Spatial distribution and assessment of biosecurity levels of pig farms in selected local government areas in Ogun State, Nigeria

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Keywords

Swine, livestock farms, spatial distribution, biosafety, Nigeria

Submitted: 6 January 2021
Accepted: 7 September 2022
Published: 30 September 2022
DOI: 10.19182/remvt.36985

Summary

This study was carried out on the spatial distribution, characterization and biosecurity assessment of pig farms in some local government areas in Ogun State, Nigeria. Data were collected with a semi-structured questionnaire. Spatial autocorrelation was used to show relations between pig farms' locations and biosecurity measures. A scoring system ranging from 0 to 1 was developed from the biosecurity measures retained. A biosecurity measure was scored 1 if present, 0 if absent. The measures were divided into two categories: bioexclusion and biomanagement/biocontainment. The total score of each measure was obtained by summing all scores from each farm. One hundred pig farms were surveyed. The average number of years since farm establishment was 7.32 ± 5.19 years, farms were confined, mostly small scaled (81.0%), with an average herd size of 58.9 ± 99.40, and 1.8 ± 1.52 farm workers. The distribution of pig farms with different biosecurity levels was significant ($p = 0.002$) and leaned toward a clustered scenario with a Moran's index of 0.27, z score of 3.18. Out of a maximum obtainable score of 100 for each measure, 'prophylactic herd treatment' and 'cleaning done daily' had scores higher than 80. On the other hand, 'absence of rodents, wild birds and stray animals on the farm', 'workers mandated use of clean and disinfected protective clothing before entering the farm' and 'vehicle disinfected at the entrance of the farm' had scores lower than 5. The mean scores for bioexclusion and biomanagement/biocontainment were 21.42 ± 18.07 and 49.83 ± 25.07, respectively. The overall biosecurity score of 35.63 ± 25.84 was significantly associated with herd size, number of years since farm establishment, and owners' education level. In order to ensure sustainable productivity and prevent disease outbreak, pig farmers must give the utmost importance to biosecurity.

■ How to quote this article: Awoyomi O.J., Agbalu O., Oladipupo O.R., Adebowale O.O., Kehinde O.O., Awoyomi F.O., Tope-Ajayi O.O., 2022. Spatial distribution and assessment of biosecurity levels of pig farms in selected local government areas in Ogun State, Nigeria. *Rev. Elev. Med. Vet. Pays Trop.*, 75 (3): 77-85, doi: 10.19182/remvt.36985

■ INTRODUCTION

A geographic information system (GIS) is a computer based system that can be used for capturing, processing, storing, checking, integrating, manipulating, analyzing, displaying, retrieving and sharing all types of data related to position on the surface of the earth (Hay, 2000). When GIS is optimally utilized, it can inform and educate (professionals and the public), empower decision-making at all levels, help in planning and eventually bring about unprecedented clinically and cost-effective actions (Boulos, 2004). Auchincloss et al. (2012) wrote: "Epidemiologists use GIS to assess proximity, aggregation, and clustering, as well as to perform spatial smoothing, interpolation

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and spatial regression." Specifically, GIS can be used in recording and reporting disease information which is easier to comprehend when visualized on the map. Furthermore, GIS can also assist in understanding disease dynamics and spreading patterns, planning disease prevention and eradication strategies, and correlations of disease trends with climate for disease prediction.

Biosecurity is defined as "the implementation of measures that reduce the risk of disease agent being introduced and spread. It requires that authorities and people set and adopt some attitudes and behaviors to reduce risk in all activities involving animals (domesticated or wild) and their products" (FAO/OIE/World Bank, 2008). There are basic measures for biosecurity which include bioexclusion, biocontainment and biomanagement. These measures have been identified as indispensable preventive approaches for diseases and the cornerstone of herd health maintenance.

Pig production plays a vital role in food security, poverty eradication and employment generation in Nigeria (Ogunniyi and Omoteso, 2011). In the past decade, the supply of pork for human consumption has expanded compared to the supply of other meats. Also, changes in the pig production systems have occurred in many countries, "among which are a shift from extensive, small-scale, subsistence, mixed production systems toward more intensive, large-scale, geographically-concentrated, commercially-oriented and specialized production" (Robinson et al., 2011). These changes have enabled increase in production of pork per capita and per farm (Robinson et al., 2011; Poapongsakorn and Naranong, 2003).

Eradication of diseases from pig farms remains an important goal although it is one rarely achieved. The strong link between the occurrence of diseases, pig production systems and farm scale has been established (Cameron, 2000; Otte et al., 2007). Smallholders' pig production systems have been reportedly linked to poor hygiene and low biosecurity with few barriers to potential contacts between pigs, humans and wildlife (Thanapongtharm et al., 2016). At the same time large pig farms are often associated with build up of pathogens both in the environment and carrier animals, and it may foster emergence of antimicrobial resistant pathogens. Many diseases limit pig production among which are African swine fever (ASF), foot-and-mouth disease, brucellosis, trypanosomosis, helminthosis and mange (Igbokwe and Maduka, 2018).

Visualizing and spatial statistical analysis of pig farms' information make it easy for specialists to identify relative distances and overlapping between farms. More details have to be integrated to the map to help predict outbreaks before they erupt and for early warning to enhance the commencement of disease management plans. Therefore, a need to map out pig farms and their characteristics, common diseases and biosecurity measures put in place for disease prevention is crucial (Moustafa et al., 2012). The results could be used to identify weak links in biosecurity, and to promote the development of policies for the establishment of pig farms and a rapid response in disease outbreaks. In this study we mapped, characterized and assessed biosecurity measures of pig farms in areas of Ogun State, Nigeria. We tested the hypotheses that the pig farms in the study area were uniformly distributed and that there was no significant correlation between bioexclusion and biomanagement/biocontainment scores.

