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The Influences of Production Factors with Profit on Agricultural Heritage Systems: A Case Study of the Rice-Fish System

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Abstract: With the mobility and off-farm employment of rural villagers, agricultural production has been influenced by the absence of labor force in the past few years. In particular, the inadequate assignment of resources has threatened the sustainability of some Globally Important Agricultural Heritage Systems due to their low profit. In this paper, the influences of labor force and capital on agricultural heritage systems are analyzed, taking the Qingtian Rice-Fish Culture System (QRFCS) as an example, so as to maximize profit along with the sustainability of agricultural heritage. The Cobb-Douglas Production Function is applied to examine the impacts of these major factors on agricultural productivity based on a survey held among 32 households in Longxian Village, Qingtian County, China. Subsequently, the profit maximization problem can be solved by a marginal rate of technical substitution under production standard. We come to the conclusion that the output elasticity coefficients of labor and capital are 0.6 and 0.4. Our results also indicate that the maximum yield of rice and field-fish is 0.84 kg under the level of 9 Yuan RMB and 0.24 man-days per square meter. The net profit can hit 24.8 Yuan RMB regardless of human resource cost. In contrast, the demand of 218,800 m^2 paddy fields exceeds the human resources available for the Rice-Fish system in QRFCS, thereby it is necessary to promote the refluence of skilled farmers.

Keywords: Qingtian Rice-Fish Culture System; Globally Important Agricultural Heritage Systems; sustainability; labor force; capital input; input-output; profit maximization

1. Introduction

China is a large traditional agricultural country, and agriculture is an important pillar in the development of the national economy, comprising 11.3% of Chinese Gross Domestic Product (GDP) [1]. Both natural and social factors are all crucial to agricultural production in the development process, such as farmland, farmer labor, and land-leveling work [2]. However, with the acceleration of industrialization and urbanization, rural labor transfer has been commonplace and a tendency seen after reformation in China. By late February 2017, more than 281 million farmers search for jobs outside their hometowns, with 112 million in local township enterprises and 169 million outwards [3]. The farmer labor migration stimulates economic growth and brings in more non-farm income for farmers [4–7]; meanwhile, it has caused many problems, such as land abandonment [8–10], hollow villages [11–15], and a trend of leaving elders and children behind [16–19]. On the other hand, pesticides and chemical fertilizers are in a serious overuse and low efficiency situation [20,21], and have generated negative environmental consequences, such as biodiversity loss [22]. Agricultural non-point source pollution, caused by fertilizers and pesticides and the emission of animal waste from

livestock breeding, have become the most important causes of water eutrophication and pollution in some regions [23].

However, Globally Important Agriculture Heritage Systems (GIAHS) are characterized by food and livelihood security, agro-biodiversity, local and traditional knowledge systems, as well as cultures and values systems that, by interaction, aim to decrease environmental pollution from the source [24,25]. These compound systems also require more people to promote sustainable development than other agriculture single modes [26]. So, the massive outflows of villagers lead to some difficulties regarding the protection and development of these traditional systems. The available research on factors affecting GIAHS are concentrated on farmer loss, and are divided into two groups in both physical and intangible ways. One group considers that labor loss has left fields desolated, extensive running, and also caused a decrease of biodiversity [27–29]. The other group examines the reduction of ecosystem service function, traditional ecological knowledge, and technology formed in the long history of practice [30–32]. In these studies, researchers conclude that the remaining labor force in the village is the principal ingredient for the qualitative management of the systems. However, quantitative analysis of the influences of production factors (e.g., labor force, capital) on agricultural heritage systems is relatively deficient. Persuasive and constructive measures suggested according to specific data are also lacking.

