

Original Research

Comparative Analysis of Characterization Methods of Potential Environmental Pollution Risk from Livestock and Poultry Breeding

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Abstract

Based on statistics data of livestock and poultry of Guangdong Province, seven characterization methods were used to characterize potential environmental pollution risk of livestock and poultry breeding (LPB) of Guangdong and were analyzed comparatively. The results showed that the results of different characterization methods of potential environmental pollution risk of LPB were generally uneven in spatial distribution. The maximum value of seven characterization methods of potential environmental pollution risk of LPB were all in Shunde District, but the minimum value of seven characterization methods of potential environmental pollution risk of LPB were in different counties. In addition, the number of counties exceeding the safety thresholds also had large differences among different characterization methods of potential environmental pollution risk of LPB. The maximum number, second number, and minimum number of counties exceeding safety thresholds was by the alarm value of pig manure equivalent load of farmland calculated by nitrogen (AVPMELFN), livestock density (LD), and the pig manure equivalent load of farmland calculated by phosphorus (PMELFP), which accounting for 82.22%, 53.89%, and 11.11% of total counties, respectively. It showed that the most stringent method was the AVPMELFN followed by the LD, and the least stringent method was the PMELFP.

Keywords: livestock and poultry, potential, environmental pollution, characterization methods, comparative analysis

Introduction

With the rapid development of China's national economy, LPB has been expanding rapidly, resulting in

a large amount of livestock manure. Previous studies have demonstrated that the livestock manure in China was 3.264 billion tons, which was 1.6 times the total amount of industrial solid waste in 2009 [1-3]. Fischer et al. [4] forecasted China's livestock manure in 2020 will increase by 37% compared to China's livestock manure in 2007. Obviously, a large number of livestock manure

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would pose a great threat to the environment at present and in the future. In order to solve the problem of environmental pollution caused by LPB, characterizing the potential environmental pollution risk of LPB scientifically was the critical first step.

A series of research has focused on the potential environmental pollution risk of LPB [5-6]. At present, the research mostly adopted methods such as LD, AVPMELFN, PMELFP, and so on. Using the LD, Tamminga [7] found that the LD in Holland and Belgium was 3.29 AU/ha and 3.18 AU/ha in 2000, while the average LD in EU was only 0.91 AU/ha. Li et al. [8] analyzed the spatial distribution of the LD and calculated the LD in three northeastern provinces. The results showed that the LD in Liaoning Province, Jilin Province, and Heilongjiang Province was 1.64 AU/ha, 1.91 AU/ha, and 0.73 AU/ha, respectively, in 2005. In addition, the LD was often used as a standard for the prevention of potential environmental pollution risks of LPB. For example, the LD in the EU cannot exceed 2 AU/ha [9]. Moreover, Song et al. [10] evaluated potential environmental pollution risks of LPB of Anhui Province by the livestock manure nitrogen load of farmland (LMNLF) and livestock manure phosphorus load of farmland (LMPLF). Liu et al. [11] calculated the total livestock manure of China and evaluated environmental pollution risks by the PMELFN while other researchers carried out related research on potential environmental pollution risks of LPB by the alarm value of the pig manure equivalent load of farmland (AVPMELF) [12-14].

In summary, the existing research was to use different methods to characterize the potential environmental pollution risk of LPB in different scales and regions. However, the different methods for

characterizing the potential environmental pollution risk of LPB were different from each other because of different indicators, which made differences in results.

At present, there is still a lack of standard characterization methods of potential environmental pollution risk of LPB and comparative analysis research of different characterization methods of potential environmental pollution risk of LPB in the same area or on the same scale. Therefore, it was difficult to make clear which characterization methods of potential environmental pollution risk of LPB were relatively scientific and reasonable.

