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A Conservation Approach of Globally Important Agricultural Heritage Systems (GIAHS): Improving Traditional Agricultural Patterns and Promoting Scale-Production

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Abstract: Heritage conservation is an important recurring research theme on agricultural heritage systems. Improving the income of farmers from agriculture is regarded as an effective conservation approach. This study examined how the improved rice-fish-duck coculture (IRFDC) promotes the protection of the Honghe Hani Rice Terraced System (HHRTS) by keeping farmers farming in their hometowns. A semi-structural interview and a questionnaire survey were used to collect data on agricultural input–outputs and household employment in HHRTS. As a result, a fairly large proportion of HHRTS rice terraces were used for the hybrid rice monoculture (HRM) with chemical inputs, and most of these rice terraces were wasted for half a year on account of being left unused; the IRFDC requires considerable time input for farming and breeding, but barely needs any chemical inputs. IRFDC entails a higher cost than HRM, but also has a higher return than HRM. Driving a family to do full-time farming requires extra more than 0.71 ha rice terraces for IRFDC. In conclusion, Globally Important Agricultural Heritage Systems (GIAHSs) can be used for protecting terraces from abandonment and destruction by improving agricultural economic benefits for farmers. At present, a shortage of laborers in HHRTS sites is false. Agricultural heritage sites do not actual need so many people if peasant households can do large-scale farming.

Keywords: monoculture; coculture; Globally Important Agricultural Heritage Systems (GIAHS); Hani rice terraces; scale-production; industrial development

1. Introduction

In the past few decades, with industrialization and agri-technology progress, many traditional agricultural systems have been replaced by modern ones or abandoned by farmers due to low profits and tiring work processes [1–5]. However, environmental problems and food unsafety caused by modern agriculture [6,7] and sustainability of traditional agriculture identified by many studies [8–11] have prompted people to pay renewed attention to traditional agriculture. Unlike modern agriculture relying on chemical inputs, traditional agriculture has rich biodiversity and plenty of traditional species with high environmental adaptivity. These characteristics cause them to have strong resistance to pests and diseases [12] and resilience to extreme climate change [13,14]. Besides, Landscape diversity and better eco-environment quality give traditional agriculture a higher recreational value [15]. These advantages of traditional agriculture have attracted research interests from scientists in some countries. Literature shows that conservation for traditional agriculture has been conducted by scientists across the world [16–20]. The Globally Important Agricultural Heritage Systems (GIAHS) launched by the Food and Agriculture Organization of the United Nations (FAO) in 2002 is an important symbol, that the international society attached importance to the protection of traditional agriculture. In 2005, FAO began to search typical traditional agricultural systems around the world and designated them as GIAHS. Thirty-seven GIAHSs around the world were designated by FAO at the end of October 2016. Thus, how to protect GIAHSs more effectively has become a critical problem for governments in GIAHS sites under the context of urbanization.

Labor outmigration is widely regarded as an important factor threatening the sustainability of GIAHS. Studies showed that the income from traditional agriculture is far lower than the income from non-farm jobs in cities for the farmers in GIAHS sites [21]. Thus, improving the farmers' income from jobs in their hometowns is an advocated way for conservation of GIAHS. Although GIAHSs have many disadvantages in terms of economic benefits at present, they have so many advantages in natural and cultural ecosystem services, for instance, higher indirect economic values in agricultural landscapes, water, and soil conservation, purifying the environment, etc. [3,22,23]. However, these advantages did not generate economic benefits for the people in GIAHS sites. Therefore, many conservation mechanisms that improve the income of farmers using resource advantages in GIAHS sites were put forward by researchers. Tian et al. [24] and Sun et al. [25] thought that Agricultural Heritage System Tourism (AHST) could diversify the channels of income through providing more job opportunities for farmers in GIAHS sites. Zhang et al. [26] considered that raising the prices of agricultural products by developing organic production can also improve the earnings of local farmers. Given that traditional agricultural systems also provide better ecosystem services such as climate regulation, carbon sequestration and oxygen release, water and soil conservation, etc. besides food, Liu et al. [27] proposed that these services should be viewed as public goods, and that their suppliers should also be paid by the consumers according to payment standards. Moreover, they established dynamic standards of Payment for Ecosystem Services (PES) based on an investigation of the willingness of farmers to accept. Actually, productive functions of some traditional agricultural systems still have a considerable potential of enhancing a farmer's earning if they can be developed scientifically; however, little research on these aspects was reported.

