ASSOCIATION BETWEEN DOMESTIC PIG FARM'S CHARACTERISTICS IN RELATION TO THE AFRICAN SWINE FEVER OCCURRENCE IN PENINSULAR MALAYSIA

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ABSTRACT. As ASF outbreaks among domestic pig farms in Peninsular Malaysia involve farms of various scales with different numbers of pig populations, determination of the risk factors related to farm characteristics would be useful to develop and strategise risk-based preventive measures. The present study was conducted to determine the pig farm's characteristics and related risk factors associated with the ASF outbreaks in domestic pig farms in Peninsular Malaysia. The association between the 441 domestic pig farm characteristics and the farm's ASF status at the farm level was analysed using univariate and multivariate logistic regression. The farm characteristics included in the study are the season at the farm during the outbreak period, location of the farm based on the population of pigs, housing system, farm scale based on SPP, farm density, breed type, BOD, buffer zone and MyGap certification status. Meanwhile, ASF-positive farms are farms which had reported ASF cases confirmed through Real Time PCR (RT-PCR) method. Farms located in states with high pig populations and the season at the farm during the outbreak period were identified to be more likely exposed to ASF outbreaks. The finding of this study provides an important insight that farms located in states with high pig populations and the season during the outbreak period are significantly associated with the introduction of the ASFV into domestic pig farms.

Keywords: African swine fever, farm characteristics, pig population, season

INTRODUCTION

The pig industry in Malaysia has moderately developed and improved in terms of management and breeding in recent years. Based on the year 2021 census, the standing pig population in Malaysia is 1,857,839 (Peninsular Malaysia: 1,444,952; Sabah: 91,374; Sarawak: 321,513). Malaysia's pork self-sufficiency level is 93.7 % with 91.9 % in Peninsular Malaysia with 17.1 kg/year per capita consumption of pork. The per capita consumption of pork was calculated based on 40 % of the non-Muslim population in Malaysia (Department of Veterinary Services, 2022).

African swine fever (ASF) is a worldwide deadly viral disease of domestic pigs causing widespread haemorrhage and mortality almost up to 100 % among affected pigs (Penrith *et al*., 2019). Till today, there is no effective commercial vaccine against ASF. Thus, the disease control strategy to prevent the spread of the disease mainly focuses on animal movement restriction, improved border control, control of contact between domestic and wild swine populations, improved sanitation and hygiene, and culling of infected animals (Costard *et al*., 2009). The disease causes a major impact on pig health and production, and also poses a threat towards the global pig and pork trade industry and food security (Nielsen *et al*., 2019). The rapid spread of ASF in recent years has alarmed the industry players and veterinary services for a constructive approach to prevent and control the disease.

In Malaysia, ASF is a disease which needs to be reported mandatorily and is notifiable by the World Organisation for Animal Health (WOAH).

In Malaysia, the first ASF outbreaks were confirmed in February 2021 in the state of Sabah and ASFV Genotype 2 strain was identified to be responsible for the deaths of the wild boars (*Sus scrofa*) and domestic pigs. The disease then spread to Sarawak in July 2021 (WAHIS, 2023; Khoo *et al*., 2021). In Peninsular Malaysia, the first ASF case was detected among dead wild boar carcasses in the Batang Padang District in the state of Perak (WAHIS, 2023). Following that, several ASF cases were reported among wild boar carcasses retrieved from the forest, natural parks, and oil palm plantations in the state of Melaka, Perak, Penang, Johor, Pahang, Terengganu, and Kelantan (WAHIS, 2023). Meanwhile in the state of Negeri Sembilan, ASFV was detected in a decayed carcass of wild boar found in a farm (WAHIS, 2023). ASF outbreaks among domestic pigs were first recorded in the state of Melaka in December 2021, followed by Perak in March 2021, and Penang in January 2023 (WAHIS, 2023).

