Farmer Seed Systems and Sustainable Livelihoods of Highland Farmers: A Case Study from Hani Terrace in Southwest China

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Abstract

While globalization has led to the deterioration of mountain ecosystems, loss of biodiversity, cultural decay, and difficulties for smallholder livelihoods, it has also presented new opportunities and challenges for the development of mountain terraced communities. Informal seed systems-- the collection, propagation, and exchange of seeds are a valuable strategic resource for farmers' survival, economic development, and resilience to unpredictable changes in the future. Informal seed systems that conserve broad genetic diversity, and the related practices involved in managing the informal seed system, play an important role in the sustainable development of terraced fields and poverty reduction. In this paper, we analyzed the characteristics of production behavior in informal, farmer seed systems from four livelihood types across 26 villages in the Hani Terrace, Yunnan Province, in China. We measured the efficiency of the farmers' chosen seed management system in achieving sustainable livelihoods using data envelopment methods, and filtered the data to identify a total of 6 key factors that affect livelihood efficiency of informal, farmers seed systems using methods of un-ordered multi-classification logistic regression and tobit regression. Results from our analyses indicate that while there are no significant differences among different livelihood types in labor distribution, seed storage, seed treatment, and range of seed exchange, . However, there are significant differences in proportion of migrant workers, per capita farmland income, planting scale, pesticide application methods, and crop changing rotation methods among different livelihood types; which suggests that opportunity costs and economic scale of the farming operation affect the efficiency of the seed system to contribute to sustainable livelihoods. Furthermore, the order of seed system livelihood efficiency of different livelihood types is: pure farmers > part-time farmers > less than part-time farmers > mainly farmers; the order of effective ratio of seed system livelihood efficiency of different livelihood types of farmers is: pure farmers > mainly farmers >less than part-time farmers > part-time farmers. Importantly, richness (genetic diversity) of rice seed and income of rice seed have a significant positive impact on the livelihood efficiency of farmers, while non-rice seed income, planting area, and farming methods have a significant negative impact on farmers' livelihood efficiency. Moreover, household size and seed treatment methods have no significant impact on farmers' livelihood efficiency. Planting temperature, village net income per capita, the scale of village workforce available for farming labor (village labor), and farming methods have significant positive effects on rice planting efficiency, while the proportion of village workforce, and the seed treatments used have significant negative effects on the scale of rice planting efficiency. Our analyses conclude that increasing diversity of rice planting and rice seed income can significantly improve the livelihood efficiency of farmers, but simply increasing planting area, non-agricultural income and proportion of village labor does not directly improve farmers' livelihood efficiency. Our research highlights the challenges of small-scale production, which limits the application of new technology and restricts development of the rice farming industry, and the importance of improving the quality of the informal labor distribution and allocating strategic and appropriate technical inputs to refine farming methods in highland mountain terrace communities. endogenous development ability of terrace community as a breakthrough, enhance ecological, economic and cultural value of seed system, and create sustainable agricultural production and lifestyle with local characteristics, so as to truly improve the livelihood efficiency of farmers.

Keywords: *Farmer seed systems; sustainable livelihoods; traditional ecological knowledge (TEK); efficiency evaluation; Hani Terrace*

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I. Introduction

The Hani Terrace in the Yunnan Province of China is an important agricultural landscape and World Heritage site, an area rich in genetic diversity and national culture, with some of the most abundant landscapes, ecosystems, and biological species in the world [1]. The region supports strong cultural values of integrating agriculture and ecology, as observed in the management of terraced agricultural fields along the steep mountain landscape, and the conservation and dissemination of plant varieties with strong adaptability to the local environment. The adaptive value of highland terraced agricultural systems plays an important role in poverty reduction, sustainable development, and the preservation of traditional ecological knowledge (TEK) and management of resilient agro-ecosystems [2, 3]. However, generational shifts in social and economic interests towards globalized industrialized agriculture has led to the promotion of intensive, simplified mono-cropping that has significantly shifted the cultural landscape and led to significant changes in land use. The adaptive value of highland terraced agricultural systems have been largely ignored, while farmers continue to contend with poverty and struggle to survive despite the rich natural and human resources surrounding them. While global industrialized agricultural systems have greatly increased yields of a handful of major food crops through advances in science and technology, it has not improved access and availability of the genetic diversity of culturally important foods, nor has it achieved food security for the very farmers cultivating food crops [4,5],. Worse still, the global industrialized agricultural system has had overwhelmingly negative consequences for the natural environment through the simplification and degradation of local agroecosystems [6-8], exacerbated the of biodiversity loss and environmental degradation [9,10] .The very source of all food, seeds and all the genetic information have once again become irreplaceable, precious resources amongst poor, rural farmers in remote areas, and may well be the key to solve these problems. Mainstreaming Agricultural Biodiversity can address food and nutrition security and sustainable livelihood development [11,12] .

Informal seed systems refers to local varieties of crops, as well as farmers' farming activities such as seed selection, production, exchange, preservation, dissemination, small-scale seed production and exchange, and relevant knowledge, wisdom, management customs, farming culture, and spiritual beliefs [13-15] . The unique natural geography and human environment of terraces make informal seed systems an important foundation to maintain reproduction and survival of people in terraced fields. Sustainable livelihoods are defined as those that can cope with and recover under pressure and shocks, maintain and strengthen its capacity and assets in present and uncertain future without damaging natural resources [16]. The production of informal seed systems is compatible with the capital saving and environment-friendly sustainable livelihood model, which supports the existence of an ecological civilization, and is representative of low-carbon agriculture. Its' strong productivity and sustainability can help farmers resist natural and social risks such as extreme climate and economic fluctuations, and provide a strong buffer to cope with adversity and unpredictable global changes (such as to the climate, environment, economy, etc.) [17-19]. Informal seed systems has become a strategic and valuable resource to promote benign or sustainable development, and to ensure farmers' livelihood and long-term stability and food security in terraced agricultural systems [2,3] .

In this paper, we examine informal farmer seed systems practiced in rice cultivation as described in 26 local village survey, and combined the sample survey data of farmers with the goal to understand and improve the efficiency of informal seed systems on farmers' livelihoods and community development. We analyze the production behavior of different farmer livelihood types of those who practice informal seed system management, analyze production efficiency of informal seed systems, extract influencing factors of informal seed systems efficiency, to understand the key factors and main impetus that can improve efficiency, and propose economic and ecological livelihood measures and long-term strategies for sustainable livelihood development of highland farmers located in the Hani Terrace of the Yunnan Province in China.

II. Data sources and Research methods

The research area is located in Honghe Hani and Yi Autonomous Prefecture in the south of Yunnan Province, between 102°27′-103°13′ E and 22°49′-23°19′N, and at an altitude ranging from 1,070m to 1,990m, which is the core distribution area of the Hani Terrace. Data were sourced from background survey of 26 villages, and investigation on villages and farmers of 141 households in 14 villages between in the year (s) 2016-2018. The survey includes 14 village committees in 5 townships of Yuanyang, and includes Yi, Hani, Zhuang, Yao, and multi-ethnic villages. The survey methods include literature review, questionnaire survey, semi-structured interview, participatory observation and measurement, the survey is as below.

Farmers' rice planting status and income was determined by analyzing the diversity of rice species at the village and household levels, rice varieties, planting methods, income derived from harvests and so on; measuring rice species diversity in villages and household by richness, evenness, and difference; measuring farmers' rice income through per capita farming income, total income, and farmers' agricultural self-sufficiency condition. Based on the farmers' income structure, we analyzed the behavior of the informal seed systems of different categories of farmer livelihoods using ANOVA, chi square test, correlation analysis and group comparison statistical analyses to generate our results.