The Honghe Hani Rice Terraces System (HHRTS) in Yunnan Province, southeast China is a well-known traditional landscape system that is 1,300 years old, which was designated by FAO as GIAHS in 2010 and listed by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a world cultural heritage in 2013. Rice-fish-duck coculture (RFDC) is an old agricultural pattern in the HHRTS. The pattern still exists in this GIAHS site nowadays, but its area is sharply decreasing due to labor outmigration. Moreover, those retained RFDCs were managed extensively by local farmers solely to meet their own demands, rather than to increase earnings. Therefore, the traditional compound ecosystem was not fully developed and did not play a role in promoting HHRTS conservation.

With tourism development in the HHRTS site, consumption of fishes and duck eggs from paddies rapidly increased in recent years. The price of fishes and duck has also rapidly risen. This trend provides a good development opportunity for RFDC. At the same time, the traditional coculture pattern will become an effective approach for sustainability of HHRTS. Through enhancing the profit per unit area, it can attract some farmers to do full-time agriculture and prevent the rice terraces from disrepair and the traditional rural socio-cultural system from disappearance. There are some successful cases. For instance, an improved rice-fish-duck coculture (IRFDC) that has proven to generate a high profit is being generalized in the HHRTS site. However, it is not clear whether or not and how the

IRFDC promotes GIAHS conservation. Thus, this study aims to contrast the IRFDC with the hybrid rice monoculture (HRM) in the HHRTS site and to assess the IRFDC effects on HHRTS conservation.

2. Materials and Methods

2.1. Study Area

HHRTS is distributed in Honghe County, Yuanyang County, Lüchun County and Jinping County in Honghe Hani and Yi People Autonomous prefecture, located on the south bank of the upstream area of Yuanjiang River, 22°49′~23°19′N and 102°27′~103°13′E. The climate of this area is a subtropical hilly monsoon type with obvious vertical change. The highest monthly mean temperature and the lowest monthly mean temperature are 30.1 °C and 12.0 °C, respectively. The precipitation has a considerable change from the relative arid northern region to the humid southern region in this area, which is between 700 mm and 2300 mm. The landform is comprised of mountains. The altitude varies from 105 m to 3074 m and the average altitude is 2637 m. The soil consists of yellow–red soil and red soil, with high water tightness [28]. All these natural features provide good conditions for digging terraces. Throughout 1,300 years, the Hani people and the Yi people created the Hani terraces with a vast area, cliffy slopes and a landscape structure of forest-paddy-village-river.

The core area of HHRTS includes eight towns in the four counties, which are Baohua Town and Jiayin Town in Honghe County, Xinjie Town, Panzhihua Town and Liujiaozhai Town in Yuanyang County, Sanmeng Town in Lüchun County, and Adebo Town and Maandi Town in Jinping County. In this study, we selected Yuanyang County as our study area because it has the largest area and the most typical landscape of terraces in the four counties. Yuanyang County is a minority county, where the minority population is 89.2% of the total population (the Hani people account for 61% of the total population). Agricultural income per person was just 5652 Yuan RMB in 2015. Terraces are the most important source of livelihood for the local people. Agriculture is still the most important industry though it covers 32.5% of the gross domestic product (GDP) of the county. The farmers are up to 91.5% of the total population. Currently, livelihoods of the local farmers depend on agriculture and part-time non-farm jobs in nearby cities. Rice as a staple food still covers most areas of cropland. In addition, corn, beans, green vegetables, and sugarcanes are also widely planted. For water terraces, HRM has become the main planting pattern due to its needing little labor inputs, though the traditional agricultural systems still widely exist in many places. The coculture such as rice-fish-duck or rice-fish only accounted for a small part.

2.2. Research Methods

Currently, most rice terraces in HHRTS are being used with extremely low efficiency. For example, terraces are only used for HRM during the growth period (from April to September, about five months), but are left unused at other times. For the traditional RFDC, its economic potential is also not developed due to a lack of intensive management. However, according to our survey, in some places, the IRFDC has produced a good profit with the yield increase of fishes and ducks under intensive management. In this study, the profits of HRM and IRFDC will be calculated respectively using the input-output method. A balance equation will be established for identifying the minimum area of driving a family to do full-time farming. Based on these results, impacts of IRFDC on conservation of HHRTS will be assessed.

