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REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

Research on the Identification Pattern and Optimal Pattern of Livelihood Patterns of Rural Households in Mountainous Areas rural households in mountainous areas--Based on the Analysis of Tracking Survey Data in Yunnan

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Abstract

The livelihood patterns of rural households in mountainous areas pattern is an important part of the researches on rural households' behavior, which is of great significance to rural households' income growth and sustainable development. This research used the micro-survey data in 2010, 2015 and 2020 and conducted an empirical analysis on the livelihood patterns of rural households in mountainous areas in Yunnan, a province in southwestern China. This research depicted the transformation process of rural households' livelihood patterns in Yunnan and summarized the livelihood patterns of rural households in mountainous areas. Besides, this research identified the optimal patterns of the livelihood patterns of rural households in mountainous areas. This research has provided micro-evidence and the basis for authorities to develop policies for the sustainable development of mountainous areas and income growth of rural households in mountainous areas. At the same time, the experience of livelihood transformation of rural households in mountainous areas in Yunnan is of important extension and application value for the development of tropical and subtropical regions which can benefit from the cooperation between China and ASEAN and countries in the Greater Mekong Sub-region.

Key words: rural households in mountainous areas, livelihoods of rural households, livelihood transformation, livelihood pattern

1.Introduction

In order to obtain the best welfare, rural households in mountainous areas usually choose diversified livelihood patterns to guard against the shocks from uncertainties. Rural households will choose activities whose returns are not perfectly correlated to minimize risk (Raju & Poh, 2019). The livelihood resource endowment is different for rural households in mountainous areas, which makes their livelihood patterns different and the livelihood patterns of rural households in mountainous areas patterns obviously different. In the transformation process of livelihood for rural households, the change of livelihood patterns is important. The livelihood patterns of rural households show a diversified development trend.

Livelihood is a way of making a living which is based on capabilities, resources and activities (Pang et al., 2021; Zhou & Chen, 2018; Xiang et al., 2016), and the livelihood patterns of rural households in mountainous areas is a dynamic changing process (He, Zhou, & Zhang 2021; Wu &Wang, 2020). The so-called "sustainable livelihood" refers to the ability, resources and income-generating activities that individuals or families have and obtain to improve their long-term living conditions (Feng & Hu, 2021). Most of the current researches are based on the "sustainable livelihood patterns" for analysis (Chetty & Phung, 2018). In terms of domestic researches, Zhang et al. (2008) studied the livelihood diversification and cultivated land use patterns of Keerma Village in Jinchuan County, a mountainous farming and pastoral area in eastern Qinghai-Tibet Plateau, and believed that non-agricultural activities-based livelihood diversification may be at the heart of sustainable livelihood patterns there (Polas et al., 2020). Wang & Zhang (2011) believe that whether peasants can fundamentally transform into citizens in large, medium and small cities or small towns depends on whether they can continue to live in the urban society, in the other words, it depends on the rural households' ability to make a living in the urban society (Raju, 2021). They believe that to solve rural households' problems in the process of urbanization is firstly to strengthen the guarantee and develop the sustainability of the livelihood of rural households in mountainous areas. Wang & Liu (2021) believe that the sustainable livelihood of landless rural households should be based on the establishment of a scientific and reasonable institutional system, with the realization of productive employment of landless rural households as the core and supplemented by guiding and helping rural households to accumulate resource (Raju, 2021).

He (2020) believes that under the reconstruction of the basic framework of sustainable livelihood patterns, the establishment of a social security system for landless rural households is an important institutional resource and basic element. In-depth analysis of the influence of the social security system over landless rural households in replacing land is required to solve the subsistence problems (Raju, 2021). The advantages and effectiveness of such a system should be guaranteed and countermeasures and suggestions should be put forward to improve the performance of substitutability and sustainable development of the system. Lei & Zhang (2021), Hu & Wen (2021) point out that unsustainable livelihood is the core problem faced by landless rural households (Raju & Phung, 2020). By analyzing the current situation and problems of natural resources, financial resource, human resource, physical resource and

