

Association between the swine production areas and the human population in Pinar del Río province, Cuba

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Abstract

Aim: The aim of this study was to demonstrate the association between high human population density and high pig production in the province of Pinar del Río, Cuba.

Materials and Methods: Records on pig movements at the district level in Pinar del Río province from July 2010 to December 2012 were used in the study. A network analysis was carried out considering districts, as nodes, and movements of pigs between them represented the edges. The in-degree parameter was calculated using R 3.1.3 software. Graphical representation of the network was done with Gephi 0.8.2, and ArcGIS 10.2. was used for the spatial analysis to detect clusters by the Getis-Ord G_i^* method and visualize maps as well.

Results: Significant spatial clusters of high values (hot spots) and low values (cold spots) of in-degree were identified. A cluster of high values was located in the central area of the province, and a cluster of low values involving municipalities of the Western zone was detected. Logistic regression demonstrated that a higher human population density per district was associated (odds ratio=16.020, 95% confidence interval: 1.692-151.682, $p=0.016$) with areas of high pork production.

Conclusion: Hot spot of swine production in Pinar del Río is associated with human densely populated districts, which may suppose a risk of spillover of pathogens able to infect animals and humans. These results can be considered in strategy planning in terms of pork production increases and improvements of sanitary, commercial, and economic policies by decision-makers.

Keywords: cluster, Getis-Ord, logistic regression, network analysis, swine.

Introduction

Pig rearing contributes decisively to the domestic economy of many families and national food security. It was an alternative for facing the economic constrictions. Since the last decade of the past century, a new strategy has been developed to stimulate pig rearing by private and cooperative sectors under a previous agreement with the state farming, which includes an improvement of sanitary measures and the veterinary control. The increases of swine population under the above conditions could also mean an increase of risk for human health since a higher animal-human health interface supposed an increased risk for human cases by zoonotic diseases.

This commercial agreement between the state swine enterprises and private producers, known as “swine agreements” (in Spanish “Convenios porcinos”), briefly consists in a sort of vertical integration, in which the state swine farms sell post-weaning animals to the other sectors with a partial support of feeding, considering the retail of animal at a market weight of approximately 90 kg. This alternative allows sharing pig production costs by its decentralization while creates employment opportunities and economic benefits for many stakeholders. However, such production system increases pig movement across the territory and may entails an increased risk of animal disease spreading and even zoonoses [1].

The network analysis is a useful method to assess animal movements, and it has been widely applied in veterinary epidemiology and in many other fields as well [2]. Among other applications, spatial analyses have been used to visualize spatial patterns in data, aiming to explain the observed patterns [3].

A spatial relationship between human and domestic pig populations has been shown in the

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risk of disease transmission between animals and humans (zoonosis), such as salmonellosis, leptospirosis, brucellosis, influenza, and hepatitis E, among others [1,4-7], and also in the spread of animal diseases such as classical swine fever (CSF), which is the most important disease affecting the pig production in Cuba. The association between CSF occurrence and the ingoing contact chain in Pinar del Río province was demonstrated by the network analysis [8].

Combining network analysis with spatial cluster detection to identify areas with higher or lower importance according to the level of production or with high risk of occurrence of disease outbreaks has been established as an interesting approach for the implementation or improvement of prevention, control, and surveillance activities [9].

In addition, the spatial link of animal production with human population densities may allow identifying areas with a higher risk of zoonosis. Identification of geographical areas where swine introduction is either significantly higher or lower and their association with human population density can be useful for those specialists working in the fields of production and health, and for decision-makers as well, taking into account their sanitary and productive potential impact. Therefore, this problematic issue is approached in the present work.

Materials and Methods

Ethical approval

This article does not contain any studies (experiment) with human or animal subjects performed by any of the authors.

Study area

The western most province of Cuba, Pinar del Río, was the study scenario. This province is divided into 11 municipalities comprising 97 districts, which are the smallest administrative division in Cuba. In this province, the districts have an average of 90.57 km².