Several risk factors associated with the regional spread and transmission of ASF virus transmission among domestic pig farms have been identified based on the underlying epidemiological situation. The majority of the studies have identified biosecurity-related risk factors as an important factor for the transmission of the disease among the domestic pig population (Viltrop *et al*., 2021). Swill feeding and close contact between susceptible and infected pigs are among the main risk factors reported in most studies (Bellini *et al*., 2016). However, there are not many published studies on the risk factors at the herd-level for the introduction of ASF among domestic pig herds, especially in Asia. So far, there are seven published studies on herd-level risk factors for ASF introduction from the years 1994 to 2021 which include two from Nigeria, one from Uganda, one from Kenya, one from Sardinia, one from Estonia, and one from Romania (Viltrop *et al*., 2021).

In Peninsular Malaysia, following the first outbreak, the Department of Veterinary Services (DVS), Malaysia has stamped out pigs in infected farms, enforced pig movement control, conducted disease investigations, surveillance, and several other preventive measures to control the spread of the disease (WAHIS, 2023). Despite all the efforts, the source of infection was still unclear and ASF continued to spread across Peninsular Malaysia even after more than one year after the first introduction of the virus. This highlights the need for an assessment of the risk of the disease spreading from various perspectives to facilitate the implementation of risk-based ASF control measures. As ASF outbreaks among domestic pig farms in Peninsular Malaysia involve farms of various scales with different numbers of pig populations, determination of the risk factors related to farm characteristics would be useful to develop and strategise risk-based preventive measures. Thus, this study aims to assess the domestic pig farms' demographic variables on the occurrence of ASF in Peninsular Malaysia.

MATERIALS AND METHODS

Source of Data

The data for this study were obtained from the Swine Unit, Livestock Development Division, Department of Veterinary Services (DVS), Malaysia. The data comprise eight demographic variables and the ASF status of 441 commercial pig farms, either positive or negative, in Peninsular Malaysia. ASF-positive farms are farms which had reported ASF cases confirmed through Real Time

PCR (RT-PCR) method. The farm characteristics in the data were the location of the farm by state, housing system, breed, biochemical oxygen demand (BOD) level of the farm waste effluent discharge, presence of buffer zone, Malaysia Good Agricultural Practice (MyGap) certification status, farm area in hectare, and standing pig population (SPP) of the farm. Four new variables were created namely "region", "farm size", "farm density" and "season". Based on pig populations, Perak, Penang, Melaka, Johor, and Selangor were grouped as highly populated regions, while Kedah, Negeri Sembilan, and Pahang were grouped as lowly populated regions. States with a population of 100,000 pigs and more were categorised as highly populated regions while states with a population of pigs less than 100,000 were categorised as lowly populated regions. Farm scale variable is categorised as small (when SPP of the farm is less than 2,000), medium (SPP between 2,000 and10,000), or large scale (SPP greater than 10,000). In addition, the SPP of the farm was divided by the farm area in hectare to form the farm density variable. Season at the farm during the outbreak period was categorised as Northeast monsoon (December 2021 to February 2022) and first inter-monsoon (March 2021 to May 2022) based on the season at the state where the farms are located. In summary, nine farm characteristic variables (i.e., independent variables) of this study are season at the farm during the outbreak period, location of farm based on population of pigs, housing system, farm scale based on SPP, farm density, breed type, BOD, buffer zone, and MyGap certification status.

