Regional Analysis of the Demand-supply Balance for Organic Household Waste Composting and Resource Utilization: A Case Study of Zhoukou City, Henan Province, China

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Abstract: *This study aims to explore the regional utilization of organic household waste composting and its resource recycling. Taking Zhoukou city in Henan Province, China, as the case study, the research focuses on two districts, one county-level city, and seven counties within the city's administrative boundaries. Using methods such as literature review, field investigation, data collection, and quantitative analysis, the study quantitatively examines the demand-supply balance of organic waste conversion into compost for greening in each research region. In 2021, the total potential demand for greening compost in Zhoukou city was approximately 247.28 kt/a, while the total potential supply of organic waste compost was about 426.54 kt/a, resulting in a demand-supply ratio of 0.58. The demand was found to be lower than the supply, indicating that not all organic household waste compost can be utilized for greening purposes across the city, and there are significant deviations in the demand-supply ratio between different regions. Furthermore, assuming actual supply rates of 85% and 70% for the organic waste compost, the demand-supply balance was analyzed under these conditions. The results show that when the actual supply rate is 85% or 70%, the demand-supply balance improves, with a more pronounced increase at a 70% supply rate.*

Keywords: *Household waste, Organic matter, Composting, Greening, Demand-supply ratio.*

Introduction

In recent years, China's economic development has attracted worldwide attention. With the continuous improvement of residents' living standards, the amount of household waste has also been increasing rapidly [16]. The current waste disposal issues are not in line with the country's highly developed economy. The proper classification of household waste [14] and its rational recycling for resource utilization [17] are of great significance to achieving a sustainable, circular society in China.

Currently, over 97% of urban household waste in China is disposed of through incineration and landfilling, with the proportion of recycled resources in waste disposal being less than 3% [8]. The pollutants produced by waste incineration and the environmental problems such as leakage

and gas emission from sanitary landfills are serious issues. The most effective method for waste disposal is source reduction and the proper recycling for resource utilization. Waste classification not only facilitates incineration and sanitary landfilling [19], but more importantly, promotes recycling and resource utilization. Organic materials account for a high proportion of waste incineration [18]. In recent years, China has made significant progress in the research of organic household waste composting technology [4, 13], soil application techniques of organic household waste compost [5], environmental impact countermeasures [3], pollution treatment technologies for urban waste [6, 10], and integrated treatment processes [12]. The first discussion in the recycling of organic household waste is the application of treatment technology [1]. Under the allowable technical conditions, exploring the demand and supply possibilities of recyclable materials, as well as the economic feasibility of utilization strategies, is also an important scientific method for promoting their effective use. Currently, waste classification in China is still in the exploratory stage, which is one of the main reasons for the relative lack of research in the field of organic household waste composting and resource recycling.

In December 2016, General Secretary Xi Jinping proposed that "waste classification is an important livelihood project". Since 2019, waste classification has been comprehensively launched in cities at the prefecture level and above, and by the end of 2025, a waste classification and treatment system will be basically established in cities at the prefecture level and above nationwide. The implementation of waste classification in China will bring new opportunities for the recycling of organic household waste. Promoting the recycling of organic household waste and gradually reducing the environmental pollution caused by waste incineration and sanitary landfilling is of great significance for protecting the ecological environment and promoting green development.

Kitchen waste is an important component of urban waste [2]. Currently, in urban waste classification in China, organic waste mainly consists of kitchen waste (hereinafter referred to as organic household waste). Organic household waste is mainly utilized through composting [15], feed farming, and biogas production for resource recycling. Due to differences in the composition and quality of organic household waste, there is a significant variation in the efficiency of utilization during recycling [1]. Organic household waste mainly follows resource recycling strategies such as composting and fermentation for biogas production. There are several disadvantages in urban organic household waste, such as unstable organic content and difficulties in large-scale transportation. Biogas fermentation is challenging. Additionally, the use of composted urban organic household waste in agriculture faces problems such as nutrient instability and the economic challenges of transportation, making large-scale agricultural application difficult [20]. Therefore, effectively utilizing organic household waste in urban areas is an important intensive recycling method. To promote the composting and recycling of urban organic household waste, it is necessary to understand the potential demand and supply of composting in the research area and explore the demand-supply balance.