■ MATERIALS AND METHODS

This study was carried out in Abeokuta Metropolis (Abeokuta North, Abeokuta South and part of Obafemi Owode Local Government) and Odeda Local Government, all in Ogun State (Figure 1). Abeokuta Metropolis and Odeda have estimated areas of 879 km^2 and 1560 km^2, respectively. The estimated populations of Abeokuta Metropolis and Odeda were 449,088 and 109,449 inhabitants, respectively (NPC, 2006).

A cross-sectional survey was conducted with pig farmers in August 2017 and August 2018. The locations of all pig farms were captured using the snowball sampling technique in order not to miss any existing farm. At the time of the study 98 pig farms were registered in the whole State. A pilot study was carried out to predetermine the average time it would take respondents to fill the questionnaire, to correct and adjust ambiguous questions as well as to improve clarity prior to administration to the pig farmers. The coordinates (longitude and latitude) of each pig farm were recorded with a global positioning system (Garmin Etrex 20). Demographic data and other information were gathered in a semi-structured questionnaire of four pages and 45 questions, divided into four sections: section A, farm owners' demographic data; section B, information on the management systems of the various farms; section C, information on the biosecurity measures adopted; and section D, information on the farms' disease history. The questionnaire was translated into the local language (Yoruba) for farmers who were unable to read or write in English, and their responses were recorded.

A scoring system was developed from the biosecurity measures of the study ranging from 0 to 1. A biosecurity measure was scored 1 if present and 0 if absent. For a given measure the total score was obtained by adding the score of each farm. Twenty-four biosecurity measures were categorized into two: bioexclusion 12 measures, and biomanagement/biocontainment 12 measures. Each measure was graded based on the number of respondents with positive responses; the highest obtainable score for each measure was thus 100. The mean of each category and overall biosecurity scores were then obtained. Furthermore, the biosecurity levels were categorized as good or poor based on the number of biosecurity measures adopted on the farm. Farms with at least 12 biosecurity measures were categorized as good whereas those with less than 12 measures were categorized as poor.

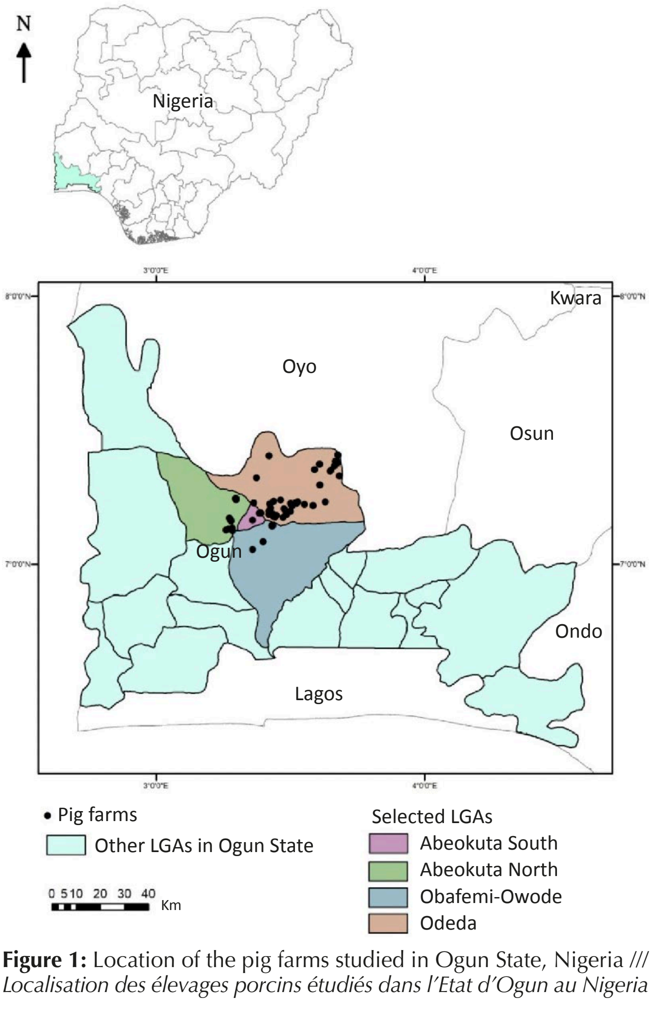

Figure 1: Location of the pig farms studied in Ogun State, Nigeria /// *Localisation des élevages porcins étudiés dans l'Etat d'Ogun au Nigeria*

The spatial distribution of the farms was mapped. A spatial autocorrelation was carried out with Moran's I (subset of Spatial Statistics Tools in ArcMap 10.5) to determine whether there was any cluttering, randomness or dispersion in farm locations. To calculate the minimum distance any pig farm was from a neighbor we used the 'Calculate Distance Band from Neighbor Count' tool. The incremental spatial autocorrelation analysis allowed us to identify at what scale or distance the autocorrelation was maximized. Cluster and Outlier analyses (Anselin Local Moran's I) and Hot Spot Analysis (Getis-Ord Gi) allowed for the identification of hot spots.

The data gathered through the questionnaire were coded and entered into a spreadsheet using Microsoft Excel then the data was analyzed using descriptive statistics. Responses from the two locations were compared with the Chi square test or the independent sample t test. Both the hierarchical classification and principal component analyses (PCA) of all the parameters across the two biosecurity measures on the pig farms were carried out to obtain more detailed information on observations made. Suitability of the data for factor analysis was measured with the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy. A logistic regression analysis was also carried out to determine factors affecting biosecurity scores. All statistical analyses were carried out with the statistical package for social science (SPSS) software.