The objectives of this study were 1) to characterize the potential environmental pollution risk of LPB in Guangdong counties in seven characterization methods; 2) to display characterization results of different characterization methods of potential environmental pollution risk of LPB visually using geographic information system technology; and 3) to comparatively analyze seven characterization methods of potential environmental pollution risk of LPB with each other by combining with GIS spatial analysis method.

Material and Methods

Data Sources and Processing

In order to carry out this research, the basic data should be gained and processed as follows. Firstly, the statistics data of livestock and poultry and farmland in Guangdong counties were gained from the Rural Statistical Yearbook of Guangdong in 2014. The livestock species included cow, beef cattle, draft cattle, pig, sheep, chicken, duck, goose, and rabbit. Secondly, parameters

Table 1. Excretion coefficients and nutrient content of livestock manure and equivalent conversion coefficient in different livestock.

Livestock type	Livestock unit	Manure and urine type	Feeding cycle/d	Excretion coefficients/ (kg/d)	Nitrogen content/ (g/d)	Phosphorus content/ (g/d)	Pig equivalent manure (N)	Pig equivalent manure (P)
Pig	9.09	Manure	199	2.00	5.88	3.41	1	1
Draft cattle	1	Manure	365	20.00	4.37	1.18	0.74	0.35
Beef cattle	1.14	Manure	365	20.00	4.37	1.18	0.74	0.35
Cow	0.74	Manure	365	25.00	4.37	1.18	0.74	0.35
Sheep	6.98	Manure	365	2.60	7.50	2.60	1.28	0.76
Chicken	250	Manure	210	0.12	9.84	5.37	1.67	1.57
Duck	250	Manure	210	0.13	11.00	6.20	1.87	1.82
Rabbits	151.30	Manure	90	0.16	7.73	1.60	1.31	0.47
Pig	9.09	Urine	199	3.30	3.30	0.52	0.56	0.15
Draft cattle	1	Urine	365	10.00	8.00	0.40	1.36	0.12
Cow	0.74	Urine	365	13.00	8.00	0.40	1.36	0.12
Beef cattle	1.14	Urine	365	10.00	8.00	0.40	1.36	0.12

such as feeding cycle, excretion coefficient of livestock, and the nutrient content coefficient of livestock manure were gained by references (Table 1) [8, 14-17]. Thirdly, the digital distribution map of in Guangdong counties was digitized according to the administrative map of Guangdong of 1:100 000 using ArcGIS9.3 software. Furthermore, ArcGIS9.3 software was used to realize the correlation between the digital distribution map of Guangdong counties and the statistics data of livestock and poultry and farmland.

Feeding cycle, excretion coefficients, nitrogen content, and phosphorus content derived from [8, 14, and 16]; livestock unit derived from [15] and [17]; pig equivalent manure (N) and pig equivalent manure (P) is calculated according to nitrogen content and phosphorus content.

Calculation Method of Livestock Density

LD was the amount of livestock units per unit farmland area, which was often used as one of the indicators to measure agricultural loss risk of nitrogen and phosphorus [8]. Due to the difference of excretion coefficient of livestock and nutrient content coefficient of livestock manure. Therefore, to facilitate LD calculation, the amount of livestock was converted into the international standard livestock unit. The LD was calculated as follows [8, 17]:

$$M = W_{num} / S \quad (1)$$

...where M is the LD, AU/ha; W_{num} is the amount of livestock unit, AU; and S is farmland area, ha.

Calculation Method of Livestock Manure Nutrient Load of Farmland

At present, the main way livestock manure was treated was as organic fertilizer to farmland. Therefore, farmland was taken as the actual load area for calculating the livestock manure phosphorus load. The livestock manure nutrient load of farmland (LMNLF) was calculated as follows [5, 18]:

$$F_{farmland} = \sum_{i=1}^m (Num_i \times D_i \times f_i \times Nutri_i / S) \quad (2)$$

...where $F_{farmland}$ is the LMNLF, kg/ha; Num_i is the amount of livestock; D_i is the feeding period, d; f_i is excretion coefficient of livestock, kg/d; $Nutri_i$ is nutrient content coefficient of livestock manure, g/kg; m is number of livestock manures source; and S is farmland area, ha.