Materials and methods

This study takes Zhoukou city in Henan Province, China, as the research object, assuming that after waste classification and collection, organic waste will be composted and used for greening purposes. The study focuses on the administrative areas within Zhoukou city, including two districts, one county-level city, and seven counties (Chuanhui district, Huaiyang district, Xiangcheng city, Fugou county, Xihua county, Shangshui county, Shenqiu county, Dancheng county, Taikang county, and Luyi county, hereinafter referred to as: the districts and counties). While calculating the potential supply of organic waste converted into compost for the research

area, the potential demand for compost in greening within the region was also estimated. Based on the calculation results of demand and supply, a quantitative analysis of the demand-supply balance for organic waste composting for greening in each research region was carried out to clarify the feasibility of organic waste composting for greening in the study areas. The demand-supply balance analysis model for organic household waste composting in this study is shown in Fig. 1.

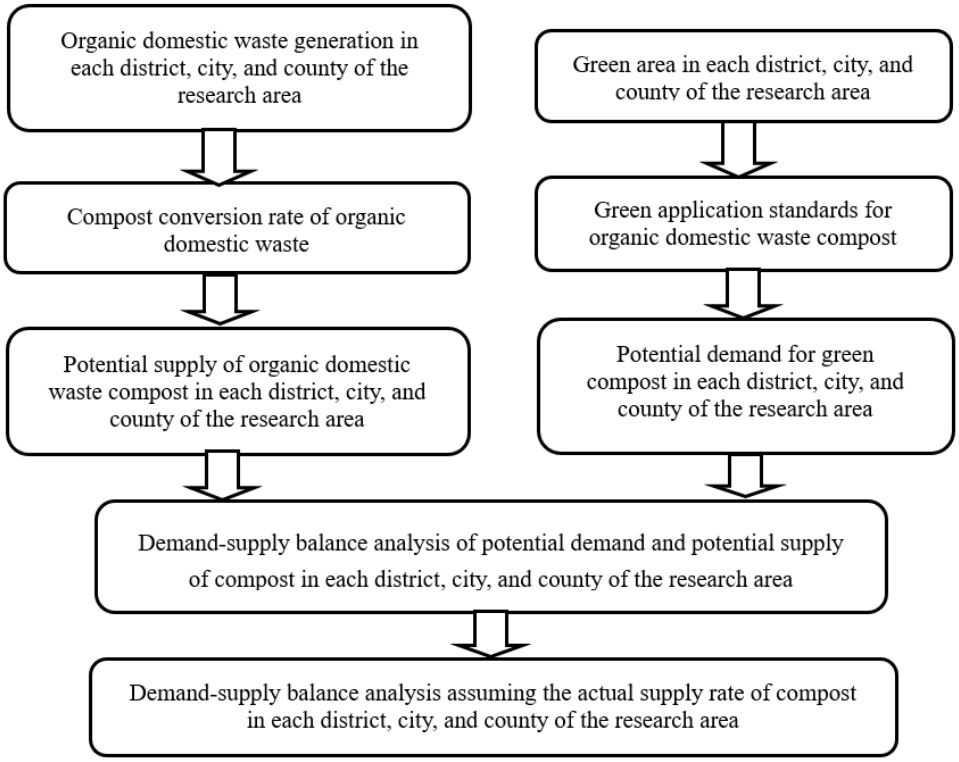

Fig. 1 Analysis model of demand and supply balance for green utilization of organic domestic waste compost

As shown in Fig. 1, this study analyzes the demand-supply balance of organic household waste composting and resource utilization for greening in the districts and counties within the administrative area of Zhoukou city. Using methods such as literature review, field investigation, data collection, and quantitative analysis, the occurrence of organic household waste in the research area was first examined. Based on the occurrence of organic waste and the composting conversion rate, the potential supply of compost from organic household waste was estimated. Additionally, based on the greening area and the compost application standards within the research area, the potential demand for compost for greening was estimated. Finally, based on the above calculation results, a quantitative analysis of the demand-supply balance for organic waste converted into compost for greening was conducted, to clarify the feasibility of using organic waste compost for greening in each of the study areas.

