a high utilization of veterinary services indicates proactive management practices that contribute to disease prevention and early detection (Deka et al., 2019).,

Vaccination Coverage and Immunization Strategies:
A moderate vaccination coverage (62% to 62% of farm) suggests ongoing efforts to enhance pig health and ASF resilience (FAO, 2020). However, optimizing vaccination programs based on local disease prevalence and strain dynamics can further bolster farm biosecurity against ASF outbreaks.

Isolation and Quarantine Practices:
Effective isolation and quarantine of sick and new pigs are pivotal in preventing disease spread within and between farms (OIE, 2021). Varied adherence to these practices in the three study areas underscores the need for standardized protocols and farmer education to minimize ASF transmission risks and stricter biosecurity measures (Kabir, 2020).

Role of Regular Health Checks:
Active farmer involvement in health monitoring complements official efforts, enhancing overall disease surveillance and management (Roche et al., 2020). Disparities in regular health checks by livestock officials and farmers in this study highlight challenges in disease surveillance and early detection (Lapar et al., 2018). Strengthening collaborative efforts between farmers and veterinary authorities can improve disease monitoring effectiveness and response times.

4.3.5 Waste Management Practices and Hygiene

Manure Management Strategies:
Composting is an effective method for managing pig manure, reducing odor and pathogens while producing organic fertilizer (FAO, 2020). However, composting by only 24% to 50% farms across the study areas is low and remains underutilized compared to its potential benefits in waste reduction and nutrient recycling. Increasing awareness and providing technical support could enhance adoption rates and improve farm sustainability. Septic tanks provide safe containment of waste, preventing contamination of water sources and reducing disease transmission (FAO, 2020).

Risk of Direct Waste Disposal:
Direct disposal poses environmental and biosecurity risks, highlighting a need for improved waste handling practices (FAO, 2020). With about 19% to 52% farmers practicing the direct manure disposal method poses environmental and health risks, including disease transmission and water contamination. Encouraging alternative methods like composting and septic tank use through education and policy support is crucial for mitigating these risks.

Carcass Disposal and Biosecurity:
Deep burial minimizes exposure to scavengers and potential disease vectors, essential for controlling ASF outbreaks (OIE, 2021). Therefore, a high adherence to deep burial for carcass disposal in all the three study areas reflects a positive biosecurity measure to prevent ASF transmission. However, the incidences of 2 to 3 household disposing parts of the carcass in the nearby bushes poses biosecurity risks, necessitating proper disposal methods to prevent disease spread.

Hygiene of Pen's:
Daily cleaning of pen's minimizes pathogen buildup and maintains hygienic conditions essential for pig health (FAO, 2020). In this study. daily cleaning of pens and equipment is widely practiced (65% to 91% farm) but varies in frequency, affecting disease prevention efficacy (FAO, 2020). Therefore, standardizing hygiene practices and promoting regular training can enhance biosecurity measures against ASF and other infectious diseases.

4.3.6 Disinfection Facilities and Practices

Effectiveness of Foot Bath Facilities:
Foot baths containing disinfectants at farm entrances help prevent the introduction and spread of pathogens (OIE, 2021). Foot baths were widely implemented across the study areas (63% to 74%), indicating a recognized need for biosecurity measures. However, the variability in disinfectant use and proper dilution in the three study areas suggests room for standardization and training to ensure consistent effectiveness. The absence of foot baths may increase the risk of disease transmission between farms and visitors.

Challenges in Disinfectant Use:
Using appropriate disinfectants in foot baths enhances biosecurity measures by reducing microbial contamination (OIE, 2021). While most farms (53% to 62%) in the three study areas used disinfectants, the proportion (33% to 42%) that correctly dilutes the disinfectant is relatively low. Proper dilution ensures effective disinfection without harming animals or the environment, critical for biosecurity (OIE, 2021). There is a need to promote training on proper disinfection practices which could improve efficacy and reduce the risk of resistance development among pathogens.

Importance of Hand Wash Facilities:
Hand wash facilities are essential for maintaining hygiene standards among farm workers and visitors reducing the risk of disease transmission (OIE, 2021). The lower presence of these facilities (34% to 61%) in some of the study areas underscores a need for infrastructure investment and awareness campaigns to promote hygiene practices. This is because the absence of hand wash facilities may compromise biosecurity efforts, and therefore there is a need for improvement.

4.3.7 Record Keeping Practices

Farm record-keeping is an essential tool to enhance the resilience of the farm's biosecurity measures (FAO, 2020). Table 3.13 gives the various levels of record-keeping practices in the three study areas of Sarpang dzongkhag, Bhutan.

Impact of Record Keeping on Biosecurity:
Effective record-keeping is fundamental for biosecurity in pig farming. According to FAO (2020), detailed records are crucial for tracking feed quality, usage, and equipment maintenance, enhancing farm management and biosecurity; basic records provide essential insights into operational efficiency but may lack the granularity needed for comprehensive biosecurity management, however, the absence of records hinders disease traceability, resource management, and adherence to biosecurity protocols.

In this study, the proportion of farms that did not maintain animal feedstock and use ranged from 19% to 61%. While animal health records such as morbidity and mortality were not kept by 63% to 76% of the farms. Such noncompliance limits the ability to monitor disease trends and implement timely interventions (FAO, 2020). Global practices emphasize the importance of comprehensive record keeping in disease management and biosecurity and therefore highlight a critical area for improvement to enhance farm resilience against ASF.

Challenges in Record Keeping:
The predominance of farms without records suggests challenges in awareness, training, and resource availability (FAO, 2020). Addressing these gaps through capacity-building initiatives and technical support could foster better adherence to biosecurity protocols.