Calculation Method of Pig Manure Equivalent Load of Farmland and the Alarm Value of Pig Manure Equivalent Load of Farmland

Due to fertilizer efficiency, differences of livestock manure between different types of livestock manure vary greatly, so the different types of livestock manure were often converted into the pig equivalent manure. And the PMELF and AVPMELF were used to characterize potential environmental pollution risk of LPB. It was calculated as follows [19]:

$$Z = Y_{num} / S \quad (3)$$

$$R = Z / Z_{max} \quad (4)$$

...where Z is the PMELF, kg/ha; Y_{num} is the amount of pig manure equivalent; S is farmland area, ha; R is the AVPMELF; and Z_{max} is the maximum suitable application amount of organic fertilizer taking pig manure equivalent as standard, kg/ha.

Results and Discussion

We determined the grading standards of different characterization methods of potential environmental pollution risk of LPB from the relevant literature (Table 2) [8, 10, 19-21].

On this basis, seven characterization methods were used to characterize potential environmental

Table 2. Grading standard of seven characterization methods of potential environmental pollution risk of LPB.

Characterization methods of potential environmental pollution risk of LPB	Grading standards					
LD (AU/ha)	<1	1-1.5	1.5-2	2-2.5	2.5-3	>3
LMNLF (kg/ha)	<90	90-110	110-130	130-150	150-170	>170
LMPLF (kg/ha)	<20	20-25	25-30	30-35	30-40	>40
PMELFN (t/ha)	<10	10-15	15-20	20-25	25-30	>30
PMELFP (t/ha)	<10	10-15	15-20	20-25	25-30	>30
AVPMELFN	<0.4	0.4-0.7	0.7-1.0	1.0-1.5	1.5-2.5	>2.5
AVPMELFP	<0.4	0.4-0.7	0.7-1.0	1.0-1.5	1.5-2.5	>2.5

pollution risk of LPB in Guangdong counties in 2013 (Fig. 1).

The results showed that potential environmental pollution risk of LPB in Guangdong counties of different characterization methods were generally uneven in spatial distribution. In general, the potential environmental pollution risk of LPB in counties of Guangdong had gradually increased from the northeast to the southwest. In view of the spatial distribution scope of counties exceeding the safety thresholds of potential environmental pollution risk of LPB, the largest, second largest, and least largest characterization methods was the alarm value of the PMELFN, LD, and PMELFP. Comparing and analyzing the seven characterization method results, the spatial distribution scope of counties exceeding the safety thresholds by the LMPLF included the spatial distribution scope of counties exceeding the safety thresholds by the LMNLF, while the spatial distribution scope of counties exceeding the safety thresholds by the PMELFN was more than the PMELFP.

According to statistical results, the number of counties exceeding the safety thresholds had large differences among different characterization methods. The maximum number of counties exceeding safety thresholds was 74, accounting for 82.22% of the total number of counties in the AVPMELFN. Among them, the maximum and minimum values of potential environmental pollution risk of LPB were 6.43 in Shunde District and 0.23 in Longmen County. The second number of counties exceeding safety thresholds was 53, accounting for 53.89% of the total number of counties in the LD. Among them, the maximum and minimum values of potential environmental pollution risk of LPB was 22.60 AU/ha in the Shunde District and 0.79 AU/ha in Longmen County. The minimum number of counties exceeding safety thresholds was 10, accounting for 11.11% of the total number of counties in the pig manure equivalent load of farmland calculated by phosphorus (AVPMELFP). Among them, the maximum and minimum values were 151.80 t/ha in Shunde District and 3.87 t/ha in Longmen County. The LMPLF was consistent with the AVPMELFP in a number of counties

exceeding safety thresholds, and the maximum and minimum values of potential environmental pollution risk of LPB.