Data Analysis

The database was created in Microsoft Excel, and all statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics (SPSS) (Version 26, IBM Corp. Armonk, New York, United States of America). Descriptive statistics were computed for the nine farm characteristics, i.e., independent variables and the farm's ASF status as the dependent variable. The relationship between the farm characteristics and the farm's ASF status was assessed with Chi-square and Fisher's exact test where appropriate. The association between the farm's characteristic variables and the farm's ASF status at the farm level was analysed using univariate and multivariate logistic regression. Variables with a p-value < 0.1 in univariate analysis were included in the multivariate logistic regression model. The multivariate logistic regression models were fitted using the Backward LR method with a selection threshold of p-value < 0.05. The multi-collinearity among the variables included in the final multivariate logistic regression model was checked by examining the variance inflation factor (VIF) of the variables. VIF value exceeding 5 or 10 indicates high multicollinearity (James *et al*., 2013), while tolerance value <0.20 is considered as possible multicollinearity (Hair *et al*., 2010). The overall fit of the final models was assessed using Hosmer–Lemeshow goodness-of-fit test. The ability of the model to discriminate between ASF-positive and ASF-negative farms was assessed using the receiver operating characteristic (ROC) curve. The area under the curve (AUC) value between 0.8 to 0.9 was regarded as a good discriminatory value of the Likelihood Ratio (LR model in correctly predicting positive and negative outcomes (Hosmer & Lemeshow, 2000).

RESULTS

Description of the Study Herd

Table 1a and Table 1b summarise the characteristics of 441 domestic pig farms in Peninsular Malaysia including the farms affected with ASF outbreaks from December 2021 to

May 2022. The categorical farm characteristic variables include the farms' ASF status, number of farms by states, pig population by states, season at the farm during the outbreak period, location of farm based on the population of pigs, housing system, farm scale based on SPP, farm density, breed type, BOD level, presence of buffer zone, and MyGap certification status. The continuous farm characteristic variables include the farm size, SPP, and farm density.

Table 1a. Number of pig farms according to the ASF outbreak status and the farm characteristics in categorical variables

	Variable	Subgroup	Frequency	Percentage
1.	Farm's ASF status	Negative	406	92.10
		Positive	35	7.90
2.	Number of farms by states	Penang	142	32.20
		Selangor	119	26.98
		Perak	95	21.54
		Johor	42	9.52
		Melaka	35	7.94
		Kedah	6	1.36
		Negeri Sembilan	1	0.23
		Pahang	1	0.23
3.	Pig population by states (number of heads)	Perak	566,906	39.23
		Penang	344,334	23.83
		Johor	279,218	19.32
		Selangor	209,248	14.48
		Melaka	39,750	2.75
		Pahang	3,156	0.22
		Kedah	1,980	0.14
		Negeri Sembilan	360	0.02
4.	Season at the farm during the outbreak period	Northeast monsoon (December 2021 to February 2022)	78	17.70
		First inter-monsoonal (March 2021 – May 2022)	363	82.30
5.	Location of farm based on the population of pigs	Highly populated region (>100,000 heads)	398	90.20
		Lowly populated region (≤100,000 heads)	43	9.80
6.	Housing system	Open	406	92.10
		Close	35	7.90

7.	Farm scale (based on SPP)	Small (SPP < 2,000)	229	51.90
		Medium (2,000 < SPP < 10,000)	187	42.40
		Large (SPP > 10,000)	25	5.70
8.	Farm density	Low (<100)	10	2.30
		Medium (100-500)	94	21.30
		High (> 500)	337	76.40
9.	Breed type	Landrace, Yorkshire, Duroc (LYD)	388	88.00
		Landrace, Duroc, Large White (LDLW)	10	2.30
		Landrace, Duroc (LD)	38	8.60
		Others	5	1.10
10.	BOD	< 50 ppm	391	88.70
		> 50 ppm	50	11.30
11.	Presence of a buffer zone	Present	250	56.70
		No buffer zone	191	43.30
12.	MyGap certification status	Certified	14	3.20
		Not certified	427	96.80

Table 1b. Number of pig farms according to the ASF outbreak status and the farm characteristics in continuous variables

No.	Variable	Median	Range
1.	Farm size (hectare)	2.00	123.13
2.	Standing pig population (SPP) (heads)	1,900.00	39,750.00
3.	Farm density (pigs per hectare)	960.00	9,935.00

Univariate Logistic Regression Results

The univariate logistic regression analysis findings presented the farm characteristic variables that were significant to predict the occurrence of ASF in the farm (p-value ≤ 0.001) were season during the outbreak period, location of the farm, based on the population of pigs, presence of buffer zone, and farm scale (Table 2).