4.4 Farm Biosecurity Ranking

4.4.1 Evaluative Analysis

The findings from Table 3.14 reveal both similarities and disparities in biosecurity measures among smallholder pig farms in different regions of Sarpang, Bhutan. The study highlights significant disparities in biosecurity measures across the three areas, particularly in farm access control and disinfection facilities

The results from the higher median rankings in Gakiling for these measures suggest better implementation and adherence to biosecurity protocols, potentially reducing the risk of ASF outbreaks. Farm access control and disinfection measures were significantly higher ($P<0.05$) in Gakiling compared to Gelegphu and Samtenling, which are pivotal in preventing the introduction and spread of ASF. The significant differences in these measures between the areas can be attributed to varying levels of awareness, resources, and possibly differing local policies or enforcement of biosecurity practices.

The uniformity in infrastructure, feed and water safety management, animal health management, and record-keeping suggests that these areas have standard practices in place, which is a positive finding. However, the variation in waste management and hygiene practices, with Samtenling showing lower median rankings, indicates a need for targeted interventions to improve these aspects.

4.4.2 Comprehensive Analysis

Farm Access Control and Infrastructure:
While farm access control shows statistically significant differences ($P<0.05$), with Gakiling employing stricter measures, infrastructure standards are consistent across the study areas. Effective access control is crucial for preventing ASF introduction and spread (FAO, 2020), highlighting the need for enhanced measures in regions with lower scores.

Feed & Water Safety Management and Animal Health:
Uniform scores between the three study areas in feed and water safety management and animal health suggest consistent practices. Standardized protocols are essential for disease prevention (Deka et al., 2019), emphasizing the need for ongoing training and monitoring to maintain these standards.

Waste Management & Hygiene:
The variability in waste management and hygiene practices between the three study areas indicates potential areas for improvement, particularly in Samtenling where lower scores were observed. Adequate waste management reduces disease risks (FAO, 2020), necessitating tailored interventions to elevate practices.

Disinfection Facilities and Records Keeping:
Significant differences in disinfection facilities in the three study areas underscore uneven infrastructure development, with Gakiling excelling. Comprehensive record keeping supports disease surveillance (FAO, 2020), advocating for capacity-building initiatives to enhance data management capabilities. Global best practices stress integrated biosecurity approaches to safeguard against ASF and other diseases (Deka et al., 2019). Disparities observed in disinfection and waste management highlight opportunities for aligning local practices with international benchmarks.

4.4.3 Comparative Analysis

Comparing the findings with existing literature, it is evident that biosecurity measures play a crucial role in controlling ASF OIE, 2021). A study by Costard et al. (2013) highlights that smallholder farms often have gaps in biosecurity practices, making them vulnerable to ASF outbreaks. The higher adherence to farm access control and disinfection in Gakiling aligns with findings from larger-scale farms in other regions where stringent measures are associated with lower disease incidence (Gallardo et al., 2015).

Additionally, the study's results are consistent with the observations by Penrith and Vosloo (2009), who noted that comprehensive biosecurity protocols, including disinfection and access control, are essential in preventing ASF spread. The uniform infrastructure and management practices across the areas reflect a baseline level of biosecurity awareness and implementation, which is crucial for disease control. Based on the findings, it is recommended that targeted training and resource allocation be directed toward improving farm access control and disinfection practices in Gelegphu and Samtenling. Additionally, enhancing waste management and hygiene practices in Samtenling could significantly bolster the overall biosecurity framework.

4.5 Farm Biosecurity Index

4.5.1 Overall Farm Biosecurity Index of the Study Areas

4.5.1.1 Evaluative Analysis

The overall Farm Biosecurity Index in all three study areas were “Fair” categories between 0.477 to 0.590 biosecurity index values (Table 3.18). Gakiling (0.590) had the highest overall Farm Biosecurity Index among the three study areas, which may indicate a more robust implementation of biosecurity measures crucial in preventing ASF outbreaks. The higher index values in Gakiling for specific biosecurity measures such as farm access control and disinfection facilities and practices underscore its commitment to stringent biosecurity practices.

In contrast, Samtenling, with the lowest overall biosecurity index (0.4764), shows areas that require improvement, particularly in waste management and hygiene (0.038) and record keeping (0.019). The relatively lower indices in these components suggest gaps in biosecurity measures that could potentially increase the risk of ASF spread.

4.5.1.2 Comparative Analysis

Comparing the findings with existing literature, the findings of this study align with existing literature on the importance of comprehensive biosecurity measures in controlling ASF. The biosecurity measures across the three study areas in Sarpang, Bhutan, are generally suboptimal except for Gakiling. Most indices fall within the "Fair "category, with Disinfection facilities and Practices falling in the "Poor: category especially in Gelegphu and Samtenling (Tables 3.16, 3.17 and 3.18). These findings align with previous studies indicating that biosecurity practices in smallholder pig farms in developing countries are often inadequate (Penrith & Vosloo, 2009).

A study by Costard et al. (2013) highlights the need for stringent biosecurity practices in smallholder farms to mitigate ASF risks. The higher biosecurity indices in Gakiling for farm access control and disinfection facilities and practices are consistent with the recommendations by Gallardo et al. (2015) that emphasize these measures as critical for disease prevention. Further, the World Organization for Animal Health (OIE, 2021) underscores the importance of access control and disinfection practices, which are well-implemented in Gakiling, as indicated by the biosecurity indices. The uniformity in disinfection facilities and practices across the three areas suggests a baseline level of awareness and implementation, which is crucial for maintaining biosecurity.

To enhance biosecurity measures, it is recommended that targeted interventions focus on improving waste management and hygiene practices in Samtenling. Additionally, better record-keeping practices should be encouraged in all areas, with a particular focus on Samtenling, which had the lowest index in this component. Training and resource allocation should be prioritized to address these gaps and ensure comprehensive biosecurity implementation.