Net profits of HRM and IRFDC are decided by product prices, yields, input costs. Thus, the net profit per unit area of HRM and IRFDC (NFI_P) can be calculated by the Equation (1).

$$NFI_P = \sum_{i=1}^{n} Y_i \times P_i - \sum_{j=1}^{m} IC_j \quad (1)$$

Here Y_i is the yield of the product i per unit area (i = 1, 2, 3, . . . , n), P_i is the price of the product i, IC_j is the cost of the input j per unit area (j = 1, 2, 3, . . . , m).

The labor outmigration in HHRTS site is mainly caused by the gap between farming income and non-farm income. It means that farming has a higher opportunity cost. Thus, farmers will not do full-time farming in their hometowns unless they can get at least the same income from the full-time farming as from non-farm jobs in cities. Considering the better work environment, the more recreational conditions and the more convenient facilities in cities, most young people prefer to work in cities when earning the same income. Therefore, the preference coefficient needs to be considered when assessing the minimum net farming income of driving a farmer to do full-time farming. Then, the minimum net farming income (MNFI) a year for a laborer ($MNFI_l$) can be calculated by Equation (2).

$$MNFI_l = \mu \times SI \times WT \tag{2}$$

where μ is the preference coefficient; SI is the mean monthly salary income from non-farm jobs; WT is the mean work time for non-farm jobs in a year.

As for a family, the minimum net farming income a year can be calculated based on the $MNFI_l$. In an HHRTS site, families in villages usually do not give up farming their croplands, although a fairly large portion of laborers go out for non-farm jobs. One or more full-time farmers in each family stays at home to manage their croplands (in this study, the laborer number is considered as 1). Therefore, the minimum net farming income for a family a year ($MNFI_f$), which makes them work on full-time agriculture, can be calculated by Equation (3)

$$MNFI_f = \left(ML_f - 1\right) \times MNFI_l \tag{3}$$

Here, ML_f is the number of laborers in a family.

In an HHRTS site, the part-time farmers usually not only do non-farm jobs in the slack farming seasons, but also farming work during the busy farming seasons. Thus, they actually also spend their time in farming every year, but they do not do field management and the work of enhancing terraced ridges. These tasks are done by the full-time farmers per family. According to statistics, there was only a mean of 0.11 ha of rice terraces for a family in 2015. This indicates that the full-time farmers in each family actually have a long period of free time due to little farming work. In this study, it is hypothesized that the current full-time farmers in each family can fully perform the extra field management and enhancement of terraced ridges when adding the area of rice terraces. Besides, due to the seasonality of agriculture, when the part-time farmers become full-time farmers, they can still only do the work on several farms in the time that they worked on non-farm jobs, for example, the breeding ducks, a part of harvest and enhancement of terraced ridges. Thus, the time that part-time farmers spend seeding and harvesting should be subtracted when calculating the minimum area of IRFDC per family (MA_{min}) from which a family can gain a satisfactory income. So, the MA_{min} can be calculated by Equation (4).

$$\mathrm{MA}_{min} = \frac{D_{non} \times \left(ML_f - 1\right)}{D_M - D_R} \times \frac{MNFI_f}{MNFI_P} \tag{4}$$

Here, D_{non} is the mean time that one people in HHRTS worked at non-farm jobs, days per person a year; D_R is the time (except the field management and enhancing terraced ridges due to the field management generally only performed by the full-time farmer in each family) HRM needs in a year, days per person a year; D_M is the time IRFDC needs in a year, days per person a year; $MNFI_P$ is the net profit of the IRFDC per hectare (ha).

2.3. Inputs and Outputs of Monoculture and Coculture

HRM and IRFDC have many differences in inputs and outputs. In inputs, for instance, chemical fertilizers, pesticides and herbicides are usually used for HRM, but not for IRFDC because the chemical inputs harm the fishes and ducks (see Table 1). Moreover, IRFDC needs farmers to spend more time on breeding ducks and fishes. In outputs, only rice and straws are obtained from the HRM system, but extra products can be produced from IRFDC, such as fishes, ducks and duck eggs, and loaches. Due to the very small area of terraces, heavy machinery cannot be used. As a result, cattle are still a main power of ploughing cropland. Therefore, the cost of breeding cattle is part of the farming inputs for HRM and IRFDC. Fortunately, a perfect landscape structure makes Hani rice terraces enjoy enough water all the time, thus farming usually does not entail irrigation costs.