Table 2. Results from the univariate logistic regression analyses

Variable	Subgroup	Frequency	OR	95 % CI	*p*-value
Season at the farm during the outbreak period	Northeast monsoon	78	44.75	16.57 - 120.86	<0.001*
	First inter monsoon	363	1.00	Ref	-
Location of farm based on the population of pigs	High populated region	398	181.39	60.61 - 542.83	<0.001*
	Low populated region	43	1.00	Ref	

Type of housing	Open	406	0.00	0.00	0.99
	Close	35	1.00	Ref	-
Farm scale (based on SPP)	Small (SPP < 2,000)	229	0.22	0.09 – 0.55	0.001*
	Medium (2,000 < SPP < 10,000)	187	0.00	0.00	0.99
	Large (SPP > 10,000)	25	1.00	Ref	-
Farm density	Low (<100)	10	0.00	0.00	0.99
	Medium (100 -500)	94	0.44	0.15-1.28	0.13
	High (> 500)	337	1.00	Ref	-
Breed type	LYD	388	0.00	0.00	0.99
	Landrace, Duroc, Large White (LDLW)	10	0.21	0.09 – 0.51	0.99
	Landrace, Duroc (LD)	38	1.00	Ref	-
BOD	<50 ppm	391	0.00	0.00	0.99
	>50 ppm	50	1.00	Ref	-
Presence of a buffer zone	Present	250	1.00	Ref	-
	No buffer zone	191	4.22	1.93 – 9.24	<0.001*
MyGap certification status	Certified	14	0.00	0.00	0.99
	Not certified	427	1.00	Ref	-

Notes: OR = odds ratio; 95 % CI = 95 % confidence interval; Ref = Reference; * = Statistically significant
ppm = parts per million

Multivariate Logistic Regression Results

Results from the final multivariate logistic regression model (Table 3) showed that there is a significant association between the occurrence of ASF outbreaks and farms located in states with high pig populations (*p*-value < 0.001, OR=44.09, 95 % CI 10.98 -177.13) and the season at the farm during the outbreak period (*p*-value = 0.002, OR=0.12, 95 % CI 0.03 -0.45). In other words, there is an increasing risk of ASF outbreaks in domestic pig farms with increasing pig population, while the risk for ASF outbreaks decreases during the Northeast monsoon. The Hosmer-Lemeshow statistics indicate the final model achieved a good fit (*p*-value = 0.07) with a good AUC of 0.901. No multicollinearity was found among the variables in the multivariate regression model (VIF < 5 and tolerance value > 0.2). The final model was statistically significant (X^2 (5) = 15.89, *p*-value < 0.05) and explained 67.2 % (Nagelkerke R^2) of the variance in the occurrence of ASF outbreaks, and correctly classified 97.5 % of cases.

Table 3. Results from the final multivariate logistic regression analysis

Variable	**Subgroup**	**OR**	**95 % CI**	***p*-value**
Season at the farm during the outbreak period	Northeast monsoon	0.12	0.03 – 0.45	0.002*
	First inter-monsoonal	Ref	-	-

Location of farm based on the population of pigs	Highly populated region	44.09	10.98 -177.13	<0.001*
	Lowly populated region	Ref	-	-
Presence of a buffer zone	Present	Ref	-	-
	No buffer zone	1.03	0.30 – 3.53	0.97
Farm scale (based on SPP)	Small (SPP < 2,000)	0.73	0.18 – 2.98	0.66
	Medium (2,000 < SPP < 10,000)	0.00	0.00	0.99
	Large (SPP > 10,000)	Ref	-	-

*Notes: OR = odds ratio; CI = confidence interval; Ref = Reference; * = Statistically significant; SPP = standing pig population

DISCUSSION

The significant farm characteristics associated with the occurrence of ASF outbreaks in domestic pig farms identified in this study include season during the outbreak period, location of the farm based on the population of pigs, buffer zone, and farm scale.

