Value flow analysis based on EAP industrial chain: case of Huaning in Xichang, Sichuan

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A B S T R A C T

In this paper, based on symbiotic network of Eco-agricultural Park (EAP), value flows of different industrial chains are studied, and input–output efficiencies of industrial chain and individual enterprise accounted independently are compared in the case of Huaning EAP. The results indicate: (1) the total profit of industrial chain of feedstuff processing, breeder duck breeding, laying-hen breeding, farm garden, dairy farm and milk processing is more than the sum of profits of individual enterprises independently accounted, with a difference of 950,800 RMB yuan. Input–output efficiency of this industrial chain is 1.30 times higher than the average that of individual enterprises accounted independently. (2) The total profit of industrial chain of feedstuff processing, dairy farm, grass farm, laying-hen breeding and milk processing is more than the sum of profits of individual enterprises accounted independently, with a difference of 3,258,800 RMB yuan. Input–output efficiency of this industrial chain is 1.45 times higher than the average that of individual enterprises accounted independently. (3) Through collaboration among enterprises in the industrial system, the benefits of the industrial chain are much higher than the sum of those obtained by individual enterprises, which is benefited from the performance of resource and by-product exchange network among enterprises in the EAP.

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1. Introduction

So far, world agriculture has experienced several development stages such as infant faming, traditional agriculture and modern agriculture. Since the 1970s, with improvement of environmental awareness and naissance of sustainable development idea of human beings, various thoughts on agricultural development were developed such as green revolution, natural agriculture and sustainable agriculture. Under guidance of these thoughts, different development patterns came into being, such as natural agriculture, biodynamic agriculture, organic agriculture, no-doing agriculture, eco-agriculture and low-input sustainable agriculture [1–4]. Through long-term practice, people gradually recognized that eco-agriculture is an effective way for sustainable development of agriculture in the future [5].

Since the early 1980s, eco-agriculture has being constructed in more than 2000 counties, villages and towns across China [5,6]. From 1995, the State Environmental Protection Administration of China has successively launched the construction of eco-agriculture demonstration zones all over the country. At present, eco-agriculture demonstration area has reached 667,000 hm², accounting for 7% of national cultivated areas [7]. Early study on eco-agriculture conducted in China was mainly focused on technology application test, and then turned to study on technology integration after the 1990s. During the period of 10th Five-Year Plan (2000–2005), major special programs for tackling key problems in eco-agriculture were started up in China, among which eco-agricultural technology integration and innovation were still one of important issues. Green food production and research took a prominent position, with the research aiming to realize cleaner and high efficiency of production, etc. [7].

It is increasing clear that researcher puts more emphasis on: the role of diversified planting and husbandry [8,9] model of symbiosis [10,11], system approaches and design of sustainability [12–14], material, energy flow analysis and efficiency [15–17].

For economic benefits, many scholars did much research from various aspects [6,18–20]. In addition, Wang et al. [21] introduced the recycling scheme for wastes of Beijing Xiedao Eco-agricultural Park (EAP), an eco-agricultural model with organic combination of planting, breeding and fertilizer processing. Zhu [22] made a brief evaluation on benefits of the EAP in Yuhang of Zhejiang Province where paddy planting is combined with duck breeding.
For value flow, Li and Zheng [23] analyzed value flows of ecological–economic systems of different types of farmers. Bian [24] compared input–output ratio of Shengli Oil Field through value flow in 1990. Zhu [25] and Wang [26] analyzed the value flow of paddy–crab–loach ecosystem through field test, and demonstrated significance of this system for sustainable development of paddy field. However, it has not attracted enough attention to systematically analyze value flow based on EAP, especially, to analyze cost–benefit difference between industrial chain and individual enterprise of EAP. And the literature focusing on value flow is very limited at present.

In this paper, from the dimension of symbiotic industrial network in the park, value flows of different industrial chains are studied, and input–output efficiency of industrial chains and individual enterprise accounted independently are compared in the case of Huaning EAP in Xichang, Sichuan. The aim is to sufficiently exert advantages of material exchange network in EAP, and discuss the way for sustainable development of agriculture based on community scale.