The maximum value of potential environmental pollution risk of LPB was in Shunde District in all seven characterization methods. The minimum value of potential environmental pollution risk of LPB of the LMPLF, PMELFP, and PMELFP was in Shixing County. The minimum value of potential environmental pollution risk of LPB of the other four characterization methods was in Longmen County. Moreover, ten counties (including Sanshui, Xinyi, Nanxi, and Shunde District) were all exceeding safety thresholds of potential environmental pollution risk of LPB in seven characterization methods.

To avoid the environmental pollution risk of LPB in these ten counties, the solutions should be prepared, such as reducing the amount of livestock and poultry, increasing farmland area, transporting excess livestock manure to other counties not exceeding safety thresholds of potential environmental pollution risk of LPB, transforming livestock manure into biogas, and so on. Which solution would be adopted depends on the actual situation of each county.

The results demonstrated that there is a great difference in spatial distribution scope and the number of counties exceeding the safety thresholds of potential environmental pollution risk of LPB in seven characterization methods. The reason was that different characterization methods adopted different indicators that have the stress. Results of studies conducted by [10] and [20] also found that the results obtained by characterization methods of LMNLF and LMPLF were distinctly different. The results in this paper were essentially consistent with the research conducted by [21] in that there existed significant discrepancies among characterization methods of LD, LMNLF, and LMPLF.

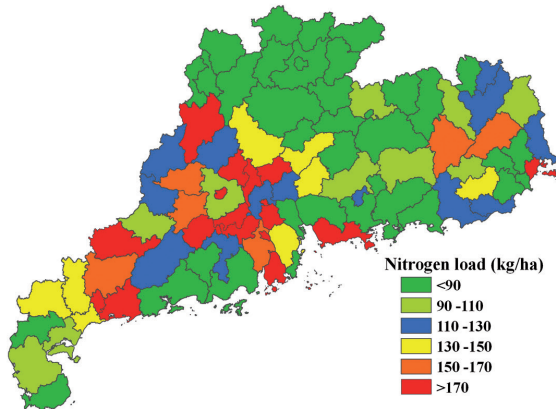
The results also showed that the number of counties exceeding the safety thresholds had large differences among different characterization methods. And the alarm value of the PMELFN had the maximum

Table 3. Statistical results of different characterization methods of potential environmental pollution risk of LPB.

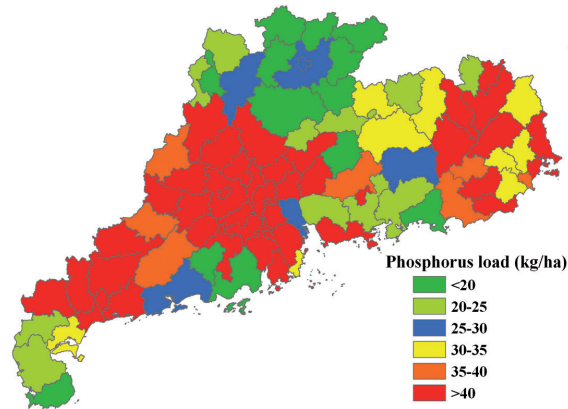
Characterization methods of potential environmental pollution risk of LPB	Safety thresholds	Ratio of exceeding safety threshold	Maximum value	Minimum value	Average value
LD (AU/ha)	2	53.89%	22.60	0.79	3.33
LMNLF (kg/ha)	170	20.00%	1129.54	163.78	38.54
LMPLF (kg/ha)	40	48.89%	516.88	13.14	52.81
PMELFN (t/ha)	30	23.33%	192.75	7.01	27.42
PMELFP (t/ha)	30	11.11%	151.80	3.87	17.10
AVPMELFN	0.4	82.22%	6.43	0.23	0.98
AVPMELFP	0.4	50.00%	5.06	0.13	0.52