The significant association between the seasons at the farm during the outbreak period with the occurrence of ASF outbreaks in this study may raise a hypothesis concerning possible climatic risk factors for the introduction of ASFV into pig herds and ASF tenacity in the field environment at different climate conditions could be further researched. This is because the ASFV virus may survive for long periods on a variety of organic matrices and in the environment, and the association of environmental temperature and climate has been identified as an important factor for the spread of ASFV (Dixon *et al*., 2020). A study by Ungur *et al*. (2022) discovered that areas with an average spring temperature of 10–14 °C had higher numbers of both ASF-affected pigs and outbreaks. Meanwhile, Fischer *et al*. (2020) reported that cooler temperatures during the rainy season may increase the survivability of ASFV in the environment which leads to a greater possibility of virus transmission. Studies have also shown that slower decomposition rates of ASF-infected wild boar carcasses in colder conditions have an impact on ASFV persistence in parts of Eastern Europe (O’Neill *et al*., 2020; Podgórski & Smietanka, 2018). Further to that, even though ASFV could not be isolated from wild boar carcasses from different stages of decomposition, Zani *et al*. (2020) speculated that climatic variations might have an impact on the persistence of infectious viruses in the carcasses of wild boars. In this study, it was observed that ASF outbreaks occurred during the northeast monsoon and first inter-monsoonal period which usually have higher amounts and frequency of rainfall compared to the southwest monsoon. In Malaysia, the northeast monsoon begins in November and lasts until February followed by the first inter-monsoonal period from March to May (Tan, 2018). The final regression model demonstrated that the risk for ASF occurrence in domestic pigs decreases during the northeast monsoon season. The finding could be attributable to many other related factors which present during the period despite the rainfall and environmental temperature. Production and other activities carried out on the farm during the period may influence the risk of ASF occurrence.

In Southwest Nigeria, it was found that the risk of ASF occurrence was higher during the rainy season due to the stock replacement activity from external farms (Awosanya *et al*., 2015).

The significant association between ASF occurrence with the buffer zone in the farm is consistent with findings from previous studies by Fasina *et al*. (2012) and Boklund *et al*. (2020), which reported that past ASF outbreak in a farm and the existence of an infected pig farm nearby as a risk factor to enhance the likelihood of an ASF outbreak. In this study, it was observed that a minimum of 200-meter buffer zone between the farm and other amenities were absent in 26 (74.28 %) of the ASF-infected farms which could be one of the reasons for the rapid transmission of African swine fever virus (ASFV) among the infected farms. Even though ASFV is transmitted primarily by direct contact with infected pigs, transmission may also occur through aerosol routes over short distances (Bellini *et al*., 2016). This has been proved by a study by Olesen *et al*. (2017) which identified a Polish ASFV isolate (POL/2015/Podlaskie/Lindholm) to be highly infectious and may be transmitted among domestic pigs through direct contact or aerosol.

Meanwhile, a significant association between ASF occurrence with the farm scale is consistent with findings by several studies which have reported that disease outbreaks are more likely to occur on smaller farms which are often regarded to have low biosecurity level ineffective physical or disinfection barriers to prevent the introduction of disease (Sánchez-Cordón *et al*., 2018; Cwynar *et al*., 2019; Boklund *et al*., 2020; Nurmoja *et al*., 2020, You *et al*., 2021). In this study, 29 (82.85 %) of the ASF outbreaks occurred in small-scale farms (SPP < 2,000). As this study is limited by incomplete information on the biosecurity level of the farms, the contribution of the biosecurity levels at the small farm scale to the ASF outbreaks could not be determined.

