

the district level. There was significant improvement in the estimators by the use of auxiliary information through calibration estimation technique for estimation of rice yield. In Bareilly district, there was maximum improvement in %CV of the calibration ratio-type estimator (\bar{y}_{cal}) over the simple HT estimator (\bar{y}_{HT}) for estimation of paddy yield when the sampling design under consideration was two-stage equal probability without replacement sampling design at each stage of selection. Further, the yield estimates of wheat crop varied from 3797.89 to 4686.76 kg/ha in case of HT estimator, whereas it varied from 3601.40 to 5136.72 kg/ha in case of the proposed calibration ratio-type estimator. The %CV varied from 2.49 to 3.42 in case of the HT estimator and it varied from 0.43 to 0.90 in case of the proposed calibration ratio-type estimator. So for estimation of wheat yield in the above-mentioned districts of UP, it can be seen that calibration ratio-type estimator of crop yield performs better than the usual HT estimator with respect to improvement in %CV under two-stage equal probability without replacement sampling design.

It can be concluded that for estimation of crop yield, the proposed estimator is more efficient than the HT estimator with respect to %CV under two-stage equal probability without replacement sampling design. Further, it can be concluded that no prior assumptions are made about the assisting model for formation of estimators with the help of auxiliary informations, calibration estimation technique can be treated as a better alternative.

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Estimation of carrying capacity of livestock farm based on maximum phosphorus load of farmland and GIS spatial analysis technology

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To avoid the environmental pollution caused by livestock manure and provide rational layout of livestock farm, we estimated the livestock manure phosphorus load by the excretion coefficient method and have developed a livestock manure nutrient distribution model. The livestock manure phosphorus was distributed to farmlands using this model and spatial analysis technology. The carrying capacity of livestock farms was calculated based on the maximum livestock manure phosphorus carrying capacity of farmlands and expressed in pig for the Shangjie town, China. The results showed that the maximum, minimum, average and total livestock manure phosphorus carrying capacity of farmlands was about 55.97, 0.74, 12.21 and 13,382.90 kg respectively, and the total load of

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2854.79 kg manure phosphorus from livestock farms surpassed the carrying capacity of farmlands in Shangjie town in 2011. The results also demonstrated that the maximum, minimum, average and the total carrying capacity of livestock farms was respectively, 792, 10, 157 and 9128 pigs. Most of the livestock farms in the town had carrying capacity of less than 300 pigs and only six farms had carrying capacity of livestock more than 500 pigs. The results could provide decision support for the spatial layout of livestock farms, controlling environmental pollution caused by livestock manure.

Keywords: Carrying capacity, farmlands, livestock manure, phosphorus load.

THE livestock industry has developed rapidly, generating massive livestock manure, that has then resulted in many environmental problems. On the other hand, livestock manure could help improve soil fertility as it is rich in nutrients like nitrogen, phosphorus and potassium. However, studies have shown that the transportation distance of livestock manure is limited from livestock farm to farmland and livestock manure was mostly applied to farmlands located near the livestock farms¹⁻³. Although livestock manure is an important source of organic nutrients, the unsafe use of manure nutrients has a negative impact on sustainable development of agriculture⁴.

Once the amount of livestock manure applied surpasses the carrying capacity of a farmland, it would cause various environmental issues^{5,6}. In order to minimize these environmental issues and promote sustainable development of livestock farms, the density of livestock needs to be controlled according to the carrying capacity of livestock in certain regions^{7,8}. So it is important to estimate the carrying capacity of regional livestock farms intuitively and scientifically.

At present, many countries and regions have made various regulations of the maximum livestock density based on nutrient budget of farmland, such as 2.0 AU (Animal unit)/hm² in the European Union, and 3.5–4.5 AU/hm² in Germany, etc.^{9,10}. A series of studies have focused on the carrying capability of livestock in different regions^{11,12}. Thapa and Pandel¹³ studied the carrying capability of livestock in Nepal's Shyangja district and evaluated the number of existing livestock according to livestock carrying capacity of the land. Depending on geographical information technology and remote sensing technology, Yu *et al.*¹⁴ estimated herbage yield and the maximum carrying capacity of livestock of alpine grassland in Golog Prefecture, Qinghai, China. Moreover, the grazing capacity of livestock in the grasslands of Tibet was studied based on carrying capacity of livestock of grasslands¹⁵. According to the theory of farmland nutrient balance, Gerber *et al.*¹⁶ estimated the space density of livestock and poultry. Wu *et al.*¹⁷ made comparative analysis on carrying capacity of livestock and load index

of farmlands in Yucheng city of Shandong and TaoYuan county of China's Hunan Province. Hao *et al.*¹⁸ studied the carrying capacity of livestock based on the configuration of farmland area. The farmland areas and types also affect farmland nutrient requirements¹⁹. Therefore, if the carrying capacity of livestock manure of farmlands is estimated by distributing livestock manure to the farmlands equally, it would result in error and not reflect the actual carrying capacity of livestock manure of farmlands.