4.5.2 Individual Biosecurity Variable Indices

The analysis of Biosecurity Variable Indices (BV indices) provides a detailed evaluation of biosecurity measures across farms in three key regions of Sarpang, Bhutan: Gelegphu, Samtenling, and Gakiling. These indices are calculated by combining normalized compliance scores with assigned weights, reflecting the perceived importance of each biosecurity variable in preventing disease outbreaks and maintaining livestock health.

4.5.2.1 Biosecurity Variable Indices of Gelegphu

In Gelegphu, the analysis reveals a mixed performance in biosecurity practices. Farm Access Control, which holds the highest weight, underscores its critical role in safeguarding farms from external threats. However, despite its importance, the compliance score for this variable is relatively low, indicating room for improvement. Feed & Water Safety Management stands out with a higher compliance score, earning a "Good" rating. However, the overall Biosecurity Index for Gelegphu falls into the "Fair" category, suggesting that while certain practices are robust, key areas such as Farm Access Control and Disinfection Facilities need significant enhancement to elevate the region's biosecurity status.

4.5.2.2 Biosecurity Variable Indices of Samtenling

Samtenling presents a similar scenario of Gelegphu, where Farm Access Control and Disinfection Facilities & Practices are heavily prioritized but show varying degrees of compliance. Feed & Water Safety Management again emerges as a strong point, but Disinfection Facilities lagged, revealing a critical area for intervention. The overall Biosecurity Index for Samtenling is slightly lower than

Gelegphu, indicating a moderate biosecurity level that would benefit from focused improvements, particularly in disinfection and record-keeping practices.

4.5.2.3 Biosecurity Variable Indices of Gakiling

In contrast to Gelegphu and Samtenling, Gakiling demonstrates relatively strong adherence to biosecurity measures, especially in Farm Access Control, Feed & Water Safety Management, and Animal Health Management. These variables contribute significantly to the overall biosecurity status, which approaches the "Good" category. However, there remains a need to improve Record Keeping and Disinfection Facilities, which are comparatively weaker. Addressing these gaps could further bolster the biosecurity of farms in Gakiling, reducing the risk of disease outbreaks and enhancing livestock health.

4.5.2.4 Comparative Analysis

The comparative analysis across the three study areas indicates that while certain biosecurity variables are consistently well-managed, others require targeted intervention. The variability in assigned weights and compliance scores underscores the need for region-specific biosecurity strategies.

To enhance overall biosecurity, it is recommended that resources and training focus on improving weaker areas, such as infrastructure and disinfection practices, while also bolstering record-keeping. These targeted interventions are supported by literature, which suggests that tailored biosecurity measures can significantly improve farm-level outcomes, ultimately promoting sustainable livestock management and reducing disease risks.

4.5.3 Biosecurity Index Based on Farm Category, Education & Experience

4.5.3.1 Farm Category

The results indicate that commercial farms tend to have a higher Biosecurity Index (BI) compared to backyard and semi-commercial farms. This suggests that commercial farms may have better resources and infrastructure to implement biosecurity measures. However, the lack of statistical significance (P=0.248) suggests that while there is a trend towards higher BI in commercial farms, it is not strong enough to be conclusive (Table 3.19). This aligns with the findings by Costard et al. (2015), who noted that larger commercial operations often have more rigorous biosecurity protocols due to higher investment capabilities.

4.5.3.2 Farmer Education

The data show that farmer education levels have a minimal impact on the BI, with no significant differences observed (P = 0.611) (Table 3.19). This could imply that regardless of educational background, farmers might be gaining practical knowledge of biosecurity through extension services or community learning. This contrasts with the findings of Otte et al. (2007), who suggested that education level could significantly influence the adoption of biosecurity measures. The disparity could be due to the effectiveness of local livestock extension programs in Sarpang, Bhutan, which might be successfully bridging the education gap.

4.5.3.3 Farming Experience

Interestingly, farming experience did not significantly affect the BI (P = 0.313) in this study (Table 3.19). This suggests that newer farmers might be as competent in biosecurity practices as their more experienced counterparts, possibly due to strong extension support and initial training programs.

However, Dixon et al. (2020) found that experience generally correlates with better biosecurity practices, implying that Bhutan's extension services might play a crucial role in providing immediate, high-quality biosecurity education to new farmers.

4.5.3.4 Comparative Analysis

Comparatively, the results align with global trends where commercial farms generally have better biosecurity due to resources (Costard et al., 2015). However, the lack of significant impact from education and experience highlights the unique context of Bhutan, where extension services might be exceptionally effective. This underscores the importance of continued investment in agricultural education and extension services to ensure all farmers, regardless of background, can maintain high biosecurity standards.

4.6 Farmer's Levels of Knowledge and Awareness of ASF

4.6.1 Evaluative Analysis

The results of the study indicate that farmers in all three study areas possessed a moderate to high level of knowledge and awareness on the basics of ASF (Table 3.20). This basic knowledge is crucial for the early detection and control of ASF outbreaks. The majority of farmers had heard of ASF, were aware of recent outbreaks, and knew that wild pigs could transmit the disease. However, the farmer's understanding of specific transmission modes and symptoms of ASF is moderate and varies across the areas. For instance, Samtenling had a notably higher proportion of farmers who knew about the transmission modes compared to Gelegphu and Gakiling. This indicates a need for targeted educational programs to enhance specific knowledge about ASF transmission and symptoms.

Participation in biosecurity training is relatively low in all three study areas. This was not their lack of interest but the lack of such training programs and opportunities. Given the importance of biosecurity measures in controlling ASF, increasing training opportunities and encouraging farmer participation are essential.