The status of farmers' informal seed systems was conducted by analyzing local rice varieties planted at present and 5 years ago; primary source of rice seeds; selection and retention of seeds; the interval and reasons for changing seeds; the scope of changing seeds; criteria for seed selection; methods of seed selection; seed preservation and seed exchange, and other information relevant to informal seed conservation and dissemination. We measured the efficiency and comprehensive efficiency of seed system of different categories of farmer livelihoods by using DEA method, evaluated the technical efficiency, pure technical efficiency, and scale efficiency of input-oriented and output-oriented using the BCC model to generate our results.

To statistically analyze the internal and external factors that affect the efficiency of rice seed systems, we used a regression model to identify the key factors that affect the efficiency, to propose clear metrics and strategies to improve the efficiency of the farmers' informal seed systems.

III. Results

3.1 Seed system production behavior of different categories of farmer livelihoods

3.1.1 Situation of different categories of farmer livelihoods

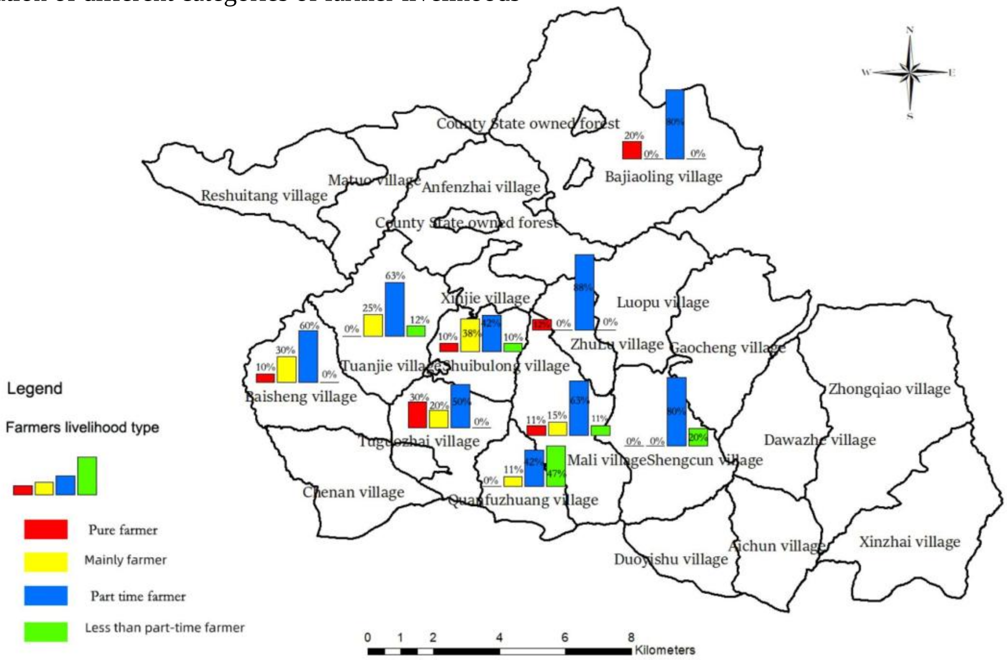

Fig 1: Distribution of farmers with different livelihood types

As shown in Fig 1, farmers were classified into four different livelihood types according to the proportion of agricultural income to total annual income. These were defined as: (1) Pure farmer- farmers fully engaged in agricultural production, whose proportion of agricultural income accounts for more than 80% of total income in the current year, and have no income from off-farm/supplementary sources; (2) Mainly farmer - farmers mainly engaged in agricultural production, whose proportion of agricultural income to total income is between 80% and 50%, whose family income is mainly agricultural income, and whom earn off-farm supplement income; (3) Part time farmer- farmers mainly engaged in non-agricultural income generation, but whom also earn a small proportion of agricultural income to total income of between 50% and 20%, and whose family income structure is mainly non-agricultural income; and (4) Less than part-time farmer - farmers that are mainly engaged in non-agricultural income generation, and whose proportion of agricultural income to total income is less than 20%.

(1) Labor distribution for different categories of farmer livelihoods

For our purposes, labor distribution is defined as the allocation of available labour force in family, which is the proportion of labor distribution to family size. According to our analysis, the majority of labor distribution to family size across all four categories of farmer livelihoods (Table 1) is between 40% - 70%, and less than 40% (39.7% and 34.6%, respectively). Pure farmers had the highest proportion of labor distribution of more than 70% (23.1%), while the average labor distribution across all four livelihood categories was generally low (14.0% and 11.8%), which indicates that the existing labor force in Hani Terrace may be insufficient to meet the labor demands. To verify if there was a statistical difference in scale of labor force between the four different categories of farmer livelihoods, we used the chi square test and found with a value of 10.21 (and a significance level of 0.334), there is no statistically significant difference in proportion of labor distribution in family size, between different livelihood types. Therefore, there is no correlation between different livelihood types and their labor scale distribution. However, our chi square test results (value = 48.85, significance level = 0.00) indicates that there are significant differences in proportion of migrant workers working for different categories of farmer livelihoods.

Part-time farmers accounted for the largest proportion of migrant workforce (44.9%), concentrated at 40% - 70%, which indicates that the proportion of migrant labor and household labor is well balanced and evenly distributed, and is consistent with the economic realities of part-time farmers requiring additional help during non labor intensive cultivation and harvest periods to maintain part-time agricultural income. While, less than part-time farmer’s proportion of migrant labor and household labor is also balanced .Comparatively, pure farmers and mainly farmer have a small proportion of migrant working. These farmers' willingness are will to maintain their livelihood by rice farming.

Table 1 Labor distribution for different categories of farmer livelihoods

Farmer livelihood category	Labor distribution (to proportion of family size)				Proportion of migrant workforce (to proportion of household labor distribution)				
	Below 40%	40%-69.9%	70%-99.9%	100%	0%	1%-39.9%	40%-69.9%	70%-99.9%	100%
Pure farmer	38.5%	15.4%	23.1%	23.1%	84.6%	0.0%	15.4%	0.0%	0.0%
Mainly farmer	48.0%	28.0%	12.0%	12.0%	52.0%	12.0%	16.0%	4.0%	16.0%
Part-time farmer	28.6%	48.1%	11.7%	11.7%	16.7%	10.3%	44.9%	7.7%	20.5%
Less than part-time farmer	38.1%	38.1%	19.0%	4.8%	4.8%	23.8%	38.1%	0.0%	33.3%

(2) Income structure for different categories of farmer livelihoods

There is no significant difference in the total income per capita between different categories of farmer livelihoods (Table 2), as verified by chi square test (chi square value = 4.252, asymptotic significance = 0.894). However, results

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of chi square test show that there are significant differences in per capita farmland income of different categories of farmers (chi square value = 78.224, asymptotic significance = 0.000), with the higher proportions of per capita farmland income earned by Pure farmers (23.1% earning 3000-4000 yuan, and 7.7% over 4000 yuan) and Mainly farmer (4.0% earning 3000-4000 yuan, and 16.0% over 4000 yuan).

Table 2 Income structure of different categories of farmer livelihoods

Farmer livelihood category	Total income per capita (unit: yuan)				Per capita farmland income (unit: yuan)				
	below 2000	2000 - 3000	3000 - 4000	Over 4000	Below 1000	1000-2000	2000-3000	3000-4000	Over 4000
Pure farmer	23.1%	15.4%	38.5%	23.1%	7.7%	30.8%	30.8%	23.1%	7.7%
Mainly farmer	32.0%	24.0%	24.0%	20.0%	16.0%	52.0%	12.0%	4.0%	16.0%
Part-time farmer	23.1%	26.9%	28.2%	21.8%	48.1%	48.1%	1.3%	1.3%	1.3%
Less than part-time farmer	33.3%	33.3%	14.3%	19.0%	100.%	0.0%	0.0%	0.0%	0.0%

3.1.2 Production behavior of different categories of farmer livelihoods

Differences in rice seed production for different categories of farmers are mainly reflected in labour input, capital investment, technology investment, and planting scale. These differences reflect opportunity costs for different categories of farmers, and result in differences in seed system functions between different categories of farmers. The rice production behavior of farmers includes: (1) Decision-making behavior of planting scale, (2) Planting management behavior, and (3) Seed management behavior, as described below.