The Qingtian Rice-Fish Culture System (QRFCS), created 1200 years ago to make the agricultural system more adaptive to rough terrain, retains the traditional patterns of the rice-fish terrace and related cultural knowledge. Thus, it became a GIAHS designated by the Food and Agriculture Organization of the United Nations (FAO) in 2005 [33]. Farmers' product income as well as indirect economic values are raised with natural and cultural ecosystem services [30,34,35]. In QRFCS sites, as more local residents have opted for resettlement abroad (e.g., Japan, France, Brazil) from the onset of the Qing Dynasty till now [36,37], labor forces who work in agriculture do not number enough to match the available farmlands, so that farming areas and yields of rice and fish have declined for years [28].

In this paper, a quantitative assessment of the human resources and capital of GIAHS is undertaken, taking the QRFCS as a case study. The research intends to calculate the profit maximization of systems to achieve harmonious development according to the current situation. The promotion of human investment with capital in factors to contribution rates of output is compared based on the Cobb-Douglas Production Function. The optimal production output of fish and rice with the related labor force is captured to gain the most profit. The results are used to identify the most effective ways of dynamic conservation to solve the contradiction that labor forces cannot match the farmlands, caused by outmigration.

2. Materials and Methods

2.1. Study Area

The QRFCS is distributed in Qingtian County, Zhejiang Province, China, traversed by the middle or lower reaches of Oujiang River, 119°47′~120°26′ E and 27°56′~28°29′ N. It covers 2493 km^2 in size, of which 89.7% constitutes mountains, 5.3% plains, and 5% rivers, streams, lakes, bays, ports, and so forth. The climate of this area is a subtropical monsoon type with abundant annual illumination for 1664 h and precipitation for 1698 mm, similar in terms of time scales. The average temperature reaches 18.6 °C in a year. All of these features provide natural conditions for fish culture in paddy fields. There are 548,800 registered residents in this area. However, 287,900 residents still dwell in 414 administrative villages today, and 60% have emigrated overseas in 121 countries and regions. The labor force population is 181,700 in the region, while only 64,800 engage in the primary industry, majoring in single crop rice, freshwater fishery, fruit, or vegetables. In 2016, the total value of the GDP was 21 billion Yuan RMB; of this, 12.2 million originated from agriculture, forestry, animal husbandry, and fishery, except for their service values in Qingtian County. The Disposal Personal Income (DPI) of the rural residents is 18,830 Yuan RMB.

Longxian administrative village covers an area of 4.64 km^2 in the southernmost direction of Qingtian County. Paddy fields are located in the landforms of low mountains and hills, which are less than 1 km. The registered population of Longxian is 1465. Currently, it is known as the hometown of overseas Chinese, as more than 800 people make livings by catering to industry and department stores in Spain, Italy, and France. One hundred and seventy-nine villagers in 81 households cultivate a small area of 144,300 m^2 for rice-fish farming, and the gross rice and fish yields 175,000 kg and 7400 kg, respectively. In 2015, Longxian village had a revenue of 1.58 million Yuan RMB in agricultural product, 81,100 Yuan RMB in primary food, and 1.5 million Yuan RMB in processed goods. However, 74,300 m^2 of fields are discarded, resulting in a potential value loss of 814,000 Yuan RMB.

Farm activities are just for the basic daily requirements of some related food for most of the present residents (present residents refer to villagers who live in Longxian for over six months in one year.). However, along with the development of tourism, a large quantity of visitors (0.14 million) became the major income-maker in 2015. Meanwhile, the tourism revenue accounts for a higher proportion in the gross income, accounting to 4.77 million Yuan RMB, and grew by 500% in 2015 compared with the same period of the previous year.

2.2. Research Methods

Currently, the compound outputs of the QRFCS differ greatly from various representative farmers, and the economic potential of the system has not been developed due to extensive management. In this study, the profits are calculated using the input-output method with market price. The level of labor and material inputs are discussed to achieve profit maximization by a marginal rate of technical substitution. Based on all analyses, the gap between the optimal and present condition is assessed.