4.6.2 Comparative Analysis

The findings of this study align with existing literature that highlights the importance of farmer awareness and knowledge in disease control. According to Costard et al. (2013), educating farmers about ASF transmission and symptoms is vital for preventing and managing outbreaks. The relatively higher awareness of basic ASF information in this study is consistent with findings by Gallardo et al. (2015), who emphasize the role of farmer knowledge in effective disease management.

The study by Penrith and Vosloo (2009) also underscores the need for continuous education and training for farmers to maintain and enhance biosecurity measures. The low participation in biosecurity training observed in this study reflects a gap that needs to be addressed to improve overall farm biosecurity, as also noted by the World Organization for Animal Health (OIE, 2021).

4.7 Economic and Social Impacts of ASF Outbreaks

4.7.1 Evaluative Analysis

Table 3.21 reveals significant economic and social impacts of ASF outbreaks on farmers in the three study areas, Sarpang, Bhutan. Most farmers across all areas reported a significant decrease in farm income ($P<0.05$) and increased costs for biosecurity measures. These findings align with the economic challenges faced by smallholder pig farmers during ASF outbreaks as documented in the literature. For instance, Costard et al. (2013) emphasize that ASF outbreaks lead to substantial economic losses due to decreased productivity and increased costs for disease control measures.

The social impact of ASF outbreaks is also considerable. A significant proportion of farmers reported increased stress and anxiety levels, as well as feelings of isolation due to strict biosecurity measures. These findings are consistent with the psychosocial effects of disease outbreaks reported in other studies. According to OIE (2021), the stress and social isolation experienced by farmers during ASF outbreaks can have long-term effects on their mental health and well-being.

4.7.2 Comparative Analysis

A comparative analysis of the economic impact observed in this study is consistent with the findings of Gallardo et al. (2015), who reported that ASF outbreaks result in decreased farm income and increased costs for biosecurity measures. The uniformity in the economic impact across the three study areas suggests that ASF outbreaks pose a significant financial burden on smallholder pig farmers in Bhutan.

The findings of the social impact align with the observations of Penrith and Vosloo (2009), who highlighted the increased stress and anxiety levels among farmers during disease outbreaks. The feelings of isolation due to biosecurity measures reported in this study are also consistent with the findings of other studies on the psychosocial effects of ASF outbreaks (Costard et al., 2013).

To mitigate the economic and social impacts of ASF outbreaks on farmers, it is essential to offer financial assistance to help cover the costs of implementing biosecurity measures and to compensate for income losses. Providing mental health support programs can also play a crucial role in helping farmers manage the stress and anxiety associated with these outbreaks. Additionally, fostering community engagement initiatives can reduce feelings of isolation among farmers and promote peer support networks, creating a more resilient farming community.

4.8 Adoption of Biosecurity Measures

During the survey conducted in the three study areas, it became evident that despite some farmers being aware of the biosecurity measures needed for their farms, there was a reluctance to adopt these practices. This observation aligns with findings by Heffernan et al. (2008) and Garforth et al. (2013), who noted that farmers often resist implementing recommended biosecurity measures due to a combination of socioeconomic, cultural, and mindset-related factors.

Through interactions with farmers during the survey and focus group discussions, several reasons for the poor or non-adoption of biosecurity measures were identified, ranging from economic constraints to perception issues.

4.8.1 Causes of Poor or Non-Adoption

Primary Causes:
One of the main barriers to adopting biosecurity measures is economic constraints. Many smallholder farmers have limited financial resources, leading them to view the costs of implementing biosecurity measures as prohibitive. Additionally, there is a general lack of knowledge and training among these farmers, with limited awareness of the importance and methods of implementing biosecurity measures, contributing to non-compliance.

Mindset and Perception Issues:
Several psychological and perceptual factors also play a role in the reluctance to adopt biosecurity practices. For example, farmers may not perceive African Swine Fever (ASF) as a significant threat, especially if they have not experienced an outbreak. This low-risk perception diminishes their motivation to take preventive actions. Furthermore, there is often resistance to change, as farmers are accustomed to established routines and may see alterations to these as burdensome. Economic prioritization is another factor, where immediate financial pressures lead farmers to focus on short-term gains rather than investing in long-term biosecurity measures.

4.8.2 Strategies to Promote Adoption

Education and Training:
Addressing the barriers to adoption requires a multifaceted approach. Education and hands-on training are essential to improve farmers' understanding and skills in biosecurity. Bennet and Balcombe (2012) suggest that economic incentives, such as financial support or subsidies, can also help farmers cover the costs of biosecurity measures, particularly in regions where ASF is endemic.

Communication Strategies:
Effective communication is crucial in ensuring that farmers understand and adopt biosecurity measures. This can be achieved through mass media campaigns that utilize radio, television, and newspapers to spread information about the importance of biosecurity and how to implement it. Workshops and training programs that offer practical, hands-on experiences can engage farmers directly. Digital platforms, including mobile applications and social media campaigns, can provide ongoing information and updates. Additionally, printed materials like brochures and posters can communicate biosecurity practices in simple, easy-to-understand language.

Addressing Mindset Issues:
To tackle the perception-related barriers, it is important to educate farmers on the economic and health risks posed by ASF, using case studies and data to illustrate the potential impacts of an outbreak. Training on change management can demonstrate how biosecurity measures can be integrated into existing practices with minimal disruption. Emphasizing the long-term economic benefits of biosecurity, such as improved herd health and productivity, can also help shift farmers' priorities towards more sustainable practices.