(1) Decision-making behavior at planting scale

In the sample area, 85% of farmers surveyed cultivate using local rice seeds. The scale of rice cultivation in this area is generally between 2 and 4 mu (Table 3). The cultivation areas planted with local rice seeds accounted for 71.4% of the total agricultural area, with an average rice cultivation area of only 2.69 mu. This indicates that the proportion of seeds sourced through informal seed systems is large, but the scale of planting is generally small.

Results from the chi square test (chi square value = 17.681, asymptotic significance = 0.039) show that there are significant differences in planting scale between the different categories of farmers (Table 3). Results from our correlation analysis show that there is a significant negative correlation between different categories of farmer livelihoods and planting scale (correlation coefficient = -0. 225, significance = 0.008). In other words, the higher the farmers' income is, the larger the planting scale; the lower the farmer's income is, the smaller the planting scale.

Table 3 Planting scale of local rice varieties between different categories of farmer livelihoods

	Planting scale of local rice varieties				
Farmer livelihood category	Below 1 mu	1~2 mu	2~4 mu	Over 4 mu	Average value
Pure farmer	8.3%	16.7%	66.7%	8.3%	2.81
Mainly farmer	12.0%	28.0%	40.0%	20.0%	3.58
Part-time farmer	10.3%	41.0%	43.6%	5.1%	2.49
Less than part-time farmer	28.6%	28.6%	42.9%	0.0%	1.89

For example, the order of average planting scale of rice seed system of different categories of farmer livelihoods is as follows: Mainly farmer > Pure farmers > Part-time farmers > Less than part-time farmer. Income of Mainly farmer mainly comes from agriculture, and their primary economic interest is to increase agricultural output. Because these farmers are engaged in both non-agricultural income generation activities and agricultural production, they have earned enough financial capital to rent other people's land to expand production in order to expand the scale of rice planting. Likewise, pure farmers' households earn the majority of their income from agricultural production, therefore, they too have economic incentive to invest financial capital into subletting other people's land in order to increase total yield from farmland cultivated, though have less financial liquidity than mainly farmers to invest in subletting additional land.

Comparatively, less than part-time farmer earn the majority of their income from non-agricultural related source, therefore do not have as high of an economic incentive to expand farmland yield. That said planting scale is deliberate, and relative to their labor capacity and economic interests. For example, they could choose to sublet their land or plant a small area of land (in the case of frequent crop rotation) but that is done more as a exercise of risk mitigation, allowing them to return to the countryside for agricultural production in the event that their non-agricultural related income source does not provide for their needs anymore. Culturally important to understand is that while less than part-time farmer earn the majority of their income from non-agricultural related sources, they are not necessarily separated from the land. The phenomenon of "leaving the countryside without leaving the land" is quite common in this region. Under this cultural influence, the scale of rice planting by less than part-time farmers is not very large, but it is maintained to a certain degree and will therefore remain unchanged in land use from agricultural to non-agricultural purposes.

(2) Planting management behavior

Because of the labor distribution and other factors, villagers who stay in the village no longer cultivate rice as intensively as before. Part-time farmers are busy working off the farm to earn supplemental income. Few farmers are willing to work harder than necessary. Pure farmers rely on external inputs, such as pesticides and chemical fertilizers, to reduce rice seedling diseases and insect pests. The proportion of farmers applying chemical fertilizer and compound fertilizer is 85.3%, and the proportion of pesticide application is as high as 86.1% (Table 4). The loss of available labor for farming activities, and interventions of modern agriculture may contribute to this high proportion. With loss of labor and involvement of modern agriculture, this proportion may increase.

Table 4 Planting management between different categories of farmer livelihoods

Farmer livelihood category	Farming methods				Fertilization methods			Insecticide application methods			
	Three plows three/two rakes	Two plows two rakes	Two plows one rake	One plow one rake	Farm manure	Farm manure and fertilizer	Fertilizer	Untreated	Once a year	Two/three times a year	Four/five times a year
Pure farmer	46.2%	38.5%	0.0%	15.4%	16.7%	41.7%	41.7%	0.0%	38.5%	38.5%	23.1%
Mainly farmer	40.0%	44.0%	12.0%	4.0%	8.0%	28.0%	64.0%	8.0%	40.0%	32.0%	20.0%
Part-time farmer	41.0%	30.8%	19.2%	9.0%	15.4%	23.1%	61.5%	16.7%	28.2%	39.7%	15.4%
Less than part-time farmer	50.0%	35.0%	10.0%	5.0%	19.0%	28.6%	52.4%	19.0%	57.1%	19.0%	4.8%
Total	42.6%	34.6%	14.7%	8.1%	14.7%	26.5%	58.8%	13.9%	35.8%	35.0%	15.3%

Results from the chi square test shows that there are no significant differences in farming methods (chi square value = 6.515, asymptotic significance=0.687), fertilization methods (chi square value =3.493, asymptotic significance=0.745), and insecticide application methods (chi square value=11.881, asymptotic significance=0.220) between different categories of farmer livelihoods. Results from the correlation analysis (Table 5) indicate there is a significant negative correlation between the different categories of farmers and the application methods (correlation coefficient=-0.200, significance=0.019) In other words, the more agricultural income farmers has, the more pesticides farmers use.

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Table 5 Correlation analysis of planting management methods between different categories of farmer livelihoods

	Farming methods	Fertilization methods	Number of fertilizer applications	Insecticide applicatio n methods
Pearson correlation	-.006	-.008	-.009	-.200*
Sig. (2-tailed)	.943	.926	.916	.019

(3) Management behavior within differing informal, farmer seed systems

Informal, farmer seed systems includes seed source, seed exchange, seed selection basis, seed circulation, and storage, and all related traditional wisdom and knowledge associated therein [20,21]. Different categories of farmer livelihoods maintain different expectations and metrics in the management of their seeds, and in the introduction of new seed varieties. Farmers control the occurrence of rice seed disease using natural and ecological measures that are based on traditional ecological knowledge (TEK), such as the selection of disease-resistant and insect-resistant varieties; the panicle selection of rice seeds; and the practice of inter-planting and mixed-planting in the field, all of which can improve the ecological stability of traditional rice production to achieve food security.

There are three methods for storing rice seeds: (1) placed bare and exposed under the canopy, (2) stored in a granary (grain warehouse), or (3) bagged. At the time of this study, rice seeds are stored in cloth bags by 58.1% of farmers surveyed in each of the four different livelihood categories, and represents the preferred or most common method of seed storage (Table 6). Across all four farmer livelihood categories, seed storage in granary was second most common method of seed storage (equal to cloth bag storage for both pure farmers and less than part-time farmers, at 38.5% and 42.9% respectively). Consistent across all four farmer livelihood categories is the appropriate treatment of seeds (soaking/washing); further information needs to be collected to understand the factors that influence farmers across all livelihood categories to refrain from seed soaking/washing. farmers dry rice seeds on the roof of the second floor of mushroom house, and then store them under the canopy. Other farmers store rice seeds in a special barn or bag located in the mushroom house to avoid invasion of insects and rats.

Farmers who mainly engage in farming (pure farmers and mainly farmers) mainly introduce new rice varieties into their fields by homonymous substitution, and the range of this exchange is mainly within the same village. Less than part-time farmer often exchange seeds from other places. Because of unique microclimate found in terraced fields, there are not many rice varieties that are well adapted to this context. Therefore, farmers often lack varieties that can be appropriately introduced and exchanged, the period between introducing new varieties is longer, and the exchange range remains mostly local. Some farmers change seeds in their own fields, but do not change their land. These rotate crops not only solves problems that they unable to change varieties caused by less varieties, but also reduces field diseases, and ensure stability of yield, It fully embodies local farmers' farming wisdom.

