Semi-quantitative risk evaluation reveals drivers of African swine fever virus in smallholder pig farms and gaps in biosecurity, Tanzania

Folorunso O. Fasina (folorunso.fasina@fao.org)
Food and Agriculture Organization of the United Nations
Niwael Mtui-Malamsha
Food and Agriculture Organization of the United Nations
Hezron E. Nonga
Ministry of Livestock and Fisheries
Svetlana Ranga
Ministry of Livestock and Fisheries
Rosamystica M. Sambu
Ministry of Livestock and Fisheries
Jerome Majaliwa
Ministry of Livestock and Fisheries
Enos Kamani
Tanzania Veterinary Laboratory Agency
Sam Okuthe
Food and Agriculture Organization of the United Nations
Fredrick Kivaria
Food and Agriculture Organization of the United Nations
Charles Bebay
Food and Agriculture Organization of the United Nations
Mary-Louise Penrith
University of Pretoria

Article

Keywords: African swine fever, biosecurity, risk driver, facilitator, ASF transmission

Posted Date: May 10th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1508068/v2

Abstract

African swine fever (ASF) has remained persistent in Tanzania since the early 2000. Between 2020 and 2021, twelve districts in Tanzania were infected with ASF, and ≥ 4,804 pigs reportedly died directly due to the disease with disruption to livelihoods. We conducted semi-quantitative field investigations and rapid risk assessment (RRA) to understand the risk factors and drivers of ASF virus (ASFv) amplification and transmission in smallholder pig farms, and determine the gaps in biosecurity through hazard profiling, focused group discussions and experts' opinions. Outbreaks were connected by road and aligned along the pig product value chain and reported in the northern, central and southern parts of Tanzania. The patterns of outbreaks and impacts differed among districts, but cases of ASF appeared to be self-limiting following significant mortality of pigs in farms. Movement of infected pigs, movement of contaminated pig products and fomites associated with service providers, vehicles, and equipment, as well as the inadvertent risks associated with movements of animal health practitioners, visitors and scavengers were the riskiest pathways to introduce ASFv into smallholder pig farms. Identified drivers and facilitators of risk of ASFv infection in smallholder pig farms were traders in whole pigs, middlemen, pig farmers, transporters, unauthorized animal health service providers and the traders in pork. All identified pig groups were susceptible to ASFv, particularly among shared adult boars, pregnant and lactating sows and adult female. The risk of ASF for smallholder pig farms in Tanzania remains very high based on a systematic risk classification. Majority of the farms poorly implemented biosecurity and no single farm implemented all the identified biosecurity measures. Risky practices and breach of biosecurity in the pig value chain in Tanzania are profit-driven and are extremely difficult to change. Behavioural change communication must target identified drivers of infections, attitudes and practices.

Background

African swine fever (ASF) remains an important pig disease globally in view of its rapid spread, economic impacts and food implications, with no option of vaccination or treatment. Tanzania probably has a long history of ASF, because in the first published description of ASF [1], in addition to the outbreaks in settlers' pigs in Kenya, the author reported receiving a letter from the Chief Veterinary Officer of Tanzania (then German East Africa) describing two outbreaks of what he believed to be ASF in pigs in that country. Tanzania was also the first country in which ASF was first reported from ticks of the *Ornithodoros moubata* complex collected in animal burrows frequented by warthogs [2]. Confirmed ASF in domestic pigs was first reported in Tanzania in 1962 [3], and since that period, outbreaks continue to occur in Tanzania periodically. However, as from the early 2000, it will appear that the frequency and intensity of ASF occurrence in Tanzania has increased considerably (Fig. 1), and many foci of regular infections have been established in the major pig producing areas of Tanzania. Particularly, since the year 2010, incidences of ASF have taken a dramatic turn following a major outbreak that started in Kyela, Mbeya region, and, which again occurred in 2012 [3, 4]. In 2013 an unrelated focus of the disease was detected in the Northern Highlands region of Kilimanjaro which later spread to the Arusha region. Since that period, ASF has more or less persisted as an endemic disease with annual cycles of infection in Tanzania.

Based on retrospective analysis and trace back data, the outbreak of ASF in 2020–2021 started with some sporadic incidences of ASF in the Katoro Ward of Geita District council in June 2020. This later spread to Geita Town council by July 2020, and this was officially notified to the National Epidemiological Unit of the Directorate of Veterinary Services, Ministry of Livestock and Fisheries (DVS-MoLF). The disease was later introduced to, and disseminated in the neighbouring districts of Mbogwe DC, Sengerema and Kahama Municipal Councils (Fig. 2).

There was a period of quiescence between July and early November 2020, and whether this was due to absence of cases or no report from the farmer was not established. The disease was again reported in early November 2020. In total, between March 2020 and March 2021, twelve Local Government Authorities in the regions of Mwanza, Geita, Shinyanga, Kagera, Dodoma, Mbeya and Iringa reported outbreaks (Fig. 2). At least 4,804 pigs were reported to have died directly due to the disease in the affected regions by 29th March 2021 in Tanzania.

Initial supports to the subnational animal health authorities included intensive awareness campaigns using risk communication and community engagement (RCCE) strategies and laboratory diagnosis. Additional support was provided to the Government of the United Republic of Tanzania by the Food and Agriculture Organization of the United Nations (FAO), including support to conduct additional field investigations, rapid risk assessment (RRA), data collection for socioeconomic evaluation and scaled up RCCE.

To conduct the comprehensive risk assessment for the ASF epidemiological situation in high-risk districts of the country, and identify the plausible risk factors and drivers that amplified or facilitated the transmission in the ongoing outbreaks, a triaging process was undertaken with a threshold of 7/14 score to justify or negate the follow-up field activities (Supplementary Fig. 1, Supplementary Table 1) [5]. In addition, the teams were established, hazard was profiled, risk questions were formulated, data collection and literature review were conducted and the process was reviewed through experts' opinion as per the established protocol for rapid risk assessment [5].

Materials And Methods

Field data collection, sampling and laboratory analysis

Using a snowballing method, field data collection was done using qualitative participatory approaches including key informants (KIIs), focused group discussions (FGDs), visualization/observations and transect walk with stakeholders in the value chain, and expert knowledge elicitation (EKE). A combination of semi-structured interviews and predetermined checklists were utilized for data gathering. Exhaustive literature review was also conducted to explore missing data that are available from relevant peer-reviewed publications from PubMed, Google Scholar and available grey literature.

Furthermore, the secondary data on timelines of outbreaks, mortalities and estimated cost implications were obtained from the District Veterinary Officers (DVOs) of the infected districts. Through the KII and FGD, risk pathways were developed, including the identified risk factors (release / entry of the disease, the exposure / transmission and transmission of the pathogen (hazard)) in the outbreak areas. During the field data collection, biological samples (spleen, mesenteric and gastro-hepatic lymph nodes) from sick or dead pigs, or from stored samples at the Zonal Veterinary Centers were obtained and dispatched to the African swine fever (ASF) laboratory at the Sokoine University of Agriculture (SUA), Morogoro, or the Tanzania Veterinary Laboratory Agency - Centre for Infectious Diseases and Biotechnology (TVLA - CIDB), Temeke, Dar es Salaam, Tanzania. ASF laboratory diagnosis was based on the partial amplification of major structural protein VP72 gene of ASF virus (ASFV) as previously described [6, 7].

Self-rated biosecurity assessment

For the purpose of assessment among smallholder pig farmers, biosecurity, which refers to measures taken to minimize the risk of introduction of new pathogens into or outside the farm premises, was grouped under three elements viz segregation, cleaning and disinfection [8]. It consists of: 1) Bio-exclusion (external biosecurity), which involves the prevention of the introduction of new diseases into a farm animal population from an outside source). Practices such as gates at entry, observation of downtime, documented entry/exit into the farm, showers, quarantine barns, inlet filters, where feasible, decontamination and changing rooms, feed supply from outside the farm alone over the fence, transportation biosecurity, etc. constitute the above. 2) Bio-containment, which is the keeping in of extremely pathogenic organisms (such as viruses, bacteria and others) through internal isolation, farm-level best practices and such ideals in the secure facilities within the farm as a way to prevent their inadvertent or accidental release into other farms and facilities; and 3) Bio-management, which is the application of theory, principles and practices of hygiene protocol aimed at reducing the risk of disease transmission in a farm and to other farms. Within this context, a 25-item biosecurity checklist was prepared based on biosecurity measures protective against ASF with potential for uptake among smallholder and small commercial confined production. This checklist was used to capture farm-level compliance on biosecurity measures (Supplementary Table 2).