4.9 Strengths and Challenges of the Methodological Approach

According to Wangdi and Bidha (2022), there is a significant gap in comprehensive studies on biosecurity practices in pig holdings in Bhutan, which is critical for managing animal health and addressing the challenges of TADs. Addressing these challenges are vital for sustaining livelihoods, enhancing

national food security, and fostering economic development in Bhutan. This study aims to help fill this gap by focusing on the local specificities, socio-economic conditions, and practical challenges faced by Bhutanese pig farmers in implementing biosecurity measures.
The use of a mixed-methods research approach, including quantitative surveys and qualitative interviews with a wide range of stakeholders, enabled to do a holistic study. This analysis provides individual Biosecurity Variable Indices and an overall farm Biosecurity Index for three study areas in Sarpang, Bhutan. The study also developed comprehensive biosecurity intervention packages tailored for the prevention and control of African Swine Fever (ASF) in Sarpang, which could potentially be adapted for other regions in Bhutan.

A challenge in this study was the subjectivity involved in ranking the biosecurity measures by the enumerators and the focus groups for different study areas. However, subjectivity in quantifying variables or indicators is often unavoidable and should be managed rather than eliminated (Kemp & Martens, 2007). Subjectivity for the ranking in this study was managed by transposing them into quantitative ordinal data (Table 2.2). The first and last ranks for the biosecurity measures were consistent across all three focus groups, with some variations in the other ranks.

5. RECOMMENDATIONS

5.1 The Concerns & Approach to Designing Biosecurity Intervention Packages

5.1.1 The Concerns & of Farm Biosecurity Index Values

The results reveal that the biosecurity measures across the three study areas in Sarpang, Bhutan, are generally suboptimal and are a major concern. While the average Biosecurity index of all the three study areas came in the “Fair” category. Most indices fall within the "Very Poor" and "Poor" categories, highlighting significant biosecurity gaps. The findings of this study indicate a need for significant policy, technical, and practice interventions. The results of this study also align with previous studies indicating that biosecurity practices in smallholder pig farms in developing countries are often inadequate (Penrith & Vosloo, 2009).

5.1.2 The Approach to Designing Biosecurity Intervention Packages

The poor biosecurity indices indicate an urgent need for comprehensive biosecurity interventions tailored to the specific conditions of smallholder pig farms in Bhutan. Based on the findings of the study, policies should largely focus on improving infrastructure, enhancing farmer education, and enforcing biosecurity regulations.

As per the findings of this study, biosecurity intervention packages are required for all the Biosecurity measures in all three study areas with varying levels of intensity. Investment in farm infrastructure such as adequate housing and proper perimeter fencing is critical to enhancing biosecurity measures (Laanen et al., 2013). However, in this study, no Biosecurity intervention packages are proposed for infrastructural investments such as animal housing and farm perimeter fencing as these involve large financial investments and are subject to available resources of the government, and farmers' commitment to make their investments. Therefore, this study proposes a balanced biosecurity intervention package urgently required to enhance the biosecurity measures of the smallholder pig farmers in Bhutan. Further, the recommendations suggested are those that are economically viable and socially acceptable and address pertinent biosecurity areas that need attention and can be implemented without huge resources or capital investments. Education and Training of farmers is considered a priority. According to Dione et al., 2014), farmer education programs should be implemented to improve awareness and practices related to various biosecurity measures such as proper feed and water management, waste disposal, and animal health management.

Based on the findings from this study, key informant interviews, focus group discussion in study areas and literature review, the following biosecurity intervention packages, with key components are proposed.

5.2 Farm Biosecurity Intervention Packages

5.2.1 Farm Access and Control Intervention Packages

A pertinent area of concern in this study was the unregulated movement of vehicles and personnel's to and from the pig farms. According to Dorji (2022), one of the causes of spread of ASF in Sarpang dzongkhag in 2022 was due to the movement of personnel from one farm to another.

The biosecurity intervention package is described as follows:

i) Rationale

- Access control: Preventing unauthorized access reduces the risk of introducing ASF.
- Cross-contamination: Managing human movement minimizes the risk of cross-contamination between farms.

ii) Components for implementation

Movement of Vehicles and Visitors:

- Visitor Protocols: Limit visitor access and implement strict protocols for necessary visits.
- Disinfection: Ensure all vehicles and visitors are disinfected before entry.

Movement of people between farms:

Protocols: Develop and enforce protocols for farm workers to minimize cross-farm movement.

iii) Benefits

- Farmers: Lower risk of ASF introduction and spread, leading to more secure operations.
- Country: Stronger biosecurity infrastructure and enhanced disease control.

iv) Government, Community, and Farmer Roles

- Government: Provide guidelines and resources for access control measures and conduct inspections.
- Community: Support and comply with access control measures.
- Farmers: Implement and maintain access control measures and educate visitors on protocols.

5.2.2 Basic Infrastructure Intervention Package

Foot baths and foot dips at the pig farm and pig pens are simple yet effective measures to prevent the spread of ASF by disinfecting footwear (FAO, 2019). Foot bath facilities are essential for preventing the spread of pathogens by ensuring that all individuals entering and exiting pig pens disinfect their footwear. This practice is critical in breaking the transmission cycle of ASF and other diseases.

The biosecurity intervention package is described as follows:

i) Rationale

- Cross-contamination: Foot baths and dips prevent cross-contamination between different farm areas.
- Pathogen Control: Disinfection of footwear reduces the risk of introducing ASF virus.

ii) Components for Implementation

- Foot baths: Install foot baths with disinfectants at the entrance of pig farms and individual pens.

- Signage: Place clear instructions and signs to remind all farm workers and visitors to use the foot baths.
- Foot dip Maintenance: Ensure regular maintenance and replenishment of disinfectants in foot dips. Replace the solution daily or more frequently if it becomes visibly dirty.
- Training: Educate farm workers on the importance and proper use of foot baths and foot dips.
- Compliance monitoring: Monitor compliance with foot bath usage and maintenance protocols.

iii) Benefits
- Disease prevention: Reduces the risk of ASF and other pathogens being carried into pig pens via footwear.
- Cost-effective: Relatively low-cost intervention with significant benefits in disease prevention.
- Easy implementation: Simple to set up and maintain with minimal disruption to farm operations.

iv) Government, Community, and Farmer Roles
- Government: Provide guidelines and support for foot bath installation and maintenance.
- Community: Promote the use of foot baths through awareness campaigns.
- Farmers: Install and maintain foot baths, ensure proper use by all farm workers and visitors.

