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A Study on Compost Shift in Agriculture of Henan Province, China

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This paper analyses the potential supply and demand of compost in subordinated prefecture-level cities of 5 comprehensive utilization regions in Henan Province, China. Besides, the author discussed the (potential) demand to supply ratio, and analyse the shift among zones (cities) in response to the change of actual demand rate (actual demand/potential demand) in each comprehensive utilization region in ton·km. Finally, it is concluded that the shifted quantity of compost in ton·km is affected by demand to supply ratio of various prefecture-level cities, and the region with significantly deviated demand to supply ratio between zones has more frequent shift of compost between zones, while that with relatively less deviation tend to keep compost not flowed.

1. Introduction

Henan Province is a province bestowed with the largest agricultural industry in China (Zhang et al., 2013). Compared with other provinces, it has the largest annual straw and animal manure output in China, which account for around 11% and 17.5% of the total national output respectively (Yuan, 2013; Zhu et al., 2015). However, the utilization rate of compost here is low (Shen et al., 2007), which can not only reduce organic wastes in agriculture, alleviate environmental stress, but also promote cyclic utilization of resources (Mouri and Aisaki, 2015). To promote the effective utilization of compost, it is essential to enhance shift between zones (Tanikawa et al., 2006). Hence, it is of crucial importance to investigate how to increase compost shifting efficiency, on condition that the balance between demand and supply of compost is stricken in a certain region.

There already exist some studies on efficient utilization of organic wastes in agriculture. For example, An and Wang (2010). calculated potential supply (theoretical maximum supply) and demand (theoretical maximum demand) of organic substance in organic wastes in agriculture, and discussed the regional balance of demand and supply; Aramaki et al. (2001) calculated potential supply of nitrogen fertilizer in certain region based on the content of nitrogen in organic wastes; they further calculated potential demand of nitrogen fertilizer of the region based on its application, and analyzed demand and supply balance; Endo and Nakamura (2008) produced compost and liquid fertilizer from organic wastes of a research area for crops planted in soil and paddy to meet their different needs in fertilizer, and discussed the demand and supply balance. Suzuki (2004) emphasized the importance of study on demand and supply balance of compost in response to regions (administrative regions), as it is difficult for compost to be comprehensively utilized due to the discrepancy of demand and supply relations among different regions. Zhou and Kitawaki (2009) analyzed the demand and supply balance of compost from organic wastes on a monthly basis and found out the seasonal differences. However, shift of compost between zones has not turned out to be a concern of these previous studies, though it is an important factor on compost utilization efficiency. Therefore, this study investigates possible scenarios of compost shift between zones and analyzed the change of shifted quantity of compost in ton. km.

2. Research method

This study investigates the utilization of compost in agriculture in Henan Province, which includes a total of 18 prefecture-level cities. In the principle of geographical adjacency and similarity in agricultural production, the

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author classified the province into five compost utilization regions, namely, east Henan region (including Sangqiu City, Zhoukou City, and Kaifeng City), west Henan region (including Pingdingshan City, Sanmenxia City, and Luoyang City), south Henan region (including Zhumadian City, Xinyang City, and Nanyang City), north Henan region (including Hebi City, Puyang City, Anyang City, Jiaozuo City, Jiyuan City, and Xinxiang City), and central Henan region (including Xuchang City, Luohe City, and Zhengzhou City).
Potential demand and supply of compost in agriculture of each prefecture-level city within a utilization region are calculated respectively. First, the author assumed different demand rates, and then calculated compost shortage or surplus based on demand to supply ratio of compost. Then, the compost shift from surplus zones to shortage zones was analyzed based on compost shifting distance and quantity between prefecture-level cities in a comprehensive utilization region. The research method is shown in Figure 1.