2. Materials and methods

2.1. Study area

Huaning EAP is a private enterprise and built in 1993, with 160 employees at present and areas of 111.67 hm². The park is located at Anning River flood bed of Xichang City in Sichuan Province (Fig. 1), with altitude of 1750 m, average annual rainfall of 1014 mm, and average annual temperature of 16.9 °C and sunlight time of 2365 h. The park takes livestock and poultry breeding and fruit planting as core, mainly developing breeder duck, meat duck, laying-hen, feedstuff, grass, cow breeding, milk processing, pomegranate (Punica granatum L.) and vegetable, etc. There are 26.7 hm² areas of pomegranates planted in farm garden. Intensive breeding farm is the largest breeder duck and laying-hen breeding base in southwest Sichuan.

With the expansion of breeding scale, the discharged wastewater increases rapidly. Under the pressure of wastewater pollution, the park began to attempt wastewater reuse demonstration
from 1998. Farm garden constructed an eco-industrial chain with pomegranate planting as anchor and vegetable and grass interplanted. After treatment, wastewater is drained into canal to irrigate the farm garden. Planting, breeding and primary processing of agricultural products are combined together and form an EAP with material exchanged network according to principle of ecology. Subsidiaries of the park include feedstuff factory, laying-hen farm, breeder duck farm, farm garden, dairy farm, milk plant and grass farm.

2. Categories of industrial chain

Industrial chain refers to the network structure constructed by all the related sectors involved through the process of "production–circulation–consumption" of one or several products. It's the internal reflection of industrial levels, industrial linkage, and the degree of resource processing and meeting the demands. The stronger the industrial linkage is and the closer the chains are, the higher the resources allocation efficiency will be achieved; the longer industrial chain is and the deeper processing degree will be. An industrial chain generally starts from natural resources and terminates at consumption market, but the starting and ending point are not so fixed.

Huaning EAP is an integrated agricultural products development park with fruit planting and livestock breeding bases, which includes the whole process of planting, breeding and processing. Taking farm garden and milk plant as anchor and based on the industrial chain composition levels, material input–output relationship and production scale, the domain industrial chain of Huaning EAP is divided into 2 parts:

1. An industrial chain of feedstuff processing, breeder duck breeding, laying-hen breeding, farm garden, dairy farm and milk processing (Fig. 2), and;

2. An industrial chain of feedstuff processing, dairy farm, grass farm, laying-hen breeding and milk processing (Fig. 3).

2.2. Categories of industrial chain

2.3. Principles of input–output analysis

2.3.1. Type of input and output materials

According to the industrial linkage relationship, types of input and output materials of all subsidiaries of Huaning EAP are divided in details (Table 1).

2.3.2. Principle of value flow analysis

- Accounting principle of value flow of individual enterprise: take individual enterprise as the basic unit of value flow accounting, practice classification accounting at the market price on all the input and output materials of individual enterprise, and sum them up term by term.
- Accounting principle of value flow of industrial chain: take a certain industrial chain as a whole of value flow accounting,

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Types of input and output materials of subsidiaries of Huaning EAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise name</td>
<td>Input materials</td>
</tr>
<tr>
<td>Feedstuff factory</td>
<td>Corn, soybean meal, CaCO₃, wheat bran, additive, electricity, manpower, production facility</td>
</tr>
<tr>
<td>Laying-hen farm</td>
<td>Chickling, manpower, chicken feeds, electricity, land, disease prevention drugs, breeding facility</td>
</tr>
<tr>
<td>Breeder duck farm</td>
<td>Duckling, duck feeds, electricity, manpower, water, land, disease prevention drugs, breeding facility</td>
</tr>
<tr>
<td>Farm garden</td>
<td>Chicken dropping, duck fecal sewage, phosphate fertilizer, potassium sulfate, ferrous sulfate, land, manpower</td>
</tr>
<tr>
<td>Dairy farm</td>
<td>Dairy cow, grass, dairy cow feeds, water, Fresh milk, cow fecal sewage, electricity, disease prevention drugs, manpower, breeding facility</td>
</tr>
<tr>
<td>Milk plant</td>
<td>Fresh milk, water, electricity, coal, manpower, packaging material, processing equipment</td>
</tr>
</tbody>
</table>
input and output materials in the industrial chain are internally digested through material exchange of related sectors, the value of these materials is not accounted, practice classification accounting only on the material input at the starting point and the material output at the terminal (market) at the market price and sum them up term by term.