5.2.3 Animal Health Management Intervention Package

5.2.3.1 Disease Surveillance and Reporting

Effective disease surveillance and reporting are crucial for early detection and timely response to ASF outbreaks. Early detection helps contain the disease and prevent its spread to other farms, which is vital in minimizing economic losses and protecting national food security (FAO, 2019).

The biosecurity intervention package is described as follows:

i) Rationale
- Early Detection: Identifying outbreaks early can prevent the spread of ASF and minimize economic losses.
- Data Collection: Surveillance provides essential data for epidemiological studies and risk assessments.
- Response Coordination: Efficient reporting systems enable coordinated responses and resource allocation.

ii) Components for implementation

Surveillance Systems:
- Monitoring: Implement continuous health monitoring of pig herds.
- Diagnostic Testing: Use reliable diagnostic tests to confirm ASF cases.
- Field Surveillance: Conduct regular field visits and inspections.

Reporting Mechanisms
- Digital Platforms: Develop digital platforms for real-time reporting.
- Training: Train farmers and veterinarians on proper reporting protocols.
- Transparency: Ensure transparent and timely sharing of information.

iii) Benefits

- Early detection and response: Surveillance and reporting systems enable early detection of ASF, allowing for swift response to contain outbreaks.
- Data collection and analysis: Surveillance programs collect valuable data on disease prevalence and spread, informing better decision-making and policy development.
- Community engagement: Engaging farmers in surveillance and reporting fosters a sense of responsibility and collaboration in disease prevention efforts.

iv) Government, community, and farmer Roles

- Government: Establish and maintain surveillance infrastructure, provide training and resources.
- Community: Participate in surveillance programs, report suspicious cases.
- Farmers: Monitor herd health, promptly report any signs of illness.

5.2.3.2 Isolation of Sick Animals and Quarantine of New Pigs

Isolating sick animals and quarantining new pigs are essential to prevent the introduction and spread of ASF within and between farms. These measures ensure that infected animals do not come into contact with healthy ones, reducing the risk of disease transmission (Bellini et al., 2016).

The biosecurity intervention package is described as follows:

i) Rationale

- Containment: Isolation prevents the spread of the disease to healthy animals.
- Risk Reduction: Quarantine of new pigs reduces the risk of introducing ASF to the farm.

ii) Components for implementation

Isolation Protocols:

- Designated areas: Establish designated isolation areas for sick animals.
- Health monitoring: Regularly monitor the health of isolated animals.

Quarantine Procedures:

- Quarantine facilities: Set up quarantine areas for new pigs before introducing them to the herd
- Standard Operating Procedures (SOPs): Develop and enforce SOPs for the isolation and quarantine processes.
- Quarantine duration: Implement a minimum quarantine period for new pigs.
- Health assessment: Conduct thorough health checks before integrating new pigs into the herd.

iii) Benefits

- Prevention of disease spread within and between farms.
- Healthier pig populations and reduced mortality rates.
- Lower risk of economic losses due to disease outbreaks.

iv) Government, Community, and Farmer Roles

- Government: Provide guidelines and support for isolation and quarantine measures.
- Community: Educate members about the importance of isolation and quarantine.
- Farmers: Implement isolation and quarantine protocols on their farms.

5.2.4 Swill Feeding Biosecurity Intervention Package

Swill feeding, or feeding pigs with food waste, is a common practice among smallholder farmers due to its cost-effectiveness. However, it poses a significant risk for the transmission of ASF as the virus can survive in uncooked or improperly treated food waste (Penrith et al., 2019). Therefore, ensuring safe feeding practices is crucial for preventing ASF outbreaks (OIE, 2021).

The biosecurity intervention package is described as follows:

i) Rationale

- Disease transmission: Swill feeding can introduce ASF virus through contaminated food waste.
- Risk reduction: Implementing biosecurity measures around swill feeding practices is critical for ASF prevention.

ii) Components for Implementation

Education and awareness:

- Training Programs: Conduct training for farmers on the risks associated with swill feeding.
- Information Campaigns: Distribute informational materials on safe feeding practices.

Regulations and enforcement:

- Legal Framework: Develop and enforce regulations prohibiting the use of untreated swill.
- Penalties: Establish penalties for non-compliance to deter risky feeding practices.

Alternative feeding strategies

- Commercial Feed: Promote the use of commercial feed as a safe alternative.
- Local Feed Resources: Encourage the use of locally available, non-contaminated feed resources.

iii) Benefits

- Farmers: Reduced risk of ASF outbreaks and improved herd health.
- Country: Enhanced biosecurity and food safety reduced economic losses from disease outbreaks.

iv) Government, Community, and Farmer Roles

- Government: Develop and enforce regulations and provide training and resources.
- Community: Participate in awareness campaigns, and support compliance efforts.
- Farmers: Adopt safe feeding practices, attend training sessions, and comply with regulations.

5.2.5 Waste Management & Hygiene Intervention Package

Proper waste management is critical to prevent the spread of ASF, as contaminated waste can be a source of infection. Effective waste management practices reduce the risk of environmental contamination and disease transmission (Penrith et al., 2019).

The biosecurity intervention package is described as follows:

i) Rationale

- Disease prevention: Improper waste disposal can serve as a vector for ASF transmission.