■ RESULTS

Farmers and farm characteristics

Out of a total 106 farms identified, 52 were from or around Abeokuta, and 54 from Odeda LGA. However, only 100 farms were operational as six had relocated or recently closed down. Among the respondents 82% were males, 73% were 31–55 years old, 90% were Christian, and only 38% had farming as their primary occupation. Most of them were educated to the tertiary level (56%), married (85%) and had 8.30 ± 6.84 mean years of experience (range = 1–32 years) (Table I).

Mean age of farm establishment was 7.32 ± 5.19 years (range = 1–34 years). The management system was mostly confined and small scale (81%), with a mean herd size of 58.9 ± 99.40 pigs (range = 3–500 pigs). The mean number of farm workers was 1.80 ± 1.52 (range = 1–10) (Table I).

Biosecurity practice on pig farms

Table II presents the mean score of each biosecurity measure. Overall mean score in bioexclusion was 21.42 ± 18.07 (range = 0–55). 'Screening of new stocks for specific diseases' was the only measure in this category with a score higher than average (50). The measures

Table I: Farmers' and pig farm characteristics in two areas of Ogun State, Nigeria /// *Caractéristiques des éleveurs de porcs et de leurs élevages dans deux zones de l'Etat d'Ogun au Nigeria*

Characteristics	Total (n = 100)	Odeda LGA (n = 48)	Abeokuta M (n= 52)	P
Sex				0.169
Male (%)	82.0	87.5	76.9	
Female	18.0	12.5	23.1	
Age				0.672
18–30 (%)	9.0	8.3	9.6	
31–40 (%)	34.0	31.2	36.5	
41–55 (%)	39.0	37.5	40.4	
> 55 (%)	18.0	22.9	13.5	
Religion				0.597
Christianity (%)	90.0	91.7	88.5	
Islam (%)	10.0	8.3	11.5	
Primary occupation				0.36
Civil servant (%)	10.0	12.5	7.7	
Farming (%)	38.0	25.0	50.0	
Others (%)	52.0	62.5	42.3	
Educational level				0.373
No formal education (%)	3.0	4.2	1.9	
Primary education (%)	5.0	8.3	1.9	
Secondary education (%)	36.0	37.5	34.6	
Tertiary education (%)	56.0	50.0	61.5	
Marital status				0.48
Single (%)	11.0	14.6	7.7	
Married (%)	85.0	77.1	92.3	
Widow/er (%)	4.0	8.3	0.0	
Experience in pig farming (years)	8.30 ± 6.84	7.30 ± 6.67	9.19 ± 6.93	0.166
Herd size (num.)	58.9 ± 99.40	52.58 ± 98.22	64.73 ± 101.09	0.544
Farm establishment (years)	7.32 ± 5.19	7.60 ± 5.80	7.06 ± 4.61	0.601
System of farming				0.36
Confined small scale (%)	81.0	89.6	73.1	
Intensive large scale (%)	19.0	10.4	26.9	
Farm workers (num.)	1.80 ± 1.52	2.36 ± 1.73	1.34 ± 1.15	0.001

Odeda LGA: Odeda Local Government; Abeokuta M: Abeokuta Metropolis /// *Odeda LGA: zone administrative de Odeda; Abeokuta M: Abeokuta Métropole* with scores lower than ten were 'absence of rodents, wild birds and stray animals on the farm', 'workers mandated use of clean and disinfected protective clothing before entering the farm', 'vehicle disinfected at the entrance of the farm' and 'all in all out restocking'. However, overall mean score in biomanagement/biocontainment was 49.83 ± 25.07 (range 17–89). Measures with scores higher than average were 'prophylactic herd treatment', 'cleaning done daily', 'water not from streams, rivers and unreliable sources', 'maintenance of animal movement record', 'farm wastes disposed of outside the farm' and 'vaccination of pigs'. The measures with lowest scores included 'functional foot dip at the entrance of each pen', 'train farm attendants on biosecurity measures after employment' and 'domestic animals do not have contact with pig's feedstuff and water source' (Table II). The grand mean biosecurity score on the farms was 35.62 ± 25.84. Biosecurity levels of only 15% of the pig farms were good. There was a significant difference between the means of bioexclusion and biomanagement/biocontainment components of the biosecurity measures (p < 0.001), however there was a significant correlation between both components (p = 001).

Table II: Scores (maximum: 100) of biosecurity measures on pig farms in two areas of Ogun State, Nigeria /// *Scores (maximum : 100) des mesures de biosécurité dans les élevages porcins de deux zones de l'Etat d'Ogun au Nigeria*

Biosecurity measures	Score	SD
Bioexclusion		
Distance to nearest farm ≥ 500 m	36.0	0.48
Farm fenced	21.0	0.41
Vehicle disinfected at the entrance of the farm	4.0	0.20
Mandatory quarantine of new stocks	48.0	0.50
At least three weeks of quarantine of new stocks	20.0	0.40
Workers mandated use of clean and disinfected protective clothing before entering the farm	3.0	0.17
Human and vehicular traffic into the farm restricted	33.0	0.47
Procurement of all your replacement stock from the same source	18.0	0.39
All in all out restocking method	7.0	0.26
Absence of rodents, wild birds and stray animals on the farm	0.0	0.00
Screening of new stocks for specific diseases	55.0	0.61
Other domestic animals absent from the farm	12.0	0.33
Overall score mean 21.42 ± 18.07		
Biomanagement and biocontainment measures		
Water not from streams, rivers and unreliable sources	79.0	0.41
Functional foot dip at the entrance of each pen	17.0	0.38
Isolation pen available for sick animals	41.0	0.49
Cleaning done daily	84.0	0.37
Farm wastes disposed of outside the farm	58.0	0.50
Domestic animals do not have contact with pig's feedstuff and water source	26.0	0.44
Restrictions on farm equipment in and out of farm premises	36.0	0.48
Train farm attendants on biosecurity measures after employment	19.0	0.39
Vaccination of pigs	52.0	0.50
Maintenance of animal movement record	63.0	0.49
Prophylactic herd treatment	89.0	0.31
Record of animal disease incidence	34.0	0.48
Overall mean score: 49.83 ± 25.07		
Grand mean score: 35.63 ± 25.84		