Farms located in states with high pig populations were identified to be most significantly associated with the occurrence of ASF in domestic pig farms. This finding agrees with the earlier studies on the risk factor for intraregional ASFV transmission. Huang *et al.* (2017) proved that there was a positive correlation between regional ASF occurrence and pig density in West Africa. The size of the pig population was identified as the significant risk factor for the presence of ASFV infection among domestic pigs in Samara Region, Russian Federation (Glazunova *et al*., 2021). Similarly, Viltrop *et al.* (2021) reported that larger herds were more likely to be ASF outbreak herds compared to smaller herds due to increased pig density and movement of pigs. Farms located in the highly populated areas have a higher risk of acquiring ASF infection as the high population of pigs promotes higher interaction between pig farms and their related premises which may facilitate ASFV transmission, especially among small-scale farms with low biosecurity levels (Korennoy *et al*., 2014; Vergne *et al*., 2016). Human activities which include the movement of pigs and pig products, and infected pigs, as well as poor biosecurity practices were identified as the greatest risk factor linked to ASF outbreaks in domestic pigs in Russia, Nigeria, Uganda, and Asia (Glazunova *et al*., 2021; (Olugasa & Ijagbone, 2007); Mighell & Ward, 2021). A similar observation was also reported during the Nipah virus outbreak in Malaysia in 1998 whereby the spread of the virus was caused by the movement of infected pigs from the states in the north to the south which had more intensive pig farms with higher pig population and higher density of human population (Epstein *et al*., 2006).

No conclusion can be made with regards to the role of biosecurity and the movement of pigs or vehicles into the farms with the occurrence of ASF outbreaks due to lack of data on the biosecurity practices in the farms and movement of pigs and pig products in this study. Data on the MyGap certification status in this study was not relevant as an indicator for the biosecurity level of a farm since the scheme is mandatory only for export farms which are adopted by only 3.2 % of pig farms in Peninsular Malaysia on a voluntary basis.

CONCLUSIONS

In conclusion, this study highlights that the location of farms in highly populated regions and the season during the outbreak period were significantly associated with the occurrence of ASF outbreaks in domestic pig farms in Peninsular Malaysia. In addition, this study also reflects that factors which may have caused ASF introduction to the outbreak farms may be closely associated with human activities which include poor biosecurity practices, movement of pigs and pig products, and close interaction between farms or premises. These activities may facilitate ASFV transmission through infected pigs, contaminated products, and infected fomites such as vehicles, human clothes, shoes, and equipment during contact between the farms. This highlights the importance of the need for further studies to identify factors related to climate conditions, biosecurity practices and movement of pigs, pig products and vehicles as this would help determine the exact disease-causing factor among farms located in highly populated states or areas for an effective preventive strategy. Despite the limitations, this study provides an important insight that farms located in states with high pig populations and the season during the outbreak period is significantly associated with the introduction of the ASFV into domestic pig farms.

COMPETING INTEREST

The authors declare that they have no competing interests.