Expert opinion/Expert knowledge elicitations

Based on the subjective but specific information (data, facts, arbitrary, anecdotal information, etc.) gathered from the value chain actors, an expert knowledge elicitation (EKE) was used to validate the knowledge and provide additional judgements (probabilities, estimates, etc.) based on experts' experience. To implement EKE, a total of 25 people were invited through an independent email (facilitated Delphi survey), but 19 experts responded (76% response rate), including 12 national and seven international experts from the field of infectious diseases, epidemiology, animal health, border vigilance and epidemio-surveillance. In this study, an expert is defined as a person with at least five years of field or clinical experience related to African swine fever, or significant peer-reviewed publications in the field of African swine fever (the list of experts is available on request). A set of six questions was provided to this pool of national and international experts through an email post. The list of variables that formed the questions originated from issues previously identified by the stakeholders during the KII, and FGD. Responses to questions 1–3 were provided through a rank order scaling system, while questions 4 and 5 were through a Likert scale score (1–10) (Supplementary Tables 3–6; Supplementary Figs. 2–3). For question 6, a pool of opinions was provided to which the expert can add or remove with empirical reasons for the decision. Each expert independently responded to the questionnaire. All responses were entered into Microsoft Excel 2016® spreadsheet for filtering and analysis.

To reduce the effects of experts' personal and subjective views and own beliefs, Delphi opinion survey's analysis was conducted through consensus or mathematical aggregation of experts' estimates until a general agreement was reached after two rounds of surveys. Mean scores obtained were utilized to triangulate original information gathered through the field data collection.

Identification of hazard and its potential pathways

Based on the qualitative risk assessment method, all potential risk contributors, drivers and factors were identified and listed. The pathways of exposure and transmission were mapped with local field experts, and the estimates and risk levels were done using the experts' opinions. The categories of risk for introduction of ASF to smallholder pig farms were the fomites to pig, feed to pig, by products to pig and pig to pig. The wild boar to pig, ticks to pig, as well as environment to pig were the lowest ranking factors. In northern Europe, where wild boars die of ASF and their carcasses contaminate the environment, if these carcasses are not rapidly removed, it help to keep the infection going, the ticks to pig cycles are either related to warthogs or to ticks that live in pig sties, as described in Malawi (Supplementary Fig. 3). The plausible measures aimed at risk reduction were identified for each of the pathways (Supplementary Table 6). The risk analysis was based on the broad pathways evaluated during the mission for the possible entry of the disease into Tanzania, dissemination within the country and the further spread to contiguous countries.

Furthermore, using ASF as the current hazard, the risk of introduction, intra and inter-farm transmission (spread) of African swine fever within Tanzania's smallholder farms and from across the border were classified through experts' consensus opinions. In addition, the risk of hazard among the groups of pigs in the farm (adult shared boars, non-shared boars, pregnant sows, adult female, growers, porkers, weaners and piglets) was compared.

Statistical Analysis

Descriptive statistics and other analyses were conducted using Microsoft Excel 2016® spreadsheet. Briefly described, variables were listed in the order in which they appeared on the questionnaire. Ranks, as provided by the experts were listed against the ordered variables. Frequency tables were created to determine the number of times each variable was ranked from 1–15), and the rank frequencies were determined using the function "=COUNTIF($Range,$Criteria)" on the spreadsheet. The sum of rank frequencies was determined for the rows and columns using the function "=SUM(Range)". This process was repeated for each variable. On a separate sheet, a tabulation was made by transposing the variables on the column against the ranks on the on the rows. Using the transposed results, the total scores for the ranks were obtained by calculating the total points for each row (Rank 1*15 + Rank 2*14 + Rank 3*13 ………….. Rank 15*1). The final mean rank for all experts was obtained by using the function "=RANK(deposition,$Range) (https://www.youtube.com/watch?v=eza1XbeD2Hc).

For question 4–5, interrater agreement between foreign and local experts' scores were calculated using the modified method of Landis and Koch [9], and Beck et al., [10]. Briefly, mean scores of local and international experts were obtained for each question, and the disparity from full score was calculated, e.g. (10.0–9.33 = 0.67). Using the online Cohen's Kappa calculator (https://www.graphpad.com/quickcalcs/kappa1/?K=3), the mean scores and the disparity from full scores were entered into the appropriate cells to generate the Kappa scores, standard errors and the 95% confidence intervals.

Ethical approval and consent to participate

This study was fully approved by the Government of Tanzania under the project code GCP/GLO/074/USA. No human participants, data or tissues were involved. All experimental protocols were approved by the review Committee of the Ministry of Livestock and Fisheries, Tanzania, with the approval number MA 154/355/16. All methods were carried out according to the relevant guidelines and regulations [11]. All participants gave informed consent and willingly signed the consent register independently. They were also informed of their right to withdraw participation at any stage of the study.

Results

In total, we conducted 45 key informant interviews, 34 focus group discussion and 19 expert opinion elicitations covering five regions and nine districts. The key issues that arose from the discussions include the following:

Spatio-temporal and epidemiological data

Based on our field mission, discussion with stakeholders involved in the pig and pig products value chain in Tanzania, ASF had been reported in 12 district councils between March 2020 and March 2021 (Table 1). These outbreak locations covered an area from the extreme north-west part of the country through the central part and from the southern part of the country (Fig. 2, Table 1). The majority of the outbreak locations were connected by road and are aligned along the pig and pig product value chain in Tanzania. Outbreaks in the lake zone were reported from Sengerema DC, Geita DC, Geita TC, Mbogwe and Kahama Municipal council. In addition, the districts of Ngara, Muleba, Chamwino, and Dodoma municipality ave reported outbreaks (Table 1). Other district or municipal councils with outbreaks but were not covered in the current investigation include Mpwapwa, Kyerwa, Misungwi, Mbeya, Busokelo, and Iringa, mainly in the southern axis of Tanzania. The patterns of outbreaks and impacts differed from one district to the other with some wards reporting up to 100% mortality and over 80% of the pig farming households directly affected with ASF through farm-to-farm infections. All clinical-pathological samples (n = 12) submitted to the laboratory were confirmed by PCR using the vp72 gene of ASFV. In the visited district councils, cases and deaths associated with ASF appeared self-limiting following significant mortality of pigs in farms or emergency sale of apparently healthy pigs to reduce farm-level losses. Using the historic outbreak reports (2003–2013) to model from 2014–2021, our modeled estimated number of outbreaks was in excess of 230 farm-level infections (Fig. 1). As at the time of compiling this outbreak report (16th May 2021), a total of 79 farm-level infections have been reported. The national and subnational veterinary authorities put quarantine in place during the active outbreaks, but such quarantines were lifted in batches in selected districts following the end of outbreaks and no report of a new case for a period of at least 28 days. Furthermore, the urban and peri-urban districts have relatively higher numbers of animal health officers compared to the more rural districts (Table 1).

Hazard classification, risk pathways, risk factors, contributors and drivers

Based on stakeholder identification and experts' opinions, movement of infected pigs, movement of contaminated pig products and fomites associated with service providers, vehicles, and equipment, as well as the inadvertent risks associated with movements of animal health practitioners, visitors and scavengers were the riskiest pathways to introduce ASFv into smallholder pig farms in Tanzania (Table 2, Supplementary Table 7). Similarly, the laboratory personnel, arthropods (flies, ticks and Stomoxys), infected live pigs imported through the formal routes and manure and beddings are the least likely risk pathways to introduce ASFv into smallholder pig farms in Tanzania (Table 2, Supplementary Table 7). In terms of drivers and facilitators of risk of ASFv infection in smallholder pig farms, traders in whole pigs, middlemen, pig farmers, transporters, unauthorized animal health service providers and the traders in pork are the most important drivers and facilitators identified (Table 3, Supplementary Table 8). The least risky facilitators include feed manufacturers, wild pig hunters, police and other enforcement officers and the border control officers. Finally, based on experts' opinions, the risk of ASFv is relatively high in all farmed pig groups, but are particularly high among the shared adult boars, pregnant and lactating sows, adult female, non-shared adult boars and growers. The weaners, piglets and the porkers are less likely to be infected but may still die from consequences from other pig groups. For instance, it was reported that piglets often die due to starvation associated with the death of their dams (Table 4, Supplementary Table 9). Overall, using the stakeholder consultations (KII and FGD), and the experts' opinions, the risk of ASF for smallholder pig farms in Tanzania was considered very high based on a systematic risk classification (Fig. 3). The mean agreement score was 9.6 ± 0.7, and the Kappa inter-rater agreement score was 0.90 ± 0.10 (95% CI: 0.88–0.92).