Table 6 Seed systems management across four different categories of farmer livelihoods

Farmer livelihood category	Seed storage			Seed treatment		Seed exchange methods				Seed exchange range		
	Bare exposure	Cloth bag	Granary	No seed soaking / washing	Seed soaking / washing	Namesake	Namesake / Synonym	Synonym	Non-local	Outer Village	Non-local /Outer Village	Native village
Pure farmer	23.1%	38.5 %	38.5%	30.8%	69.2%	61.5%	7.7%	30.8%	16.7 %	0.0%	33.3%	50.0%
Mainly farmer	12.0%	72.0 %	16.0%	12.0%	88.0%	64.0%	8.0%	28.0%	20.0 %	0.0%	36.0%	44.0%

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Part-time farmer	18.2%	61.0 %	20.8%	23.4%	76.6%	55.1%	6.4%	38.5%	16.7 %	2.6%	20.5%	60.3%
Less than part-time farmer	14.3%	42.9 %	42.9%	9.5%	90.5%	19.0%	4.8%	76.2%	33.3 %	4.8%	0.0%	61.9%

Across the four different farmer livelihood categories, there are no statistically significant differences in seed storage (chi square = 8.437, asymptotic significance = 0.208), seed treatment (chi square = 3.951, asymptotic significance = 0.267), or range of seed exchange (chi square = 12.787, asymptotic significance = 0.172). However, there are statistically significant differences in seed exchange methods between the different livelihood types (chi square = 13.381, asymptotic significance = 0.037). Further comparisons between groups (Table 7) show that there are statistically significant differences in seed exchange methods between Less than part-time farmer and the other three farmer livelihood categories. Moreover, our analysis shows key differences between seed exchange ranges, representing the reach of exchanging genetic diversity of unique seed varieties.

The loss of labor distribution leads to farmer no longer intensive farming, especially for part-time farmers. Farmers' income structure and level of rice variety diversity are result of this series of consciousness and behavior. Different ways of farmers changing varieties fully reflect farmer wisdom. Farmers interrupted directional selection and parasitic fitness of rice blast by changing varieties continuously, so as to achieve purpose of stabilizing physiological races in field, which is also the important point of producing dominant races in Hani Terrace.

Table 7 Comparative analysis of seed exchange methods between different categories of farmer livelihoods

Dependent variable	Data fetch	Group (A)	Group (B)	Mean Difference (A-B)	Std. Error	Sig.
Seed exchange methods	LSD	Less than part-time farmer	Pure farmer	0.2071*	0.863	0.018
			Mainly farmer	0.2545*	0.706	0.000
			Part-time farmer	0.1853*	0.586	0.002

* The mean difference is significant at the 0.05 level.

3.2 Evaluation of livelihood efficiency of farmer seed systems

3.2.1 Selection of evaluation index and construction of model
(1) Evaluation index

To evaluate the efficiency of farmers' seed systems to support sustainable livelihoods at the household level, the authors selected indicators based on labor, land, or capital inputs that demonstrated a measurable impact on farmer outputs such as rice production and diversity of rice seed varieties(Table 8). The input indicators include: household size, labour scale, planting area of traditional varieties, farming methods, and seed treatment. Household size and labour scale were used as a proxy for agricultural labor, and farmer farming methods and seed treatment methods were used as a proxy for agricultural capital input. The land input were measured by analysing the proportion of rice planting area of traditional varieties to total planting areas at the household level. The output index included two primary indicators: farm-based income and non-farm income, and their relationship to rice seed diversity at the household level. Since the rice seed of farmers is organic agricultural product, its price should be given higher value than that of conventional product.

To evaluate the efficiency of villages' seed systems to support sustainable livelihoods at the village level, the authors selected input indicators based on village labor, land, and capital, all of which have measurable impacts on agricultural output and seed variety diversity. Of those input indicators, the agricultural labor distribution is was measured using the village's primary industry (agricultural) labor distribution; the capital input was measured by using the values for effective irrigation area, this is because the irrigation systems are managed at the village-level, and the other agricultural inputs are individually varied by household. the land input was measured by calculating the cultivated land per capita. The output index was determined by selecting indicators that measure farm-based income (such as per capita net income of villages and village agricultural income) and rice species diversity of the villages (using rice seed richness at the village level as a proxy).

Table 8 Evaluation index of informal, farmer seed systems efficiency in achieving sustainable livelihoods

		Indicators	
Evaluation index of farmers' rice livelihood efficiency	Input index (X)	Capital input	Farmer farming method (X4) Seed treatment method (X5)
		Labor input	Household size (X1) Labor scale (X2)
		Land input	Proportion of rice planting area to Total planting area (X3)
	Output index (Y)	Per capita farm-based income	Per capita non-farm income (Y2, Unit:Yuan) Per capita farm-based income (Y3, Unit:Yuan)
		Rice species diversity of farmers	Rice seed richness at household level (Y1)
Evaluation index of villages' rice livelihood efficiency in	Input index (X)	Capital input	Effective irrigation area (X3, Unit: Mu)
		Labor input	Labor distribution in primary industry (X1)
		Land input	Cultivated land per capita (X2, Unit: Mu)
	Output index (Y)	Farm-based income	Per capita net income of villages (Y1,Unit:Yuan) Village agricultural income (Y2,Unit:ten thousand yuan)
		Rice species diversity of villages	Rice seed richness at village level (Y3)

(2) Evaluation model

DEA is to evaluate the relative effectiveness of decision-making units in the multi input and multi output mode [22], which are divided into two forms: input oriented and output oriented. Input oriented model is to measure the proportion of input factor reduction without reducing output; output oriented model is to measure the proportion of output increase under given factor input. The methods of DEA analysis include CCR model and BCC model, CCR model is a fixed return to scale model, but in reality, not every decision-making unit (DMU) is a fixed return to scale model. BCC model is a variable return to scale model [23,24].

BCC model is to measure the relative efficiency of decision making unit (DMU) by constructing a nonparametric envelope front line. If the DMU is on the production frontier, the DMU has the optimal efficiency, and the comprehensive efficiency value is 1; while the DMU that does not fall on the production frontier is called invalid rate, and its efficiency value is between 0 and 1.

The authors chose to evaluate these indicators using the BCC model whose scale is variable. In this model, there are n decision making units (DMUs), and the corresponding input and output vectors are as follows:

$$x_j = (x_{1j}, x_{2j}, \ldots x_{mj})^T > 0,\ j = 1, 2, \ldots, n$$
$$y_j = (y_{1j}, y_{2j}, \ldots y_{mj})^T > 0,\ j = 1, 2, \ldots, n$$

The model is as follows:

$$\begin{cases} \max (\mu^T y0 + \mu_0) = V_p \\ \text{s. t. } \omega^T x_j - \mu^T y_j - \mu_0 \geq 0,\ j = 1, 2, \ldots, n \\ \omega^T x_0 = 1 \end{cases} \quad (1)$$

$$\omega \geq 0,\ \mu \geq 0$$
$$\begin{cases} \min\theta = V_D \\ s.t.\ \sum_{j=1}^{n} x_j\lambda_j + s^- = \theta x_0 \\ \sum_{j=1}^{n} y_j\lambda_j - s^+ = y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ s^- \geq 0,\ s^+ \geq 0,\ \lambda_j \geq 0,\ j = 1, 2, \ldots, n \end{cases} \quad (2)$$

In this model, if the optimal solution ω0, μ0, μ_0^0 of (1) satisfy Vp= μ_0^Ty0+ μ_0^0= 1, then, DMU_{j0} is regarded as "weak DEA efficient". If it further satisfies ω > 0, μ > 0, then DMU_{j0} is regarded as "DEA efficient". If optimal value of (2) satisfies θ= 1, then, DMU_{j0} is regarded as "weak DEA efficient". Likewise, if the optimal value of (2) satisfies θ= 1, and each optimal solution s1, s+, θ0 satisfies s0+= 0, s0-= 0, then DMU_{j0} is regarded as "DEA efficient".