social resource of landless rural households, drawing on the Nanhai pattern and Wuhu pattern, and taking institutional reform as a breakthrough, this research proposed that under the current institutional framework of establishing a land based natural resource livelihood pattern for landless rural households, it is necessary to innovate the path of urbanization development, realize the rural property rights system reform with land property rights reform as the core, clarify land property rights and empower rural households (Raju & Phung, 2018). This research examined the status of the livelihood patterns of rural households in mountainous areas under survey and the transformation status of the livelihood patterns of rural households in mountainous areas patterns over the past ten years. This research analyzed the livelihood outcomes of rural households under different livelihood patterns, such as housing, income and food self-sufficiency. The livelihood patterns of rural households in mountainous areas during that period were distinguished and the optimal livelihood pattern of rural households was identified with the stochastic dominance method.

2. Literature Review

2.1 Data sources

The data used in this research were from the follow-up survey on the livelihood patterns of rural households in mountainous areas carried out by researches on mountainous areas of Yunnan in 2011, 2016 and 2021. The survey on rural households was conducted in the two regions of Pu'er City and Xishuangbanna Prefecture. Two counties were randomly choosing in each region, Menglian County and Lancang County of Pu'er City Menghai County and Jinghong County of Xishuangbanna Prefecture. In each county, villages were chosen based on different economic conditions and different altitude conditions, and a total of 12 villages were surveyed. About 30 rural households were randomly surveyed in each village, and a total of 405 valid questionnaires were recovered (Raju et al., 2021). The rural household survey chose a structured questionnaire design and the main contents include: basic demographic information of rural households, including population, labor force, education and ethnicity, etc.; rural household resource endowments, including human resource, natural resources, physical resource, social resource and financial resource; the annual income of rural households, including income from crop farming, animal husbandry, wage income, property income and transfer income; rural households' crop farming structure and crop output; peasants' choices of agricultural technologies and government policy support (Raju, 2021).

2.2 Basis for the division

2.2.1 Theoretical basis

It is assumed that rural households in mountainous areas take part in a series of feasible livelihood activities ($i=1,2,\cdots,N$) to maximize their income under a given resource endowment portfolio. Resource endowment (household or individual asset status) is the basis for the opportunity choices a household or an individual has, the livelihood patterns chose and the risk environment they are in (Huang & Liu, 2017; Su & Zhou, 2017; Peng et al.,

2016). Livelihood patterns are the ways rural households seek to develop and comprehensively utilize their current resource endowments to sustain their livelihoods and different resource allocation strategies will generate different income and welfare for rural households(Polas et al., 2020) . For a rational peasant, choosing a low-return livelihood pattern is due to his resource constraints of choosing a better livelihood pattern (Wang & Wang, 2021). Identifying low-return livelihood patterns and the rural households that choose these strategies is critical for developing effective policy interventions. It is assumed that the rural household in the mountainous area makes the optimal livelihood pattern based on the combination of livelihood resource endowments, so as to maximize the income or welfare of the peasant. The equation is demonstrated as follows.

$$y_i = F_i(A_i)\varepsilon_i \quad (1)$$

where y_i is the livelihood activity chosen by rural households in mountainous areas, F_i an increasing function of the livelihood resource endowment of rural households in mountainous areas, A_i the livelihood resources owned by rural households in mountainous areas, and ε_i a random error term. Generally speaking, the final allocation outcome of the livelihood patterns of rural households in mountainous areas resource portfolio is the rural households' livelihood patterns. With different livelihood patterns, their livelihood activities are different, and the outcomes obtained are also different. The income of the whole family of the mountain peasant is $Y = \Sigma_i y_i$. If the peasant i wants to maximize the utility of the livelihood resource portfolio (maximum income or welfare), the mountain peasant i needs to optimize its resource endowment under the current resource conditions, namely A_0 .

$$y_i = \max_{A_i} U(\Sigma i y_i = \Sigma i F_i(A_i) + \varepsilon_i) \qquad \text{s.t} \quad \Sigma_i A_i \le A_0 \qquad (2)$$

where the final choice made by rural households is the optimal livelihood pattern choice of rural households. Different livelihood patterns of rural households are generated by classifying the optimal livelihood patterns chosen by rural households.