Place Table 3 here

Farm-level biosecurity evaluation

Based on the 25-item biosecurity checklist,, approximately 82.9% (29/35) of all respondents' farms implemented up to 10 of the items listed, 8.6% (3/35) implemented between 11 and 15 items and only 5.7% (2/35) implemented 17 out of the 25 item checklist (Fig. 4). No single farm implemented all the 25 measures in the pig farm. While these scores are based on a checklist, observation and in-depth queries during the KII and FGD raised the questions on whether the measures were applied regularly (constantly) or just periodically (episodically). Using the farm-level evaluation of the 25-item score on specific biosecurity measures implemented in 35 pig farms, the mean score for all premises evaluated was 29% [(n = 7/25 measures) (min = 12% (n = 3), median = 24% (n = 6), maximum = 68% (n = 17)). It is noteworthy that only two farms implemented 17 of the 25 biosecurity measures, and only three farms exceeded 50% of all biosecurity measures implemented. These findings have implications for increased infection risks for animal diseases (Fig. 4).

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Discussion

Disease reporting, epidemio-surveillance, value chain and implications for amplification of inter-farm, inter-district and national spread of ASF in Tanzania

Immediate incidences of diseases are reported by farmers to the field extension officer (EO), agricultural officer (AO) or livestock field officer (LFO), or where these are not available, to the village or ward executive officers (VEO or WEO), who in turn report to the responsible district veterinary officer (DVO). The shortfalls in number of staff needed at district levels sometimes have implications for the effectiveness of delivery of animal health services including reporting and timely responses (Table 1). Sometimes, the delayed reporting by the farmers increased the intensities and impacts of the outbreaks and this influences the morbidity and mortality rates. The plausible explanations for this delay include inadequate staffing at wards level, poor knowledge regarding the disease by field staff, resorting to self-help by farmers, as well as poor knowledge of biosecurity, the hazard, and its transmission pathways among the farmers. For instance, in some districts under investigation, farmers indicated to have administered pen-strep, tylosin or other antibiotics, and only reported later to the official authorities when no positive response was obtained. Oftentimes, on receipt of reports, the DVOs conduct clinico-pathologic examination, report to the Directorate of Veterinary Services, and liaise with the relevant zonal veterinary centres and Zonal veterinary laboratory under the TVLA for sample collection. These facilities have competent manpower and medium-level resources for sampling but may not be effective for confirmatory diagnosis of ASF, often due to lack of reagents and consumables. With the introduction of Event Mobile Application (EMA-i) in over 60% of LGAs in Tanzania, the quantity and quality of animal disease reports have improved as the DVOs can interconnect and undertake near real-time reporting electronically. In the current evaluation, approximately 66.7% of the districts under investigation have submitted recent ASF reports through the EMA-i applications within weeks of outbreaks.

With regard to awareness, the field officers, pig farmers, butchers/traders and many of the stakeholders could clearly describe ASF symptoms and clinical signs, a useful attribute for epidemio-surveillance. However, the knowledge of infection and transmission varied widely among work groups, best among the veterinarians and the animal health/livestock field officers, medium to high among the extension and agricultural officers, medium among the farmers, traders and butchers, but medium to poor among the ward and village executive officers [12, 13].

Inter-district complementarities in movement restrictions during outbreaks are often lacking among contiguous districts and regions. For example, when quarantine was imposed in an infected district during the period of intense outbreaks, it was initially in the affected wards only, however, because the compliance level was poor, such quarantines were often extended to cover the whole district, yet inter-district movement sometimes occurs from non-infected districts into infected districts and vice versa. Typically, the non-infected districts have no quarantine imposition and no border vigilance, primarily because of the overstretched workforce. Similarly, intra-district, multi-district distribution and international cross-border movements, particularly to the large livestock markets and slaughter slabs are depicted by the DVOs in charge in each district (Supplementary Figs. 4–6).

The smallholder farmers sourced their pigs from within their immediate wards, districts, regions or from distant districts. Some purchase directly from nearby livestock markets or from the traders who purchase pigs for slaughters. These farmers, particularly those who live in border towns and villages sometimes source pigs from Burundi, Rwanda, Uganda and Kenya but also from Zambia, Malawi and Mozambique.

There exists an official movement and import permit system, however, farmers and traders sometimes evade the official systems by moving the pigs and pig products across intra-national and international borders in the night and at odd hours. Due to the extensive stretch of Tanzania's borders, it is difficult to effectively police, or carry out effective vigilance and surveillance duties due to limitations in available manpower in the government system. In addition, the stakeholders most often do not seek professional guidance ahead of purchase, and the traders and butchers sometimes intentionally or inadvertently buy infected pigs, which are sold much cheaper (between 20 and 50% of the normal trade values). Similar observation has been reported from earlier works from Vietnam [14]. Furthermore, there is a tendency for traders/butchers to source pigs for slaughter from Burundi and Rwanda, and neither these traders nor farmers do isolate the new arrivals.

Identified drivers and risk factors

Upstream water source

A good number of the smallholder farmers depend on water from streams as drinking source for their pigs, and for washing the pig houses/pens and equipment, and the run off goes back to the stream. This consequently regularly contaminates the stream, especially if any of the farms along the stream are infected. This phenomenon was clearly demonstrated in Sengerema as well as Geita where following ASF infections in the upstream farms, the ASF infection spread down streams and affected other pig farms. Similar observation was earlier noticed in the Southern Highlands through contaminations from slaughter slabs upstream, which later flow downstream towards Lake Nyanza [4]. In some areas, such as Mabatini in Mwanza, and in the city centres such as Dodoma, smallholder farmers have abandoned the use of water from the streams and rather utilize piped or well water, following infections from the previous outbreaks of 2017; anecdotal evidence pointed to causation between the contaminated waters and ASF infection of pig farms. The possibility of carcasses being thrown into streams, thus creating heavy contamination and a source of infection is not impossible. A high oral dose is needed to produce infections in pigs, which is plausible for streams with low volumes of water, which are receiving a lot of run-off from farms and slaughter slabs. With large rivers, the source of infection is more likely to be carcasses that wash up on the banks and are feasted upon by scavenging pigs. In our evaluation, most commercial farmers constructed and use boreholes and treated water for their farms.

Slaughter slabs/areas

There are no appropriate handling and slaughter facilities for pig farmers and traders to take their animals for slaughter. Neither has any standard design been constructed as a proof of concept for the farmers and other stakeholders. In addition, because many communities have a significant number of Muslim populations, the construction of pig slaughter facilities cannot be combined with that of other livestock species, and such facilities must be constructed in societally acceptable locations. Given the foregoing constraints, pigs are slaughtered mostly in poor, unhygienic or decrepit slaughter slabs, often located within the pig farms, or in some distant location. Selected numbers of stakeholders have made personal efforts to improve the standard of the slaughter slabs but these facilities still lack the necessary equipment and tools expected for a standard abattoir facility. Pigs slaughtered in these slabs come from various sources within the different districts, or from other districts, and as far as from outside the country. In case of illegally imported animals, efforts are made by farmers and traders to mix them with the owned stock within the farms as decoys to evade confiscation and destruction of untested but imported pigs. Most of these slaughter slabs lack disposal pits and are not fenced hence easily accessed by dogs and free-roaming pigs.