REFERENCES

1. Awosanya, E. J., Olugasa, B. O., Ogundipe, G. a. T., & Gröhn, Y. T. (2015). Sero-prevalence and risk factors associated with African swine fever on pig farms in southwest Nigeria. *BMC Veterinary Research*, *11*(1).
2. Bellini, S., Rutili, D., & Guberti, V. (2016). Preventive measures aimed at minimizing the risk of African swine fever virus spread in pig farming systems. *Acta Veterinaria Scandinavica*, *58*(1).
3. Boklund, A., Dhollander, S., Vasile, T. C., Abrahantes, J. C., Bøtner, A., Gogin, A., Villeta, L. C. G., Gortázar, C., More, S. J., Papanikolaou, A., Roberts, H. D., Stegeman, A., Ståhl, K., Thulke, H., Viltrop, A., Van Der Stede, Y., & Mortensen, S. P. (2020). Risk factors for African swine fever incursion in Romanian domestic farms during 2019. *Scientific Reports*, *10*(1).
4. Costard, S., Wieland, B., De Glanville, W. A., Jori, F., Rowlands, R. J., Vosloo, W., Roger, F., Pfeiffer, D. U., & Dixon, L. K. (2009). African swine fever: how can global spread be prevented? *Philosophical Transactions of the Royal Society B*, *364*(1530), 2683–2696.
5. Cwynar, P., Stojkov, J., & Wlazlak, K. (2019). African Swine Fever Status in Europe. *Viruses*, *11*(4), 310.
6. Department of Veterinary Services, Malaysia. (2022). Livestock Statistics 2021/2022. Retrieved November 20, 2022, from https://www.dvs.gov.my/index.php/pages/view/4315
7. Dixon, L. K., Ståhl, K., Jori, F., Vial, L., & Pfeiffer, D. U. (2020). African Swine Fever Epidemiology and Control. *Annual Review of Animal Biosciences*, *8*(1), 221–246.
8. Epstein, J. I., Field, H., Luby, S. P., Pulliam, J. R. C., & Daszak, P. (2006). Nipah virus: Impact, origins, and causes of emergence. *Current Infectious Disease Reports*, *8*(1), 59–65.
9. Fasina, F. O., Agbaje, M., Ajani, F., Talabi, O. A., Lazarus, D. D., Gallardo, C., Thompson, P., & Bastos, A. D. (2012). Risk factors for farm-level African swine fever infection in major pig-producing areas in Nigeria, 1997–2011. *Preventive Veterinary*