2.2.2 Basis for variable selection

Since the livelihood patterns of the research subjects in the past ten years have been mainly farming, rural households have resorted to crop farming, animal husbandry and non-agricultural activities as their means of livelihood. Through the on-the-spot investigation and analysis of the survey data, this research chose variables from the following aspects.

1) Farming

The crop farming structure of rural households is mainly composed of grain crops and cash crops. Land is an important resource for the livelihood patterns of rural households (Raju, 2021). Therefore, this research used the proportion of rural households' grain crop farming area and the proportion of cash crop farming area to distinguish rural households based on grain crops. This research identified the evidence of grain crop farming or cash crop farming. If the proportion of the peasant's grain crop farming area is greater than that of the cash crop farming, that is, the proportion of the peasant's grain crop farming area exceeds 50% of the total crop farming area, meaning that the peasant mainly does grain crop farming in the crop farming structure. The proportion of peasants' grain crop farming area is less than that of cash crop farming, that is, the proportion of cash crop farming area is greater than 50% of the total crop farming area, it means that the peasant mainly does cash crop farming in the crop farming structure.

2) Animal husbandry

The research subjects mainly raise pigs, cattle and poultry. According to the rural households' purpose (output income or sales income), whether rural households engage in commercial animal husbandry is distinguished, and the number of pigs is mainly used as the judgment basis. Observing the proportion of the number of pigs sold by rural households to the number of pigs output in 2020, this research identified that in the rural households with more than 10 pigs output, the number of pigs sold per rural household accounts for 76.45% of the output volume of pigs; and that the net income of pigs per rural household accounts for 26.61% of the total net income of rural households, of which the net income of pigs per household with the output of more than 10 pigs accounts for 58.73% of the total net income. Rural households with more than 10 pigs are defined as rural households engage in commercial animal husbandry.

Table 1 *Categories of the livelihood patterns of rural households in mountainous areas patterns (households)*

Type	2010	2015	2020
Rural households (households) without crop farming behavior	42	18	5
Rural households (households) who mainly engage in grain crop farming	297	277	244
Rural households (households) who mainly engage in cash crop farming	66	110	156
Commercial rural households (households)	35	65	92
Non-commercial rural households (households)	370	340	313
Non-agricultural households (households)	14	31	91
Non-agricultural households (households)	391	374	314

Data source: *Rural household survey data.*

3) Non-agricultural activities

The non-agricultural activities of rural households under survey mainly include other business activities, non-agricultural short-term labor and long-term migrant worker activities.

Although the proportion of the labor force engage in non-agricultural activities was relatively small during the survey period, the proportion of labor force engage in non-agricultural activities continued to increase. Therefore, this research referred to the labor force in households involved in other business activities, non-agricultural short-term labor or long-term migrant worker activities. Rural households are defined as non-agricultural activity households. The distribution of various types of rural households is shown in Table 1.

2.3 Types of Peasant's Livelihood Patterns

According to the distribution of rural households under survey in crop farming, animal husbandry and non-agricultural activities, this research divided the livelihood patterns of rural households under survey into the following six combined patterns, as shown in Table 2.

Livelihood Pattern 1: pure grain crop growers (M1) - a livelihood pattern that completely engage in grain crop farming as a source of livelihood. A certain proportion of rural households in the surveyed area choose this type of livelihood pattern. In 2010, 66.17% of the livelihood patterns chosen by rural households in mountainous areas were pure grain crop growers. In 2015, this proportion dropped to 53.33%. In 2020, this proportion fell to 36.3%.

Livelihood Pattern 2: part-time households (M2) who partially engage in grain crop farming. They mainly engage in grain crop farming, and are also involved in the cash crop farming, animal husbandry and non-agricultural activities. More than 50% of the rural households choose the livelihood pattern of grain crop farming plus other livelihood activities, including animal husbandry, cash crops farming and non-agricultural activities. In 2010, 7.16% of the rural households chose this livelihood pattern, and in 2015, the proportion of rural households who chose this pattern increased to 15.06%, and in 2020, the proportion of rural households who chose this livelihood pattern increased to 23.95%. The livelihood patterns include the follows. M21 is a part-time household I, which partially engage in grain crop farming, meaning that it partially engage in grain crop farming, and is also involved in large-scale farming and non-agricultural activities. M22 is the part-time household II, which partially engage in grain crop farming. M23 is a part-time household III that partially engage in grain crop farming, indicating that it partially engages in grain crop farming and partly engage in non-agricultural activities.