Data sources

Records of pig movements at the people's council (municipality subdivision in Cuba) level from July 2010 to December 2012 were kindly provided by the provincial Animal Health Department, the Local Veterinary Authority. The number of animals entering (in-degree) the different districts was obtained by performing a network analysis. The districts were considered as network nodes and the pig movements between them as edges. The in-degree might not be the more precise parameter for our objective, but it was used in this case because the information on the number of pigs sent for slaughter was lacking and an effective pig census by producers was not available. Thus, it was assumed a direct relationship between the in-degree of pigs in a territory and the swine population.

The data of human population by districts were obtained from the official statistical records [10]. They were used to calculate the human density per km² by districts.

Statistical analysis

The in-degree parameter was calculated using the software R 3.1.3 [11]. The graphical representation of the network was carried out with Gephi 0.8.2 [12]. ArcGIS 10.2 [13] was used in the spatial analysis for detecting clusters of high and low swine in-degree by hot spot analysis (Getis-Ord G_i^*); this tool identifies significant spatial clusters of high values (hot spot) and low values (cold spot). The fixed distance band was established in 40 km, determined using Moran's index, and the Euclidean metric was used as distance method. For this study, true clusters were just considered when they were significant at least with 95% confidence.

A logistic regression was used for testing the association between clusters (>95% confidence) of swine in-degree and human population density. The dependent variable took value 1 for districts belonging to the cluster and 0 otherwise, and the human population density was analyzed as an independent variable (continuous variable) and calculated using the number of inhabitants divided by the area of each districts, this variable was standardized (i.e. subtracting by the mean and dividing by the standard deviation). The logistic regression was made using Epidat 4.2 [14].

The animal movement network and the detected clusters were visualized using ArcGIS 10.2 [13].

Results and Discussion

The yielded network of swine movements in the provinces where represented geographically, the number of pigs (in-degree) entering each district is shown in Figure-1.

The network analysis is a method applied to investigate live animal movements, and it is used each year by more and more researchers for several purposes, such as for example, for the support of disease control strategies and risk-based surveillance [15]. Within the veterinary epidemiology field, this method has been increasingly popular in the recent years [15-19]. This method can help to explore the potential of speed and range of spread of an infectious agent [17].

Significant spatial clusters of high values (hot spot) and low values (cold spot) of swine in-degree were identified (Figure-2). The significant cluster of high values was located on the central area of the province, where the provincial capital is also placed and, therefore, the largest human population density and commerce activity. The spatial analysis detected a swine in-degree hot spot of 29, 19, and 1 districts were significant for 90%, 95%, and 99% confidence. Other cluster of low in-degree involving districts of the Western zone was detected; this area has a low human population density and a low economic activity in the province. This cold spot involved four districts significant for 90% confidence and one district for 95% confidence.

On the other hand, spatial analysis to detect either hot or cold spots of different events has been widely used. Getis-Ord G_i^* can identify the locations