Safety threshold of LD derived from [17]; safety threshold of LMNLF derived from [10]; safety threshold of LMPLF derived from [21]; PMELFN and PMELFP derived from [16]; AVPMELFN and AVPMELFP derived from [19]

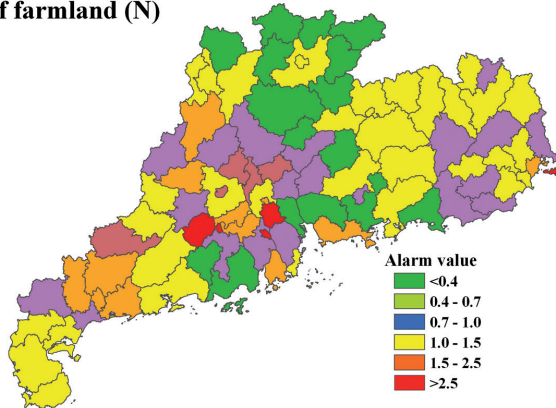
a) Livestock manure nitrogen load of farmland



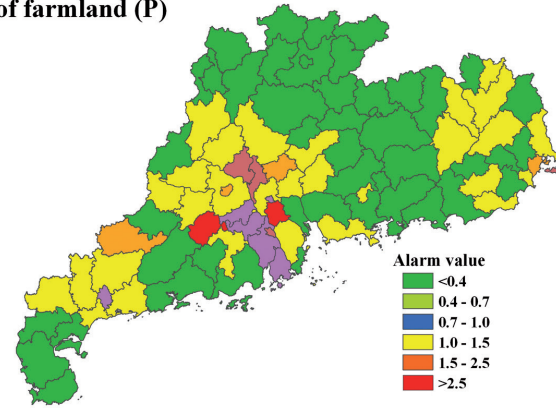
b) Livestock manure phosphorus load of farmland



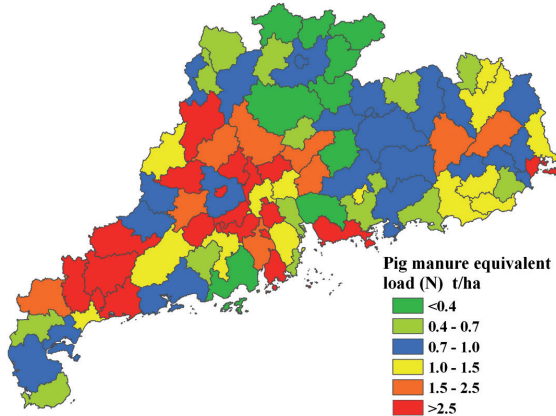
c) The alarm value of pig manure equivalent load of farmland (N)



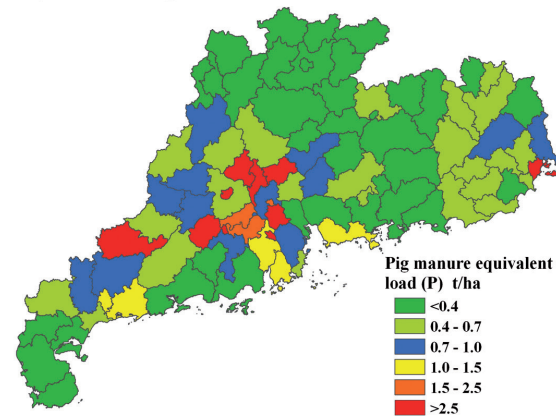
d) The alarm value of pig manure equivalent load of farmland (P)