Livelihood Pattern 3: part-time households with cash crop farming (M3) - mainly cash crop farming, plus grain crop farming, animal husbandry and non-agricultural activities. In this livelihood pattern, more than 50% of rural households engage in cash crop farming, and there are laborers in the household engage in animal husbandry, grain crop farming and non-agricultural activities. In 2010, only 2.48% of the rural households chose this livelihood pattern. In 2015, the proportion increased to 4.44%. In 2020, the proportion increased to 13.83%. The livelihood patterns include the follows. M31 is a part-time household with cash crop farming I, meaning that it partially engages in cash crop farming, large-scale farming and non-agricultural activities; M32 is a part-time household II that it partially engages in cash crop farming, indicating that cash crop farming and part-time large-scale farming; M33

is a part-time household III that it partially engages in cash crop farming, indicating that it partially engages in cash crop farming and also engages in non-agricultural activities.

Livelihood Pattern 4: pure cash crops growers (M4) - a livelihood pattern that completely take cash crop farming as the source for livelihood. In 2010, 13.83% of the livelihood patterns of rural households in mountainous areas pattern was pure cash crop growers. In 2015, the proportion of rural households increased to 22.72%. In 2020, this proportion of rural households increased to 24.69%.

Livelihood Pattern 5: pure animal husbandry households (M5): households that take pig raising as the source of livelihood and whose annual output of pigs is at least 10 or more. In 2010, only 0.25% of the livelihood patterns of rural households in mountainous areas were pure rural households. In 2015, the proportion of rural households increased to 0.49%. In 2020, there were no pure rural households.

Table 2 *Distribution of rural households with different livelihood patterns (%)*

Type	Code	2010	2015	2020
Pure grain crop grower (%)	M1	66.17	53.33	36.3
Part-time households with partial grain crop farming(%)	M2	7.16	15.06	23.95
Part-time households I(%)	M21	0.74	1.23	4.69
Part-time households II(%)	M22	5.43	10.37	10.86
Part-time households III(%)	M23	0.99	3.46	8.4
Part-time households with partial cash crop farming (%)	M3	2.48	4.44	13.83
Part-time households I(%)	M31	0.25	0.99	1.73
Part-time households II(%)	M32	1.98	2.96	5.43
Part-time households III(%)	M33	0.25	0.49	6.67
Pure cash crop growers(%)	M4	13.83	22.72	24.69
Pure animal raisers(%)	M5	0.25	0.49	0
Pure non-agricultural households(%)	M6	10.12	3.95	1.24
Households engage in other business activities or migrant workers(%)	M61	1.23	1.48	0.99
Households engage in other activities(%)	M62	8.89	2.47	0.25
Total number of households (%)		100	100	100

Data source: *Rural household survey data.*

Livelihood Pattern 6: households with pure non-agricultural activities (M6): households engage in other business activities, non-agricultural short-term labors or long-term migrant workers as the source of livelihood. In 2010, 10.12% of the livelihood patterns of rural households in mountainous areas were purely non-agricultural households. In 2015, the proportion of rural households who chose this livelihood pattern increased to

3.95%. In 2020, the proportion of rural households who chose this livelihood pattern dropped to 1.24%. The livelihood pattern includes: M61 households engage in other business activities or migrant workers, and M62 households engage in other activities.

Judging from the distribution of rural households with different livelihood patterns in different years, the pure grain crop farming pattern is the most important livelihood pattern for rural households in the mountainous areas of Yunnan in the survey year. However, the proportion of pure grain crop growers showed a rapid decline in three years under survey, while the proportions of part-time grain crops, part-time cash crops both showed an increasing trend. Few rural households chose the pattern of pure animal husbandry households, and the proportion of pure non-agricultural households has also dropped rapidly. It can be seen that the livelihood of rural households in the surveyed areas has changed from pure grain crop growers to part-time crop farming households and pure cash crop farming.