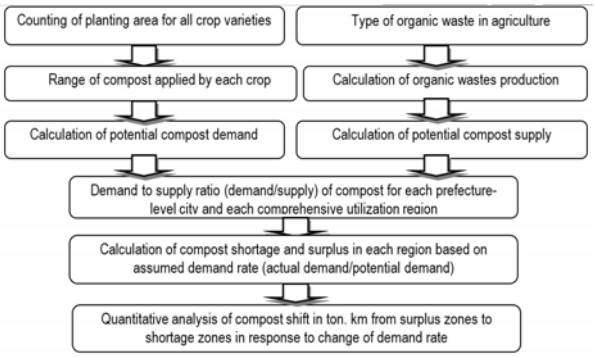

Figure 1: Flow chart of compost from organic wastes in agriculture shifted among zones in ton·km

3. Analysis on compost supply and demand balance in each compost utilization region

3.1 Calculation of potential compost demand

Potential compost demand for each crop variety can be figured out through multiplying its cultivated area by the corresponding compost quantity applied, where the cultivated area can be found in Statistical Yearbook of Henan (NBS Henan Survey Team, 2013), and the suggested quantity applied can be obtained from references (Zhou, 2011). Summing up the compost demand of each crop variety, it is possible to get the total compost demand.

3.2 Calculation of potential supply of compost from animal manure

Yearly output of fresh animal manure can be figured out by summing up the manure of all animal varieties, where the manure of one animal variety can be obtained by multiplying the total number of this animal by daily output of animal manure, and then by number of days fed. Since fermentation and drying are necessary steps to convert fresh manure to compost, a compost ratio (compost weight divided by fresh manure) complying with national standard is needed, which is unique to any one specific animal manure variety. Thus, potential supply of compost from a certain kind of animal manure in a target region can be figured out through the yearly fresh animal manure output multiplied by their respective compost ratio. The total number of animals fed in each region was extracted from the Statistical Yearbook of Henan (NBS Henan Survey Team, 2013), while the unit manure output of each animal and the compost ratio were taken from references (Bai and Ma, 2010; Zhou et al., 2010).

3.3 Calculation of potential supply of compost from straw

Since straws are basically dry after crops are harvested, they can be treated in full amount as compost. Thus, potential supply of compost from straws can be figured out through multiplying the harvest yield of each crop variety obtained from Statistical Yearbook of Henan (NBS Henan Survey Team, 2013) by its output coefficient gained from references (Guo, 2013).

3.4 Demand to supply ratio analysis

Through the above method, the author figured out the overall potential demand of compost in Henan Province to be around 186,961,600 tons/year, and the potential compost supply in agriculture to be around 154,166,200 tons/year, thus getting the demand to supply ratio of compost to be around 1.21. As is known, a ratio higher than 1.0 means a higher potential demand than potential supply, indicating that the organic wastes of Henan Province can be utilized in full amount theoretically.

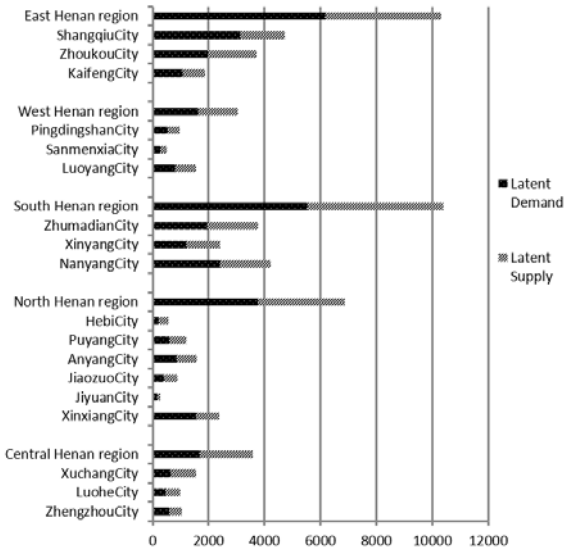

Figure 2: Potential demand and supply of compost in each prefecture-level city of each utilization region in Henan Province (10 thousand tons/year)