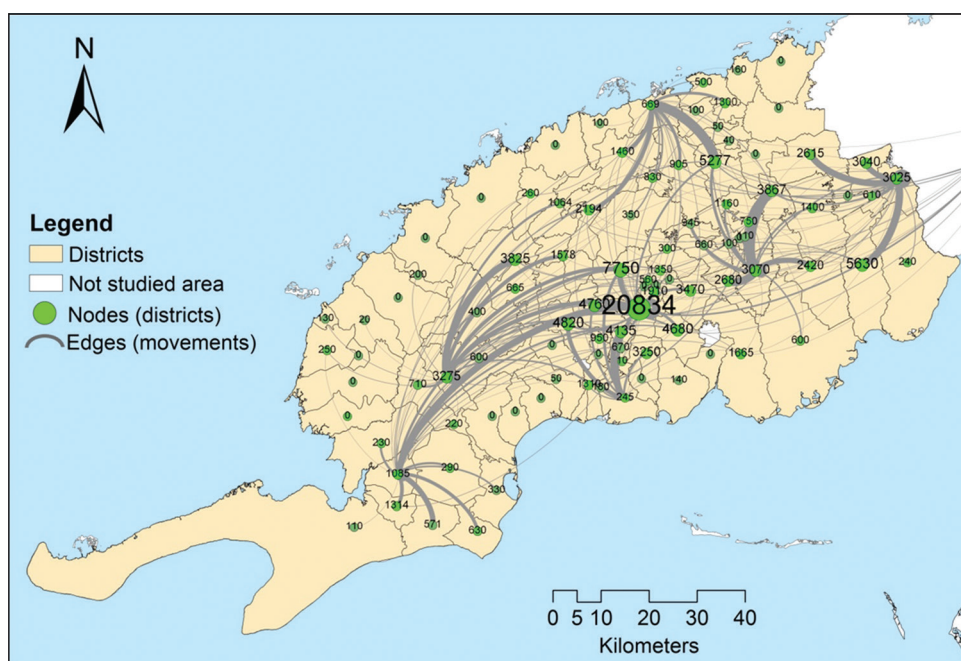


Figure-1: Spatial location of the pig movement network (numbers in green nodes represent the in-degree value).

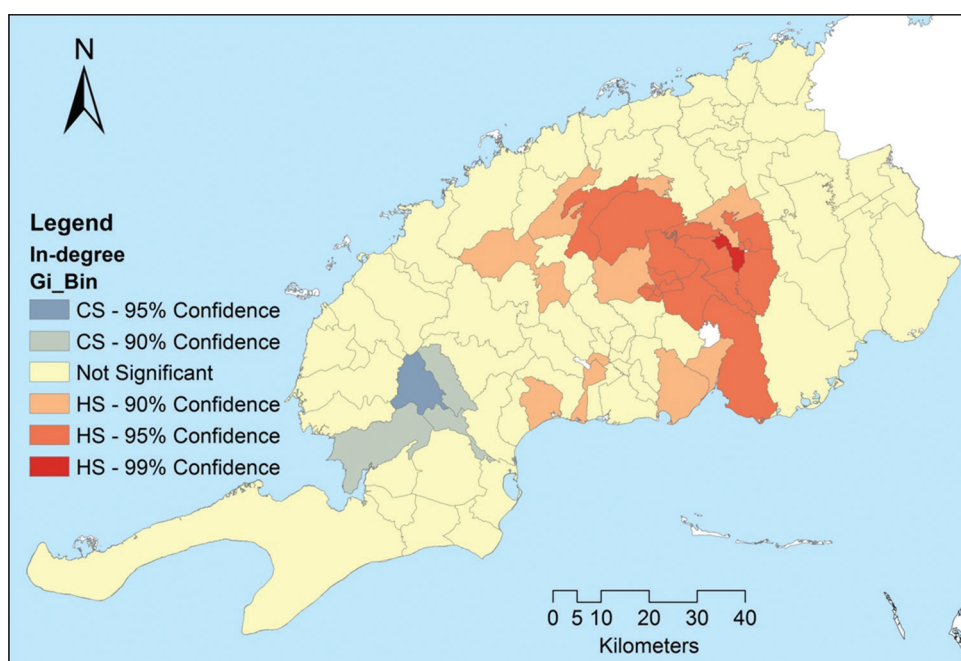


Figure-2: High and low swine in-degree spatial clusters (CS – Cold spot and HS – Hot spot).

of clusters of high and low values that are referred to as hotspots and cold spots, of respectively [20,21]. This technique has been used in epidemiology, criminology, sociology, etc. for detecting areas with high and low values of occurrence of certain events.

Spatial patterns of event distribution are widely divided into random, contagious, and regular patterns. There is special interest in clustering of events because it may help to identify a common environmental factor or source of exposure [22]. In this particular case, it was used to detect clusters of districts with high and low values of in-degree of pigs, these clusters of high and low in-degree represent areas of high and low pig production.

Other authors have combined network and spatial analysis with the aim of investigating the importance of network and spatial location in equine influenza spread in Australia [23] and also describing the equine influenza spread between horse premises, differentiating spread occurring through a known contact network from secondary local spatial spread [24]. It has also been used to identify temporal-spatial clusters of agricultural operations at high risk for the introduction and spread of diseases through the shipment of live pigs in the Spanish province of Salamanca [9].