3.2.2 Evaluation of livelihood efficiency at the farmers -level and analysis influencing factors of informal, farmer seed systems
(1) Efficiency of informal, farmer seed system between different categories of farmer livelihoods

As indicated in Table 9 and Figure 2, the order of average subsistence efficiency of seed systems of different categories of farmer livelihoods is: Pure farmer > Part-time farmer> Less than part-time farmer > Mainly farmer. The order of effective ratio of livelihood efficiency of different categories of farmer livelihoods is: pure farmer > mainly farmer > less than part-time farmer > part-time farmers. The order of proportion of farmers' input that needs to be improved is: less than part-time farmer > part-time farmer> pure farmer> mainly farmer.

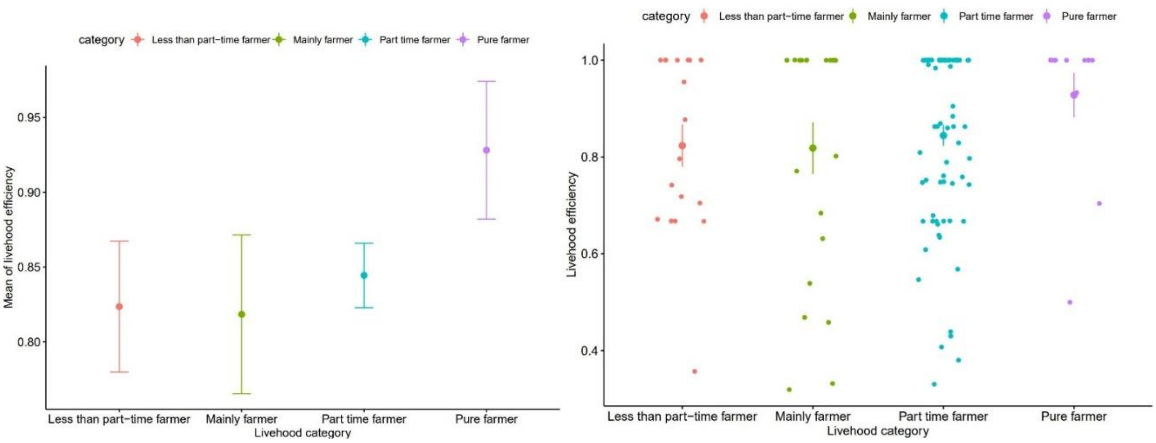

Fig 2: livelihood efficiency of different farmer livelihood category

We found that the overall (0.928) livelihood efficiency values of Pure farmers were significantly higher than those of the other three categories of farmer livelihoods (0.818, 0.844, and 0.824). There is no redundancy in labor distribution and seed treatment methods (Table 9) .This suggests that the pure farmers' rice cultivation methods are not directly proportional to current output. In other words, the farmer may pay for an increase in labor to expand their operation, but they will not necessarily receive an equal or greater increase in income from their harvests after initial labor investment. Moreover, there exists little surplus labor in terraced fields, and there is no evidence of redundancy of technical efficiency redundancy in small-scale household rice production.

Our analysis revealed the average efficiency of mainly farmer is the lowest among four categories of farmer livelihoods (0.818), and proportion of rice seed richness (1.364), and cultivated area (0.614) are also the lowest. Non-efficient farmers were those whose scale of operation is increasing, and there are basically no redundancy in labor distribution, farming methods and seed treatment methods, there is a small amount of redundancy in proportion of arable land and household labor input.

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Part-time farmer and less than part-time farmer categories with the lowest values in each of the categories (non-efficient farmers) were observed to be those whose scale of operation is increasing and, while there is redundancy in farming methods and household labor input in this increase of scale.

Table 9 Livelihood efficiency and results of different livelihood types of informal, farmer seed systems

Different livelihood farmer	Effective ratio of livelihood efficiency	Investment ratio to be improved	Family size redundancy	Labor redundancy	Area ratio redundancy	Farming methods redundancy	processing mode redundancy	Livelihood efficiency	pure technical efficiency	Scale efficiency
Pure farmer	75%	41.6%	0.035	0.003	0.014	0.097	0.005	0.928	0.975	0.952
Mainly farmer	68%	36.4%	0.011	0.005	0.051	0.004	0.000	0.818	0.925	0.869
Part-time farmer	47.3%	47.2%	0.045	0.041	0.026	0.090	0.053	0.844	0.889	0.942
Less than part-time farmer	50%	50%	0.010	0.021	0.006	0.117	0.040	0.824	0.898	0.912
Total			0.101	0.07	0.097	0.308	0.098			

Further analysis of the livelihood efficiency of informal, farmer's seed systems revealed that with respects to the scale of planting, there are basically no redundancy of farmer's farmland input, and that the redundant value of capital input is larger than that of labor input (0.406, 0.171, respectively). This suggests that the adjustment potential is greater, therefore, the question of how to retain and rationally allocate labor distribution is the key to improve livelihood efficiency. Rice cultivation methods are not directly proportional to current output. Technical efficiency is not effective, which means that maximum output are not obtained under production input factors, and agricultural production mode needs to be reasonably allocated. Data of returns to scale show that agricultural production of rice is mostly small farmers, and production scale is small and scattered, which indicates that it is necessary to develop the characteristic agriculture of rice varieties in the local unique region.

(2) Analysis on influencing factors of livelihood efficiency of farmers seed system

Comprehensive efficiency of farmers' livelihood are divided into three grades: Type I: greater than 0.95, Type II: 0.60-0.95, Type III: less than 0.60. The input-output and distribution of different livelihood efficiency types are shown in Table 10 and illustrated in figure 3.

Table 10 Input-output of different livelihood efficiency types of farmers

Categories	Average household level richness	Non rice income per household	Rice seed income per household	Household size per household	Labor distribution per household	Planting area Per household	Mean value of farming methods	Mean value of seed treatment
Type I	1.39	0.6015	0.386	0.3984	0.3228	0.517	0.633	0.6119
Type II	1.69	0.6133	0.260	0.4207	0.4000	0.896	0.786	0.7833
Type III	1.14	0.8286	0.207	0.4350	0.4375	0.964	0.829	0.8036
Total	1.47	0.6310	0.320	0.4104	0.3631	0.704	0.709	0.6944

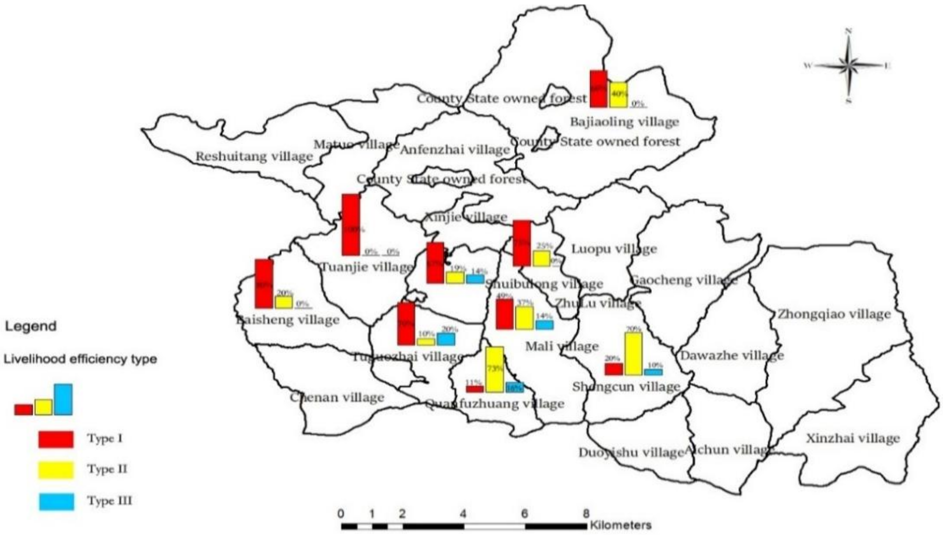

Figure 3. Geographic distribution of different livelihood efficiency types of farmers.