The results of potential demand and supply of compost in each prefecture-level city of the respective utilization region are shown in Figure 2. Hence, it is found that among all prefecture-level cities in east Henan region, Shangqiu City has the highest demand to supply ratio, 1.95; while Zhoukou City has the lowest demand to supply ratio, 1.14. In east Henan region, the demand to supply ratio is around 1.49, indicating a situation where supply is much less than the demand. In west Henan region, the potential demand and supply are lowest compared with other utilization regions, since it is a mountainous area with mining industry with a limited planting area. Even so, compost demand and supply in all prefecture-level cities of this region are basically balanced, with the overall demand to supply ratio of the region to be around 1.14. In south Henan region, the demand and supply of compost in all prefecture-level cities are both large, while an overall balance is still maintained, with the demand to supply ratio to be around 1.14. In north Henan region, the overall demand to supply ratio of compost in is 1.21, but it is seriously deviated among different cities here, with Xinxiang City has the highest demand to supply ratio, 1.83, while Puyang City has the lowest demand to supply ratio, 0.59. In central Henan region, the demand to supply ratio is 0.88, which means it is the only one region with demand lower than supply, however, prefecture-level cities in this region are basically in balance.

4. Compost shift among different utilization regions

4.1 Calculation of compost surplus and shortage

As is indicated in previous study (NBS Henan Survey Team, 2013), agricultural output in Henan Province relies heavily on chemical fertilizers, which is applied 1.9 times more than the average level in China, up to three times of national standard, because it is difficult to use compost in agricultural production in practice. Hence, the maximum demand rate of compost in this study is set to be 80%, and the compost shift from surplus zones to shortage zones is discussed in response to quantity and distance. First, the annual compost surplus or shortage in each prefecture-level city within each utilization region is calculated by deducting actual demand from the supply using Formula (1).

$$Zk_i = H_i - Dpk_i \quad (1)$$

Zk_i: Surplus or shortage in each prefecture-level city based on the corresponding demand rate (ton/year)
H_i: Potential supply of compost in each prefecture-level city (ton/year)
Dpk_i: Actual demand figured out based on actual demand rate (ton/year)
k: Actual demand rate
i: Prefecture-level city
According to the above formula, annual surplus or shortage of compost in each prefecture-level city under each utilization region can be figured out based on actual demand rate, which is assumed to be 50% ~ 80%, with an interval of 5%.

4.2 Calculation of compost shift in ton·km

To obtain an optimum solution, the linear method was adopted to figure out the compost shifted from surplus zones to shortage zones in ton·km in a utilization region (Atsushi and Toru, 2009) based on the actual demand rate. To achieve this, first, cargo vans are assumed to be used to shift compost in each utilization region. Second, the minimum highway distance between centers of prefecture-level cities are taken as the shift distance. In addition, priority is given to the nearest city when a shift of compost is required. According to Formula (2), the shifted compost in ton·km from surplus zones to shortage zones can be obtained by multiplying the tons of shifted compost by the shortest highway distance among cities, which can be found in references.

$$TL(k) = \sum_{x=1}^{18} \sum_{y=1}^{18} W(k)_{xy} \quad M_{xy} \tag{2}$$

TL(k): Shifted quantity of compost based on actual demand rate *(ton·km)*
$W(k)_{xy}$: Shifted quantity of compost from surplus zone x to shortage zone y based on actual demand rate (ton)
M_{xy}: Lowest distance of shift from surplus zones to shortage zones *(km)*
k: actual demand rate
x: zones with surplus compost
y: zones short of compost

4.3 Analysis of compost shift among different regions

(1) East Henan region: Please refer to Figure 3 for quantity of compost shifted between zones in ton·km based on actual utilization rate in east Henan region. As is shown, when the actual demand rate of compost is 50%, each zone is self-sufficient, possibly without any compost shift between zones; when the actual demand rate reaches 55%, shift of compost between zones begins; with the increase of actual demand rate, the quantity and distance of shift gradually grow. When the actual demand rate of compost reaches 70%, the total quantity of compost shifted in ton·km reaches the peak, amounting to around 1,517 million ton·km/year. This indicates that when supply is much less than demand, and demand to supply ratio among all prefecture-level cities in this region is largely deviated, there is a large quantity of compost shifted. Afterwards, the quantity of compost shifted shrinks, mainly because the compost surplus in remaining zones is reduced when the actual demand rate is above 70%.