The estimation of carrying capacity of livestock and poultry adopted in the above-mentioned studies, considered only an average distribution of the total amount of livestock manure in an administrative area. A few studies had considered the space position of livestock farm, which livestock manure phosphorus surpassed the carrying capacity of farmlands nearby^{11,19}.

The objectives of the present study are: (i) to estimate the livestock manure phosphorus by the excretion coefficient method and establish livestock manure nutrient distribution model; (ii) to distribute livestock manure phosphorus to farmlands using the livestock manure nutrient distribution model and spatial analysis technology; (iii) to estimate livestock manure phosphorus load of farmlands and also their surplus nutrient of livestock manure phosphorus load and (iv) to calculate and display the carrying capacity of livestock farms visually using geographic information system (GIS) technology.

Shangjie town is located in the western suburbs of Fuzhou, Fujian Province, China with approximately 157 sq. km and 7.74 thousand residents. It is characterized by subtropical monsoon climate, with annual mean temperature of 21°C and annual mean precipitation rainfall of 2152.6 mm.

In order to estimate the carrying capacity of the regional livestock farm, the basic data were acquired and processed as follows. The digital distribution map of basic geospatial data, including administrative, road, water, land use and farmland, was generated from the QuickBird remote sensing image with 0.61 m resolution, and administrative map of Shangjie town in 2011 using ArcGIS9.3 software and ENVI5.0 software. Furthermore, a 1096 farmlands were selected from the digital distribution maps and classified into four types: cultivated land, vegetable land, garden land and facility agriculture land (plastic house, greenhouse, etc.) based on survey data and statistical data. Also, 58 livestock farms were chosen using global positioning system (GPS) technology and field investigations in Shangjie town. Other information such as the amount and type of livestock and poultry, culture cycle, etc. was generated from statistic data and investigations.

The manure nutrient load of a livestock farm was estimated by the excretion coefficient method. The excretion coefficient and nutrient content coefficient (Table 1) were obtained from the published literature, either within or

outside the country, and from observations made in the study area²⁰⁻²². The livestock manure nutrient load was calculated as follows^{23,24}

$$M = \sum_{j=1}^m (\text{Num}_j \times D_j \times R_j), \tag{1}$$

where M is the livestock manure nutrient from livestock farms (kg), Num_j the amount of livestock, D_j the feeding cycle of livestock (d), R_j is the phosphorus content ($\text{g} \cdot \text{d}^{-1}$).

In order to accurately estimate the carrying capacity of regional livestock farms, the livestock manure nutrient requirement in a certain region needs to be distributed. Thus, based on earlier reports^{24,25}, we adopted factors like the distance between livestock farms and farmlands, farmland area, type and fertility, which influence the application of livestock manure to the farmlands, and established the manure nutrient distribution model. We also adopted the Delphi method and analytic hierarchy process (AHP) to assign weights to the factors influencing the livestock manure nutrient distribution (Table 2). The formulae used are as follows^{24,25}

$$Y = \sum_{i=1}^m \left(\left(\frac{\lambda_1}{d_i \sum_{i=1}^n (1/d_i)} + \frac{\lambda_2 s_i}{\sum_{i=1}^n s_i} + \lambda_3 b_j + \frac{\lambda_4}{c_i \sum_{i=1}^n (1/c_i)} \right) \times M_i \right), \tag{2}$$

where Y is the total amount of livestock manure nutrient requirement of the farmland (kg), M_i the total amount of livestock manure from each livestock farms (kg), d_i is the distance between the livestock farms and farmlands (km), s_i the farmland area (hm^2), b_j the farmland type, c_i the farmland fertility, λ_1 the weight of distance influencing livestock manure nutrient distribution, λ_2 the weight of farmland area influencing livestock manure nutrient distribution, λ_3 the weight of farmland type influencing livestock manure nutrient distribution, λ_4 the weight of farmland fertility influencing livestock manure nutrient distribution, n the number of farmlands within the economic hauling distance between livestock farms and farmlands, m the number of livestock farms for spreading on the farmlands.

$$d_i \leq D_{\max}. \tag{3}$$

where D_{\max} is the break-even hauling distance of transporting livestock manure to farmlands (km).