SD: standard deviation /// *SD : écart-type*

Table III presents results of the KMO test for bioexclusion (0.59) and biomanagement/biocontainment measures (0.65). PCA of all the parameters across the two biosecurity components on the pig farms extracted four principal components (PC1–PC4). In biomanagement/biocontainment measures PC1 contributed to the highest variance (28.76%). Bioexclusion measures contributed a cumulative variance of 64.17%. Absence of rodents on the farm was excluded in the parameters for factorial analysis of bioexclusion because rodents were present in all the farms. All other parameters in bioexclusion measures contributed highly to PC1 with highest contributions from "Human and vehicular traffic into the farm restricted" (0.68), "other domestic animals absent from the farm" (0.68), "farm fenced" (0.65), and "mandatory quarantine of new stocks" (0.63). The highest communality in bioexclusion measures was from "screening of new stocks for specific diseases" (0.77).

Biomanagement/biocontainment measures contributed a cumulative variance of 69.23% (Table III). All parameters contributed highly to PC1 with highest contributions from 'domestic animals do not have contact with pig's feedstuff and water source' (-0.86), 'vaccination of pigs' (0.86), 'maintenance of animal movement record' (0.80), 'restrictions on farm equipment in and out of farm premises' (-0.69) and 'farm wastes disposed of outside the farm' (0.58). In addition, PC2, PC3 and PC4 were contributed on a second, third and fourth stages, respectively, mostly from 'record of animal disease incidence' (0.82), 'cleaning done daily' (0.87) and 'water not from streams, rivers and unreliable sources' (0.90). The highest communality in biomanagement/biocontainment measures was from 'water not from stream, rivers and unreliable sources' (0.83) (Table III).

Determinants of farm biosecurity levels were number of years since farm establishment (p = 0.039, 95% confidence interval [CI] 0.005–0.194), herd size (p = 0.018, 95% CI 0.001–0.012) and educational qualification of the owner (Table IV).

Spatial distribution of pig farms and disease occurrence

The distribution of the pig farms with different biosecurity levels was significant and leaned toward a clustered scenario (z score: 3.182132) (Figure 2). Figure 3 shows Moran's I global spatial autocorrelation with various distances within the locations of the pig farms with different biosecurity levels at 10 increments against the level of significance (z score). This was achieved by incremental spatial autocorrelation analysis. The peak (distance: 4440 m, z score: 2.598851) shows where the cluster is maximum. To another pig farm the nearest distance was 10 meters, the average distance 889 m, and the maximum distance 10,425 m. Only 36 farms were at least 500 m away from their nearest neighbors, whereas the remaining farms were in close proximity. In Figure 4, the red circle shows areas of clusters with similarly high values near each other. In this case, there was an adequate biosecurity level close to each other. By contrast the blue circles show areas of clusters with similarly low values near each other. According to our analysis, there was an inadequate biosecurity level close to each other at these locations. The pink and green circles are the outliers. Pink circle outliers represent where there was adequate biosecurity surrounded by inadequate biosecurity and vice versa. The gray circles show areas where no significant clustering was observed (low z scores).

Table III: Factor analysis, KMO test and communality of each biosecurity measure on pig farms in two areas of Ogun State, Nigeria /// *Analyse factorielle, test KMO et communauté de chaque mesure de biosécurité dans les élevages porcins de deux zones de l'Etat d'Ogun au Nigeria*

Parameter	PC1	PC 2	PC 3	PC 4	Communality
Bioexclusion measures					
Human and vehicular traffic into the farm restricted	0.68	-0.15	0.40	0.13	0.66
Other domestic animals absent from the farm	0.68	0.19	-0.09	0.07	0.51
Farm fenced	0.65	-0.01	0.00	-0.27	0.49
Mandatory quarantine of new stocks	0.63	-0.47	0.27	0.07	0.69
At least three weeks of quarantine of new stocks	-0.21	0.84	-0.09	0.03	0.76
Screening of new stocks for specific diseases	-0.12	-0.83	-0.27	0.04	0.77
Distance to nearest farm ≥ 500 m	0.36	0.49	-0.24	0.22	0.48
Vehicle disinfected at the entrance of the farm	0.00	-0.04	0.86	-0.04	0.75
Workers mandated use of clean and disinfected protective clothing before entering the farm	0.09	0.06	0.83	-0.05	0.70
All in all out restocking method	0.24	0.09	-0.11	0.76	0.65
Procurement of all your replacement stock from the same source	-0.27	-0.03	0.03	0.72	0.59
Eigen values	2.44	1.87	1.58	1.17	
Percentage of variance	22.20	16.96	14.33	10.68	
Kaiser-Meyer-Olkin measure of sampling adequacy	0.59				
Biomanagement/biocontainment measures					
Domestic animals do not have contact with pig's feedstuff and water source	-0.86	-0.13	-0.11	0.15	0.79
Vaccination of pigs	0.86	-0.22	-0.03	0.04	0.79
Maintenance of animal movement record	0.80	-0.02	0.09	0.26	0.72
Restrictions on farm equipment in and out of farm premises	-0.69	0.03	-0.21	0.22	0.58
Farm wastes disposed of outside the farm	0.58	-0.48	-0.17	-0.03	0.59
Record of animal disease incidence	-0.17	0.82	0.08	-0.24	0.76
Isolation pen available for sick animals	0.02	0.73	0.13	-0.08	0.55
Functional foot dip at the entrance of each pen	-0.13	0.71	0.17	-0.02	0.56
Train farm attendants on biosecurity measures after employment	0.15	0.67	-0.21	0.31	0.61
Cleaning done daily	-0.02	0.10	0.87	0.00	0.77
Prophylactic herd treatment	0.47	0.16	0.72	0.06	0.76
Water not from streams, rivers and unreliable sources	-0.08	-0.09	0.03	0.90	0.83
Eigen values	3.45	2.59	1.16	1.09	
Percentage of variance	28.76	21.64	9.67	9.16	
Kaiser-Meyer-Olkin measure of sampling adequacy	0.65				

PC 1, PC 2, PC 3, PC 4: Principal components /// *PC 1, PC 2, PC 3, PC 4 : composantes principales*

Figure 5 shows locations of optimal clustering in biosecurity level with 90% to 99% confidence level. Red color indicates area of optimum clusters of inadequate biosecurity.