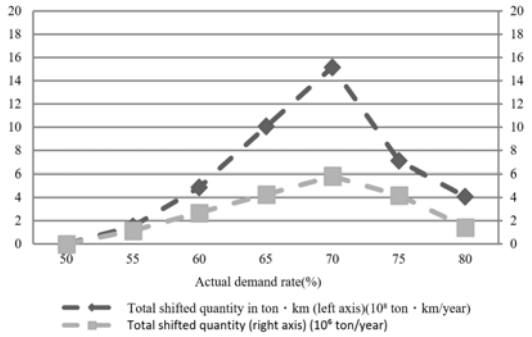

Figure 3: Quantity of compost shifted within east Henan region in ton·km, on the basis of actual demand rate

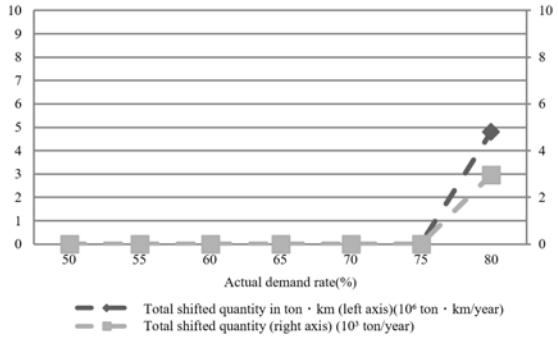

Figure 4: Quantity of compost shifted within west Henan region in ton·km, on the basis of actual demand rate

(2) West Henan Region: Please refer to Figure 4 for quantity of compost shifted between zones in ton·km based on actual utilization rate in west Henan region. As is shown, when the actual demand rate of compost is 50% - 75%, each zone is self-sufficient, possibly without any compost shift between zones. When the actual demand rate reaches 80%, shift of compost between zones begins, with a compost shift up to 4.8 million ton·km/year. Since demand and supply of compost in zones of this region are basically in balance, compost is basically not shifted in this region.
(3) South Hena n region: Please refer to Figure 5 for quantity of compost shifted between zones in ton·km based on actual utilization rate in south Henan region. As is shown, when the actual demand rate of compost is 50% - 75%, each zone is self-sufficient, possibly without any compost shift between zones. When the actual demand rate reaches 80%, shift of compost between zones begins, with the total shifted quantity reaching 186

million ton·km/year. Since demand and supply of compost in zones of this region are basically in balance, compost is prone to be efficiently utilized.

(4) North Henan region: Please refer to Figure 6 for quantity of compost shifted between zones in ton·km based on actual utilization rate in north Henan region. As is shown, when the actual demand rate of compost is 55%, shift of compost between zones begins. With the increase of actual demand rate, the quantity and distance of shift between zones gradually grow. When the actual demand rate reaches 80%, the total shifted quantity of compost between zones reaches 340 million ton·km/year. In this region, demand to supply ratio of Hebi City, Puyang City, Anyang City, Jiaozuo City, Jiyuan City, and Xinxiang City are 0.59, 0.99, 1.2, 0.81, 1.61, and 1.83, respectively. Due to large deviations in demand to supply ratio of prefecture-level cities, shifts of compost between zones are frequent.