Selected farm management practices

a) Sharing of boars

Most farmers tend to hire/borrow boars from fellow farmers during breeding. A farmer in one of the investigated districts hypothesized that her sows were probably infected from the neighboring farm. Following the dispatch of her sow to the other farm for mating, and the observation of pig deaths in the other farm, she retrieved her sow and return same to the farm. In total, she lost 14 sows, 7 growers and 44 piglets and had only six survivors left. Similarly, Muleba alone experienced 101 incidences of ASF outbreaks. Following traceback, it was concluded that the outbreaks in Muleba started from a ward where a farmer brought in a boar from another district for the purpose of genetic diversity and improving his productivity (mating). The imported boar became morbid and was slaughtered and shared in the community. Thereafter, disseminated outbreaks of ASF were reported in many wards in Muleba. At least 24 of the interviewed persons identified the practice of sharing of boar as a high risk activity that contributes significantly to spreading ASF in pig farms.

b) Unrestricted inflow and outflow of people/animals with lack of biosecurity measures

Many pig farms lack adequate fencing or are unfenced making them easily accessible to visitors, scavenging animals (dogs, cats and rodents) or stray pigs. In addition, pig traders and farm gate buyers move from one piggery to another and from pen to pen when selecting potential pigs to purchase for redistribution or for slaughter. Sometimes, these farm gate buyers, traders and butchers, who operate without observing biosecurity protocol, inadvertently serve as sources of infection through intra-district pig mobility, carriage of fomites in their shoes, clothes, knives or other tools/vehicles, on in the process of multi-sourcing of pigs from farm to farm. In addition, the inter-district and transboundary movements of people and pigs end up in farms with high possibility of inadvertent infection of farm with ASF virus. Furthermore, hardly any footbath, change of clothing and gumboots usage was observed (Fig. 4). Because most of the buildings for smallholder farms were constructed with wooden materials or scrap metal with concrete or earthen floor, it makes thorough cleaning and disinfection very difficult. Such conditions expose the pigs to risk of infection with viral, bacterial, fungal and parasitic diseases.

c) Waste disposal

None of the farms visited had a standard waste disposal pit for infected carcass and secured farm manure management. In addition, no slurry pit was sighted for the collection of solid waste mixed with liquid and these just flow freely in the gutters outside the pigpen. It was observed that many of the farms throw the manure over the pen or over the fence with predisposition to contaminate the environment. Such practices also attract more scavengers and rodents into the farm premises thereby increasing the risk of introduction of animal diseases.

d) Humans as virus spreaders (Animal attendants, farm managers, farm owners, para-veterinarian and veterinarians)

In most smallholder farms, the farm attendants, typically one per farm, are hardly trained in the good farm management practices that should provide efficient pig management and welfare to the pigs, but they are expected to gather experience in the course of farm management. These attendants serve all the pig pens, and in most cases do not observe the systematic movement protocol of going from the young to older animals, or hardly practice any biosecurity principles. Hence, the risk of random introduction of animal diseases and transmitting them within the farm is high. In addition, farm managers and owners often used their positions to invite visitors to visit their farms. These visitors are in most cases persons with interests in animal farming, and have high potentials for inter-farm introduction of diseases. Farm-gate buyers, traders, butchers are also invited by farm managers to select pigs as mentioned above. During epizootics and animal health crises like the widespread outbreaks of ASF, para-veterinarians and veterinarians are often invited to provide animal health services. Due to the shortage of these categories of workers in the peri-urban and rural areas, as well as shortfall of resources, these individuals often have to move from farm to farm rationing biosecurity-related materials like instruments and disinfectant, and may inadvertently transmit infection to new premises. Human activities (anthropogenic factors) have been identified as critical to the long-distance jumps of ASF introduction to new premises [4, 12, 14, 15]. For instance, the transport of contaminated meat or meat products, which may end up as waste or kitchen leftovers for feeding pigs, the purchase and introduction of untested boars, the transboundary informal purchase of new pigs and subsequent mixing with the local stock in order to evade confiscation all pose extreme risk of introduction of the hazard, the ASF virus.

e) Farm-level and community-level biosecurity

Based on our evaluation, only 5.7% of the smallholder pig farms practiced approximately 68% (17/25) of all identified biosecurity items, and not a single farm implemented all the 25 item measures in their pig farm. It should be understood that a breach in biosecurity protocol, particularly at a period when the farm is at a high risk of infection, or in an overwhelming endemic condition, can eliminate all the gains and hard work put into biosecurity implementation before the breach.

Trans-national, cross- border and country-level risks of ASF entry, re-introduction and exposure

Pig movements across the United Republic of Tanzania is random and diffuse, and long distance animal movements are observed along the primary and secondary roads [4]. Within-village movements are done by trekking the pigs on foot or on bicycles. However, the other forms of movements rely on motorcycles, tricycles, and motor vehicles (small vehicles and trucks). In this work, we clearly identified five patterns of movements for pig and pig products including the following:

1. Inter-ward/inter-village movements within a district.
2. Inter-district and trans-district movements across contiguous or distant districts, and from region to region.
3. Trans-boundary movements across national borders, particularly with Burundi and Rwanda in the north, and from Zambia, Malawi and Mozambique to the South, but also from Uganda and Kenya.
4. Farm → open market → abattoir/slaughter slab → Farm.
5. Farm → Farm.

The value chain, marketing and trade systems closely drive these pig and pig-products movements with many forms of sale practices: formal, informal, farm-gate and random types. These movement patterns have huge implications for disease introduction and transmission. Traders, marketers and farm-gate buyers move among farms without observing any biosecurity protocol with consequent biosecurity breaches. They often move with their potentially contaminated tools, knives, shoes, clothes, vehicles, and restraining materials. In a few instances, formal movements may prevail, wherein pigs and their products are subjected to physical clinical examination and or laboratory testing, but the largely informal movements utilized unscrupulous means to evade veterinary authority detection through night and unofficial periodic movement, through unpatrolled border areas and through smuggled pig products from across national and international borders. A key informant from Burundi (through a phone call across the border) indicated as follows:

'ASF will never stop circulating in the sub-region unless a regional approach at tackling the disease is implemented'.

He confirmed that cheaper pigs, which are a regular occurrence during outbreaks, are traded across borders freely and there are not enough officials to manage intra-national and cross-border animal health, surveillance, border vigilance and disease control along the extensive borders. Hence, the cross- border and country-level risks of ASF entry, re-introduction and or exposure from neighbouring countries remain very high.

Almost all of the farm management practices listed are anthropogenic factors, since these are human-driven factors. Similar factors were recently found in Uganda in the work of Aliro et al. [13]. In other instance, humans act directly as vectors of the virus, hence an intensified risk communication and community engagement, as well as behavioural change to target the identified anthropogenic factors should reduce the burden of ASF [13]. While the ongoing transmission in the 1) wild boar populations, 2) the wild boar – environment cycle and 3) the tick to pig transmission cycle, which cannot be linked to any specific human practice or activity are examples of non-anthropogenic transmission; the large jumps of ASF from distant infected wild boar populations to uninfected wild boars hundreds or thousands of km away, and the situation observed in the current outbreaks in Tanzania, are definitely anthropogenic [16].

Consequences of the outbreak and its socio-economic importance to the pig industry, including identification

Among the individual stakeholders interviewed, the majority (86%) had experienced ASF in their herds between June 2020 and February 2021, most of the respondents have lost between ≤ 95% and 100% of their stock due to ASF. The salvaged pigs were sold rapidly or slaughtered to recover approximately 25–30% of the normal market values; sometimes the young ones (piglets and weaners) were recovered and kept as replacement stock. There are deficiencies in the knowledge of transmission, mitigation measures and application of biosecurity in order to reduce the risk of infection. The farmers have lost businesses including 1) the loss of supply of pork to a niche market in the mining sector, 2) loss of major sources of income and livelihoods, 3) loss of food security and ability to support the family by providing funds for school/college fees and hospital bills and constructions in the homes. Narrating his experience, a farmer stated as below,

‘*The children are back from school/college for the Easter break and I am disturbed and heartbroken; my pens are empty and I have lost everything. In total, I have lost as much as TSh 80 million (≈ US$ 34,500) based on the scale of my operations*’.