Two thirds of the farmers did not record any disease incidence, and 85% had no disease outbreak in the preceding year. There was no veterinary presence on most of the farms (67%) although farmers carried out prophylactic treatment of pigs (89%). The most previously encountered diseases/conditions on the farms were mange (57%), swine dysentery/diarrhea (47%), other diseases were ASF (3%), erysipelas (1%), brucellosis (1%), and foot and mouth (1%). More than a third of the farmers (37%) could not identify the sources of diseases on their farms; however, some identified contaminated feeds (7%), poor biosecurity (2%), roaming animals (2%), introduction of new stock (2%), visitors (1%), and flies (1%).

■ DISCUSSION

Farmers and farm characteristics

This study provided a baseline tool in the reorganization of the pig sector for strategic disease control in the study area. The predominance of male at their prime age in pig production as observed in this study is in agreement with the findings of Obayelu et al. (2017) who reported that pig production is dominated by men in Nigeria. Results showed that Christians made up the majority of the farmers (91%). This outcome is not surprising as the Muslim confession forbids keeping pigs. This corroborates findings in Nigeria by Obayelu et al. (2017), and in Cameroon by Kouam and Moussala (2018). The proportion of part-time farmers (professionals, students, civil servants, etc.) recorded in this study was in agreement with reports by Ajala (2007). However, this result was contrary to a study by Adesehinwa et al. (2003), who report that the majority of pig farmers surveyed in Oyo State, Nigeria, are in this business full time. Despite this variation, which might be due to differences in the closeness of study areas to urban centers, it implies that people in other occupations are also involved in pig farming as an additional source of income. The high number of the respondents in this study who had formal education, compared to the low rate of those who had no formal education, agreed with the observation of Obayelu et al. (2017), and will impact positively the adoption rate especially for the application of new technology in swine production, management and disease reporting. The majority of the respondents had at least five years of experience in pig farming (68%); this showed that most of the

Table IV: Determinants of biosecurity scores of pig farms in two areas of Ogun State, Nigeria /// *Déterminants des scores de biosécurité des élevages porcins dans deux zones de l'Etat d'Ogun au Nigeria*

Parameters	Regr. Coef.	P	95% confidence interval	
			Lower bound	Upper bound
Farmers' socioeconomic characteristics				
Sex				
Male	-0.612	0.255	-1.674	0.450
Female	0[a]			
Age				
18–30	-0.142	0.892	-2.205	1.922
31–40	1.069	0.121	-0.287	2.425
41–55	1.448	0.026	0.179	2.717
> 55	0[a]			
Religion				
Christianity	0.475	0.504	-0.933	1.884
Islam	0[a]			
Primary occupation				
Civil servant	0.014	0.984	-1.345	1.374
Farming	-0.157	0.706	-0.984	0.669
Others	0[a]			
Educational level				
No formal education	-1.568	0.233	-4.166	1.030
Primary education	-4.002	0	-5.867	-2.137
Secondary education	-1.062	0.018	-1.938	-0.186
Tertiary education	0[a]			
Marital status				
Single	0.157	0.909	-2.580	2.895
Married	-1.343	0.232	-3.559	0.874
Widow/er	0[a]			
Years of experience in pig farming	-0.044	0.232	-0.117	0.029
Farm characteristics				
Farming system				
Confined small scale	0.634	0.372	-0.771	2.039
Intensive large scale	0[a]			
Years of farm establishment	0.099	0.039	0.005	0.194
Herd size	0.007	0.018	0.001	0.012

Regr. Coef.: Regression coefficient; [a] Reference category /// *Regr. Coef. : coefficient de regression ; [a] Catégorie de référence*

farmers were not novice in the pig industry and that pig production was self-sustaining in terms of economic gain otherwise there would have been more out of business pig farmers than what was observed during the study (5.67%).

The majority of the farms were less than nine years, which could be attributed to the fact that pig farming has been a new frontier for investment in the livestock industry in the past few years. Besides there has been no major outbreak of pig disease such as ASF that could have discouraged production. The last major ASF outbreak in the study area was in 1997 when many pig farms were closed down (Otesile et al., 2005). The management system employed by the majority of farmers was the confined system which allowed the animals to be housed and fed in confinement. This ensures an efficient feed conversion ratio, feed to weight gain, enhanced productivity, as well as less probability of exposure to disease.

Assessment of biosecurity measures

The bioexclusion and biomanagement/biocontainment components on the pig farms using PCA showed that the sample size using KMO test for pig farms in selected local government areas in Ogun State, Nigeria, was adequate. The minimum KMO test standard is 0.5. All scored parameters for the study were important for the classification of biosecurity measures.

