Study on the Appropriate Size of Scale Breeding Family Farms

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Abstract. Scale-breeding family farms can meet the demand of meat market and increase the farmers’ income. However, they may cause serious environmental problems to some extent if the waste is not properly handled. In this paper, the appropriate scale of scale breeding family farms was studied from the circular economy theory. Results show that the resource loss rate of middle-scale family farms is lowest among three kinds of scale-breeding family farms. Therefore, the middle-scale should be chosen as optimistic size for sustainable development of agricultural economy in China.

1. Introduction
Scale-breeding family farms are important parts of the agricultural economy. They may ensure food safety and satisfy the demand of the meat market, and then increase employment rate and farmers’ income. However, they may lead to pressure on the environment if the waste caused by scale-breeding is not disposed correctly [1]. With the development of breeding technology and the rising of market requirement, more and more scale-breeding family farms appear, changing the smallholder farm-based breeding model in China [2]. Expansive scales will result in large amounts of waste. If the corresponding management and technology do not keep up with the development of scales, environment pollution will happen [3]. This will cause very tremendous negative influence on the environment, ecology, economy, and then the sustainable development of scale-breeding. However, if the breeding-scales are too small, the breeding capacity of family farms is not satisfied so that the breeding efficiency is very low because of their high investment, but low-income [4]. Therefore, it is very important to probe the appropriate breeding scales for the sustainable development of family farms. For family farms with the appropriate breeding appropriate scales, the waste may be recycled efficiently. Correspondingly, the environmental pollution will be least and the utilization rate of resources will be maximum.

Hong et al. insisted that the management cost should be an important factor for choosing appropriate scale [5-7]. De Haan et al. thought the livestock and poultry breeding should be based on mediate scale, and the farms’ operation activities and the external environment should be in balance [8-10]. Wu et al. suggested that the environment cost should be internalized to find appropriate scale [11, 12]. Ma et al. analyzed the determination of mediate scale from the perspective of technology level and labor transferring [13, 14]. In brief, some success had been made to study the appropriate scale for breeding farms. However, the critical factor, namely resource consumption as the bond between the family farms’ internal management and the external environment, has been not considered in these studies. Therefore, the effective advices for the sustainable development of scale-breeding...
have been not offered so far. In fact, based on the resource flow of family farms, the resource consumption lies in every link of the breeding process, including the investment, the production, the sale, the consumption and the discharging process of the waste. The resource utilization efficiency is closely related to the development route of family farms. Resource endowment may restrict the improvement of technology level and the environment cost internalization [2, 15]. Therefore, the role of resource consumption is so important that it should be not neglected. On the other hand, the circular economy should be considered to increase the recycling rate of the waste, and then increase the resource utilization efficiency.

In this paper, the appropriate scale of scale-breeding family farms will be studied based on the analysis of the resource loss under the background of the circular economy. Furtherly, some effective advices will be offered for the sustainable development of scale-breeding family farms.

2. Flow Analysis of Resource Loss

Generally, resources mean the natural elements and conditions for generating economic values and improving human well-being. In this paper, resources include natural, social, information and environmental resources, namely, the material, equipment, energy source, capital, technology, information, and human resources during the production and management processes of family farms. The resource loss is embodied in the physical flow accounts (PFA) based on the United Nations integrated System of Environmental and Economic Accounting (SEEA). They may come from many links of production and consumption. The production process of family farms was shown in figure 1. From figure 1, there are three stages for the production process of family farms with the example of the pig-breeding family farms, namely stage 1 (S1), stage 2 (S2) and stage 3 (S3), respectively. In the stage 1, namely the preparation phase, factory, equipment and piglets, feeds, medicine etc, should be prepared and invested. In the second stage (breeding stage), fattening pigs will be cultivated, and then more resources such as labor, water, electricity and depreciation should be supplied. In these two stages, all investments may be looked as resources.