Taking into account the spatial coincidence of the swine in-degree hot spot and districts with high human population density and, on the other hand,

a priori knowledge about the social tradition of pig breeding and its economic importance for the people, it was made the test for the spatial relationship between swine in-degree hot spot detected and human population density.

It was shown that a higher human population density per districts is associated (odds ratio=16.020, 95% confidence interval: 1.692-151.682, $p=0.016$) with the areas of high swine production (Table-1), and the probability of belonging to the cluster of high swine in-degree and the human population density was represented graphically (Figure-3).

As it is shown in Table-1 and Figure-3, the human population density was associated with the pig production activity in Pinar del Río province. In Cuba, backyard pig rearing and pig contracts, both by the same producers in very close facilities, is very common because the pork and its by-products are highly demanded and results in high incomes; it is why the most densely populated districts are those where the pig production is concentrated.

Livestock production is frequently concentrated near and around cities to meet the food needs of human settlements. These are the cases of cow milk and poultry egg production belonging to producers of medium and low income [25].

In Cuba, pork is an important source of animal protein in the people diet, and the retail network is very complex and extensive among informal sellers and also the official market. Detection of areas with high or low importance from the productive point of view could help to improve the best logistic plans as well as epidemiologic surveillance. The hot spot zone

should be considered a place in the province with the highest probability of entry of animal diseases and zoonosis through live animal movements. Movement of animals is considered the main risk factor for the introduction of many infectious diseases [26,27].

Veterinary medicine plays an essential role in protecting and promoting public health, especially in the prevention and control of zoonotic diseases [4]. Zoonotic disease agents account for approximately 75% of emerging human pathogens and for over half of known human pathogens [28].

Some of the diseases affecting livestock are zoonotic, and transmission can occur through direct contacts, indirect environmental contacts, or through food [29]. A lot of zoonotic diseases are well known to be a public health concern, for example, *Salmonella* is one of the most common and serious zoonotic foodborne pathogenic bacterium worldwide [4]; it is also widely recognized that the influenza virus has the ability to jump the species barrier and infect humans [6]; leptospirosis is a potentially fatal zoonosis occurring in many mammalian species, including humans, and maintenance of leptospire in the natural environment is largely determined by the ability of the pathogenic leptospire to adapt to a large number of wild and domestic animals that serve as reservoir host(s) including pigs [5]; brucellosis and leptospirosis, both of which are zoonoses and whose mechanisms of disease between human and non-human populations have to be considered. An important factor that determines the occurrence of such occupationally acquired zoonosis (in veterinarians, abattoir workers and farmers) is the amount of disease in domestic animals [1]. Veterinary and public health

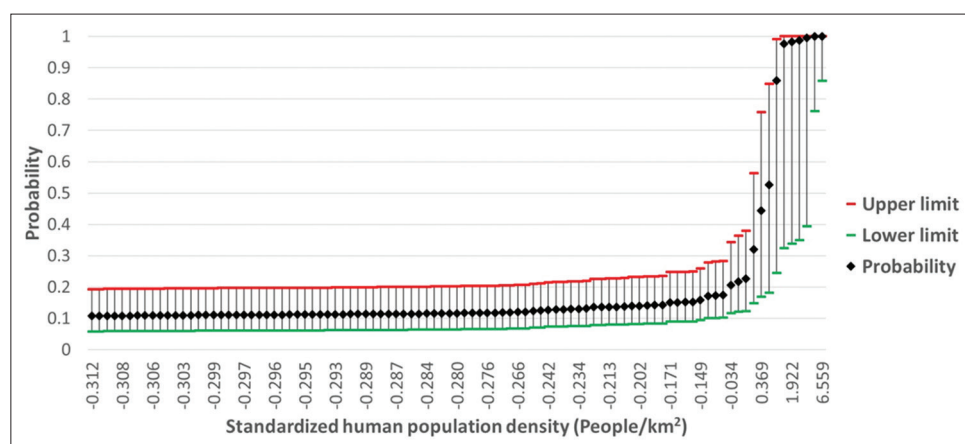


Figure-3: Association between high swine in-degree area and human population density.

Table-1: Output of logistic regression model analyzing associations between hot spot of swine in-degree area (95% confidence) and human population density.