The study revealed that the biosecurity level on the pig farms in the study area was very low. Although, a significant correlation was observed between bioexclusion and biomanagement/biocontaiment scores, the mean scores significantly varied; farmers paid more attention to biomanagement/biocontainment. This is contrary to findings of Kouam and Mousala (2018), who reported an equal level of implementation of both components of biosecurity in Cameroon. Among the bioexclusion measures, screening of new stocks for specific diseases had the highest score; this may be because the major disease mostly reported was mange as it can be easily spotted through close observations by farmers. Farmers' experience and increased awareness or knowledge on pig diseases and management might also have contributed to this finding. Most other measures in bioexclusion were perceived as less important and scored lowest, especially the control of rodents, wild birds and stray animals on the farm. These animals are a great threat to livestock production because they transmit, among other diseases, trichinosis, leptospirosis, swine dysentery, and salmonellosis. Rodent control needs an integrated pest management strategy and must encompass habitat and biological control, rodent proof farm building, elimination of hiding places, trapping, and removal of food and waste.

For biomanagement/biocontainment, measures such as prophylactic herd treatment had the highest score followed by daily cleaning of pen. It has been observed that farmers tend to spend much in disease treatment instead of in prevention. Heffernan and Misturelli (2000) report the same trend in Kenya as farmers fail to realize that disease prevention is better than control since most times treatment measures are not always successful in the emergence of challenging disease outbreaks. Also, pig farmers may perceive disease prevention as costly, difficult and time consuming, whereas control is less demanding. Furthermore, most farmers in our study had never experienced an outbreak of a major devastating disease with almost 100% mortality such as ASF. The last two measures with the lowest scores in this component were 'functional foot dip at the entrance of each pen' and 'train farm attendants on biosecurity measures after employment'. Backhans et al. (2015) in Sweden also report limited use of footbath. These two measures do not require large investments, but farmers downplay them. This may result from lack of disinfectants and unavailability of extension officers to emphasize their importance. Farm workers' training by experts on risk management and biosecurity cannot be overemphasized. Farm workers need to be trained periodically in order to change attitude toward risk management, accountability and responsibility for each process on the farm. Investment in farm workers' training will be recouped through reduced losses caused by ignorance.

Many factors have been adduced for variation in biosecurity levels on farms, such as perceived cost, utility importance, increased workload and lack of knowledge (Fasina et al., 2012). In this study the determinants of the biosecurity level were farmers' educational level, herd size, and number of years since farm establishment. Education played a major role in rational decision-making. Also the herd size appeared as a type of economic indicator which played an important role in the decision-making process. Furthermore, the herd size was directly

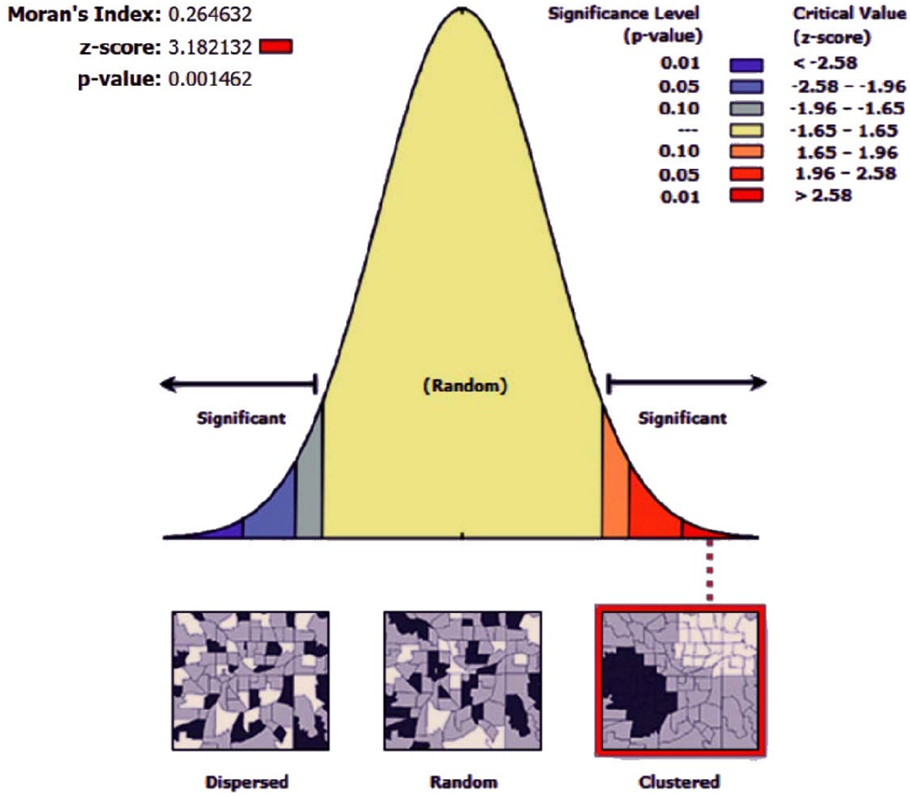

Figure 2: Spatial autocorrelation report on distribution of the pig farms with different biosecurity levels in Ogun State, Nigeria /// *Rapport d'autocorrélation spatiale sur la répartition des élevages porcins avec différents niveaux de biosécurité dans l'Etat d'Ogun au Nigeria*

associated with the levels of investment and income, consequently disease outbreaks in large herds could be highly devastating and with huge animal loss.