Medicine, *107*(1–2), 65–75.
10. Fischer, M., Hühr, J., Blome, S., Conraths, F. J., & Probst, C. (2020). Stability of African Swine Fever Virus in Carcasses of Domestic Pigs and Wild Boar Experimentally Infected with the ASFV "Estonia 2014" Isolate. *Viruses*, *12*(10), 1118.
11. Glazunova, A. A., Korennoy, F. I., Sevskikh, T. A., Lunina, D. A., Lavrik, O. I., Blokhin, A. V., Karaulov, A. K., & Gogin, A. (2021). Risk Factors of African Swine Fever in Domestic Pigs of the Samara Region, Russian Federation. *Frontiers in Veterinary Science*, *8*.
12. Hair, J. F., Black, W. C., Babin, B. J. et al. (2010). Multivariate Data Analysis (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
13. Hosmer, D.W. and Lemeshow, S. (2000) Applied Logistic Regression. John Wiley & Sons, Inc., New York.
14. Huang, Z., Van Langevelde, F., Honer, K. J., Naguib, M., & De Boer, W. F. (2017). Regional level risk factors associated with the occurrence of African swine fever in West and East Africa. *Parasites & Vectors*, *10*(1).
15. James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An Introduction to Statistical Learning: with Applications in R*. Springer Science & Business Media.
16. Khoo, C. K., Norlina, D., Roshaslinda, D., Iti Suraya Hani M, M. S., Zunaida, B., Mohd Hasrul, A. H., Pauzi, N. A. S., Roslina, H., Aizah Hanim, M. S., & Leow, B. L. (2021). African swine fever in backyard pigs of Sabah state, East Malaysia, 2021. *Tropical biomedicine*, *38*(4), 499–504.
17. Korennoy, F. I., Gulenkin, V., Malone, J., Mores, C. N., Dudnikov, S., & Stevenson, M. (2014). Spatio-temporal modeling of the African swine fever epidemic in the Russian Federation, 2007–2012. *Spatial and Spatio-temporal Epidemiology*, *11*, 135–141.
18. Mighell, E., & Ward, M. D. (2021). African Swine Fever spread across Asia, 2018–2019. *Transboundary and Emerging Diseases*, *68*(5), 2722–2732.
19. Nielsen, S., Alvarez, J., Bicout, D., Calistri, P., Depner, K., Drewe, J. A., Garin-Bastuji, B., Rojas, J. L. G., Michel, V., Miranda, M. A., Roberts, H., Sihvonen, L., Spoolder, H., Ståhl, K., Viltrop, A., Winckler, C., Boklund, A., Bøtner, A., More, S. J.,. Schmidt, C. (2019). Risk assessment of African swine fever in the south-eastern countries of Europe. *EFSA Journal*, *17*(11).
20. Nurmoja, I., Mõtus, K., Kristian, M., Niine, T., Schulz, K., Depner, K., & Viltrop, A. (2020). Epidemiological analysis of the 2015–2017 African swine fever outbreaks in Estonia. *Preventive Veterinary Medicine*, *181*, 104556.
21. O'Neill, X., White, A., Ruiz-Fons, F., & Gortázar, C. (2020). Modelling the transmission and persistence of African swine fever in wild boar in contrasting European scenarios. *Scientific Reports*, *10*(1).
22. Olesen, A. S., Lohse, L., Boklund, A., Halasa, T. H. B., Gallardo, C., Pejsak, Z., Belsham, G. J., Rasmussen, T. B., & Bøtner, A. (2017). Transmission of African swine fever virus from infected pigs by direct contact and aerosol routes. *Veterinary Microbiology*, *211*, 92–102.
23. Olugasa, B. O., & Ijagbone, I. (2007). Pattern of spread of African swine fever in south-western Nigeria, 1997-2005. *Veterinaria Italiana*, *43*(3), 621–628.
24. Penrith, M. L., Bastos, A. D., Etter, E., & Beltran-Alcrudo, D. (2019). Epidemiology of African swine fever in Africa today: Sylvatic cycle versus socio-economic imperatives. *Transboundary and Emerging Diseases*, *66*(2), 672–686.
25. Podgórski, T., & Śmietanka, K. (2018). Do wild boar movements drive the spread of African Swine Fever? *Transboundary and Emerging Diseases, 65(6)*, 1588–1596.
26. Sánchez-Cordón, P. J., Montoya, M., Reis, A., & Dixon, L. K. (2018). African swine fever: A re-emerging viral disease threatening the global pig industry. *Veterinary Journal*, *233*, 41–48.
27. Tan, K. H. (2018). Trends of rainfall regime in Peninsular Malaysia during northeast and southwest monsoons. *Journal of Physics*.
28. Ungur, A., Cazan, C., Panait, L. C., Coroian, M., & Catoi, C. (2022). What Is the Real Influence of Climatic and Environmental Factors in the Outbreaks of African Swine Fever? *Animals*, *12*(6), 781.
29. Vergne, T., Korennoy, F. I., Combelles, L., Gogin, A., & Pfeiffer, D. U. (2016). Modelling African swine fever presence and reported abundance in the Russian Federation using national surveillance data from 2007 to 2014. *Spatial and Spatio-temporal Epidemiology*, *19*, 70–77.

30. Viltrop, A., Reimus, K., Niine, T., & Mõtus, K. (2021). Biosecurity Levels and Farm Characteristics of African Swine Fever Outbreak and Unaffected Farms in Estonia—What Can Be Learned from Them? *Animals*, *12*(1), 68.
31. World Animal Health Information System (WAHIS). (2023, March 30). *Animal Disease Event: Malaysia*. World Animal Health Information System. Retrieved April 20, 2023, from https://wahis.woah.org/#/event-management
32. You, S., Liu, T. L., Zhang, M., Zhao, X., Dong, Y., Wu, B., Wang, Y., Li, J., Wei, X., & Shi, B. (2021). African swine fever outbreaks in China led to gross domestic product and economic losses. *Nature Food*, *2*(10), 802–808.
33. Zani, L., Masiulis, M., Bušauskas, P., Dietze, K., Pridotkas, G., Globig, A., Blome, S., Mettenleiter, T., Depner, K., & Karvelienė, B. (2020). African swine fever virus survival in buried wild boar carcasses. *Transboundary and Emerging Diseases*.

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