Table 1. Input and output of hybrid rice monoculture (HRM) and improved rice-fish-duck coculture (IRFDC).

Category	Hybrid Rice Monoculture	Improved Rice-Fish-Duck Coculture
Direct inputs	Seeds (hybrid rice)	Seeds (red rice)
	Chemical fertilizers	Young fishes
	Pesticides	Young ducks
	Herbicides	superphosphate
	Amount of labor, including harvesting rice, seeding, enhancement of terraced ridges, ploughing	Amount of labor including harvesting rice and fishes, seeding, enhancement of terraced ridges, ploughing, breeding
	Cost of breeding cattle	Cost of breeding cattle
Outputs	Rice	Rice
	Straws	Straws
	-	Ducks and duck eggs
	-	Fishes
		loaches

2.4. Data Collection

The data on inputs and outputs of HRM and IRFDC were collected through semi-structural interviews. All in-depth interviews were based on the same interview outline, allowing for a systematic comparison of the multiple responses. The surveys were conducted in the core area of HHRTS, which includes Jiayin Town, Baohua Town, Xinjie Town, Panzhihua Town, Niujiaozhao Town, Sanmeng Town, Adebo Town, Maandi Town, from April to May and from July to August, 2015 (Figure 1). The contents of the interviews covered the items in Table 1, except for the cost of breeding cattle (Table 2). The data on the non-farm monthly incomes that a part-time farmer earns, the mean length of non-farm work in a year, and the mean number of laborers in a family were obtained through questionnaire surveys (Table 2). The survey was conducted at the Xinjie Town and Niujiaozhai Town, the core area of WCH or GIAHS, from July to August 2015 (Figure 1). Given the low educational level of most respondents, it was decided to use interviewers to secure comparable results. Prior informed consent and international codes of ethics were considered sufficient throughout the surveys [29]. None of the respondents were required to fill in their private information such as name, identity number, telephone number, etc.

Table 2. The contents of the semi-structural interviews and the questionnaires.

Method	Contents	
Semi-structural interviews	Part 1. Direct material inputs and outputs: Inputs HRM/IRFDC need; the amount of each input per unit area in HRM/IRFDC; the price of each input. Outputs HRM/IRFDC produce; the amount of each output per unit area in HRM/IRFDC; the price of each product. Part 2. Labor inputs and time length The working procedures in HRM/IRFDC. Work amounts of each working procedure consumed in HRM/IRFDC.	
Questionnaires	Q1. Are you a full-time farmer or a part-time farmer?	R1. (1) full-time; (2) part-time
	Q2. If yes, how long do you work on a non-farm job in a year?	R2. (month)
	Q3. How much earnings a month do you get from the non-farm jobs? (mean income per month)	R3. (fill in a number)
	Q4. How many laborers in your family? (people between 18 and 60 years old are regarded as a laborer)	R4. (fill in a number)
	Q5. How many laborers in your family go out for non-farm jobs?	R5. (fill in a number)