3. Changes in the Livelihood Outcomes

3.1 3. Changes in the livelihood outcomes of rural households with different livelihood patterns

The livelihood outcome of a rural household is the final income and manifestation of the livelihood pattern based on its resource endowment (Zhao Xu et al., 2021). The livelihood outcomes of rural households are usually measured by welfare indicators, including income status, poverty status, housing conditions and food self-sufficiency. By investigating the changes in the livelihood outcomes of rural households with different livelihood patterns, this research further discussed the outcomes of the livelihood pattern transformation of rural households in mountainous areas.

3.1 Income changes of rural households with different livelihood patterns

The net income of rural households refers to the sum of all income obtained after deducting the input of rural households. It is mainly composed of three parts: the income from crop farming, the income from animal husbandry and the income from other activities. The income from crop farming is the crop farming output of the rural household multiplies the price of that year. The income from animal husbandry is the number or weight of livestock and poultry raised in that year multiplies the price of that year. The income from other activities includes the income of rural households' self-run enterprises, wage income (such as income from work), property income (such as land rental) and transfer income (such as government subsidies, poverty relief, etc.).

Figures 1 and 2 are the per capita net income per household and the income composition of the rural households under survey. Since the rural household income data in 2020 were not available, the analysis on rural household income was mainly based on the income data of 2020, 2015 and 2010. In general, the per capita net income of the households under survey has increased year by year. Although the data of 2020 are missing, the increasing trend is significant. It can be seen that in 2010, the average net income of rural households was 9,200 yuan, and it increased to 34,500 yuan in 2020, with an annual growth

rate of 15.81%. In the income structure of rural households, the proportion of income from crop farming shows a decreasing trend, and the proportion of income from animal husbandry and other activities shows an increasing trend.

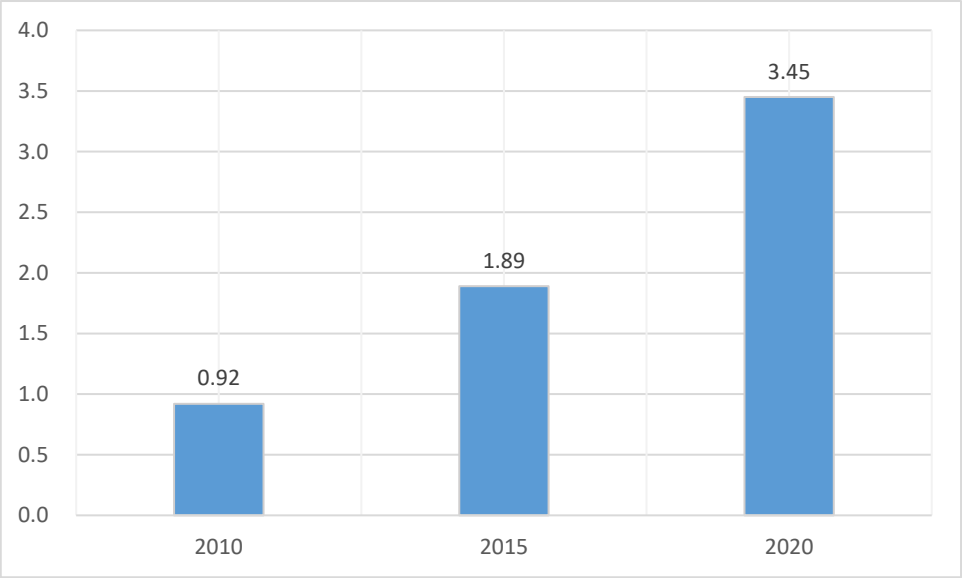

Figure 1 *Average net income of rural households under survey (unit: ten thousand yuan)*