Overview of the study area

The research area, Zhoukou city, is a prefecture-level city in Henan Province, located in the southeastern part of the province, in the heart of the Huang-Huai Plain. The total area is approximately 11,959 km^2. The administrative area consists of two districts, one county-level city, and seven counties: Chuanhui district, Huaiyang district, Xiangcheng city, Fugou county, Xihua county, Shangshui county, Shenqiu county, Dancheng county, Taikang county, and Luyi county. The population and greening areas of each district and county in

Zhoukou city in 2021 are shown in Table 1 [9]. The total population is about 8.853 million, with a total greening area of about 12,364 hm^2. Chuanhui district has a population of approximately 734,600 and a greening area of about 3,778 hm^2, the largest among all areas. Huaiyang District has a population of about 1.0439 million and a greening area of about 851 hm^2. Fugou county, with a population of about 558,700, is the least populated area among the ten districts and counties, with a greening area of about 917 hm^2. Xihua county, with a population of approximately 695 400, has the smallest greening area, about 125 hm^2. Shangshui county has a population of about 933,900 and a greening area of about 169 hm^2. Shenqiu county has a population of about 928,100 and a greening area of about 670 hm^2. Dancheng county has a population of about 967,100 and a greening area of about 1,354 hm^2. Taikang county has a population of about 1.1161 million and a greening area of about 1,096 hm^2. Luyi county has a population of about 924,700 and a greening area of about 1,896 hm^2. Xiangcheng city has a population of about 950,500 and a greening area of about 1,508 hm^2.

Table 1. Statistical data of the absorbance measurements obtained by the biosensor

District/County	Population	Green area, (hm^2)
Chuanhui district	73.46	3 778
Huaiyang district	104.39	851
Fugou county	55.87	917
Xihua county	69.54	125
Shangshui county	93.39	169
Shenqiu county	92.81	670
Dancheng county	96.71	1 354
Taikang county	111.61	1 096
Luyi county	92.47	1 896
Xiangcheng city	95.05	1 508
Total	885.30	12 364

Calculation of potential composting demand and supply

Calculation of potential compost demand

The potential demand for compost in each district and county of the research area is calculated using Eq. (1). The green area (S_i) of each district is multiplied by the compost application standard (X) to calculate the potential demand for compost in each district for greening purposes (C_i):

$$C_i = S_i \times X , \quad (1)$$

where, C_i represents the potential demand for compost (kt/a); S_i represents the green area of each district (hm^2); X represents the compost application standard for greening ($t/(hm^2 a)$); i represents each district/county.

In this study, the greening area S_i for each district, city, or county within the research target, as specified in Eq. (1), is derived from field surveys and statistical yearbooks. The benchmark application rate for compost in greening, denoted as X, is determined based on site visits to local

greening departments and reference values [11], with an approximate value of 20 $t/(hm^2a)$. Using Eq. (1), the potential demand for greening compost for each district, city, or county is calculated, with the results presented in Table 2. Among the studied districts, cities, and counties, the largest potential demand for greening compost is found in Chuanhui district, approximately 75.56 kt/a, a result primarily attributable to the extensive greening area within this urban district. Conversely, the smallest potential demand for greening compost is observed in Shangshui county, approximately 3.38 kt/a, which is mainly due to this study area having the smallest greening area among the two districts, one city, and seven counties.

Table 2. Potential demand unit of green compost for each district, city and county of the research

District/County	Potential demand, (kt/a)
Chuanhui district	75.56
Huaiyang district	17.02
Fugou county	18.34
Xihua county	2.50
Shangshui county	3.38
Shenqiu county	13.40
Dancheng county	27.08
Taikang county	21.92
Luyi county	37.92
Xiangcheng city	30.16
Total	247.28

Calculation of potential supply of organic household waste compost in each district and county

Calculation of organic household waste generation

The organic household waste generation in each district and county is calculated using Eq. (2). The population (E_i) of each region is multiplied by the per capita waste generation rate (W), and then multiplied by the organic waste generation rate (N), to calculate the organic household waste generation (D_i) for each district and county:

$$D_i = (E_i \times W \times N) \times 365, \quad (2)$$

where: D_i denotes the organic household waste generation (kt/a); E_i denotes the population of each region; W denotes the per capita waste generation rate ($d/person$); N denotes the organic waste generation rate; i denotes each district/county.

In Eq. (2), the population of each region, denoted as E_i, is obtained from a statistical yearbook [22]. The per capita waste generation rate (W) and the proportion of organic household waste (N) are determined based on reference values [7]. The per capita waste generation rate is approximately 1.1 $\frac{kg}{d}/person$, and the proportion of organic household waste is approximately 40%.