Spatial distribution of pig farms and disease occurrence

One of the characteristics of the farms surveyed was that they existed in clusters. The clustering of farmers in the same area may be due to the easy access to animal feed, market collective bargaining for incentives from government, and information sharing. Also clustering provides farmers with access to extension workers. It is relevant to note that when farms exist in clusters, each farmer of each group needs to reach a binding agreement on how to maintain an acceptable level of biosecurity, otherwise there is a limit to an individual farmer's ability to prevent the spread of disease-causing organisms in the farming community. According to Román et al. (2006), farm proximity to other pig farms is probably the main risk factor for the herd to contract a disease. This was corroborated by the recent outbreak of ASF in Ogun State,

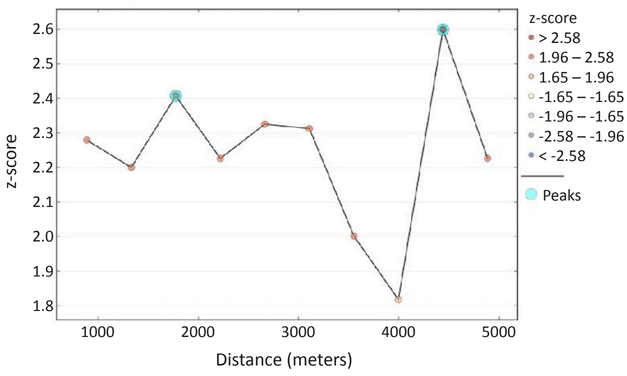

Figure 3: Global Moran's I spatial autocorrelation with distances in pig farms' location and biosecurity levels in Ogun State, Nigeria /// *Autocorrélation spatiale (indice de Moran) globale avec les distances selon l'emplacement des élevages porcins et leur niveau de biosécurité dans l'Etat d'Ogun au Nigeria*

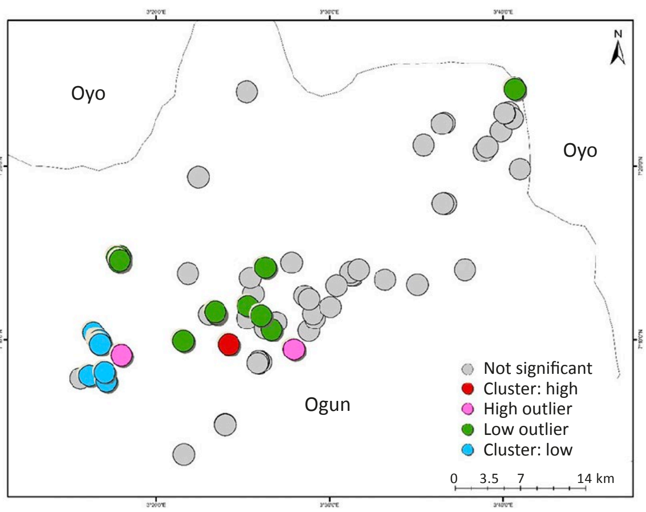

Figure 4: Pig farms' locations in Ogun State, Nigeria. Red circle: area of clusters with similar high values near each other. Blue circles: areas of clusters with similar low values near each other. Pink circles: outlier areas with adequate biosecurity surrounded by inadequate biosecurity, Green circles vice versa. Gray circles: areas where no significant clustering was observed /// *Localisation des élevages porcins dans l'Etat d'Ogun au Nigeria. Cercle rouge : zone de concentrations avec des valeurs fortes similaires proches les unes des autres. Cercles bleus : zones de concentrations avec des valeurs faibles similaires proches les unes des autres. Cercles roses : zones périphériques avec une biosécurité adéquate entourée d'une biosécurité inadéquate, cercles verts l'inverse. Cercles gris : zones où aucune concentration significative n'a été observée*

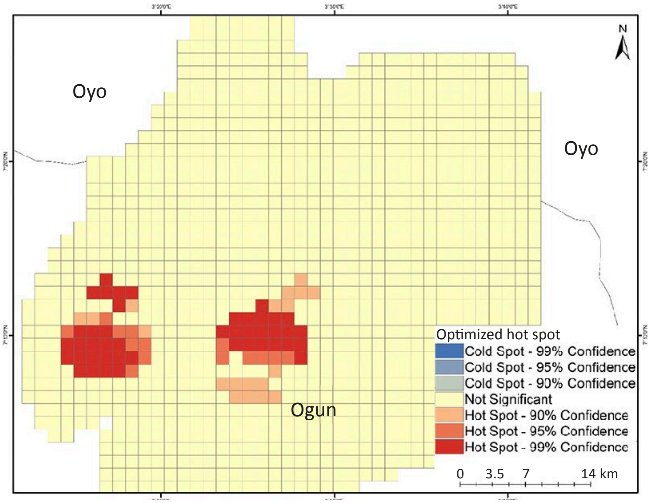

Figure 5: Locations of optimal pig farm clustering in biosecurity level with 90–99% confidence level, Ogun State, Nigeria /// *Localisation des concentrations maximales des élevages porcins en fonction du niveau de biosécurité avec un taux de confiance de 90-99 %, Etat d'Ogun, Nigeria*

where almost a million pigs were lost in a major pig farm community (FAO, 2020). The community-based biosecurity has to consider peculiarity of each herd, financial implication and preventable risk.

In our study recording of disease incidence was low (34.0%), so was veterinary consultation (33.0%). The importance of these two measures is immense. Herd health status assessments cannot be carried out without having comprehensive health and production records in conjunction with veterinarians' services. In addition, a good working relationship with veterinarians is necessary to develop a workable herd health plan which will culminate in disease prevention and control on the farm (Mee et al., 2012). In this study many farmers carried out prophylactic treatment on animals (57%) without veterinary prescriptions, which has been linked to the misuse and overuse of drugs, especially antimicrobials in pigs (Adebowale et al., 2020).

■ CONCLUSION

Results show that the implementation of biosecurity measures on pig farms in the study area is very poor. Agricultural policy makers must step in to improve the level of biosecurity on pig farms in Nigeria. Using a geographical information system to locate farms and animal populations, census of pig farms should also be carried out periodically as this will assist in developing an effective and practical policy on biosecurity on pig farms in Nigeria. Furthermore, to encourage good production practices including adequate biosecurity levels, incentives such as access to financial assistance and farm inputs could be given to farmers. The financial benefits of biosecurity on pig farms using together bioexclusion and biocontainment/biomanagement must be emphasized.