- Environmental health: Effective waste management maintains environmental hygiene and reduces pollution.

ii) Components for Implementation
- Waste Disposal Systems: Establish secure systems for the disposal of animal waste, including manure and carcasses. Incinerate infectious waste to eliminate pathogens.
- Composting: Promote composting of pig manure to kill pathogens and recycle nutrients.
- Regular Cleaning: Ensure regular cleaning and disinfection of pig pens and waste storage areas.
- Training: Educate farmers on best practices for waste management.

iii) Benefits
- Reduced risk of ASF spread through contaminated waste.
- Healthier and more hygienic farm environments.
- Improved environmental sustainability.

iv) Government, Community, and Farmer Roles
- Government: Establish waste management regulations and provide disposal facilities.
- Community: Participate in community waste management programs.
- Farmers: Implement proper waste segregation and disposal practices on their farms.

5.2.6 Disinfection Facilities & Practices Intervention Package

Disinfection and hygiene practices are fundamental in breaking the transmission cycle of ASF. These measures help to eliminate pathogens from the environment, reducing the risk of infection (FAO, 2020). The disinfection and hygiene Intervention package is designed to implement and maintain high standards of cleanliness and disinfection on pig farms, which is crucial for preventing the spread of African swine fever (ASF) and other infectious diseases

The biosecurity intervention package is described as follows:

i) Rationale
- Pathogen control: Regular disinfection reduces the presence of ASF virus on surfaces and equipment.
- Farm hygiene: Maintaining high hygiene standards prevents the introduction and spread of diseases.

ii) Components for Implementation

Disinfection Protocols:
- Routine cleaning: Implement routine cleaning schedules for all farm areas.
- Effective disinfectants: Use effective and approved disinfectants for cleaning.

Hygiene Practices:
- Handwashing stations: Install handwashing stations at strategic locations.

Training:
- Provide training on effective disinfection and hygiene practices.

iii) Benefits

- Farmers: Reduced risk of disease transmission and improved animal health.
- Country: Strengthened biosecurity and reduced economic losses from ASF outbreaks.

iv) Government, Community, and Farmer Roles

- Government: Provide guidelines and support for disinfection and hygiene practices.
- Community: Promote hygiene awareness and education.
- Farmers: Adhere to disinfection protocols and maintain high hygiene standards.

5.2.7 Record Keeping Intervention Package

Accurate record-keeping of animal feed is vital to trace sources of contamination and ensure that pigs are fed safe and uncontaminated feed. Proper documentation helps in monitoring feed quality and managing risks associated with swill feeding (Dione et al., 2014). Further, maintaining proper records of animal morbidity and mortality is essential for monitoring herd health and detecting disease out-breaks early.

The biosecurity intervention package is described as follows:

i)Rationale

Animal Feed Records:

- Traceability: Record keeping allows for traceability in case of feed-related ASF outbreaks.
- Quality control: Ensures that the feed used is safe and free from contaminants.

Animal Health Records:

- Early Detection: Detailed records help identify disease patterns and outbreaks quickly.
- Decision Making: Accurate data supports informed decision-making and timely interventions.

ii) Components for Implementation

Animal Feed Records:

- Feed records: Maintain detailed records of feed sources, types, and feeding schedules.
- Swill feeding control: Prohibit swill feeding and ensure that all feed is sourced from reliable suppliers.
- Training: Educate farmers on the importance of record-keeping and safe feed practices.

Animal Health Records:

Forms:

- Standardized Forms: Develop standardized forms for recording morbidity and mortality data.
- Digital Platforms: Pilot the use of digital record-keeping systems for ease of use and data analysis.

Data Utilization:

- Analysis: Regularly analyze recorded data to identify trends and potential outbreaks.
- Reporting: Ensure timely reporting of morbidity and mortality data to relevant authorities.

Training and Support:

- Farmer Training: Provide training on the importance of record-keeping and accurate records.
- Technical Support: Offer technical support to help farmers adopt and use digital record-keeping tools.

iii) Benefits

- Improved ability to manage animal feed use, herd health and prevent disease outbreaks.
- Enhanced disease surveillance and biosecurity, reduced impact of ASF outbreaks.

iv) Government, Community, and Farmer Roles:

- Government: Develop record-keeping guidelines, and provide training and digital tools.
- Community: Support farmers in adopting record-keeping practices, and share data with authorities.
- Farmers: Maintain accurate records, participate in training sessions, and report data promptly

5.3 Strengthening Livestock Regulatory Services Intervention Package

Strengthening the enforcement of biosecurity regulations is essential to ensure compliance among farmers and includes regular inspections and penalties for non-compliance (FAO, 2018). For example, in Sarpang the illegal importation of pork from neighboring countries like India poses a significant risk of introducing ASF into Bhutan. Strengthening border controls and ensuring only legally imported, inspected pork enters the country is crucial for biosecurity.

The biosecurity intervention package is described as follows:

i) Rationale

- Regulatory oversight: Strong regulatory services ensure compliance with biosecurity measures.
- Rapid response: Enhanced capacity allows for quicker and more effective responses to outbreaks.

ii) Components of the Package

Capacity Building:

- Training Programs: Provide ongoing training for regulatory personnel on ASF prevention and control.
- Resource Allocation: Ensure regulatory services have the necessary resources and equipment.

Regulatory Framework:

- Stakeholder Engagement: Engage with stakeholders to ensure comprehensive and practical regulations.
- Public Awareness Campaigns: Informing and educating the public about the risks associated with illegal pork importation and encouraging them to report suspicious activities.

Strengthened Border Controls:

- Enhanced Inspection: Provision of appropriate budgetary support to increase the number of inspections and improve the thoroughness of checks at border points to prevent illegal pork imports.
- Training border personnel: Providing specialized training for border personnel of Bhutan Food & Drug Authority and staffs of Integrated Check Post (located in all border towns of Bhutan) to recognize signs of illegal importation and understand the risks of ASF.