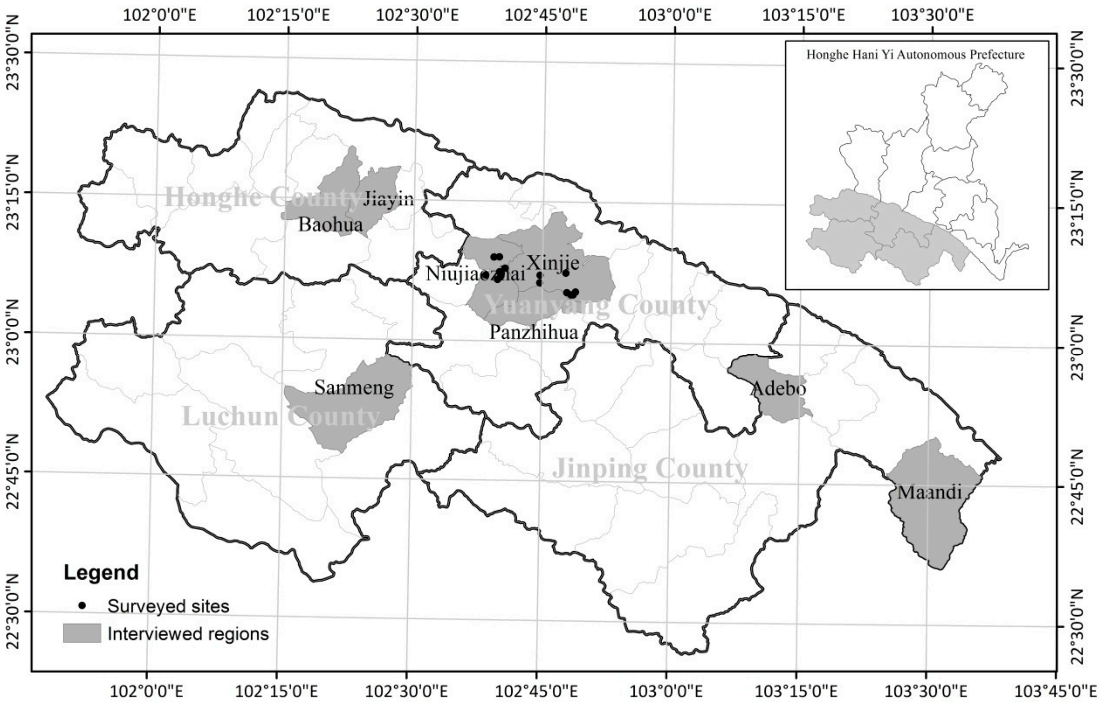

Figure 1. The distribution of the interviewed and surveyed sites in the Honghe Hani Rice Terraces System (HHRTS).

Considering that most paddies for HRM (or IRFDC) had approximate yields and many farmers cannot indicate accurate yields, the semi-structural interviews were done for those farmers who are at a well-educated level and the agri-technician in agricultural management departments. Thirty-two samples were obtained from the semi-structural interviews, but only 28 samples are effective for this study, of which the samples of HRM and IRFDC are 24 and 4, respectively. The questionnaire surveys were conducted at 15 villages in Xinjie Town and Niujiaozhai Town, and the amount of respondents per village was from 6 to 15. Eventually, 142 questionnaires were randomly handed out to different respondents, and each of them was in a different family. One hundred thirty-seven questionnaires were returned. Eighty questionnaires are effective for assessing the income of non-farming jobs and the labor amount of a family.

3. Results

3.1. Inputs of HRM and IRFDC

3.1.1. The Costs of Direct Material Inputs of HRM and IRFDC

According to the semi-structural interviews, there were several differences in direct material inputs between HRM and IRFDC (Table 3). Direct material inputs of HRM mainly encompassed seeds, chemical fertilizers (superphosphate, ammonium bicarbonate, and pesticides and herbicides) and animal power (costs of breeding cattle). IRFDC did not require very many chemical fertilizers except for superphosphate, but incurred higher costs for rice seeds and young animals such as young fishes, young ducks and young loaches. For HRM, the expense of buying ammonium bicarbonate constituted the largest part of the direct material inputs, up to 1787 Yuan RMB/ha. Power costs and seed costs were the second and the third, respectively. As for IRFDC, buying young ducks, young fishes and young loaches was the main input cost, which was much higher than the seed cost, the power cost and the superphosphate cost. In sum, the direct material input cost of IRFDC was about three times as much as that of HRM.

Table 3. The costs of direct material inputs of HRM and IRFDC.

Category	HRM	Cost per Unit Areas (Yuan/ha)		IRFDC	Cost per Unit Areas (Yuan/ha)	
		Mean	S.D.		Mean	S.D.
Direct material inputs	Seeds	981	150	Seeds	1015	131
	Superphosphate	535	161	Young fishes and loaches	5250	0
	Ammonium bicarbonate	1787	313	Young ducks	6000	750
	Pesticides and herbicides	464	199	superphosphate	580	121
	Power cost (breeding cattle)	1095 *		Power cost (breeding cattle)	1095 *	
Sum		4862			13,940	

The asterisk * means the datum is from the literature published by [26]; S.D = standard deviation.