Variable	B	SE	Wald	df	p value	OR	95% CI	
							Lower	Upper
Standardized human population density	2.774	1.147	5.849	1	0.016	16.020	1.692	151.682
Constant	-1.249	0.370	11.383	1	0.001	0.287		

OR=Odds ratio, CI=Confidence interval, SE=Standard error

authorities must pay special attention to clustered areas of pig in-degree because could be a high interaction between pigs and humans that could increase the risk of cases of zoonosis.

In Pinar del Río, the high human population density is associated with the high pork production because it is a common activity assumed by many people because of its economic benefits in the present economic context. The possibilities of a higher interaction between humans and pigs in these areas may suppose a higher risk of occurrence and transmission of zoonosis that should be investigated. Pigs have long been known to serve as reservoirs for zoonotic pathogens, some of them have become well-established in swine populations, impairing health and economic burdens [7]. Frequently changing husbandry practices and environmental factors (e.g. large scale domestic animal production, urbanization, interaction between wild and domestic animal populations with humans, population increases, etc.) may predispose humans and pigs to pathogens common to other species or may allow for the adaptation of these organisms to humans or swine [7].

These results offer insights for a better understanding of the risk of zoonosis and of those areas deserving a deeper intersectoral collaboration for surveillance and management of the associated risks. It could reveal spatial patterns of zoonosis infection and risk factors and could contribute to develop surveillance activities and control measures in animal and human populations.

Furthermore, the spatial association between high pig and human population densities could be as well a risk factor for the occurrence of diseases in the pig. In Cuba, CSF is endemic [30], this is one of the most devastating diseases in swine, concerning both economic and sanitary issues [31]. In a previous study, in which identification of risk factors contributing to CSF occurrence in Bulgaria was one of the objective, human demography variables, such as population by municipality, place of residence (urban, rural) and gender, were analyzed. Socioeconomic factors, such as household consumption and overall poverty including level of poverty, were also analyzed. This study showed interesting results identifying total urban population, among others, as a risk factor for CSF occurrence [32].

Moreover, socioeconomic and cultural factors are recognized as risk factors for the spread and maintenance of infectious disease like African swine fever (ASF). Those factors are very difficult to change because are part of the human behavior. Only the strict application of law, along with the use of new techniques to facilitate disease management, can help fight against ASF in these areas [33].

Those areas with the highest proportion of exposed humans become candidates for greater demands for biosecurity and its control. Further research works are needed to determine the prevalence and incidence

of important animal diseases and zoonoses in those areas and for identification of risk factors. Meanwhile, some actions can be implemented to reduce the potential risk of disease transmission, for example by (i) increasing the sanitary education of the population in general, but specifically of the workers having contact with swine; (ii) reinforcing the biosecurity level of the swine farms; (iii) giving special attention to the treatment of the swine farming wastewater; (iv) strengthening the epidemiological surveillance for swine and humans; (v) intensifying the control of animal movement; among others measures.

Prevention and early control of disease outbreaks could be the key to reducing the impact of epidemics and potential pandemics, especially in less developed countries (One Health proof of concept: Bringing a transdisciplinary approach to surveillance for zoonotic viruses at the human-wild animal interface, 2016).

Conclusions

Hot spot of swine production in Pinar del Río is associated with human densely populated districts, which may suppose a risk of spillover of pathogens able to infect animals and humans. Demographic and socioeconomic factors could be associated with outbreaks of infectious diseases in swine population. Policy makers must consider these results for planning strategies in terms of reforming the increasing swine production in areas with high density of human population, commercial and economic activities, and also of improving sanitary measures such as disease surveillance and control strategies.

Authors' Contributions

OFonseca: Data collecting, analyses and graphic representation of results, manuscript writing. KRS: Manuscript reviewing, reference search, study conduction, statistical assistance, research advisor. PA: Manuscript reviewing and reference search. JA: Data collecting, manuscript reviewing, reference search. MAA: Manuscript reviewing. OF: Manuscript reviewing. YC: Data collecting and analyses. DNM: Data collecting and analyses. MIP: Manuscript reviewing, reference search, study conduction, epidemiological analysis assistance. All authors read and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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