- Value flow accounting period of industrial chain: accounting based on cycle period of both chicken and duck 76 weeks.

3. Results and discussion

3.1. Value flow of industrial chain A

Material flow linked in the industrial chain A includes intermediate materials and final materials. Intermediate materials are composed of cattle feed, chicken feed, duck feed, chicken dropping, grass, fresh milk and duck fecal sewage (red mark frame shown in Fig. 4). Final materials are composed of cow manure, milk, pomegranate, vegetable, soybean, chicken, egg, duckling, duck, and duck egg (green mark frame shown in Fig. 4). Input costs of laying-hen farm, breeder duck farm, farm garden, dairy farm and milk plant at the lower part of left column in Table 2 are accounted according to external cost of the industrial chain; upper part of the left column in Table 2 (input in feedstuff factory) refers to average cost of raw materials, energy, water resources and manpower, etc. required by the varieties of feedstuff in the industrial chain. Since the feeds for laying-hen farm, breeder duck farm and dairy farm, farm garden grass, chicken dropping from laying-hen farm, fecal sewage from breeder duck, and fresh milk from dairy farm are used as internal resources of the downstream sector of the industrial chain (Fig. 4), they are not accounted in input cost of the industrial chain. And output value (green mark frame) of this industrial chain is shown in Fig. 4.

According to Table 2, input–output ratio of the industrial chain A is 1.90. From the contribution of each enterprise in this industrial chain, it can be seen that, in the total investment, the feedstuff factory occupies 52.14%, farm garden 27.48% and breeder duck farm 12.77%. For output contribution, breeder duck farm, feedstuff factory and dairy farm, respectively, occupy 57.95%, 22.29% and 0.14%, among which, dairy farm is the lowest (Fig. 5).

The average input–output ratio is 1.46 independently accounted based on individual enterprise, among which breeder duck farm is the highest, being 2.29; farm garden is 1.40; and dairy farm is the lowest, only 0.95 (Table 3).

According to Table 2, total profit of this industrial chain is 8,399,500 RMB yuan, but the total profit independently accounted for individual enterprises is 7,448,700 RMB yuan (Table 3), less than the sum of profits of the whole industrial chain, with profit difference of 950,800 RMB yuan.

Through comparison on input–output efficiency, the efficiency of this industrial chain is 1.30 times higher than the average efficiency independently accounted for individual enterprises.

<table>
<thead>
<tr>
<th>Type of input</th>
<th>External cost of the industrial chain (10,000 RMB yuan)</th>
<th>Type of output</th>
<th>Quantity</th>
<th>Value of output (10,000 RMB yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstuff factory</td>
<td>Cattle feeds 30.95</td>
<td>Laying-hen farm</td>
<td>Chicken 65.33 t</td>
<td>45.73</td>
</tr>
<tr>
<td></td>
<td>Chicken feeds 269.75</td>
<td></td>
<td>Egg 636.13 t</td>
<td>349.87</td>
</tr>
<tr>
<td></td>
<td>Duck feeds 186.68</td>
<td>Breeder duck farm</td>
<td>Duckling 3.827 t</td>
<td>995.06</td>
</tr>
<tr>
<td>Laying-hen farm</td>
<td>32.93</td>
<td></td>
<td>Duck 46.40 t</td>
<td>33.41</td>
</tr>
<tr>
<td>Breeder duck farm</td>
<td>256.86</td>
<td></td>
<td>Duck egg 0.11 t</td>
<td>0.06</td>
</tr>
<tr>
<td>Farm garden</td>
<td>119.36</td>
<td>Farm garden</td>
<td>Pomegranate 567.42 t</td>
<td>158.88</td>
</tr>
<tr>
<td>Dairy farm</td>
<td>17.23</td>
<td></td>
<td>Vegetable 2565.20 t</td>
<td>25.65</td>
</tr>
<tr>
<td>Milk plant</td>
<td>21.08</td>
<td></td>
<td>Soybean 70.93 t</td>
<td>8.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dairy farm</td>
<td>399.73 m³</td>
<td>2.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milk plant</td>
<td>Milk 862.32 t</td>
<td>155.22</td>
</tr>
<tr>
<td>Total input</td>
<td>934.84</td>
<td>Total output</td>
<td></td>
<td>1774.79</td>
</tr>
</tbody>
</table>
So it is clear that through close collaboration among the relevant enterprises in the industrial system, the economic benefit of the industrial chain is higher than the sum of benefits obtained by individual enterprises in this industrial chain, which efficiently reflects the performance of construction of material exchange network among individual enterprises in industrial chain.