A mission farm, which is supporting a popular community health program through the money accrued from the sales of live pigs and pig products, and which supplied multiplier herds to smallholder farmers and reaching ≈ 1,000 farm families in remote settings of Ngara, lost approximately 98% of the herd. Another farmer lost over 400 pigs, and in another instance, a farmer withdrew two children from educational facilities (one in the university and another in the secondary school). Stakeholders, particularly farmers were sentimental and expressed negative emotions against the authorities, whom they perceived to have left the stakeholders to their woes. The government will need to consider a reorganization of the pig farming system and associated value chain in order to mitigate risks associated with ASF.

Information and knowledge gaps

Due to the shortage of animal health staff, agriculture officers (AO), extension officers (EO), Ward Executive Officers (WEO) and Village Executive Officers (VEO) sometimes double in their roles of administration and issuing animal movement permits and attending to other animal health matters. These roles are often undertaken without relevant animal health training, hence the gaps in awareness and knowledge of ASF were obvious. Farmers indicated that such officers sometimes promote and advise on the treatment of high fever using penicillin-streptomycin, sulphur-based antimicrobials, tylosin and multivitamins. In addition, the border control staff and officers certify animals crossing the official borders while collecting revenues for the government. The FGD and KII revealed that many of such officers were untrained in the matters of animal health despite being tasked with the responsibility of issuing movement permits. A number of these officials interviewed could not identify enough clinical signs, symptoms, and pathological details associated with ASF, and could not list the risk factors or facilitators of transmission. There is a need to develop a training package customized for the need of cross-border animal health service providers.

In addition, the knowledgeable farmers only gained sufficient knowledge based on their own farm experiences of pig farm infections. Many are, however, unaware that neither treatment nor vaccine are available, and of the specific risk factors and the benefits of biosecurity in mitigating ASF risk. Traders confirmed that they prefer to continue to buy cheaply-priced pigs, even though they acknowledge that it may contribute to spreading the disease, which may damage the pig industry. Their motivation was enhanced profit margin. The butchers similarly slaughtered infected pigs, purchased at a take away price from desperate farmers during ongoing outbreaks of ASF thereby contributing to the spread of disease.

Based on the evaluation conducted, it is recommended that:

a. The relevant authorities should consider the designing and building of prototype dedicated and biosecure pig slaughter slabs that reduce environmental contamination. The siting of such slaughter slabs should be decided through consultative process taking note of socio cultural as well as religious considerations of the community and guidance from the environmental authorities.
b. Enforceable by-laws should be in place to forbid homestead or farm-directed movement of adult pigs meant for the abattoirs or slaughter slabs.
c. The knowledgeable animal health officers, especially the DVOs and the LFOs should develop scheduled timetables for training of farmers, traders and other stakeholders on biosecurity, good farming practices, movement and marketing networks that minimise the risk of infection and transmission of ASF. Resource allocation to support such training should be made available from the revenues and fees generated from animal resources within the districts or region, with support from the national government and other stakeholders.
d. The need for training and retraining of regional, district and border officials involved in the animal health services cannot be overemphasised. The training should focus particularly on emergency preparedness and response, as well as disease reporting. This should prevent delay in reporting animal health emergencies at district or regional level and facilitate coordination with the central veterinary system.
e. The issue of inadequate staffing, particularly in the more rural districts should be prioritised and addressed. This has earlier been identified in the findings of the 2016 Joint External Evaluation (JEE) in Tanzania [17]. It should include the conduct of a comprehensive inventory of the animal health personnel in the country and determine the personnel gaps at the national, regional and district levels.
f. The delivery of effective animal health services at district level needs adequate mobilization to respond promptly. The lack of mobility (motorcycles, vehicles and bicycles), identified by the district level officers must be addressed in a phased approach.
g. A comprehensive animal resources evaluation at district, regional and national levels in Tanzania must be undertaken to determine the comprehensive animal dataset, the total economic values, and the inapparent opportunities, in order for the government to generate revenues internally, some of which can be utilised to provide for the need of the animal health services at subnational level.

The authorities may consider the setting up of pig demonstration and training farms, and multiplication centres (breeding centres) in strategic districts/regions in the country. Such centres should be used to provide training on the pig value chain, integrated farm-level biosecurity, good husbandry practices and Good Management Practices (GMP) [18]. It should be understood however, that training on biosecurity practices may positively affect gain in knowledge, but it may have little or no effect on farmers' attitudes and practices [12]. In this study, despite the intensive training on biosecurity, farmers would still allow veterinarians who may not have practiced biosecurity measures into their farms, even during outbreaks, would not restrict visitors from farm visits, not likely to deny traders access to the farms, and the less educated farms are still likely to sell pigs during ASF outbreaks [12]. In the long term, the progressive reorganization of the livestock industry to align with the *Tanzania Livestock Modernization Initiative* and *Tanzania Livestock Master Plan* is imperative [19, 20].

Conclusion

Risky practices and breach of biosecurity in the pig value chain in Tanzania are profit-driven and therefore extremely difficult to change. Aliro and colleagues [13] have similarly reached similar conclusion on why the Ugandan farmers failed to prevent and control ASF in their herds including the following reasons: 1) due to costs associated with biosecurity implementation, 2) the need to prioritise family livelihood over disease transmission risks, 3) the incompatibility of current biosecurity practises with local culture, traditions and social contexts and the lack of access to veterinarians or low-quality veterinary services.

Declarations

Consent for publication

Permission to publish the material was granted by the Directorate of Veterinary Services (DVS), Ministry of Livestock and Fisheries (MoLF), Dodoma, Tanzania.

Availability of data and materials

All data used in the publication are archived with the FAO Tanzania and the DVS, MoLF, Dodoma, Tanzania. Data can be provided on reasonable request to the Director of Veterinary Services, MoLF, Dodoma, Tanzania.

Competing interests

The authors declare that they have no competing interests.

Funding

The Food and Agriculture Organization Sub-regional Office for Southern Africa funded the study through a Technical Cooperation Programme.

Authors' contributions

Conceptualization, F.O.F., N.M.-M., H.E.N., C.B.; methodology, F.O.F., N.M.-M., S.R., R.M.S., J.M., E.K., S.O., F.K.; software, F.O.F., N.M.-M., S.O., F.K., M.L.-P.; validation, F.O.F., H.E.N., F.K., M.L.-P.; formal analysis, F.O.F., N.M.-M., F.K.; investigation, F.O.F., N.M.-M., H.E.N., S.R., R.M.S., J.M., E.K.; resources, F.O.F., N.M.-M., H.E.N., C.B.; data curation, F.O.F., N.M.-M.; writing—original draft preparation, F.O.F., N.M.-M., M.L.-P.; writing—review and editing, All authors; visualization, F.O.F., N.M.-M., H.E.N., S.R., R.M.S., J.M., E.K., S.O., F.K., C.B., M.L.-P.;

supervision, F.O.F., H.E.N., C.B., M.L.-P.; project administration, F.O.F., H.E.N., C.B.; funding acquisition, F.O.F., N.M.-M., H.E.N., C.B. All authors have read and agreed to the published version of the manuscript.

Acknowledgement

We thank Astrid Tripodi and Andriy Rozstalnyy for their technical inputs to work design; Berhanu Bedane is appreciated for facilitating the emergency funds from the Food and Agriculture Organization Sub-regional Office for Southern Africa, in order to target responses; and all experts that responded to the survey and value chain stakeholders who contributed to the datasets used for the analyses.

Authors' information (optional)

Not applicable.

Author details

Folorunso O. Fasina[1,2], Niwael Mtui-Malamsha[1], Hezron E. Nonga[3], Svetlana Ranga[3], Rosamystica M. Sambu[3], Jerome Majaliwa[3], Enos Kamani[4], Sam Okuthe[1], Fredrick Kivaria[1], Charles Bebay[1], Mary-Louise Penrith[2].

[1]Food and Agriculture Organization of the United Nations, Dar es Salaam, Tanzania. [2]Department of Veterinary Tropical Diseases, University of Pretoria, Onderstepoort 0110, South Africa. [3]Directorate of Veterinary Services, Ministry of Livestock and Fisheries, Dodoma, Tanzania. [4]Tanzania Veterinary Laboratory Agency, Temeke, Dar es Salaam, Tanzania.