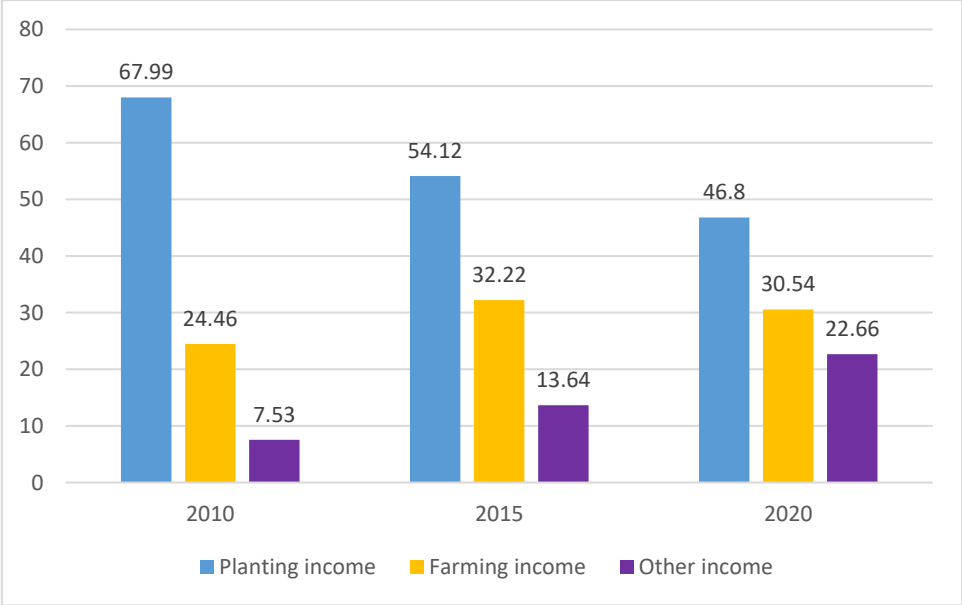

Figure 2 *The income composition of rural households under survey (%)*

3.2 Housing changes of rural households with different livelihood patterns

Housing is an important reflection of the livelihood pattern outcomes of rural households in mountainous areas. In the process of the livelihood pattern transformation of rural households in mountainous areas, the change of livelihood pattern makes the livelihood pattern outcomes of rural households in mountainous areas different and the improvement of housing is an important reflection of the success of the livelihood pattern transformation outcomes of rural households in mountainous areas.

3.2.1 Housing area

The per capita housing area of the rural households under survey is increasing. The per capita housing area of the rural households under survey was 75.46 square meters in 2010, and it increased to 87.18 square meters in 2015 and further increased to 95.95 square meters in 2020. From 2010 to 2020, the average housing area of each rural household increased by nearly 20 square meters (Figure 3).