Farmers' livelihood efficiency is varies due to differing input-output decisions made by farmers in different villages. We used a disordered, multiple classification logistic regression model to analyze which input-output indicators has a significant impact on farmers' livelihood efficiency, and analyzed whether it has a positive or negative impact. To do this, we first defined a certain level of dependent variable as the reference level, and compared other levels to establish level number -1 generalized logit. As there are three types of livelihood efficiency type of farmers, there are three levels of dependent variables, and their value level is divided into: 1, 2, and 3. Two generalized logit models were used to fit P independent variables to meet P1+P2+P3=1 [25] :

$$\text{Logit}\ (\pi_1/\pi_3)= \alpha_1 +\beta_{11}\chi_1 +\ldots+\beta_{1p}\chi_p \quad (3)$$

$$\text{Logit}\ (\pi_2/\pi_3)= \alpha_2 +\beta_{21}\chi_1 +\ldots+\beta_{2p}\chi_p \quad (4)$$

Table 11 Likelihood ratio test results

Effect	Model fitting standard: -2 Log Likelihood of Reduced Model	Likelihood ratio test: Chi-Square	df	Sig.
Intercept	157.327	43.275	2	0.000
Household level richness	158.436	44.384	2	0.000
Non-rice seed income	136.934	22.882	2	0.000
Rice seed income	120.399	6.347	2	0.042
Family size	114.591	0.539	2	0.764
Labor distribution scale	120.401	6.349	2	0.042
Planting area	165.971	51.919	2	0.000
Farming methods	131.458	17.406	2	0.000
Seed treatment methods	118.423	4.370	2	0.112

From Table 11, we can see that household-level richness, non-rice seed income, rice seed income, labor distribution scale, planting area, and farming methods all have statistically significant impacts on farmers' livelihood efficiency. However, family size and seed treatment methods had no significant impact on the livelihood efficiency of farmers.

Table 12 Parameter estimates of model

	Type I of farmers' livelihood efficiency			Type II of farmers' livelihood efficiency		
Variable	B	Sig.	Exp (B)	B	Sig.	Exp (B)
Intercept	35.073	0.018	--	28.899	0.051	--
Household-level richness	12.794	0.018	360,074.611	11.652	0.030	114,919.127
Non-rice seed income	-15.719	0.045	1.490E-7	-14.790	0.058	3.774E-7
Rice seed income	9.872	0.084	19,374.180	8.230	0.146	3,751.965
Family size	-4.913	0.494	0.007	-5.051	0.468	0.006
Labor distribution scale	-12.887	0.221	2.531E-6	-8.691	0.404	0.000
Planting area	-19.741	0.010	2.671E-9	-15.910	0.036	1.231E-7
Farming methods	-16.106	0.048	1.012E-7	-13.356	0.101	1.584E-6
Seed treatment methods	-5.949	0.301	0.003	-3.997	0.486	0.018

Table 12 lists estimated values of regression parameters for Type I and Type II of farmers' livelihood efficiency, and Type III of livelihood efficiency are taken as the reference category. From our results, we can see that household-level richness, non-rice seed income, rice seed income, planting area, and farming methods are all significant factors when farmers choose between Type I and Type III. The model we used to fit the data for is as follows: Logit (Livelihood efficiency Type I / livelihood efficiency Type III) = 35.073 + 12.794 x Household-level richness - 15.719 x Non-rice seed income + 9.872 x Rice seed income - 19.741 x Planting area - 16.106 x Farming method.

Furthermore, the probability of Type I is much higher than that of Type III for every increase of rice seed richness and rice seed income (360,074.611 times, 19,374.18 times). However, non-rice seed income, planting area, and farming methods all had negative effects on livelihood efficiency.

Our results also showed that household-level richness, non-rice seed income, and planting area are all significant factors when farmers choose between Type II and Type III. Rice seed income and Farming methods were not significant factors when farmers choose between Type II and Type III. The model we used to fit the data for is as follows: Logit (Livelihood efficiency Type II/ Livelihood efficiency Type III) = 28.899 + 11.652 x Household-level richness - 14.790 x Non-rice income - 15.910 x Planting area.

Furthermore, the probability of Type II is much higher than that of Type III (114,919.127 times) for every increase of rice seed richness. However, non-rice seed income and planting area both had negative effects on livelihood efficiency.

From the regression analysis results, we can see that increasing of diversity of rice planting and rice seed income can significantly improve the livelihood efficiency of farmers, but simply increasing of planting area and non-agricultural income cannot directly improve the livelihood efficiency of farmers. So in order to improve farmers' livelihood, we should take enhancing the endogenous development ability of terrace community as a breakthrough, and create sustainable agricultural production and lifestyle with local characteristics, seek sustainable path and measures that can improve livelihood of mountain farmers and reduce vulnerability of mountain communities by innovative practice and management system of production, ecology, life and culture of mountain crop varieties under the influence of globalization.

3.2.3 Evaluation of livelihood efficiency at the village-level and analysis of influencing factors of informal, farmer seed systems

In order to evaluate the livelihood efficiency of informal seed systems more objectively, this paper evaluates the livelihood efficiency of informal seed systems from the perspective of villages. To do this, we analyzed the input-

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output redundancy and insufficiency of agricultural production of 26 villages in Hani Terrace by measuring the Comprehensive efficiency (CE), Technical efficiency (PTE), Scale efficiency (SE), and Returns-to-scale.

(1) Analysis of village livelihood efficiency

Based on the input-oriented model of analysis, our results show that 13 of the 26 villages are DEA effective(Table 13). On scale of 0.288 to 1, there are 17 villages whose comprehensive efficiency is above 0.9, which indicates that most villages can make use of the existing production factors (land, labour, and capital) to cultivate a diversity of rice at sufficient proportion to rice-based income. Furthermore, our results show that rice seed diversity, per capita income, and planting income of non-effective decision-making units, all have insufficient output. Income redundancy of rice cultivation is the lowest among all output indicators, and only six villages show redundancy in income. Of those indicators, the average increase of output is measurably highest in per capita income.

Table 13 Efficiency of rice farming across 26 villages in Hani Terrace

Village committee	DMU	Comprehensive efficiency (CE)	Technical efficiency (PTE)	Scale efficiency (SE)	Returns-to-scale
Mali	Shangmadian	0.758	0.833	0.910	decreasing
Mali	Luomadian	1.000	1.000	1.000	remain
Zhu Lu	ShangzhuLulaozhai	1.000	1.000	1.000	remain
Zhu Lu	ShangzhuLuxinzhai	0.643	0.861	0.747	increasing
Shengcun	Huangcaoling (sheng)	0.692	0.911	0.759	increasing
Duoyishu	Pugaoxinzhai	0.288	0.671	0.430	increasing
Chenan	Liuhui	0.976	0.977	0.999	decreasing
Chenan	Heimazhai	1.000	1.000	1.000	remain
Chenan	Chenanxiaozhai	0.971	0.973	0.999	decreasing
Chenan	Chenandazhai	0.979	0.979	1.000	remain
Tuguozhai	Qingkou	1.000	1.000	1.000	remain
Tuguozhai	Xiaoshuijing	1.000	1.000	1.000	remain
Tuguozhai	Huangcaoling (tu)	1.000	1.000	1.000	remain
Tuguozhai	Dayutang	1.000	1.000	1.000	remain
Baishengzhai	Yangniuzhai	0.843	0.847	0.996	decreasing
Quanfuzhuang	Quanfuzhuangdazhai	1.000	1.000	1.000	remain
Quanfuzhuang	Quanfuzhuangxiaozhai	1.000	1.000	1.000	remain
Mali	Malizhai	0.772	1.000	0.772	decreasing
Shuibulong	Shuibulong	1.000	1.000	1.000	remain
Shuibulong	Sanjiazhai	1.000	1.000	1.000	remain
Tuanjie	Laofengdazhai	0.975	0.977	0.998	decreasing
Xincheng	Shangxincheng	1.000	1.000	1.000	remain
Zhetai	Zhetai	0.718	0.718	1.000	remain
Xincheng	Xiaxincheng	0.937	1.000	0.937	decreasing
Gota	Huangmaoling	0.614	0.683	0.901	increasing
Taiyangzhai	Zhongzhai	0.881	0.925	0.952	decreasing