To minimize pollution caused by livestock farms, the amount of livestock manure nutrient is not allowed to surpass the carrying capacity of the farmlands. Therefore, the following condition should be satisfied

$$Y \times g/S \leq F_{\max}, \tag{4}$$

where F_{\max} is the maximum livestock manure nutrient load (kg/hm^2), S the farmland area (hm^2) and g is the loss coefficient of livestock manure nutrient (%).

The calculation of the carrying capacity of livestock farms was done as follows

$$X_{\text{Num}} = C_{\text{nutrient}} / (D_j \times R_j \times g), \tag{5}$$

where X_{Num} is the moderate scale of livestock farms, C_{nutrient} the livestock manure nutrient that could be disposed by farmlands nearby (kg), D_j the culture cycle of livestock, R_j the phosphorus content ($\text{g} \cdot \text{d}^{-1}$) and g is the loss coefficient of livestock manure nutrient (%).

From the perspective of sustainable development of livestock farms, it is best to apply livestock manure as organic fertilizer to the farmlands. However, nitrogen and phosphorus load is of greater concern when applying livestock manure to the farmlands, because overloaded

Table 1. Excretion coefficients, phosphorus content and equivalent conversion coefficient in different livestock^{20,22-24}

Livestock type	Feeding cycle (d)	Excretion coefficients ($\text{kg} \cdot \text{d}^{-1}$)	Phosphorus content ($\text{g} \cdot \text{d}^{-1}$)
Pig	199	3.58	2.45
Cow	365	46.84	38.47
Draft cattle	365	21.90	12.48
Beef cattle	300	23.71	19.85
Sheep	365	0.87	0.46
Horse	365	5.9	1.60
Donkey/mule	365	5.0	1.60
Rabbits	180	0.15	0.24
Layers	210	0.15	0.51
Duck	180	0.13	0.30
Goose	180	0.19	0.22
Broiler chicken	55	0.22	0.29

Table 2. Weights assigned to the factors influencing livestock manure nutrient distribution model

	T1	T2	T3	T4	Weight
T1	1	1/2	1/2	1/3	0.121
T2	2	1	1/2	1/2	0.193
T3	2	2	1	1/2	0.269
T4	3	2	2	1	0.417

T1, Slope of farmland; T2, distance between animal manure source and farmland; T3, farmland type; T4, fertility of farmland.

nitrogen will leak into groundwater as nitrate form of nitrogen and overloaded phosphorus will cause eutrophication of surface water^{26,27}. Several surveys have indicated that water-soluble phosphorus easily causes serious environment problems^{28,29}. Therefore, to avoid the potential environment pollution, phosphorus is taken as nutrient standard for application of livestock manure in this study.

Considering phosphorus loss with ratio of 16% in the process of applying livestock manure to the farmlands^{1,30} and combining with excretion coefficient, nutrient content coefficient of manure and culture cycle of livestock and poultry (Table 1), livestock manure nutrient was estimated according to eq. (1) for Shangjie town, Minhou county for the period 2011. The results showed that the total amount of livestock manure phosphorus from the farms was 16,237.69 kg. On this basis, the livestock

manure phosphorus was distributed to 1096 farmlands in Shangjie town according to the livestock manure nutrient distribution model and a program compiled in C# and SuperMap software. Figure 1 presents results of distributing livestock manure phosphorus to farmlands.

The maximum, minimum, average, and total livestock manure phosphorus of farmlands was 55.97, 0.74, 12.21 and 13,382.90 kg respectively. The average, minimum and maximum livestock manure phosphorus load of the farmlands was 25.63, 5.49 and 34.99 kg/hm² respectively. The maximum livestock manure phosphorus load of farmlands was less than the Europe Standard of 35.00 kg/hm² (refs 31, 32), which indicated that the manure nutrient distribution was reasonable and could help to prevent the potential pollution caused by livestock manure.