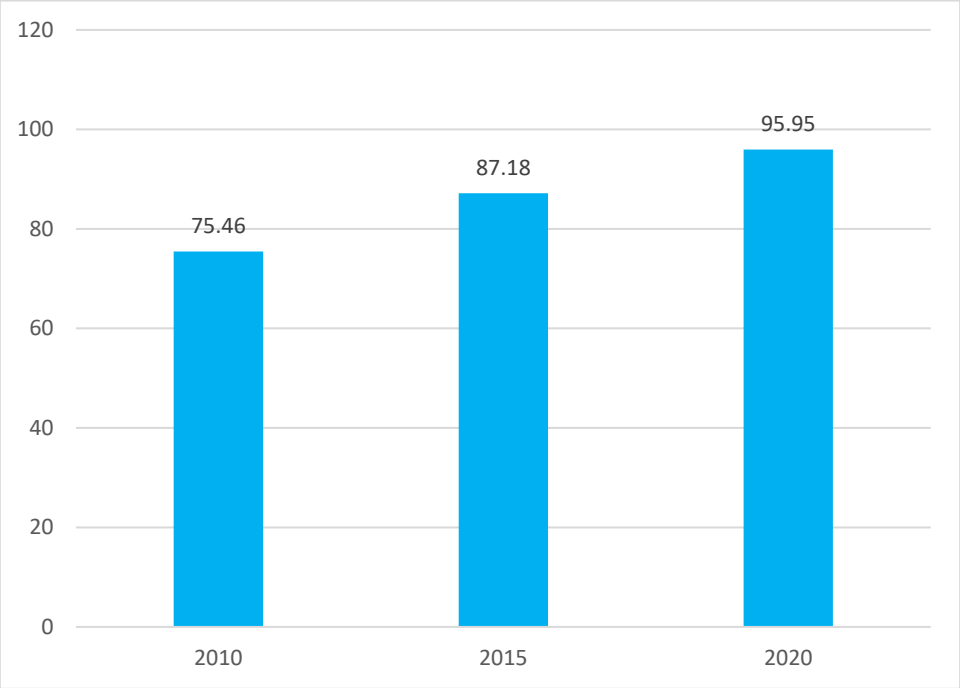

Figure 3 *The per capita housing area of the rural households under survey (unit: square meters)*

Table 4 is the housing area of rural households with different livelihood patterns. The outcomes show that the per capita housing area of rural households that choose the livelihood pattern of cash crop farming is significantly higher than that of rural households that choose the livelihood pattern of grain crop farming. Moreover, at different periods, the per capita housing area of rural households increased to different extent. For example, in 2010, the per capita housing area of rural households that chose the livelihood pattern of "part-time households with partial cash crop farming I" was 80 square meters. The average housing area of rural households that chose the "pure cash crop growers" livelihood pattern was 100.23 square meters in 2010, and the average housing area of rural households that chose this livelihood pattern increased to 125.9 square meters in 2020, an annual increase of 2.3%. In 2010, the average housing area of rural households that chose the "pure grain crop growers" livelihood pattern was only 68.63 square meters. In 2020, the average housing area of rural households that chose this livelihood pattern increased to 76.74 square meters, with an annual growth rate of 1.12 square meters. %.

Table 4 *Per capita housing area of rural households with different livelihood patterns (unit: square meters)*

Type	Housing area (unit: square meters)		
	2020	**2015**	**2010**
M1	76.74	72.27	68.63
M21	91.11	90	84.67
M22	100.36	99.31	87.5
M23	87.29	93.21	77.5
M31	120.29	123.5	80
M32	92.23	121.67	118.13
M33	102.26	145	130
M4	125.9	109.78	100.23
M5	-	180	150
M61	60	72.5	71
M62	0	63.4	66.83

3.3 Changes in the status of food self-sufficiency of rural households with different livelihood patterns

The food self-sufficiency of rural households is measured by the number of months that rural households are short of food for subsistence in the survey year. The status of food self-sufficiency of rural households refers to the status to which the food produced by rural households can meet the family's self-consumption, and it is an important manifestation of the transformation outcomes of the livelihood patterns of rural households in mountainous areas. Figure 6 shows the months of food shortage of the rural households under survey. It can be seen that the number of months of food shortage suffered by rural households under survey shows an obvious increasing trend. In 2010, the average number of months of food shortage per household was 2.89 months/year. In 2015, the average number increased to 3.56 months/year, and in 2020, it increased to 4.24 months/year.

The reasons for the increase in the number of months of food shortages for rural household and the status of food self-sufficiency are as follows. Firstly, the transformation of rural households from a grain crop farming pattern to a cash crop farming pattern. The input of rural households to grain crops is reduced, such as the input on fertilizers and labors, and the management on grain crop farming is neglected. Even though the planting area of grain crop farming has increased, the yield is not high. Secondly, the implementation of the measures of returning farmland to forests has reduced the arable land planting area for rural households, and rural households have reduced the crop farming area for grain crops. Thirdly, marketization has played an important role in this transformation process. As the output value of cash crops per unit is higher than that of grain crops, rural households are willing to put more labor and production materials into cash crops. Fourthly, rural households mainly use grain and other sideline agricultural products as feed for livestock and poultry, so they rarely buy feed from the outside, which aggravate the status of food shortages and the status of food self-sufficiency. Fifthly, the income of rural households has increased, and some rural households can meet their subsistence needs by purchasing grains from the outside.