Policies

- Policy Development: Update and enforce policies related to biosecurity and disease control.
- Stricter Penalties: Implementing and enforcing stricter penalties for those caught importing illegal pork to deter such activities.

iii) Benefits

- Reduced ASF risk: Preventing illegal pork imports significantly reduces the risk of introducing ASF into Bhutan.
- Protected livelihoods: Ensuring the health of domestic pig populations helps protect the livelihoods of smallholder farmers.
- Enhanced national security: Strengthening border controls contributes to overall national security and biosecurity.

iv) Government and Community Support

Government:

- Provide appropriate training, resources, and infrastructure for regulatory services.
- Policy enforcement: The government can implement stricter regulations and provide the necessary resources for effective border control.
- Collaboration with border authorities: Strengthened collaboration and information sharing on ASF outbreaks with counterparts on the Indian border towns to report illegal activities and support enforcement efforts.
- Incentives for compliance: Providing incentives for businesses and individuals to comply with legal importation processes.

Community and Farmers:

- Collaborate with regulatory services, report non-compliance and outbreaks.
- Comply with regulations, cooperate with regulatory personnel, and participate in training.

5.4 Enhancing Intrinsic Interventions by the Farmers

While external funding or government support for certain Biosecurity intervention are vital, concerted efforts must also be made by the farmer to control and prevent ASF in their farms through an intrinsic effort, whereby farmers should focus on self-managed, sustainable practices that are locally manageable, cost-effective and do not have to depend on external funding or government support.

In line with the various Biosecurity measures discussed in this document, some of the intrinsic robust biosecurity protocols which the farmers could uptake are outlined as follows:

5.4.1 Farm Access Control to Limit Disease Entry

- Visitor Management: Restrict access to the farm to essential personnel only. If visitors are necessary, ensure they follow strict hygiene protocols such as using footbaths and changing clothes.
- Equipment Handling: Avoid sharing equipment between farms. If sharing is unavoidable, thoroughly clean and disinfect equipment before use.
- Footbaths: Set up footbaths at the entrance to pig housing areas with disinfectant solutions at entrances to pig housing to minimize disease spread

5.4.2 Simple Infrastructure Improvements

- Physical Barriers: By utilizing locally available resources and materials, simple physical barriers or fencing can be installed to control the movement of pigs and prevent contact with wild or stray animals.
- Separate Zones: Designate specific areas for different activities such as feeding, housing, and waste management to minimize cross-contamination.
- Rodent Control: Use simple measures like sealing holes and keeping areas clean to control rodent populations that can carry diseases.

5.4.3 Essential Feed and Water Safety Management

- Proper Storage: Store feed in sealed, rodent-proof containers to prevent contamination. Avoid using feed that could be potentially contaminated with ASF.
- Clean Water Sources: Ensure that water sources are clean and free from contaminants. Regularly clean and disinfect water troughs.

5.4.4 Animal Health Management

- Regular Observations: Monitor the health of pigs daily for signs of illness, and promptly isolate any sick animals to prevent disease spread.
- Quarantine New Pigs: Quarantine any new pigs before introducing them to the existing herd to prevent introducing potential diseases.
-

5.4.5 Waste Management and Hygiene Practices

- Proper Disposal: Use composting or deep litter methods to manage pig waste, ensuring that it is kept away from pig pens and feed areas to minimize contamination.
- Secure Disposal: Dispose of dead pigs in a manner that prevents disease spread, such as burying them at a safe distance from the farm or using incineration if feasible.
- Pest Management: Control flies and other pests that could contribute to disease spread through simple management practices.
  -

5.4.6 Basic Disinfection Facilities and Practices

- Daily Cleaning: Regularly clean and disinfect pig pens, feeding troughs, and water sources using locally available cleaning agents like vinegar or diluted bleach.
- Routine Disinfection: Establish a routine for disinfecting equipment, housing, and farm infrastructure with available disinfectants.

5.4.7 Simple Records Keeping

- Record Keeping: Maintain detailed records of pig health, feed consumption, and any treatments administered. This helps in early detection of potential outbreaks.

5.4.8 Education and Training

- Knowledge Sharing: Educate yourself and your farm workers about ASF and best practices in biosecurity through free online resources, local agricultural extension services, or community groups.
- Community Involvement: Engage with local farmer groups to exchange knowledge and experiences on biosecurity measures. Participate in local farmer groups to share knowledge and experiences regarding biosecurity measures.

6. CONCLUSION

This study highlights the critical need for tailored biosecurity measures to address the threat of ASF in Bhutan, particularly within smallholder pig farming communities. The findings underscore the importance of localized strategies that consider the unique socio-economic conditions and challenges faced by Bhutanese farmers. By developing a Biosecurity Index and identifying gaps in current practices, the study provides a foundation for targeted interventions that are both economically viable and socially acceptable. The recommendations put forth aim to enhance biosecurity infrastructure, improve farmer education, and strengthen regulatory enforcement to prevent and control ASF outbreaks. These measures are vital for safeguarding the livelihoods of smallholder farmers and ensuring the sustainability of Bhutan's pig farming sector. Further, wherever possible, farmers should take an active role in controlling and preventing ASF on their farms by adopting self-managed, sustainable practices that are locally manageable and cost-effective, without always relying on external funding or government support.

While external funding or government support for certain Biosecurity interventions are vital, concerted efforts must also be made by the farmer to control and prevent ASF in their farms through an intrinsic effort, whereby farmers should focus on self-managed, sustainable practices that are locally manageable, cost-effective and do not have to depend on external funding or government support.

As the country moves forward, continued collaboration with international partners and proactive support from organizations like FAO, WOAH, and other international partners will be crucial in building resilience against ASF and securing the future of pig farming in Bhutan.

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