For the QRFCS, the total compound outputs vary widely depending on some factors, such as labor, capital, technology, and land. In particular, labor input is decided by rice seedlings, soil preparation, planting, weeding, harvesting, etc. Capital input consists of expenses for seeds, fertilizers, pesticides, fishery fodder, and other materials. Output refers to gross yields of rice and field-fish. The general function can be represented by Equation (1) [38]:

$$Q = f(A,\ L,\ K,\ R) \tag{1}$$

where Q is the output of rice and field-fish, A refers to technique level, L is the labor input, K is the capital input, and R is the total area of rice-fish fields in Longxian. Intensive and large-scale management is difficult to put into practice due to the complexity and fragmental features of the system. Besides, most terraced fields are on hill slopes, therefore the technique will be ignored in this study. Limited by restrictions on the total area of land resource, the major contributions of labor and capital input are analyzed by the Cobb-Douglas Production Function for the QRFCS, which can be calculated by Equation (2):

$$Q = AL^{\alpha}K^{\beta} \tag{2}$$

$$MP_L = \frac{\partial Q}{\partial L} = \alpha AL^{\alpha-1}K^{\beta}$$

$$MP_K = \frac{\partial Q}{\partial K} = \alpha AL^{\alpha}K^{\beta-1} \tag{3}$$

here, α and β are greater than zero and less than one, and represent the output elasticity of labor and capital, respectively. MP_L and MP_K are the marginal productivity of labor and material, respectively. The relative importance can be demonstrated by contrast.

Because of market competition, the prices also become major contributors and exogenous variables for cost and benefit. Moreover, the net profits are distinguished from the quantity and transaction value of labor and material, as well as fish and rice. Thus, the net profit per unit area of the QRFCS can be calculated by Equation (4):

$$TP = TR - TC \tag{4}$$

where TP is the total profit of the QRFCS in unit area, TR represents the total revenue of rice and fish for peasants' own use and sales, and TC is the expenditure of labor and all materials in all.

In this complex system, various primary and preliminary processed products are exported. In order to avoid double counting, rice and field-fish are adopted to support the total revenue and cost. However, the related weight coefficient should be considered when calculating farmers' production value. Then, the total profit (TR) in each unit area can be calculated by Equation (5):

$$TR = \mu_1 P_1 Q + \mu_2 P_2 Q \tag{5}$$

where μ_i is the weight coefficient, P_i is the mean prices of the compound products. In the QRFCS site, more than 50% people have emigrated to other countries, apart from those engaged in agriculture. Labor costs take a larger proportion of all expenses. Material investment mainly refers to seeds, pesticide fertilizer, and fodder payments. Therefore, the total costs can be calculated by Equation (6):

$$TC = P_L L + \sum_{i=1}^{4} P_{ki} K_i \tag{6}$$

where P_L is the price of labor engaging in catering service in Longxian, P_{ki} is the material price, and K_i is the amount of the input.

The maximization problem can be simplified to obtain the optimal labor and capital input level under production standard. From the optimal combination of production factors, the maximum profit can be achieved under the condition of Equation (7):

$$\frac{MP_L}{P_L} = \frac{MP_K}{P_K} \tag{7}$$

2.3. Data Collection

The data on the input and output of the QRFCS were collected through on-site investigation in Qingtian County from July to August in 2016. All figures were divided into two sections: one originated from structural interviews and questionnaire surveys, and the other included data extracted from ministries of population, statistics, and agriculture.

The household surveys were implemented in two steps in Longxian. For the first time, a full investigation was carried out on the quantity and structure of present residents. There were 81 households still living in the village, of which 58 families engaged in agriculture. Then, 34 farmers were selected at random to obtain more details of output and input for QRFCS production. Finally, 32 questionnaires were obtained to construct the Cobb-Douglas Production Function, with an efficiency rate of 94.1%.

In order to render the data more accurate and precise, male labor was taken as the top option in the field survey. Concerning the input and output of the QRFCS, the questionnaire involved four aspects: (i) the information of farm workers, such as the gender, age, health, etc.; (ii) the capital input, such as seeds, fertilizers, pesticides, fish feed; (iii) the labor input required for seeding rice, preparing soil, planting, weeding, harvesting, and other procedures; (iv) the gross income, including production activities, tourism, remittance, and pension.