The results of distributing livestock manure phosphorus to farmlands showed that there was 2854.79 kg difference of livestock manure phosphorus in livestock farms and farmlands. This is because the livestock manure from farms had surpassed the carrying capacity of farmlands in Shangjie town in 2011. Therefore, to avoid the environment problems caused by the extra livestock manure phosphorus, remedial measures such as reducing phosphorus content of livestock manure before being applied to farmlands or controlling the farm scale of livestock farms according to carrying capacity of the farmlands should be taken up.

In view of the sustainable development of livestock farms, the best way is to control the carrying capacity of livestock farms. For this, the spatial distribution of livestock farms that are producing extra livestock manure, surpassing the carrying capacity of the farmlands nearby, has been plotted and displayed using spatial analysis technology. The amount of surplus phosphorus from each livestock farm (Figure 2) was also calculated based on the livestock manure nutrient distribution.

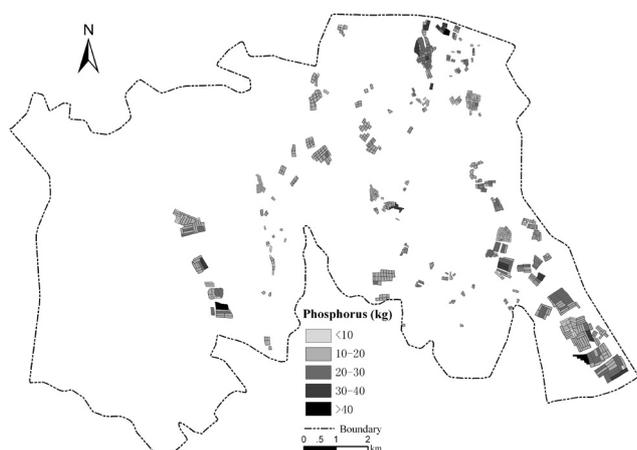


Figure 1. Results of distributing livestock manure phosphorus to farmlands in Shangjie town, China.

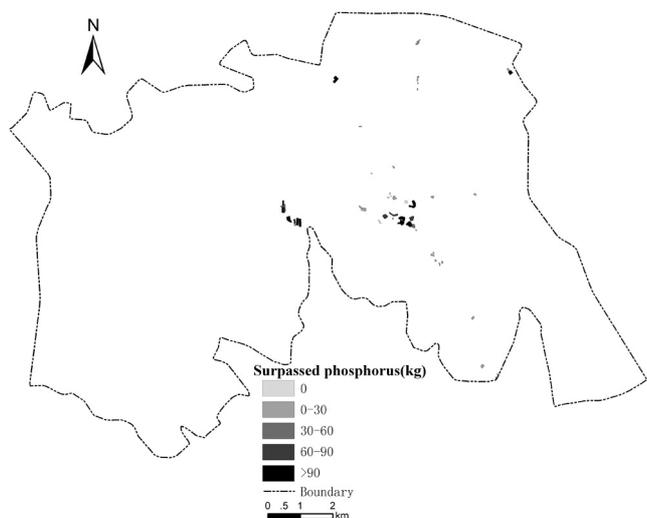


Figure 2. Surpassed phosphorus of each livestock farm in Shangjie town.

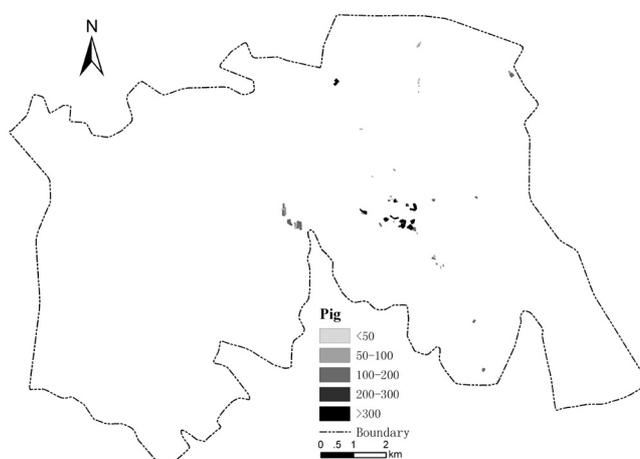


Figure 3. Result of estimating carrying capacity of livestock farms as pig.