3.1.2. Input of Labor per Unit Area

Though the labor cost is not directly shown as money in HHRTS, it is indeed the largest part of the whole cost with the continual increase of salary level and opportunity cost. From Table 4, the IRFDC requires more labor time than the HRM. The former was 2.6 times as much as the latter. Most labor time was spent on breeding ducks in IRFDC, and then on field management and harvest. This is because ducks need to be looked after every day before they are sold, and breeding fishes also require frequently examining the rice fields in case the fishes escape or die due to accidental causes. Moreover, catching fishes also consumes extra time. For HRM, field management consumes the most labor time, but other activities simply require less time; this is an important cause that most farmers engaged in non-farm jobs in cities during slack farming seasons.

Table 4. Labor input in HRM and IRFDC.

Labour Expenditure	Input Amount per Hectare (Days·Person/ha·Year)			
	HRM		IRFDC	
	Mean	S.D.	Mean	S.D.
Seeding	14.4	1.7	14.5	1
Harvesting	42.5	2.6	58.8	2.5
Enhancing terraced ridges	22.3	3.1	26.3	2.5
Field Management	83.8	4.2	117.5	5
Breeding ducks	-	-	207.5	9.6
Sum	163		424.6	

3.2. Outputs and Net Profit of HRM and IRFDC

As a compound production system, though IRFDC required far more input costs than HRM, it can produce more products and higher economic earnings than RM. As shown in Table 5, only rice and straws were obtained from HRM, but six products including red rice, ducks, duck eggs, fishes, loaches, and straws could be obtained from IRFDC. In profit structure, only hybrid rice generated earnings in HRM, whereas five products in IRFDC returned profits (due to no market demands, straws cannot be sold as a commodity for earnings at present). For IRFDC, the highest income was from red rice, and the second and third were from fishes and loaches, respectively. Ducks can also produce a considerable profit. It is obvious in Table 4 that four of the five sellable products in IRFDC generated higher benefits than the only product in HRM, of which the red rice income in IRFDC was twice the hybrid rice income in HRM. On the whole, IRFDC's benefit was about seven times that of HRM.

According to Equation (1), we can calculate that the net profit of HRM is 17,482.4 Yuan RMB a year, and IRFDC is 136,154.3 Yuan RMB a year.

Table 5. Outputs of HRM and IRFDC.

Category	HRM	Yield (kg/ha)		Price (Yuan/kg)		Production Value (Yuan/ha)	IRFDC	Yield (kg/ha)		Price (Yuan/kg)		Production Value (Yuan/ha)
		Mean	S.D.	Mean	S.D.			Mean	S.D.	Mean	S.D.	
Outputs	Rice	8594	1536	2.60	0.16	22,344.4	Red rice	4163	224	13.25	2.22	55,159.75
	Straws	-	-	-	-	-	Ducks	431	38	59.5	8.23	25,644.5
							Duck eggs	2250	324	1.75	0.21	3937.5
							Fishes	694	224	48.75	2.5	33,832.5
							Loaches	394	113	80	14.14	31,520
							Straws	-	-	-	-	-
Sum						22,344.4						150,094.3

3.3. The Situation of Non-Farming Incomes and Family Laborers in HHRTS

In order to grasp the current situation of non-farming incomes and family laborers in HHRTS, questionnaires were conducted. In the respondents, males represented 73.7% of the total, far higher than females (26.3%) (see Table 6); the groups aged 26 to 45 contributed 68.7%. It is advisable that samples be distributed based on sex and age because men or farmers in this age group are the main laborers in HHRTS. Most of the respondents only had a low education; 41.3% and 21.3% of them were at a higher primary school level and lower primary school level, respectively. The situation means that the proportion of farmers accepting compulsory education was quite low.

According to the questionnaires, the farmers who went out for non-farming jobs can earn a mean monthly salary of 2573 Yuan RMB, but the monthly salaries had quite a varying range among different respondents, as the standard deviation indicates. Similarly, the mean work time of the farmers was 8.7 months, but the actual work time was quite different for each respondent. There was an average of 3.2 laborers in the family among the respondents, and the number did not vary in different families.

Table 6. The basic characteristics of respondents and survey contents.