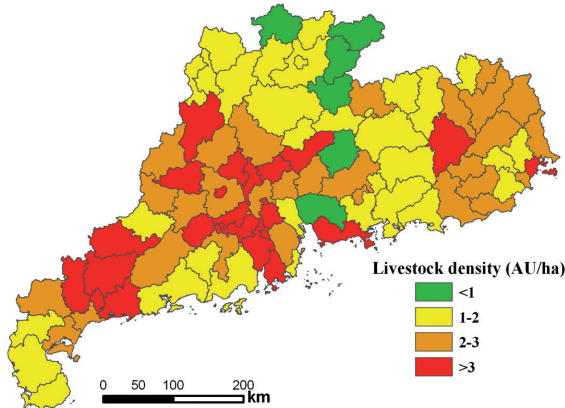
e) Pig manure equivalent load of farmland (N)



f) Pig manure equivalent load of farmland (P)



g) Livestock density



h) Counties exceed the safety threshold of seven characterization methods

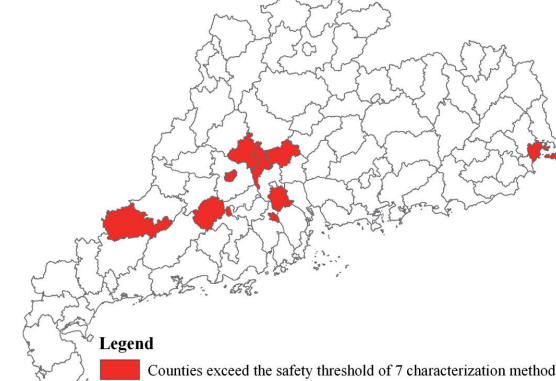


Fig. 1. Spatial distribution results of seven characterization methods of potential environmental pollution risk of LPB in Guangdong counties.

number of counties exceeding safety thresholds, while the PMELFP had a minimum number of counties exceeding safety thresholds. The Shunde District was the most serious potential environmental pollution risk of LPB in all seven characterization methods. The main reason was that the total farmland area of the Shunde District was only 1223.94 ha, which was the third least in Guangdong, only just more than 264.54 ha in Fushan city and 450.41 ha in Nanxi County. In all seven characterization methods, the stringent method was the alarm value of the PMELFN followed by LD, and the least stringent method was the PMELFP.

Compared to the results of potential environmental pollution risk of LPB characterized by one or two characterization methods in Li et al. [8], Song et al. [10], Huang et al. [12] and Zhu et al. [14], these results used seven characterization methods to characterize potential environmental pollution risk of LPB and comparatively analyzed seven characterization methods of potential environmental pollution risk of LPB with each other.

This result was basically consistent with the results conducted by Chen et al. [22] that the highest risk alert level was found in Pearl River Delta areas, particularly in the Xijiang River basin area.

Through the analysis of the existing literature, the alarm value of the PMELFN had often been used to characterize potential environmental pollution risk of LPB [19, 23]. The LD was generally used as standard to make regulations by European and American [24-25]. Our research further confirmed above research or laws, and regulations had a good scientific rationality. Therefore, in view of the sustainable development of LPB, characterization methods of potential environmental pollution risk of LPB should prefer to select the alarm value of the PMELFN and LD. And we should try to avoid selecting PMELFP, LMNLF, and PMELFN. In view of the fact that there was no unified characterization method to characterize the potential pollution of LPB in China, we suggest that the Ministry of Agriculture and Ministry of Environmental Protection take the alarm value of the PMELFN and LD as a risk assessment index to characterize the potential environmental pollution risk of LPB.

Conclusions

This study was conducted to characterize potential environmental pollution risk of LPB in counties of Guangdong Province by using seven characterization methods. And seven characterization methods were comparatively analyzed with each other. How to select suitable characterization methods of potential environmental pollution risk of LPB are the key objectives for future research. Different characterization methods of potential environmental pollution risk from livestock and poultry breeding need to be comparatively analyzed in a wider range. In our study, we have only emphasized characterization methods of potential

environmental pollution risk of LPB in county scale and single year. In the future, more work should be done to characterize potential environmental pollution risk of LPB and comparatively analyze different characterization methods of potential environmental pollution risk of LPB in different years and different scales such as city scale, town scale, village scale, and so on.

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Conflict of Interest

The authors declare no conflict of interest.

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