The results showed that there were 51 livestock farms with livestock manure supply surpassing the carrying capacity of nearby farmlands. Only seven livestock farms had manure supply that could be safely disposed in the nearby farmlands. From statistical analysis, the maximum, minimum and average livestock manure phosphorus from the farms was calculated as 259.57, 0.03 and 49.22 kg respectively.

The amount of livestock manure which could be disposed in the nearby farmlands from 51 livestock farms was calculated by subtracting surplus manure phosphorus from the original amount of livestock manure. The carrying capacity of these 51 livestock farms was worked out using the excretion coefficient, nutrient content coefficient of livestock manure and culture cycle of livestock and poultry (eq. (4)). In order to display the carrying capacity of livestock farms uniformly, pig equivalent conversion coefficient was adopted instead of other livestock types (Table 1). Figure 3 shows the results of carrying capacity of livestock farms in Shangjie town obtained using pig equivalent conversion and GIS spatial analysis technology.

The maximum, minimum, average and total carrying capacity of livestock farms was 792, 10, 157 and 9128 pigs respectively. Livestock farms with carrying capacity less than 300 pigs accounted for 82.76% of total livestock farms in Shangjie town. Only six livestock farms with carrying capacity of 500 pigs were considered as small industrial livestock industry in China. Furthermore, the carrying capacity of livestock farms would increase if the manure from the farms could be disposed by other means instead of applying to farmlands.

This study has estimated the livestock manure phosphorus load from each farm by using the excretion coefficient method, and manure phosphorus was distributed to farmlands in Shangjie town by livestock manure nutrient distribution model. The results showed that the maximum, minimum, average and total livestock manure phosphorus carrying capacity of farmlands was 55.97, 0.74, 12.21 and 13,382.90 kg respectively. The results also demonstrated that the maximum livestock manure phosphorus load of the farmlands was 34.99 kg/hm², less than the European Standard of 35.00 kg/hm². Using this model we could distribute the livestock manure to farmlands uniformly. However, the total load of 2854.79 kg livestock manure phosphorus produced from livestock farms in Shangjie town surpassed the carrying capacity of the farmlands in 2011. Hence, the carrying capacity of livestock farms was calculated based on the maximum livestock manure phosphorus load of farmlands and expressed in pig. The results demonstrated that the maximum, minimum, average and total carrying capacity of livestock farms was 792, 10, 157 and 9128 pigs respectively. Also 82.7% of livestock farms had carrying capacity less than 300 pigs and only six livestock farms had carrying capacity more than 500 pigs.

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Characterization and comparative physico-chemical studies of Manahshila (traditionally used arsenic mineral) and the corresponding polymorphs of realgar (As₄S₄)

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This communication presents characterization and comparison of the physico-chemical properties of different varieties of Manahshila with the corresponding polymorphs of realgar. Three varieties of Manahshila have been described in Ayurveda, viz. Shyamangi, Kanavirak and Khandakhya; the last two are acceptable therapeutically. Khandakhya contains high percentage of arsenic than Kanavirak. In this study, both samples of Manahshila have been collected. Their physical and chemical properties have been correlated with the polymorphs of realgar. XRD study classifies Kanavirak as alacranite and Khandakhya as realgar. EDXA study confirms 51.33% and 68.14% of arsenic in alacranite and realgar samples respectively. This work correlates the ancient description of Manahshila with contemporary mineralogical classification (polymorphs) of mineral realgar.

Keywords: Alacranite, Manahshila, physico-chemical studies, polymorphs of realgar, mineralogical classification.

REALGAR (red arsenic – an arsenic-containing mineral drug) has long been used in traditional Indian medicines for the treatment of diseases of respiratory and digestive systems, skin diseases, psychological disorders and certain eye disorders^{1–3}. Recently, it has been demonstrated that it is clinically effective for the treatment of patients with refractory or relapsed acute promyelocytic leukaemia (APL) and other hematopoietic malignancies^{4–6}; this has given rise to an upsurge of research on its oldest to newest forms. Generally, inorganic realgar is highly toxic and carcinogenic^{7,8}; however, Ayurveda has emphasized that a strong poison may be converted into a safe and potent therapeutic drug by applying specific pharmaceutical processes as described in the Ayurvedic literature (e.g. shodhana, marana, etc.)⁹. The drug Manahshila, one of the arsenicals, has been identified as realgar due to its similar chemical and physical properties. Ayurveda has advocated proper method of shodhana (purification and detoxification from the unwanted elements by intervention

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