3. Results

3.1. The Situation of Present Residents and Input of Labor

According to the analysis, the proportion of males and females are 59.8% and 40.2%, and the ratio of middle-aged people reaches 74.3%. According to the conclusion of the study by Gai et al. for productivity, one man-day is equal to the workload of a middle-aged man, ranging from 16 to 60 years of age in one day; 0.76 man-days is equal to the workload of one woman aged 16 to 55 years;

0.71 man-days is equal to the workload of one elder over 60 years for males or 55 years for females; and 0.56 man-days represents the workload of a child aged less than 16 years [39]. As shown in Table 1, the effective labor supply is 153.45 man-days in one day on account of workers' quality and productivity. Compared to the 218,700 m^2 paddy fields available, the per capita cultivated land is 1220 m^2, similar to the whole country of China, and the imbalance between the human workforce and lands is still prominent [40]. The activities of the QRFCS are concentrated in the months of April, May, July, September, and November. Assuming that all permanent farmers can attend agricultural production for five months during busy farming seasons, the supply of effective labor is 23,018 man-days in the whole year.

In Longxian, 112 farmers, 62.57% of present residents, manage 65.98% of all lands with the model of the rice-fish system. The labor force is comprised of 60% male labor and 86.7% younger workforce (Table 1). Finally, 95.64 man-days were entered to breed fish and rice in 2015. This means that a middle-aged man only devotes approximately one day in a year per unit area. However, the distributions of labor resources are obviously different among representative farmers. The greatest is equipped with 0.041 man-days and the least is given 0.003 man-days. Frequently, owning a larger area of cultivated land tends to signify a lower labor force input for each plot (Table 2).

Table 1. Demographic structure and related labor input in Longxian by 2015.

Residents (Age in Years)	Registered Residents		Present Residents		Farm Worker	
	Population	Productivity	Population	Productivity	Population	Productivity
Male and Female <16	198	110.88	3	1.68	0	0.00
Male 16–60	479	479.00	84	84.00	58	58.00
Female 16–55	443	336.68	49	37.24	39	29.64
Male >60	139	98.69	22	15.62	5	3.55
Female >55	206	146.26	21	14.91	10	7.10
Total	1465	1171.51	179	153.45	112	98.29

Table 2. The area and related labor input of Qingtian Rice-Fish Culture System (QRFCS).

Area of QRFCS (m^2)	Labor Input (10^{-3} Man-Day/m^2)
Area $\leq$ 1333	$L > 7.5$
1333 < area $\leq$ 2000	$6.0 < L \leq 7.5$
2000 < area $\leq$ 3333	$4.5 < L \leq 6.0$
3333 < area $\leq$ 4667	$3.8 < L \leq 4.5$
Area > 4667	$L < 3.8$

3.2. The Costs of Direct Material Inputs

The material cost occurs in the procedures of sowing, breeding, and harvesting in the system. The expenses of rice seeds and fish fries are indeed the largest part, and fish cost three times as much as rice. Only in 4.6% cultivated area are field-fish fed with wheat, corn, and so on. Almost all lands are composted by organic fertilizers from local governments freely. It has been proven that 0.00075 kg rice seeds are consumed for paddy fields with field-fish per square meter, and the number of fries varies widely among many different sizes. During production, the cost of seeds and fries is 0.26 Yuan RMB per unit area according to Table 3, making up 83.2% of all expenditures (without pesticide fertilizer). Aquaculture fodder is 0.053 Yuan RMB on average, and the result shows that they could increase output, and the average fish yield of aquaculture fodder field is 24 kg more than no fodder addition field for an area of 1000 m^2.

Table 3. Capital input of the QRFCS on average in Longxian.