Email addresses: F.O.F.: folorunso.fasina@fao.org; daydupe2003@yahoo.co.uk; N.M.-M.: Niwael.mtuimalamsha@fao.org; H.E.N.: dvs@mifugo.go.tz; S.R.: sveabba@gmail.com; R.M.S.: mkulamaria54@gmail.com; J.M.: majaliwa.jerome@gmail.com; E.K.: enoskamani@yahoo.com; M.L.-P.: marylouise@vodamail.co.za; S.O.: sam.okuthe@fao.org; F.K.: Fredrick.Kivaria@fao.org; C.B.: charles.bebay@fao.org

References

1. Montgomery RE. On a form of swine fever occurring in British East Africa (Kenya Colony). J Comparative Pathol. 1921;34:159–191.
2. Plowright W, Parker JA, Pierce MA. African swine fever virus in ticks (*Ornithodoros moubata* Murray) collected from animal burrows in Tanzania. Nature. 1969;221:1071–1073.
3. Arza E, Okuthe S, Okoth E. *Rapid assessment for the prevention and control of African swine fever in the Republic of Tanzania*. In Mission Report Submitted to the Crisis Management Centre Animal Health, 2012; FAO-OIE: Rome, Italy, 35p.
4. Fasina FO, Kissinga H, Mlowe F, Mshang'a S, Matogo B, Mrema A, Mhagama A, Makungu S, Mtui-Malamsha N, Sallu R, Misinzo G, Magidanga B, Kivaria F, Bebay C, Nong'ona S, Kafeero F, Nonga H.

Drivers, Risk Factors and Dynamics of African swine fever Outbreaks, Southern Highlands, Tanzania. Pathogens. 2020;9(3):155. https://doi.org/10.3390/pathogens9030155.

5. Food and Agriculture Organization of the United Nations. Technical guidelines on rapid risk assessment for animal health threats. FAO Animal Production and Health Guidelines, 2021a;No. 24. Rome. https://doi.org/10.4060/cb3187en.
6. Bastos ADS, Penrith M-L, Cruciere C, Edrich JL, Hutchings G, Couacy-Hyman E, Thomson GR. Genotyping field strains of African swine fever virus by partial p72 gene characterization. Arch Virol. 2003;148:693–706.
7. Misinzo G, Kwavi DE, Sikombe CD, Makange M, Peter E, Muhairwa AP, Madege MJ. Molecular characterization of African swine fever virus from domestic pigs in northern Tanzania during an outbreak in 2013. Trop Anim Health Prod. 2014;46:1199–1207.
8. Food and Agriculture Organization of the United Nations/World Organisation for Animal Health/World Bank. Good practices for biosecurity in the pig sector – Issues and options in developing and transition countries. FAO Animal Production and Health Paper, 2010;No. 169. Rome, FAO, available at: http://www.fao.org/3/i1435e/i1435e.pdf. Accessed 04 April 2021.
9. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159–174. https://doi.org/10.2307%2F2529310
10. Beck S, Ruhnke B, Issleib M, Daubmann A, Harendza S, Zöllner C. Analyses of inter-rater reliability between professionals, medical students and trained school children as assessors of basic life support skills. BMC Med Educ. 2016;16:263. https://doi.org/10.1186/s12909-016-0788-9.
11. World Medical Association. World Medical Association Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. JAMA. 2013;310(20):2191–2194.
12. Dione MM, Dohoo I, Ndiwa N, Poole J, Ouma E, Amia WC, Wieland B. Impact of participatory training of smallholder pig farmers on knowledge, attitudes and practices regarding biosecurity for the control of African swine fever in Uganda. Transbound Emerg Dis. 2020;67:2482–2493. https://doi.org/10.1111/tbed.13587.
13. Aliro T, Chenais E, Odongo W, Okello DM, Masembe C and Ståhl K. Prevention and Control of African swine fever in the smallholder pig value chain in northern Uganda: Thematic analysis of stakeholders' perceptions. Front Vet Sci. 2022;8:707819. doi: 10.3389/fvets.2021.707819
14. Tripodi A. Risk behaviors and flows along the pig value chain. Presentation at the *National workshop on biosecurity and animal husbandry best practices in support of prevention and control of African swine fever (ASF) in Tanzania*. 2021; 23–24 March, 2021.
15. Chenais E, Depner K, Guberti V, Dietze K, Viltrop A, Ståhl K. Epidemiological considerations on African swine fever in Europe 2014–2018. Porcine Health Management 2019;5:6, https://doi.org/10.1186/s40813-018-0109-2.
16. World Health Organization. Joint external evaluation of IHR core capacities of the Republic of Tanzania: mission report, February 2016; Available at: https://apps.who.int/iris/handle/10665/254510. Accessed 27 February 2022.

17. Food and Agriculture Organization of the United Nations. African swine fever Rapid Risk Assessment Report (Rapid Risk Assessment on African swine fever in the Central and Lake Zone, Tanzania), 2021b; Internal report.
18. Government of Tanzania. Tanzania Livestock Modernization Initiative, 2015. Available at: https://livestocklivelihoodsandhealth.org/wp-content/uploads/2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf. Accessed 01 March 2022.
19. Michael S, Mbwambo N, Mruttu H, Dotto M, Ndomba C, da Silva M, Makusaro F, Nandonde S, Crispin J, Shapiro B. Tanzania Livestock Master Plan (2017/2018–2021/2022). Nairobi, Kenya, 2018. ILRI. Available at: https://www.ilri.org/publications/tanzania-livestock-master-plan-2017-2018-%E2%80%93-2021-2022. Accessed 01 March 2022.
20. European Centre for Disease Prevention and Control. Operational guidance on rapid risk assessment methodology, 2011. Available at: https://www.ecdc.europa.eu/en/publications-data/operational-guidance-rapid-risk-assessment-methodology. Accessed 15 March 2021.
21. Guberti V, Khomenko S, Masiulis M, Kerba S. African swine fever in wild boar ecology and biosecurity. FAO Animal Production and Health Manual, 2019;No. 22. Rome, FAO, OIE and EC. Available at: https://www.oie.int/app/uploads/2021/03/en-manual-asfinwildboar-2019-web.pdf. Accessed 27 February 2022.

Tables

Table 1
Districts and Regions reporting outbreaks and covered during the field investigation and selected district-level statistics related to animal health officials.

Region	**District reporting ASF**	**No of Wards**	**Staffing (involved in animal health issues)**			**Population at risk (pig)**	**Deaths reported due to ASF**	**Mortality rate (%)**
			District office	Ward	Others (ward & village-level)			
			(DVO/ LO/LFO)	LFO	EO, AO, WEO, VEO			
Shinyanga	Kahama	20	1	9	NA	9,328	1820	19.5
Geita	Geita TC	13	2	6	NA	1,328	238	18.0
	Geita DC	37	5	11	NA	564	54	9.6
	Mbogwe	17	1	3	NA	1,567	388	24.7
Mwanza	Segerema	26	1	9	NA	2,591	444	17.1
Kagera	Ngara DC	22	1	12	NA	4,056	400	9.9
	Muleba DC	43	1	19	NA	4,233	105	2.5
Dodoma	Chamwino DC	36	5	17	4	6,120	1214	19.8
	Dodoma Jiji	41	6	30	3	3,161	141	4.5
Total		**255**	**23**	**116**	**7**	**32,948**	**4,804**	**14.6**

Source: DVOs and FGDs March 2020; DVO = District Veterinary Officer; LO = Livestock Officer; LFO = Livestock Field Officer; EO = Extension Officer; AO = Agricultural Officer; WEO = Ward Executive Officer; VEO = Village Executive Officer; TC = Town Council; DC = District Council; NA = Not available. All samples collected during the field exercise were confirmed using the partial amplification of major structural protein VP72 gene of ASF virus (ASFV). In total, 12 districts have reported outbreaks as at the time of field investigation.

Tables 2 to 4 are available in the Supplementary Files section.