Calculation of potential supply of organic household waste compost

Since organic household waste undergoes processes such as fermentation and drying during composting to meet national standards, there is a reduction in weight during the conversion to compost. Therefore, this study defines the ratio of compost weight to organic household waste weight as the composting rate. The potential supply of organic household waste compost (G_i) in each region is calculated by multiplying the organic household waste generation (D_i) by the composting rate (H), as shown in Eq. (3):

$$G_i = D_i \times H , \quad (3)$$

where, G_i represents the potential supply of organic household waste compost (kt/a); D_i represents the organic household waste generation (kt/a); H represents the composting rate of organic household waste; i represents each district/county.

In Eq. (3), the amount of organic household waste generated in each region is derived from the calculation results of Eq. (2). The composting rate of organic household waste, denoted as H, is determined based on reference values from multiple studies [9, 21], with a composting rate of approximately 30%.

Using Eqs. (2) and (3), the potential supply of organic household waste compost in each region of Zhoukou city is calculated, as shown in Table 3.

Table 3. Potential supply of organic domestic waste compost by district, city and county of the study

District/County	Potential supply, (kt/a)
Chuanhui district	35.39
Huaiyang district	50.30
Fugou county	26.92
Xihua county	33.50
Shangshui county	44.00
Shenqiu county	44.72
Dancheng county	46.59
Taikang county	53.77
Luyi county	44.55
Xiangcheng city	45.80
Total	426.54

As shown in Table 3, the total potential supply of organic household waste compost in the research area is about 426.54 kt/a. Among the districts and counties, the largest potential supply of compost is in Taikang county, with approximately 53.77 kt/a. This is mainly due to its large population compared to other areas. Additionally, Fugou county has the smallest potential supply of compost, about 26.92 kt/a, mainly due to its smallest population among the districts and counties in the research area.

Analysis of the demand-supply balance for green utilization of organic household waste compost

Analysis of potential demand-supply balance

The results of the calculation and analysis of the potential supply of organic household waste compost, the potential demand for green application, and the demand-supply ratio $\left(\frac{potential\ demand}{potential\ supply}\right)$ for each district and county are shown in Table 4.

Table 4. Potential supply of organic solid waste compost, potential demand and demand ratio of green ring application in each district of Zhoukou city

District/ County	Potential demand, (kt/a)	Potential supply, (kt/a)	Demand-supply ratio
Chuanhui district	75.56	35.39	2.13
Huaiyang district	17.02	50.30	0.34
Fugou county	18.34	26.92	0.68
Xihua county	2.50	33.50	0.07
Shangshui county	3.38	44.00	0.08
Shenqiu county	13.40	44.72	0.30
Dancheng county	27.08	46.59	0.58
Taikang county	21.92	53.77	0.41
Luyi county	37.92	44.55	0.85
Xiangcheng city	30.16	45.80	0.66
Total	247.28	426.54	0.58

In 2021, the total potential demand for green compost in the research area is approximately 247.28 kt/a, and the total potential supply of organic waste compost is about 426.54 kt/a, with a demand-supply ratio of about 0.58. The results show that the potential demand for compost is much smaller than the potential supply, meaning that organic household waste compost cannot be fully utilized for greening purposes in the research area. Moreover, the demand-supply ratios in each district and county show considerable deviations. The highest demand-supply ratio is in Chuanhui district, at about 2.13, indicating a serious situation where demand exceeds supply. The main reason for this is the moderate population and the largest per capita green area in this region. The other regions all have a situation where the demand is smaller than the supply. Among them, Xihua county and Shangshui county have demand-supply ratios between 0.07 and 0.08, the smallest values in all areas, mainly due to the small green area. Huaiyang district, Shenqiu county, and Taikang county have demand-supply ratios between 0.3 and 0.5, with demand less than half of the supply. Fugou county, Dancheng county, and Xiangcheng city have demand-supply ratios between 0.5 and 0.8, with demand slightly larger than half of the supply. In addition, Luyi county has a demand-supply ratio between 0.8 and 0.9, with the potential supply of compost slightly larger than the potential demand. In summary, the demand-supply ratio for organic household waste compost in the research area shows a severe polarization, with the overall demand being smaller than the supply, indicating a serious oversupply situation.

Analysis of demand-supply balance assuming actual supply rates

The above results show that the overall annual potential demand for compost in the research area is much smaller than the potential supply. Organic household waste compost cannot be fully utilized for greening in the region, and there are significant deviations in the potential demand-supply ratios across different study areas. Additionally, assuming that areas with a demand-supply ratio between 0.91 and 1.10 are in a nearly balanced state. The demand-supply ratio in the research area, including 2 districts, 1 city, and 7 counties, shows a severe imbalance and polarization.