Sex	Percent (%)	Age	Percent (%)	Education	Percent (%)	Survey Contents	Statistic Results
male	73.7	below 25	11.3	lower primary school	21.3	monthly salary (Yuan)	2573 ± 1195
female	26.3	26–35	28.7	higher primary school	41.3	work time (month)	8.7 ± 2.6
		36–45	40	junior middle school	30	amount of laborer	3.2 ± 1
		46–55	18.7	senior middle school	5		
		above 56	1.3	college graduate	2.5		

3.4. The Minimum Farming Income of Making a Farmer Do Full-Time Agriculture in HHRTS

According to the conclusion of the study by Zhang et al. [26] in HHRTS, the preference coefficient that farmers tend to work in cities is 1.26, i.e., if farming earnings are 1.26 times as much as non-farming earnings, farmers would be willing to engage in full-time agriculture. Using the preference coefficient and the data on monthly salary and work time in Table 5, and relying on Equation (2), a farmer in HHRTS would work on full-time agriculture in his/her hometown if he/she can earn 28,205.2 Yuan RMB a year. Then, it can be calculated by Equation (3) that 62,051.4 Yuan RMB of farming income a year is the lowest threshold at which a family would be willing to do full-time agriculture.

3.5. The Minimum Area that Drives All the Members in a Family to Do Full-Time Farming in HHRTS

According to Equation (4), the minimum area that drives all the members of a family to do full-time farming in HHRTS can be calculated. We know that the value of D_{non} is 8.7 months a year per person (equal to 261 days a year per person) and the value of ML_f is 3.2 laborers in Table 5. From Table 3, we calculated that the value of D_M is 424.6 days a year per person and the value of D_R is 56.9 days a year per person. In addition, $MNFI_f$ is 62,051.4 Yuan RMB a year calculated as Equation (3) and $MNFI_P$ is 136,154.3 Yuan RMB a year as Equation (1). Eventually, we obtained that MA_{min} is mean 0.71 ha per family, i.e., any member of the family may not work on non-farm jobs in cities again if a family has an extra 0.71 ha for IRFDC. It means that letting a family operate at least an additional 0.71 ha terraces for IRFDC will promote conservation of HHRTS.

4. Discussion

HHRTS as a GIAHS is a sustainable traditional agricultural system. The reason it can be sustained for 1300 years is because not only is its production method very scientific, but also it was the most important source of livelihood for the local people. The food production function of HHRTS drove the local people to carefully maintain it in the past. However, industrialization gives rise to the continual decrease of the comparative benefits of HHRTS due to a continued rise in the income level and the cost of living of the whole society. The local farmers have to leave their hometowns for non-farm jobs to earn a living. The phenomenon leads to population outmigration from rural regions. Laborer losses are bound to break the formed maintaining mechanism of HHRTS, such as HRM replacing the traditional RFDC and becoming the main model of planting. In sum, the low income from agriculture is the essential cause that threatens HHRTS.

Actually, Hani rice terraces have tremendous economic potential. Currently, the low benefits of Hani rice terraces are because they are not used enough for production. In Figure 2, Rice terraces in HRM are not used in the period from rice harvest completion in the first year to rice seeding in next year. The production function of those croplands is wasted for about half a year, thus its economic value is also lost. Besides, the fact that the traditional RFDC pattern is abandoned or extensively operated by many farmers results in losses of deserved economic values. The IRFDC fully exploited the wasted time and space HRM loses and obtained benefits very well. The modified production model has proven that HHRTS is still a sustainable agricultural system in its direct economic value if it is used scientifically. It also pointed out an orientation for GIAHS dynamic conservation, i.e., scientifically modifying traditional production methods and advisable-scale cropland operation.

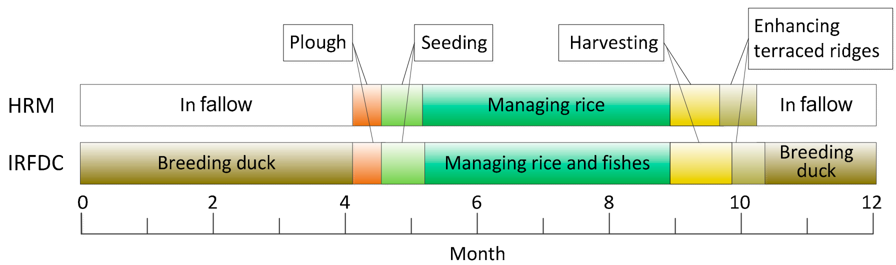

Figure 2. The comparison between HRM and IRFDC in agricultural activities.