Figures

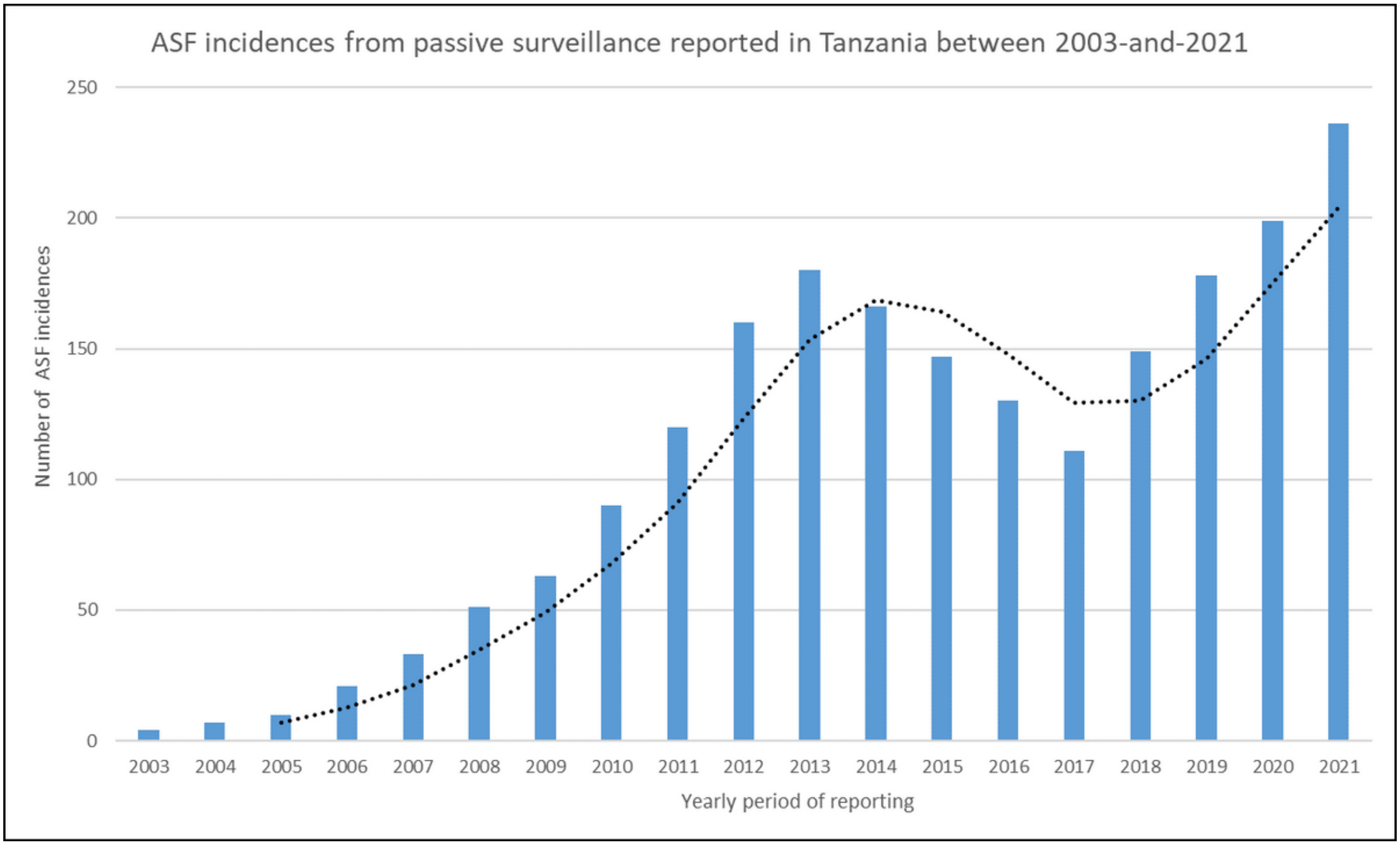

Figure 1

Modelled Epidemic curve of African swine fever introduction and transmission in the United Republic of Tanzania, 2003 to 2021, based on pattern of reporting.

Phase I: Incursion (from 2003 to 2008), Rt = 0.5 ≤ N ≥ 0.8, Sporadic events in the rural areas (Katavi and Mikumi areas); Phase II: Establishment/Persistence (2009 to 2016), Rt = 1.3 ≤ N ≥ 1.7, Persisting epizootics in the more urban areas (Kinondoni); Phase III: Dispersion (2017 to 2021 and continuing), Rt = 1.7 ≤ N ≥ 2.6, New territories are now infected. Based on seasonality, the Rt ≥ 2 for the period between November to February of the following year.

**Note that 2021 outbreak is continuing and the cumulative number of cases may exceed what was documented in the graph above.*

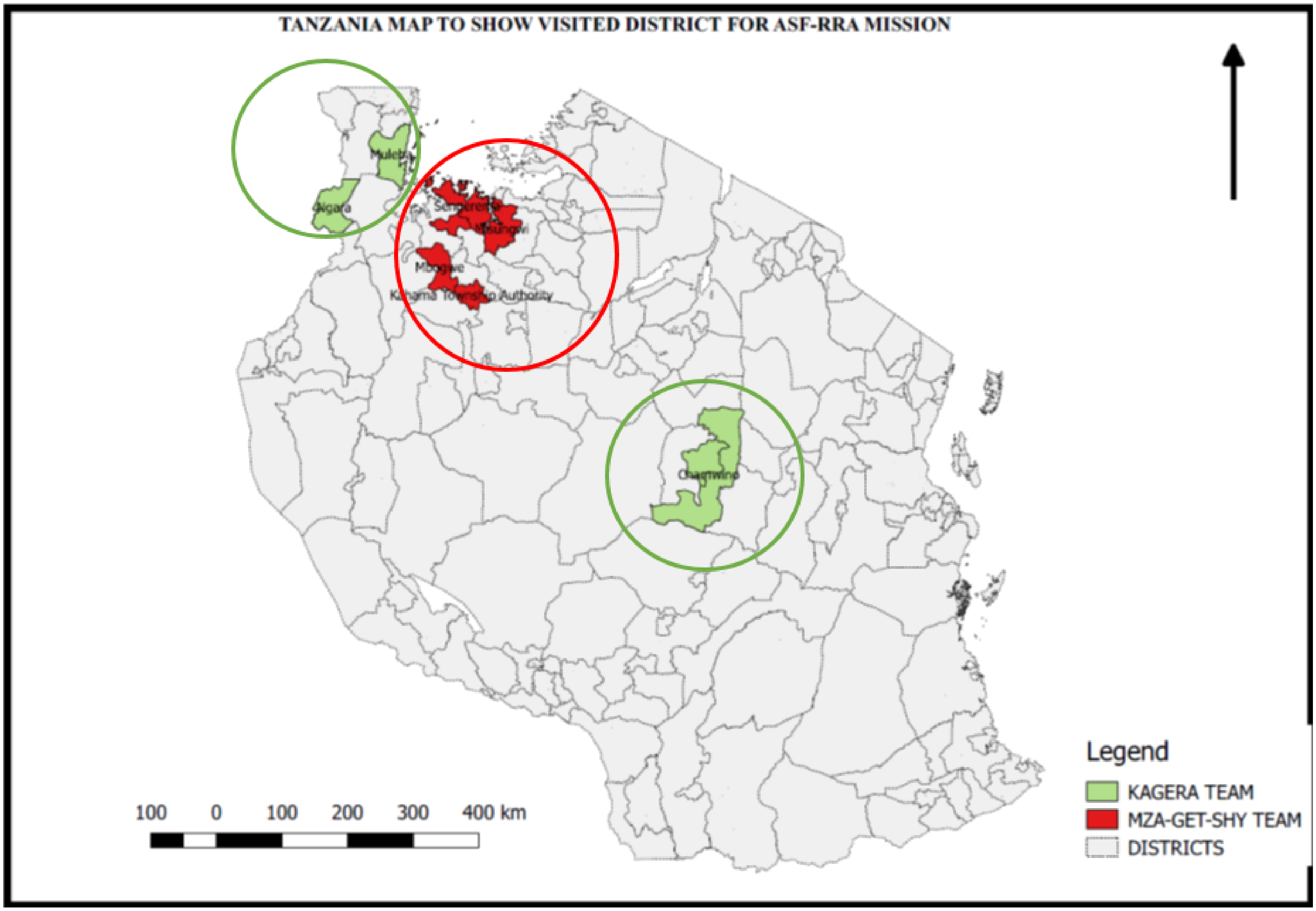

Figure 2

Map of Tanzania showing the areas visited during the ASF RRA mission

The Kagera team covered Kagera (Ngara and Muleba districts) in the extreme north west part of Tanzania and Dodoma (Dodoma Jiji and Chamwino districts) regions in the central area. The MZA-GET-SHY team covered Mwanza (Sengerema and Mwanza jiji districts), Geita (Geita district council), Shinyanga (Mbogwe and Kahama districts) regions in the north west Tanzania. A total of 5 regions and 9 districts were covered. Each team consisted of a national epidemiologist, a zonal veterinary officer, zonal laboratory personnel, the district veterinary officer of the affected district and relevant field officers.