Among the two districts, one city, and seven counties under investigation, only Chuanhui district exhibits a demand-to-supply ratio greater than 1.0, indicating a state in which the demand substantially exceeds the supply. In all other regions, the demand is found to be lower than the supply, leading to a pronounced polarization across the study area as a whole. Based on field visits and interviews conducted with the local environmental protection departments and household waste management authorities in the study region, and also to reduce the utilization of food waste with high salt content in composting, the actual usable proportion of organic household waste is estimated to range between approximately 85% and 70%. Consequently, an actual supply rate (defined as the actual supply divided by the potential supply) exists for organic household waste composting. In this study, the actual supply rate for organic household waste composting is assumed to be 85% and 70%, respectively, and a quantitative analysis of the demand-supply balance is performed under both assumptions. The calculation and analysis results are presented in Table 5.

Table 5. Actual supply of 85% and 70% of organic domestic waste converted into compost in each district, city and county of Zhoukou city and potential demand for green application

District/ County	Potential demand, (kt/a)	Actual supply rate 85%, (kt/a)	Demand-supply ratio (85%)	Actual supply rate 70%, (kt/a)	Demand-supply ratio (70%)
Chuanhui district	75.56	30.08	2.51	24.78	3.04
Huaiyang district	17.02	42.75	0.40	35.21	0.49
Fugou county	18.34	22.88	0.80	18.84	0.97
Xihua county	2.50	28.48	0.08	23.45	0.10
Shangshui county	3.38	38.25	0.09	31.50	0.11
Shenqiu county	13.40	38.01	0.35	31.30	0.43
Dancheng county	27.08	39.61	0.68	32.62	0.83
Taikang county	21.92	45.71	0.48	37.64	0.59
Luyi county	37.92	37.87	1.00	31.19	1.21
Xiangcheng city	30.16	38.93	0.78	32.06	0.94
Total	247.28	362.56	0.68	298.58	0.83

As shown in Table 5, when the actual supply rate of organic household waste compost is 85%, the overall demand-supply ratio is about 0.68. The results show that the research area is generally in a state where demand is slightly smaller than supply. Comparing with the potential demand-supply ratio when the actual supply rate is 100%, the number of regions in a nearly balanced demand-supply state is increasing, with Luyi county at about 1.00. Additionally, when the actual supply rate is 70%, the overall demand-supply ratio is about 0.83, which is close to the state of near balance. When the actual supply rate is 70%, Xiangcheng city has

a demand-supply ratio of about 0.94, Fugou county has a demand-supply ratio of about 0.97, and the regions in near balance have significantly increased.

Conclusion

This study focuses on Zhoukou city, Henan Province, China, assuming that organic household waste is collected through waste classification and used for composting and greening purposes. The research area includes two districts, one county-level city, and seven counties. Through literature review, field surveys, data collection, and quantitative analysis, the potential demand for organic household waste compost in each district and county was estimated based on the green area and compost application standards. The organic household waste generation in each district and county was then calculated based on population, per capita waste generation, and organic waste content, followed by estimating the potential supply of compost. The demand-supply balance for organic household waste compost in each study area for greening purposes was analyzed. In 2021, the total potential demand for green compost in the research area is about 247.28 kt/a, and the total potential supply of organic waste compost is about 426.54 kt/a, with a demand-supply ratio of about 0.58. The study shows that the potential demand for compost is much smaller than the potential supply, meaning that organic household waste compost cannot be fully utilized for greening, and there are significant deviations in the demand-supply ratios across the study areas. Moreover, the study assumed actual supply rates of 85% and 70% for organic household waste compost and analyzed the demand-supply balance. The results show that when the actual supply rate is 85%, the overall demand-supply ratio is about 0.68. The overall demand in the research area is slightly smaller than the supply, and compared to the potential demand-supply ratio when the actual supply rate is 100%, the number of regions in the study area (two districts, one city, and seven counties) where the demand-supply ratio is essentially balanced and is increasing. When the actual supply rate of organic domestic waste compost is 70%, the overall demand-supply ratio is about 0.83, approaching a state of basic demand-supply balance. Moreover, the number of research regions in a state of basic balance is significantly increasing.

The completion of this study provides scientific evidence for the recycling of organic household waste compost for urban greening in the research area, and also lays the foundation for reducing costs and improving utilization efficiency in future use.

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