Conflicts of interest

The study was carried without any conflict of interest.

Author contributions statement

OJA participated in the conception and design of the study; OJA, OA and ORO collected data and drafted the first version of the manuscript; OOA, OOK, OOTA and FOA participated in the design; OJA and OOTA performed statistical analyses; OOA, OOK and FOA critically reviewed the ms.

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Résumé

Awoyomi O.J., Agbalu O., Oladipupo O.R., Adebowale O.O., Kehinde O.O., Awoyomi F.O., Tope-Ajayi O.O. Distribution spatiale et évaluation des niveaux de biosécurité des exploitations porcines dans des zones de gouvernement local sélectionnées de l'Etat d'Ogun, au Nigeria

L'étude a porté sur la distribution spatiale, la caractérisation et l'évaluation de la biosécurité des élevages porcins dans des zones administratives de l'Etat d'Ogun au Nigeria. Les données ont été recueillies à l'aide d'un questionnaire semi-structuré. L'autocorrélation spatiale a permis de mettre en évidence les relations entre la localisation des élevages porcins et les mesures de biosécurité. Un système de notation allant de 0 à 1 a été élaboré à partir des mesures de biosécurité retenues. Une mesure de biosécurité était notée 1 si présente, 0 si absente. Ces mesures ont été divisées en deux catégories : bioexclusion et biogestion/bioconfinement. Le score total de chaque mesure a été obtenu en additionnant tous les scores de chaque élevage. Cent élevages porcins ont été étudiés. Le nombre moyen d'années depuis la création de l'exploitation était de 7,32 ± 5,19 ans, les élevages étaient principalement confinés, de petite taille (81,0 %), avec une taille moyenne de troupeau de 58,9 ± 99,40, et 1,8 ± 1,52 employé. La distribution des élevages porcins avec différents niveaux de biosécurité était significative (p = 0,002) et tendait vers un scénario en grappe avec un indice de Moran de 0,27 et un score z de 3,18. Sur un score maximal de 100 pour chaque mesure, le « traitement prophylactique du troupeau » et le « nettoyage quotidien » ont obtenu des scores supérieurs à 80. En revanche, « absence de rongeurs, d'oiseaux sauvages et d'animaux errants dans la ferme », « utilisation obligatoire par les employés de vêtements de protection propres et désinfectés avant d'entrer dans la ferme » et « véhicule désinfecté à l'entrée de la ferme » ont obtenu des scores inférieurs à 5. Les scores moyens pour bioexclusion et biogestion/bioconfinement étaient respectivement de 21,42 ± 18,07 et 49,83 ± 25,07. Le score global de biosécurité de 35,63 ± 25,84 était significativement associé à la taille du troupeau, au nombre d'années depuis la création de la ferme et au niveau d'éducation des propriétaires. Afin d'assurer une productivité durable et de prévenir l'apparition de maladies, les éleveurs de porcs doivent accorder la plus grande importance à la biosécurité.

Mots-clés : porcin, ferme d'élevage, distribution spatiale, biosécurité, Nigeria

Resumen

Awoyomi O.J., Agbalu O., Oladipupo O.R., Adebowale O.O., Kehinde O.O., Awoyomi F.O., Tope-Ajayi O.O. Distribución espacial y evaluación de los niveles de bioseguridad de las explotaciones porcinas en las áreas de gobierno local seleccionadas del Estado de Ogun, en Nigeria

El estudio se centró en la distribución espacial, la caracterización y la evaluación de la bioseguridad de las explotaciones porcinas en las zonas administrativas del estado de Ogun, en Nigeria. Los datos se recogieron mediante un cuestionario semiestructurado. Se utilizó la autocorrelación espacial para evidenciar la relación entre la ubicación de las explotaciones porcinas y las medidas de bioseguridad. Se elaboró un sistema de puntuación que va de 0 a 1 en función de las medidas de bioseguridad seleccionadas. Una medida de bioseguridad se puntuó con 1 si estaba presente y con 0 si no lo estaba. Estas medidas se dividieron en dos categorías: bioexclusión y biogestión/biocontención. La puntuación total de cada medida se obtuvo sumando todas las puntuaciones de cada explotación. Se estudiaron cien explotaciones porcinas. El número medio de años desde la creación de la explotación era de 7,32 ± 5,19 años, las explotaciones eran principalmente confinadas, pequeñas (81,0 %), con un tamaño medio del rebaño de 58,9 ± 99,40, y 1,8 ± 1,52 empleados. La distribución de las explotaciones porcinas con diferentes niveles de bioseguridad fue significativa (p = 0,002) y tendió hacia un escenario de clúster con un índice de Moran de 0,27 y una puntuación z de 3,18. De una puntuación máxima de 100 para cada medida, el «tratamiento profiláctico del rebaño» y la «limpieza diaria» obtuvieron puntuaciones superiores a 80. Por otro lado, «ausencia de roedores, de pájaros silvestres y de animales errantes en la granja», «uso obligatorio de vestuario de protección limpio y desinfectado por parte de los empleados antes de entrar en la granja» y «vehículo desinfectado a la entrada de la granja» obtuvieron puntuaciones inferiores a 5. Las puntuaciones medias para la bioexclusión y la biogestión/biocontención fueron de 21,42 ± 18,07 y 49,83 ± 25,07 respectivamente. La puntuación global de bioseguridad, de 35,63 ± 25,84, se asoció significativamente con el tamaño del rebaño, el número de años transcurridos desde la creación de la explotación y el nivel educativo de los propietarios. Para garantizar una productividad sostenible y prevenir los brotes de enfermedades, los criadores de cerdos deben conceder la máxima importancia a la bioseguridad.

Palabras clave : cerco, explotaciones ganaderas, distribución espacial, bioseguridad, Nigeria