### 3.2. Value flow of industrial chain B

Material flow linked in the industrial chain B includes intermediate materials and final materials. Intermediate materials are composed of cattle feed, chicken feed, grass, chicken dropping, and fresh milk (red mark frame shown in Fig. 6). Final materials are composed of cow manure, milk, chicken, and egg (green mark frame shown in Fig. 6). Similarly, input costs of laying-hen farm, grass farm, dairy farm and milk plant at the lower part of left column in Table 4 are accounted according to external cost of the industrial chain; upper part of the left column in Table 4 (input in feedstuff factory) refers to mean cost of raw materials, energy, water resources and manpower, etc. required by the varieties of feedstuff in the industrial chain. Since the feedstuff for laying-hen farm, chicken dropping for grass farm, feedstuff for dairy farm, and fresh milk for milk plant are taken as internal resources of the downstream sector of the industrial chain (Fig. 6), they are not accounted in the input cost of this industrial chain. And output value of this industrial chain is shown in Fig. 6 (green mark frame).

![Fig. 5. Input and output contribution of each enterprise in industrial chain A and chain B.](image)

**Table 3**

<table>
<thead>
<tr>
<th>Items</th>
<th>Input (10,000 RMB yuan)</th>
<th>Output (10,000 RMB yuan)</th>
<th>Profit (10,000 RMB yuan)</th>
<th>Output/input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstuff factory</td>
<td>487.39</td>
<td>506.84</td>
<td>19.45</td>
<td>1.04</td>
</tr>
<tr>
<td>Laying-hen farm</td>
<td>314.89</td>
<td>403.86</td>
<td>88.97</td>
<td>1.28</td>
</tr>
<tr>
<td>Breeder duck farm</td>
<td>449.75</td>
<td>1028.53</td>
<td>578.78</td>
<td>2.29</td>
</tr>
<tr>
<td>Farm garden</td>
<td>127.62</td>
<td>178.86</td>
<td>51.24</td>
<td>1.40</td>
</tr>
<tr>
<td>Dairy farm</td>
<td>101.41</td>
<td>96.36</td>
<td>-5.05</td>
<td>0.95</td>
</tr>
<tr>
<td>Milk plant</td>
<td>143.74</td>
<td>155.22</td>
<td>11.48</td>
<td>1.08</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1624.80</strong></td>
<td><strong>2369.65</strong></td>
<td><strong>744.87</strong></td>
<td><strong>1.46</strong></td>
</tr>
</tbody>
</table>

![Fig. 6. Input and output value flow of industrial chain B (10,000 RMB yuan).](image)
The result shows that the total input in this industrial chain is 7,996,300 yuan, and the total output is 12,066,000 RMB yuan (Table 4). The input–output ratio is 1.51.

According to contribution of input–output of each enterprise in this industrial chain, it can be seen that, of the total investment, the feedstuff factory occupies 49.61%, grass farm 19.92%, milk plant 15.92% and laying-hen farm 14.91%. For output contribution, milk plant, laying-hen farm and dairy farm occupy 72.74%, 26.94% and 0.32%, respectively (Fig. 5).

The average input–output ratio is 1.04 independently accounted for individual enterprises. At present, inputs in grass farm and dairy farm are more than their outputs. The ratio is 0.61 and 0.95, respectively. The input–output efficiency of laying-hen farm is the highest, being 1.28, followed by milk plant 1.08, and then feedstuff factory 1.04 (Table 5).

Table 4 shows that the total profit of the industrial chain B is 4,069,700 RMB yuan, but the sum of profits of individual enterprises accounted independently is 810,900 RMB yuan (Table 5), less than that of the whole industrial chain, with the difference of 3,258,800 RMB yuan.