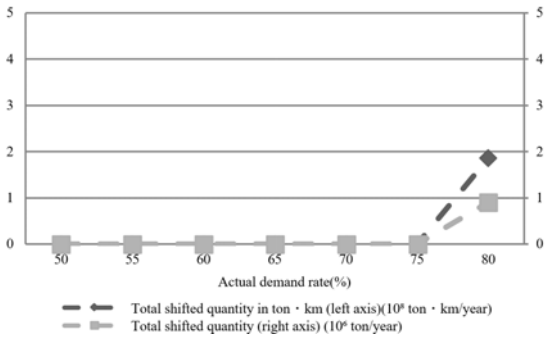

Figure 5: Quantity of compost shifted within south Henan region in ton·km, on the basis of actual demand rate

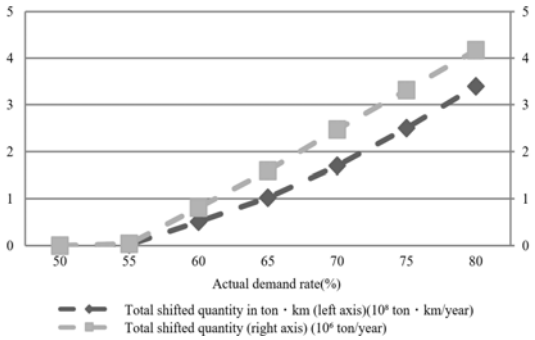

Figure 6: Quantity of compost shifted within north Henan region in ton·km, on the basis of actual demand rate

(5) Central Henan region: Please refer to Figure 7 for quantity of compost shifted between zones in ton·km based on actual utilization rate in central Henan region. As is shown, when the actual demand rate of compost is 50% - 75%, each zone is self-sufficient, possibly without any shift of compost between zones. When the actual demand rate reaches 80%, shift of compost begins, with the total shifted quantity reaching 0.95 million ton·km/year. In this region, the overall demand to supply ratio is around 0.88, and Zhengzhou City is the only city with a demand to supply ratio over 1.0. When the actual demand rate is 80%, Zhengzhou City is slightly in short of compost, while Xuchang City and Luohe City have a slight compost surplus. Generally speaking, the shift of compost within this region is very slight.

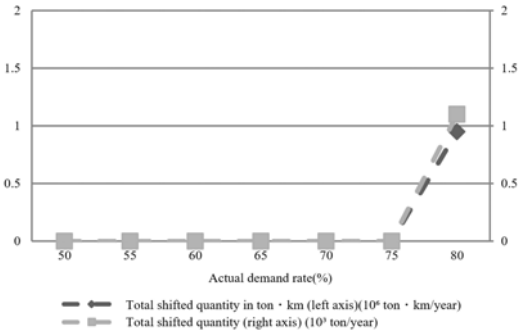

Figure 7: Quantity of compost shifted within central Henan region in ton·km, on the basis of actual demand rate

5. Conclusion

This study investigates demand and supply balance of compost in prefecture-level cities in five utilization regions of Henan Province, and analyzes the shifted quantity of compost in ton·km for each utilization region on the basis of actual demand rate. The conclusions are as follows:

(1) The total potential demand of compost in Henan Province is about 186,961,600 tons/year, while the total supply is about 154,166,200 tons/year. As can be seen, the overall demand to supply ratio of compost is around 1.21, which means that theoretically speaking, organic wastes in agriculture can be utilized in full amount for agricultural production in Henan Province.

(2) Among all utilization regions, except for central Henan region whose demand to supply ratio is 0.88, demand to supply ratio in all other regions is higher than 1.0. However, there are large deviations in demand to supply ratio of compost in prefecture-level cities of east Henan region and north Henan region.
(3) The quantity of shifted compost in ton·km is affected by the deviation of demand to supply ratio of prefecture-level cities in each utilization region. In the study, the deviation is large in east Henan region and north Henan region, therefore, the compost shift between zones in these two regions are more frequent compared with that in other three regions.
This study explores how to efficiently utilize compost in agricultural production in Henan province, by investigating demand and supply balance of compost and its shift between zones, providing support to further scientific researches. The limit of shift distance and cost-efficient utilization methods will be studied in future.

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