Direct Material Inputs		Capital (10^{-3} Yuan/m^2)
Seeds	Rice Seeds	67.5
	Field-fish Fries	195
Pesticide Fertilizer		240
Aquaculture Fodder		53

3.3. The Outputs of QRFCS

Under different conditions of labor force and material input, the average throughput ranges from 0.37 kg to 0.81 kg per square meter (Table 4). As shown in Table 4, both material and labor force are of key importance, and labor force has a substitution effect on material input to some extent from farmer A and farmer E. In general, the gross output is directly proportional to material and labor input. On the other hand, the unreasonable assignment of resources is connected to the inefficient system of the QRFCS. Thus, raising inputs is a major approach to accrue the best achievements and secure maximum profits.

Table 4. The input and output of the QRFCS among representative farmers.

Farmer	Material Input (Yuan)	Labor Force (Man-Day)	Output (kg)
A	0.13	0.01	0.37
B	0.28	0.09	0.54
C	0.35	0.10	0.70
D	0.61	0.13	0.81
E	0.09	0.34	0.57

3.4. The Production Function of the QRFCS

As seen in Table 4, the gross yields of rice and field-fish are especially affected by the labor force and the direct material cost input. For example, 0.13 Yuan RMB and 0.01 man-days are assembled to attain the output of 0.37 kg rice and field-fish in a cycle of operation per square meter. Moreover, a yield of 0.81 kg could also be reached for another farmer. Therefore, a linear regression analysis is made by Cobb-Douglas Production Function in view of all famers. Overall, for the labor force input and direct material cost in logarithmic coordinates, the two have a linear relationship at random, which can be described by Equation (8):

$$\ln Q = 0.6 \ln L + 0.4 \ln K - 0.53 \quad (8)$$

After a simple conversion of the equation, the Cobb-Douglas Production Function of the QRFCS is revealed in Equation (9). The relative contribution quotas of labor and capital are 0.6 and 0.4, respectively. Furthermore, labor force has a more notable impact than capital input on the economic benefit of primary products. The sum of α and β is equal to one, indicating that it is in the stage of constant returns to scale, and the input of all factors should be raised in proportion to promote the structure.

$$Q = 0.59 L^{0.6} K^{0.4} \quad (9)$$

3.5. The Net Profit and Maximum Situation of QRFCS

As a compound production system, the agricultural products put different weights on the total output, including 30% field-fish and 70% rice. Thus, the coefficients of fish and rice are taken as 0.3 and 0.7. By contrast, the price of fish in current market is 120 Yuan RMB per kilogram, 20 times as much as rice. According to the local labor market of farmers engaging in this service, farmers cost 150 Yuan RMB per day of work. Other materials are listed in Table 3. Eventually, we calculated that the maximum

output is 0.84 kg with 0.24 man-days from Equations (7) and (9). Under the optimal labor and certain capital input level, the TP of QRFCS is below zero, but the net profit can hit 24.8 Yuan RMB without considering the human resources it has cost. Therefore, we came to the conclusion that the economic benefit of agriculture production is less than the income for working outside. Therefore, we point to other aspects, such as ecology and food security, for the benefits of GIAHS.

4. Discussion

As a compound model of agriculture, the input of labor and capital are major factors in the QRFCS. Based on the investment cost and product benefit data, the material costs are in need of 9 Yuan RMB, as well as 0.24 man-days priced at 36 Yuan RMB (the market price of the labor force is 150 Yuan/man-day). The output of rice is up to 0.59 kg/m^2 and field-fish has reached 0.25 kg/m^2 in the unit area. Rice and field-fish are sold at the price of 6 Yuan/kg and 120 Yuan/kg, thus the value of the gross export is 33.8 Yuan RMB. In terms of investment, the ratio of labor to total import is 80%; the relative contribution share of the labor force is 60%; and the input-output ratio is 75% in the whole system. In sum, the QRFCS, classified as a labor-intensive activity, exposed the phenomenon of negative returns. However, according to the optimization model of input and output in Equation (8), the labor force input should be increased by 0.22 man-days/m^2 in the QRFCS, and thus the total cost and revenue reach 45 Yuan and 33.77 Yuan RMB, as shown in Table 5. Therefore, more labor and related capital should be implemented in proportion to promote the sustainability of the QRFCS [41].