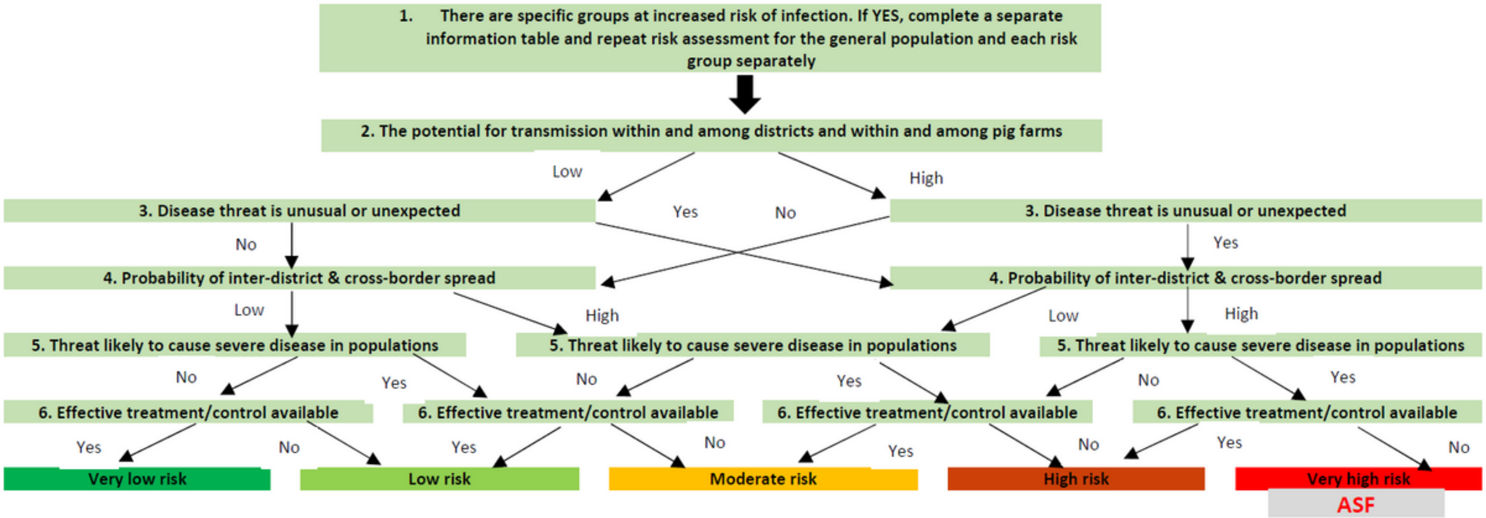

Figure 3

Risk classification for African swine fever virus (hazard) among Tanzania's smallholder pig farms, 2021

Mean agreement score ± standard deviation = 9.6 ± 0.7; Median = 10. (1 = strongly disagree to 10 = strongly agreed). Kappa±SE = 0.90±0.10 (95% confidence interval: 0.88 - 0.92); the interrater agreement between foreign and local experts' scores were calculated using the method of Landis & Koch [9].

Adapted from European Centre for Disease Prevention and Control. Operational guidance on rapid risk assessment methodology [21]. This figure was drawn based on the RRA questions in Annex 7. Based on the focus group discussions and key informant interviews, the risk was particularly high among pregnant sows, adult female, shared adult boars, non-shared boars, porkers, growers and less among weaners and piglets in that order. In most cases, survivors are the young animals (piglets and weaners), and piglets may die due to cessation of milk when the sow dies.

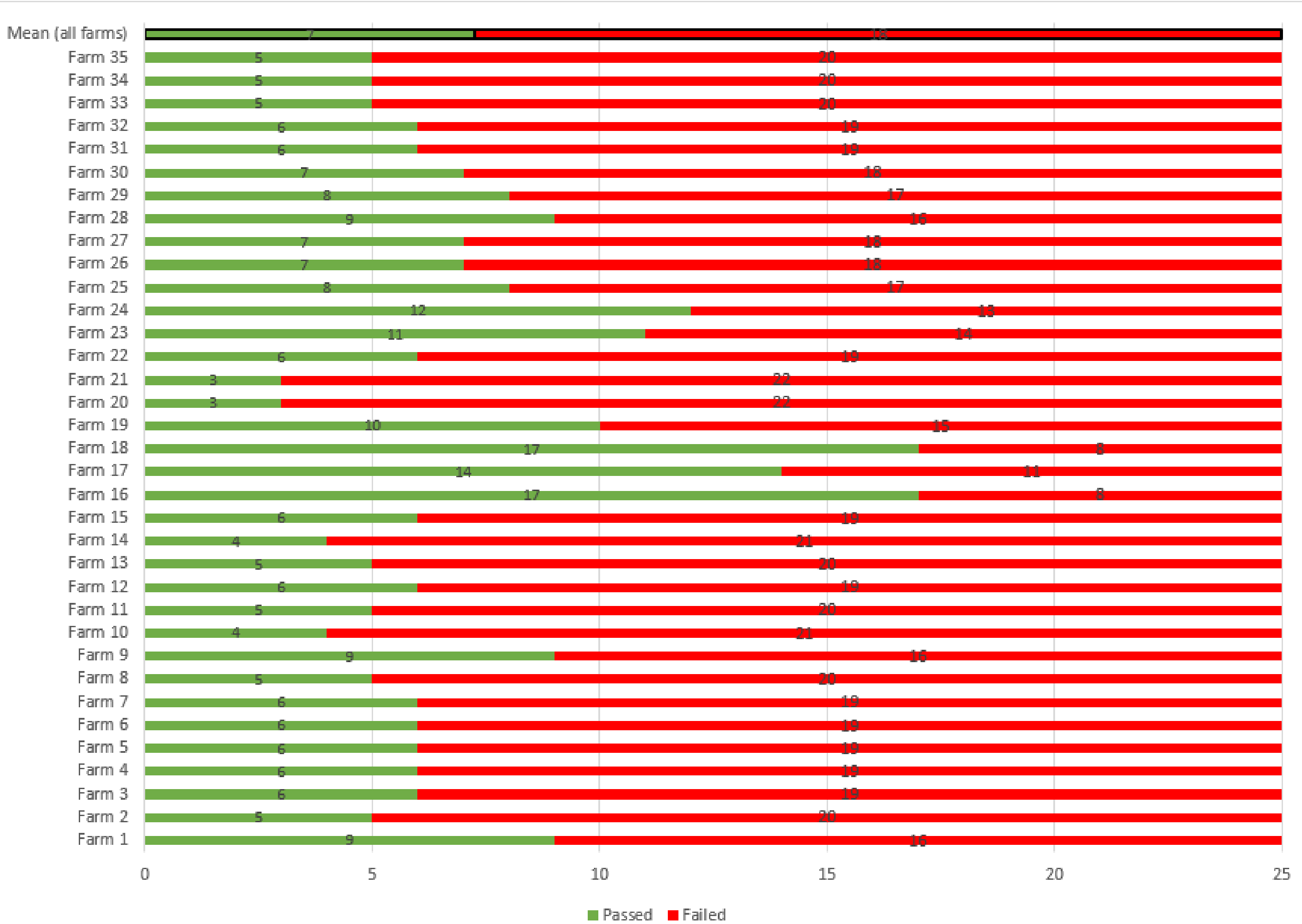

Figure 4

Biosecurity scores for smallholder pig farms using a 25-measure point scale, Tanzania. (*Mean value for all farms with bold edges)*

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2.jpg
- Table3.jpg
- Table4.jpg
- SupplementarymaterialsTables19Figure16.docx