From figure 1, the products are divided into positive products and negative products in material flow cost accounting. The positive products are the right products according to design scheme, including finished products, semi-finished products and by-products. Negative products are incidental to the production process, including pigs died from disease and the excrement. The latter is divided into recyclable parts and non-recyclable parts. Using the current recycling technology, the recyclable parts may be changed as positive products partly. If the amount of recyclable parts exceeds the capacity of the recycling system, the redundant will be discharged into natural environment, so that they may be also defined as the resource loss. The non-recyclable parts cannot be recycled by the current technology and are unnecessary for enterprise so that they belong to the resource loss. Generally, resource loss originates from three aspects, namely the low effective utilization rate of resources, the lack of comprehensive utilization ways of the waste, and the excessive consumption of materials.

From figure 1, based on characteristics of pig-breeding family farms under the background of circular economy, the resource loss may be divided into the following two categories. Firstly, dead pigs because of sickness must be handled correctly in time in order to avoid the environmental pollution. There are three kinds of approaches including incineration, burial and chemical processing usually. These approaches all need corresponding processing costs included in the resource loss. The first two approaches will cause direct resource loss, which are denoted as RL1a and RL1b. For the third approach, some negative production will be changed into organic fertilizer through harmless processing, and then are used in planting. These can be looked as supplement of positive production. The other negative production will be useless, so that it is included in resource loss (RL1c). During the process of incineration and deep burial the cost of dead pigs includes the labor, transportation cost and other corresponding cost. In the chemical process, oil, organic fertilizer and fuel will be produced, which may be recycled and reused during pig-breeding and crop planting. If the organic fertilizer exceeds the capacity of the crop planting, the unnecessary parts will be regarded as pollution and be
included in resource loss (RL_{1d}). Secondly, excrement of pigs including manure, urine and gases, should be also handled correctly. Otherwise the environmental pollution will be also caused. Here gases include hydrogen sulfide, methane and nitric oxide and others. They can be not handled by the current technology, so they will be included in resource loss (RL_{2}). However, manure and urine may be changed as biogas, which is very necessary in circular economy of family farms. On the one hand, they can be important energy sources including electric and heat resources so that they are supplement of positive product. On the other hand, the environmental pollution will be evidently decreased. The slurry may be looked as the organic fertilizer too and used to crop planting, which is including in the positive production. It is noticed that the slurry and the biogas may both exceed the capacity of the crop planting. The unnecessary parts will be regarded as pollution, which are included in the resource loss (RL_{3}).

![Figure 1. The production procession of the resource loss of pig-breeding family-farms.](image)

3. Influence of Breeding Scale on the Resource Loss

Generally, there are four kinds of disposal methods of the recyclable excrement, which result in different resource loss. Firstly, returning recyclable excrement directly to field. The mount of pig excrement per year is about 33000 kg, but the excrement bearing capacity of an acre farmland is about 3478 [16-21], which is far less than the excrement mount. The amount of discarded fresh excrement exceeds the carrying capacity of the farmland, the environmental pollution will happen.
Correspondingly, the treatment cost of the pollution or the redundant excrement will also happen, which is looked as the resource loss $R_{L(3a)}$. Secondly, compost plus returning the recyclable excrement to field. The composting method is often microbial decomposition of the manure that is directly unfavorable for crop. The dry matter of fecal is decomposed to produce heat and water evaporation, and then dry pathogenic bacteria, parasite eggs and weed seed will increase. Furtherly, the fertilizer will be gotten by farmers. Based on this method, the bearing capabilities of an acre farmland and fishpond are about 15000 kg and 15306 kg [16, 17], respectively. The composting amount that exceeds the bearing capability of farmland and fishpond is defined as the resource loss $R_{L(3b)}$. Thirdly, the biogas treatment plus returning the recyclable excrement to field. Biogas and the corresponding fertilizer will be produced after the recyclable excrement is handled by the anaerobic chemical method. Considering the actual gas production rate, the annual biogas yield may be calculated [16]. The actual utilization rate of the biogas is also important to determine the resource loss. Unused biogas will be considered as the resource loss. About 14.5725 tons biogas fertilizer will happen in one cubic meter methane tank a year [10]. The amount of biogas fertilizer exceeding the environmental capacity of farmland and fishpond is defined as the resource loss $R_{L(3c)}$. Fourthly, the biogas treatment plus composting plus returning to field. Based on this method, the excrement may be treated in methane tank. The amount of excrement overloading the biogas tank capacity is always treated by composting. The resulting compost and the excrement will be reused as the water and the fertilizer for farmland. If the fertilizer exceeds the farm environmental absorptive capacity, the excessive emissions are looked on as the resource loss $R_{L(3d)}$. Evidently, $R_{L(1a)} > R_{L(1b)} > R_{L(1c)}$ and $R_{L(3a)} > R_{L(3b)} > R_{L(3c)} > R_{L(3d)}$. Especially, the fourth method not only results in least resource loss, but also is most beneficial for the environment.