(2) Adjustment direction of village livelihood efficiency

Our results also show the average comprehensive technical efficiency of the sample farmers is 0.886. We analyze the input-output redundancy and insufficiency of agricultural production of each of these 26 villages. Our results show that across all 26 villages, the adjustment potential of capital input is the greatest, which indicates that the input of villages' labor into rice cultivation is not directly proportional to the current output of yields. In the input index, the average farmland input redundancy is low, with the adjustment proportion the lowest. The average redundancy of labor input reported is negligible. Based on our input-oriented analysis of efficiency of technology and planting scale, the villages' livelihood efficiency can be roughly divided into the following categories:

1) Optimal pure technology and scale efficiency (CE = 1, PTE = 1, SE = 1). In this category, the production input of village has realized optimal combination, optimal scale of rice production, and rice seed diversity. Our results indicate that there are 12 villages that can maintain the efficiency of livelihood by reasonable allocation of resources:Luomadian,Shangzhululaozhai,Heimazhai,Qingkou,Xiaoshuijing,Huangcaoling,Dayutang,Sanjiazhai,Quanfuzhuangdazhaie,Quanfuzhuangxiaozhai,Shuibulong and Shangxincheng.

2) Easy to improve (0.9 < PTE < 1, 0.9 < se < 1, diminishing benefit). In this category, the villages have better production conditions and production technology, but per capita cultivated land is small and labor loss is of serious concern. Our results indicate that there are 6 villages that are in stage of diminishing benefit to production scale: Laofengdazhai, Zhongzhai, Chenanxiaozhai, Chenandazhai,Liuhui and Xiaxincheng.These results suggest the need to rely on advances in rice tillage technology to seek sustainable ecological agricultural path and further improve production efficiency. Under these conditions, the scale efficiency can be optimized through the adjustment of policy or strategic investment, and there is more room for further improvement.

3) Technical inefficiency (PTE < 0.85, 0.9 < se < 1, diminishing benefit / increasing benefit). In this category, output is invalid, which means that the villages' output value is small, but input of labor and land is not low. Our results indicate that there are 4 villages that are in the stage of diminishing or increasing benefit to production scale: Shangma, Yangniuzhai, Zhetai and Huangmaoling.Inefficiency of production output in these villages is due to weak technical efficiency. With the continuous loss of labor, agricultural production links such as pest control and field management are no longer sufficient, and low technical efficiency are largely caused by the relatively extensive production methods.

4) Small scale (PTE < 0.95, Se < 0.8, increasing benefit). In this category, rice production in the villages is increasing benefit to scale. Our results indicate that there are 4 villages that operate at small scale efficiency levels:Huangcaoling,Shangzhu Luxin, Pugaoxinzhai and Malizhai. Due to the narrow terrain of villages, intensive terraced rice farming have been practiced for a long time. However, due to low proportion of labor distribution, low per capita cultivated land, insufficient cultivated land, and the small scale of investment, the application of technology is limited. Therefore, the technical efficiency measured by income is affected by the small-scale level, which leads to low overall efficiency, in this context, it is recommended to expand planting scale.

The distribution of different livelihood efficiency types is shown in Fig 4.Due to local special geographical environment, small farmers' farming has always been main farming method of terraced fields for a long time. Especially in the middle and high mountain areas with altitude above 1500, the reasons that village livelihood efficiency is not effective are mainly due to the low scale efficiency. Production scale of village farmers is small and scattered, and it is difficult to unify management. Scale limits application of technology, and restricts rice cultivation in terrace field to some extent. So in order to promote the rational expansion of the scale of rice farming, we should pay attention to proportion of planting area, labor input and technical resources, and give full play to resource advantages, adjust measures to local conditions, improve the ecological, economic and cultural value of seed system, and effectively improve the livelihood efficiency of farmers.

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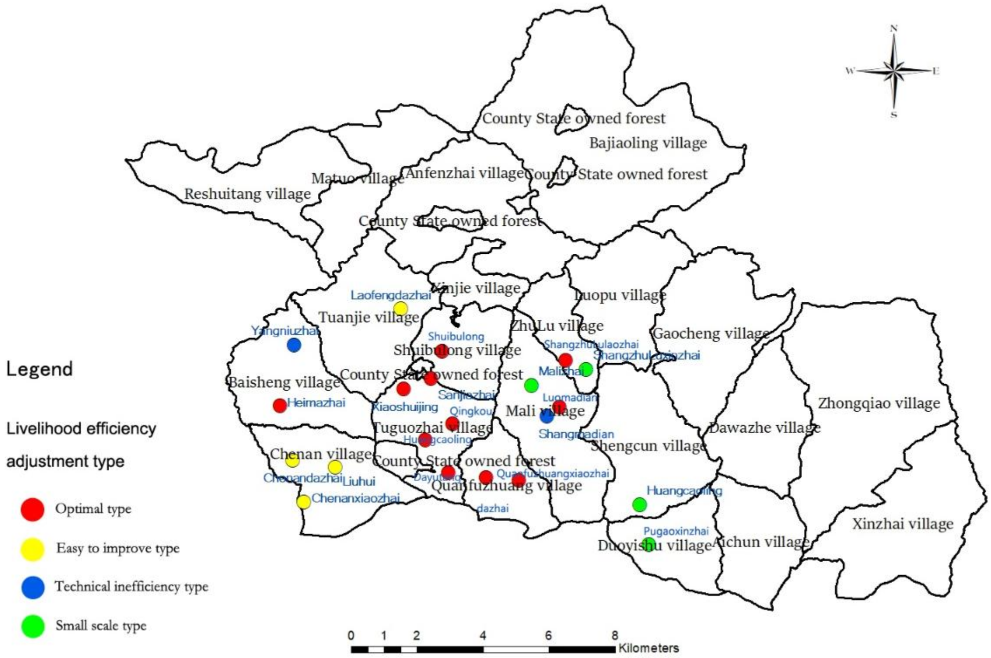

Fig 4. Distribution of different livelihood efficiency types in villages

(3) Analysis of influencing factors of informal, farmer seed systems on village livelihood efficiency

From the above analysis, we can understand that the planting scale efficiency of the informal, farmer seed systems in the studied area is not high. The factors that affect the planting scale efficiency of the seed systems include both external regional factors and internal factors. External regional factors mainly refer to the natural, social, and cultural factors that influence traditional rice planting under the specific environment, such as local altitude, temperature, transportation, economic development, and other factors. Internal factors refer to the influencing factors related to farmers' agricultural decision-making and behavior, such as farmers' planting structure, planting methods, and labor distribution. In order to further understand the reasons for inefficiency of village livelihoods, we use a regression model to analyze the efficiency of informal, farmer seed systems, and the internal and external influencing factors, to elucidate significant factors that affect the planting efficiency of traditional rice.