Table 5. The labor input and outputs of the QRFCS under two scenarios.

QRFC		Mean		Optimization	
		Quantity (Man-Day)	Value (Yuan)	Quantity (Man-Day)	Value (Yuan)
Labor Input		0.022	3.31	0.24	36.00
Output	Rice	0.45	1.89	0.59	3.53
	Field-fish	0.022	2.64	0.25	30.24

In total, 14,743.75 man-days are required in the QRFCS for farm workers, and 23,017.5 man-days are available from present residents. Thus, it is clear that the current input-output condition has heavy disparity from the best optimal point. The supply of labor force is insufficient for the rice-fish system. We conclude that there are two primary reasons that cause the present situation of the QRFCS in this discussion. On one side, local residents work outside the home or abroad, so less human resources can be harnessed to manage fields, resulting in some fields even being abandoned, and 34% of arable land are lying exposed and unused. As a result, the QRFCS of cultivated area in that region has decreased incessantly, and the imbalance between land and the human workforce is intensifying. On the other side, a wave of emigrants dampens their own enthusiasm for production, accompanied with the remittance sent by emigrants. It is evident that substantial funds have been poured into the sites, taking up 42.2% of the total income. The substantial capital is a major source of income for 92.6% households, which improves the general living level noticeably. Nevertheless, the system faces more pressure than before, with low economic profits, as well as extensive management requirements with low labor and capital inputs.

With the intention of maintaining the sustainability of agricultural heritage sites by profit maximization, 52,488 man-days are in demand for 218,700 m^2 paddy fields with fish according to Equation (8). The demand of human resources is far beyond the supply. Therefore, human resources are needed for the situation of QRFCS sites in order to implement reasonable and sustainable utilization of the abundant land resources.

In this paper, we only assessed the factors of labor force and capital input for the QRFCS. Actually, many other factors, such as water environment, the experience and skills of farmers, and the type of fish and rice, also play an important role in output. For example, the hybrid rice could produce 0.75 kg foxtail millet, and polished glutinous rice can produce 0.6 kg in the same conditions.

In addition, we only considered the economic benefits from the perspective of its food production function. The QRFCS also has many ecological benefits [42]. The QRFCS is able to control pests and disease by the interaction of organisms, as well as reduce the pollution of water, soil, and products [37,43]. In conclusion, the rice-fish system represents a typical example of GIAHS in promoting the sustainability of modern agriculture.

5. Conclusions

Labor input has the highest contribution to the growth, and the availability of land resources restricts the total yields according to the Cobb-Douglas Production Function. With the capital input of 0.56 Yuan RMB, the level of labor force input presents a wide gap, from 0.003 man-days to 0.02 man-days per unit in the current situation.

The output and related labor input with a given quantity capital was analyzed in a standard way. The results show that the system is in need of 0.24 man-days and 9 Yuan RMB to produce 0.84 kg rice and field-fish under the optimal scenario. The net profit is 24.8 Yuan RMB, except for the investment of the farmers' own labor cost. Besides, there is a gap of 29,470 man-days in total in the labor force; therefore, the present residents could not meet paddy fields' requirements to develop the rice-fish system.

Large amounts of labor outmigration in countryside is the main reason for this land being left to waste by different degrees. The QRFCS site of Longxian proved this causal relationship, and an increased workforce is essential to promote the sustainability of GIAHS. Moreover, the first and most important thing is to mobilize enthusiasm as well as corresponding capital for current villagers. This study is only an example, and it presents a scenario for continual development by optimizing return on investment. The reason why local workers leave for other countries and regions is significant to make policies [44]. Therefore, establishing dynamic standards based on Payment for Ecosystem Services will provide income for present villagers. Eco-tourism and cultural tourism pave the way for new advances to push for economic growth. However, the benefit should be distributed equitably among government, enterprises, and farmers. The mechanism and ecological benefits require further research, and related tourism development is a significant perspective for future study.

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