Through comparison on input–output efficiency, the efficiency of the industrial chain B is 1.45 times higher than the average efficiency independently accounted for individual enterprises. This advantage similarly is benefited from performance of the intermediate input materials (feedstuff for laying-hen, chicken dropping for grass farm, feedstuff for dairy farm, fresh milk for milk processing) are internally digested through material exchange of related sectors, these materials are not accounted into the input cost of industrial chain B, which reduces the total cost of industrial chain B;

The average input–output ratio is 1.04 independently accounted for individual enterprises. At present, inputs in grass farm and dairy farm are more than their outputs. The ratio is 0.61 and 0.95, respectively. The input–output efficiency of laying-hen farm is the highest, being 1.28, followed by milk plant 1.08, and then feedstuff factory 1.04 (Table 5).

Table 4 shows that the total profit of the industrial chain B is 4,069,700 RMB yuan, but the sum of profits of individual enterprises accounted independently is 810,900 RMB yuan (Table 5), less than that of the whole industrial chain, with the difference of 3,258,800 RMB yuan.

Through comparison on input–output efficiency, the efficiency of the industrial chain B is 1.45 times higher than the average efficiency independently accounted for individual enterprises. This advantage similarly is benefited from performance of the resource and by product exchange network among Huaning EAP enterprises.

The difference of the profit of individual chain B and that when individual enterprise is accounted is 3,258,800 yuan, the major reason is:

(1) According to the accounting principle of value flow of industrial chain, the intermediate input materials (feedstuff for laying-hen, chicken dropping for grass farm, feedstuff for dairy farm, fresh milk for milk processing) are internally digested through material exchange of related sectors, these materials are not accounted into the input cost of industrial chain B, which reduces the total cost of industrial chain B;

(2) According to the accounting principle of value flow of industrial chain, only the terminal (market-facing) material output of industrial chain B (chicken and egg produced by laying-hen farm; milk products produced by milk plant) is accounted at the market price, while the feedstuff factory, grass farm and dairy farm only provide intermediate materials for industrial chain B without profit output (Fig. 5). In fact, laying-hen farm and milk plant are not only the value flow accounting units with the largest scale and profit of industrial chain B (Fig. 5), but also the value flow accounting units with the largest scale and profit of the whole Huaning EAP, which obviously leads to the increase of the total profit of the industrial chain B;

(3) According to the accounting principle of value flow of individual enterprise, the profit of feedstuff factory is only 158,900 yuan, while the inputs of grass farm and dairy farm are more than their outputs, with losses of 442,600 yuan and 285,500 yuan, respectively, and negative profits (Table 5), which reduces the total amount of profits of individual enterprises to a certain extent. As for individual enterprises, operation at a loss means the enterprise has little chance of survival. But what should be noticed here is, feedstuff factory, grass farm and dairy farm are inseparable parts of industrial chain B, they are important sectors and ties connecting the material input–output relationship of industrial chain B; besides, they are subsidiaries of Huaning EAP, which means there doesn’t exist profit reallocation. This is the important foundation for the formation, development and stabilization of the industrial chain.

4. Conclusions

The following conclusions can be drawn from analysis of the case:

(1) The total profit of industrial chain of feedstuff, breeder duck, laying-hen, gardening, dairy farm and milk processing is higher than the sum of profits of the individual enterprises independently accounted, with the difference of 950,800 RMB yuan, wherein the shares contributed by breeder duck farm, laying-hen farm, farm garden, milk plant and dairy farm are 57.95%, 22.29%, 10.88%, 8.75% and 0.14%, respectively. The input–output efficiency of this industrial chain is 1.30 times higher than the average efficiency of the individual enterprises independently accounted.

(2) The total profit of industrial chain of feedstuff, dairy farm, grass, laying-hen and milk processing is higher than the sum of profits of individual enterprises independently accounted, with the difference of 3,258,800 RMB yuan, wherein the shares contributed by milk plant, laying-hen farm and farm garden are 72.74%, 26.94% and 0.32%, respectively. Input–output efficiency of this industrial chain is 1.45 times higher than the average efficiency of individual enterprises independently accounted.

(3) Through collaboration among the enterprises in industrial system, the economic benefits of the industrial chain are more than the sum of the benefits obtained by individual enterprises, which is benefited from the performance of resource and by product exchange network among individual enterprises in
EAP. Construction of industrial symbiotic chain based on EAP does not only feature obvious economic benefit, but also provide an effective way for sustainable development by internal abatement of pollutants produced in industry process and exchange of by-products.

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