From the above analysis, the total resource loss may be calculated by

$$RL = R_{L(1a)} + R_{L(1b)} + R_{L(1c)} + R_{L(1d)} + R_{L(2)} + R_{L(3a)} + R_{L(3b)} + R_{L(3c)} + R_{L(3d)}$$  \hspace{1cm} (1)$$

From the formula (1), the total resource usage efficiency can be also gotten as the division of RL by the total resources. High resource loss rate will cause great negative impacts on the external environment and decrease the income of family farmers. Therefore, family farms should try their best to decrease the total resource loss rate. The excrement and the resource loss are both related to the breeding size. In China, there are mainly three kinds of scale-breeding pig family farms, namely the small-scale pig family farms whose pigs are less than 500, the middle-scale pig family farms whose pigs are more than 500, but less than 1000, and the large-scale pig family farms whose pigs are more than 1000, respectively. For small-scale family farms, their low breeding technology level, insufficient funds, deficient professional knowledge, and less farmland to absorb the excrement will result in high resource loss. On the other hand, most small-scale family farms select incineration or burial for dead pigs and select returning the excrement directly to the farmland confined by their insufficient capitals and technology. Therefore, the RL of small-scale family farms are mainly

$$RL_{sa} = R_{L(1a)} + R_{L(1b)} + R_{L(3a)}$$  \hspace{1cm} (2)$$

With the increase of the breeding-scale, investments and the technology level will be improved, and then family farms have more ways to get professional knowledge. Therefore, the waste will be recycled in scientific ways for middle-scale pig family farms. Considering the environmental friendliness and the sustainable development of economy, they will refuse incineration or burial for dead pigs and returning the excrement directly to the farmland. Therefore, the RL of middle-scale family farms is mainly

$$RL_{ma} = R_{L(1c)} + R_{L(1d)} + R_{L(3b)} + R_{L(3c)} + R_{L(3d)}$$  \hspace{1cm} (3)$$
Larger the scale of family farms are, stronger their capitals and professional knowledge. Especially, family farms with enough capitals and knowledge will select the fourth method to dispose the recycled excrement because the corresponding resource loss \( RL_{(3d)} \) is much less than \( RL_{(3b)} \) and \( RL_{(3c)} \). Therefore, the resource usage efficiency of middle-scale family farms is much larger than that of small-scale farms.

For large-scale family farms, there are strongest capitals and knowledge, so the RL of large-scale family farms is

\[
RL_{L} = RL_{(1c)} + RL_{(2)} + RL_{(3d)} \tag{4}
\]

From the formula (4), they often select the environment-friendliest method to dispose the dead pigs and the recycled excrement. However, if the breeding-scale is too large, the amount of the waste may exceed environmental carrying capacity, which results in more resource loss rate than the middle-scale family farmer.

Therefore, under the background of recycling economy, the recycling system may enhance utility of resources and extend energy transferring chain. The reused efficiency of the waste is closely related to the breeding scale. The middle-scale farms have high circular economy level, and its’ effective utilization degree of recycled excrement is highest. The variation trend of the resource loss rate with breeding-scales should be U-type. Considering the profit maximization, the breeding scale with minimum resource loss rate, namely the middle-scale, should be chosen as optimal size for scale-breeding family farms in China.

4. Conclusions

Scale-breeding family farms are very important for agricultural environment and meat supply. The resource loss of scale-breeding family farms is closely related to the breeding scales. The resource loss rate of medium-scale family farms is lowest among three kinds of scale-breeding family farms. The middle-scale should be chosen as optimal size for scale-breeding family farms for sustainable development of agricultural economy in China.

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