From this study, we found an interesting paradox. Population outmigration seems to be an important cause leading to the unsustainability of rice terraces in HHRTS, but if we compute the labor demand amount for the entire rice terraces in the HHRTS site based on the results of this study, we shall arrive at a different conclusion. Taking the Xinjie Town, Yuanyang County as an example, there were 15,221 peasant households, 2087.2 ha of rice terraces in this town, and mean 0.11 ha rice terraces for per household [30]. According to 0.82 ha (including the current 0.11 ha per family and the extra 0.71 ha) terraces a family operates, the entire town only needs about 2545 peasant households to farm rice terraces. It is obvious that the HHRTS site does not actually lack laborers even if so many populations migrate out at present. Thus, the essential problem is how to let a part of families become full-time farmers through modification of production patterns and improvement of the land transfer system. It will be a significant research topic on GIAHS conservation in the future.

This study only considered the direct economic potential of IRFDC from the perspective of its food production function. In fact, the IRFDC has a great many ecological benefits. Firstly, some studies have shown that RFDC is able to increase cropland biodiversity [11] and control pests and disease, and then reduces the amount of chemicals used [8–10,31]. Ecological and cultural values of HHRTS are also capable of bringing some income to local farmers, for instance, via Payment for Ecosystem Services (PES) and eco-tourism and cultural tourism [32,33]. Secondly, products from rice terraces such as red rice, fishes, loaches, duck eggs, etc. can also generate more additional values by developing deep processing. In addition, the IRFDC shows the important role of GIAHS in promoting eco-environmental sustainability of modern agriculture, and also showcases the significance of GIAHS conservation.

Currently, RFDC is not widely employed by farmers in HHRTS although it has so many advantages. The fact that fertilizers, herbicides, and pesticides are not being used in RFDC results in a low yield of rice, whereas more labor inputs for looking after the fishes and ducks increase RFDC's labor opportunity cost. The products such as fishes, ducks and red rice from RFDC have low demands before tourism rise. Farmers in HHRTS, due to weak economic consciousness and a lack of agri-technologies, do not discover the economic potential of RFDC. In recent years, the IRFDC as a typical example of GIAHS dynamic conservation has shown the potential economic advantages of RFDC. Therefore, promoting the conversion from HRM to IRFDC is significant for HHRTS conservation and requires a comprehensive strategy such as the development of tourism, related technical training for farmers, scientific experiments, moderate scale operation by land transfer, etc.

This study was conducted to identify the minimum area of rice terraces driving a family to do full-time farming based on theories of opportunity cost and personal preference influence, if, according to labor time of a family, a larger area that a family can farm will be gained. Besides, the economic benefits of IRFDC are calculated based on current prices and yields. With the development of the GIAHS brand, a higher rate of return may be gained. Thus a more effective survey method and a long-term survey plan need to be explored in future. Family as a social cell is the basis of traditional agriculture, and plays an extreme role in maintaining and inheriting traditional culture. However, its inheriting function for traditional knowledge is decreasing according to Yuan et al. [34]. Regarding family as a unit, this study aims to probe a new family livelihood model to restructure current rural society and to absolutely change the situation whereby rural community mainly consists of old people and children most of the time.

5. Conclusions

Our research methodology on identifying the minimum farming area driving a family to do full-time farming provides a new economic perspective for GIAHS conservation. Our research shows that most rice terraces of HHRTS are used for HRM. Moreover, chemical inputs contribute the largest part of the total cost of HRM. Although the rice yields increase in HRM, the agricultural income per unit area does not rise due to the low price of hybrid rice. In the HRM, most rice terraces are left unused and waste for half a year. It saves many time costs, but also reduces the diversity of products and agricultural income per unit area, and allows farmers to be able to work on non-farm jobs in cities. In the IRFDC, farmers need to spend almost an entire year's time in farming and breeding and to invest more costs, but they get more products and seven times the income of HRM. The IRFDC model improves agricultural economic benefits and also protects terraces from abandonment and destruction by using the advantages of GIAHS. In this study, we also found that the laborer shortage due to population outmigration in the HHRTS site is false at present. For a family, earning the same income from farming as from non-farm jobs requires more than 0.71 ha of rice terraces for IRFDC. It means that agricultural heritage sites do not need so many people if peasant households can do large-scale farming. Therefore, the land transfer system in agricultural heritage sites needs to be reformed for an advisable scale of IRFDC farming.

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