Tobit regression model is a regression model proposed by American scholar, James Tobin, to study the problem of constrained dependent variables [26] . We take the efficiency values between 0 and 1 calculated by DEA as explanatory variables, and use the influencing factors as the explanatory variable to find the maximum target value. The regression model equation (5):

$$Y = \beta_0 + \sum_{i=1}^{j} \beta_i x_i + \varepsilon \qquad (5)$$

Y is defined as the efficiency coefficient (calculated based on DEA), β0 as the constant, β_i as the regression coefficient of the influencing factor, xi as the influencing factor, i=1, 2 …… j, and ε as the random error value.

We choose nine variables as explanatory variables: planting altitude (X1), planting temperature (X2), per capita net income (X3), per capita cultivated land (X4), labor ratio (X5), market basis (X6), labor scale (X7), farming methods (X8), seed treatments (X9), and ethnic culture (X10). We choose the overall scale efficiency of villages as the explanatory variable y. SPSS was used for correlation and regression analysis. The results are as follows:

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Table 14 Influencing factors of informal, farmer seed systems on village livelihood efficiency

Variables	Coefficient	Std.Error	Sig.
X1	0.067	0.047	0.288
X2	0.294*	0.075	0.059
X3	0.419**	0.046	0.012
X4	0.032	0.053	0.608
X5	-1.206***	0.083	0.005
X6	-0.052	0.107	0.679
X7	0.719**	0.099	0.019
X8	0.623**	0.082	0.017
X9	-0.390**	0.043	0.012
X10	-0.425	0.096	0.142

***、**、* represent the significance level of 1%, 5% and 10%, respectively.

From table 14, we observe that six variables (planting temperature, per capita net income, labor distribution proportion, labor scale, farming methods, and seed treatment) have significant influence on the scale efficiency of rice planting (Sig<0.05), and four of variables (planting altitude, per capita cultivated land, market basis, ethnic culture) have an insignificant influence on the scale efficiency of rice planting (Sig>0.05). Village per capita income (X3) has significant positive impact on the input-output efficiency (0.419**). The village per capita income and rice planting efficiency demonstrates synchronous growth. Therefore, an increase of farmers' overall income will stimulate the further development of the local rice industry. The proportion of rural labor distribution (X5) and the scale of rural labor distribution (X7) also have a significant impact on the efficiency of input-output, but the proportion of rural labour distribution is inversely related to efficiency of planting scale (0.719**). This shows that an increase in village labour does not necessarily improve the efficiency, which have been seen from the previous empirical study of efficiency. Furthermore, the labor input of rice seed is not directly proportional to the current output, but an increase in the scale of household labor is conducive to output efficiency (significantly positive correlation Sig=0.019), which indicates that it is necessary to reasonably allocate the labor distribution according to cultivated land and family members of farmers. Only when quality of labor distribution is improved can we improve the income and efficiency. The input-output efficiency are significantly affected by technical inputs such as farming methods (X8: 0.623**), and seed treatments (X9: -0.390**). This shows a significant positive correlation between increasing intensive farming methods and to achieve a greater overall efficiency ratio of inputs to outputs efficiency (Sig=0.017).

Additionally, we found a negative correlation between seed treatments (X9) and input-output efficiency, which is inconsistent with the expected impact. Upon further investigation, we found that the main reason for this problem is that the farmers' seed preservation, seed treatment technology, and the methods used before sowing seed are not particularly mature, and some farmers deliberately do not utilize seed treatment. There is a significant positive correlation between market-basis (X6) and the input-output efficiency (correlation coefficient = 0.617 **, significance = 0.025). The convenience of transportation also improves comprehensive efficiency.

IV. Conclusion and Discussion

4.1 Conclusion

Results from our analyses indicate that while there are no significant differences among different livelihood types in labour distribution, seed storage, seed treatment, and range of seed exchange, there are significant differences in rice production behaviours, such as proportion of migrant workers, per capita farmland income, planting scale, pesticide application methods, and crop changing rotation methods among different livelihood types; which suggests that opportunity costs and economic scale of the farming operation affect the efficiency of the seed system to contribute to sustainable livelihoods. The order of seed system livelihood efficiency of different livelihood types is: pure farmers > part-time farmers > less than part-time farmers > mainly farmers; the order of effective ratio of seed system livelihood efficiency of different livelihood types of farmers is: pure farmers > mainly farmers >less than part-time farmers > part-time farmers.

household-level richness of farmers' rice seeds, non-rice seed income, rice seed income, planting area, and farming methods are all have a significant impact on farmers' livelihood efficiency. Improving diversity of rice planting and rice seed income can significantly improve the livelihood efficiency of farmers, but simply increasing planting area and non-agricultural income cannot directly improve the livelihood efficiency of farmers. We should take enhancing the endogenous development ability of terrace community as a breakthrough, and create sustainable agricultural production and lifestyle with local characteristics, seek sustainable path and measures that can improve livelihood of mountain farmers and reduce vulnerability of mountain communities by innovative practice and management system of production, ecology, life and culture of mountain crop varieties under the influence of globalization.As well as temperature of the village, per capita net income, labor distribution proportion, labor scale, farming methods, and seed treatment also have significant influence on efficiency of rice planting. Increase in village labour does not necessarily improve the efficiency, but an increase in the scale of household labour is conducive to output efficiency, it is necessary to reasonably allocate the labour distribution according to cultivated land and family members of farmers. Only when quality of labour distribution is improved can we improve the income and efficiency.

4.2 Discussion

The preliminary analysis showed that rice yield in Hani Terrace is small and scattered, which limits the application of technology and restricts development of rice farming industry. It is necessary to allocate labor distribution and technical input reasonably according to cultivated land and family members of farmers, improve quality of labor distribution and refine farming methods. We should take endogenous development ability of terrace community as a breakthrough, design adaptive management measures and strategies for community development of informal seed systems efficiency radiation effect.

- Improve industrial model of informal seed systems, endow seed system with ecological, cultural and cognitive values, and create sustainable agricultural production with local characteristics.

We should change industrial model of traditional rice varieties, let local farmers become the biggest beneficiaries of terraced fields, bring them into production process, industrialize labor distribution, increase price of terraced rice, and enhance sense of public recognition by improving value consciousness of healthy and nutritious of rice varieties, fully integrate the tangible resources of terraced rice and intangible resources of long-standing farming culture that created by various ethnic groups in terraced fields, endow them with social, cultural and ecological labels, enhance farmers' desire of planting and promote sustainable agricultural production of terraced fields.

- We should encourage and attach importance to the seed system of farmers in the community, help the community to establish the germplasm bank and improve the seed management mechanism

We should pay attention to improving farmers' cultivation quality, including understanding of the production process and agricultural technology, and strengthening preservation of local rice seeds, encouraging and protecting the exchange, exchange and retention of seeds in the community, establishing a scientific local seed resource bank, improving the community-based seed management mechanism, and encouraging the inheritance of traditional farming wisdom

- Design and build adaptive framework to enhance the informal seed systems and promote community development

Through combination of internal driving factors and external driving factors, we should cultivate adaptability of community to maximize radiation driven effect of seed system. We should build an effective and reasonable labour mobility mechanism, and guide selection of terraced field growers in combination with local tourism poverty alleviation policies and measures. With the opportunity of applying for the world heritage, we should further explore and reflect social and cultural values of small-scale peasant economy through ecological and cultural compensation and product development, enhance local farmers' sense of regional pride and community participation, reasonably allocate farmers' labor distribution, and try to keep farmers in the local area, so as to provide basic support for the improvement of planting scale efficiency

- Design and construct community participation security system to enhance the informal seed systems efficiency

We should comb social interaction and social network of the economic effect of the farmer seed system, design and construct farmer seed network and community mutual aid agriculture (CSA), share significance, value, concept and practice of farmers and communities in other areas on the seed system identification, design and construct the "participatory security system (PGS)" with farmers, communities, governments, enterprises, research institutions, NGO and consumers. We should use knowledge and innovation systems, local global networks, working with scientists to develop resilient food systems and innovation for community development.

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