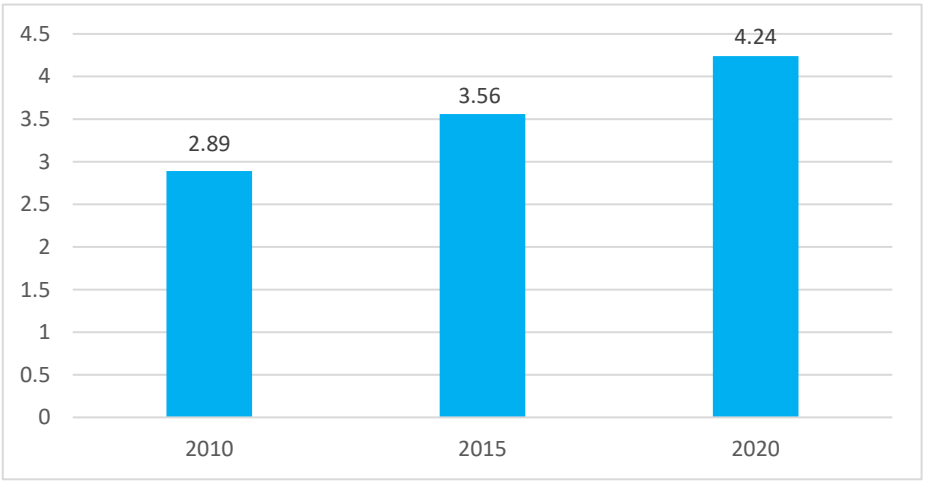

Figure 6 *Number of months of food shortage per rural household (months/year)*

Table 7 *The average number of months of food shortage per rural households with different livelihood patterns (months/year)*

Type	Number of months of food shortage (months/year)		
	2010	2015	2020
M1	2.86	2.56	2.38
M21	0	4.8	3.63
M22	1.86	2.76	2.77
M23	4.25	4.64	3.41
M31	0	5.74	5.14
M32	5.5	6.33	5.77
M33	12	12	5.74
M4	4.75	5.98	7.07
M5	0	6	0
M61	0	0	6
M62	0.67	0	12

4.Identification of the Optimal

The direct outcome of livelihood pattern transformation is the improvement of the livelihood pattern outcome for rural households in mountainous areas (Xing et al., 2019). Generally speaking, if a peasant's livelihood has improved, it means that given livelihood patterns have provided the peasant with a higher welfare. Such needs were accurately measured and identified, and the advantages of the livelihood patterns of rural households in mountainous areas were ranked in order to provide the optima livelihood pattern for rural households. The livelihood pattern choice requires careful design and policy intervention. Some studies have quantitatively characterized the livelihood patterns of rural households. They classified the livelihood patterns of rural households into different categories according to their income proportion under different rural economic sectors with the most commonly used method. For example, Barrett et al. (2005) used a hierarchical approach to analyze the correlation between total household income and the proportion of income from agricultural

and non-agricultural activities. Deron & Krishman (1996) used the composition of income proportion to examine the correlation between income, household characteristics and entry barriers to high-rewarding activities. The main problem with this measurement method is that sustainable livelihood methods focus on livelihood activities based on household resource endowments, on household behaviors rather than the income, which is influenced by some random and exogenous factors. Therefore, the quantitative study of the livelihood pattern needs to go back to the livelihood patterns of rural households in mountainous areas, that is, to classify and sort the livelihood activities of rural households in mountainous areas by quantitatively describing the various types of livelihood activities engaged by rural households, and then screening out the optimal livelihood pattern for rural households. Generally speaking, the livelihood pattern chose by rural households in the later period is better than that chosen in the earlier period, so this research discussed the status of the optimal livelihood pattern of rural households in 2020.

4.1 Cluster analysis

Since the livelihood patterns of rural households in mountainous areas have been classified earlier, in order to explore the optimal livelihood pattern for rural households, this research included factors such as the varieties of crops farmed, livestock and poultry raised, and specific non-agricultural activities rural households engaged in 2020 with a clustering analysis. The analytical method further classified the livelihood patterns of rural households in mountainous areas. Among them, cluster analysis, also known as group analysis and point group analysis, is a method of dividing observed samples into different groups or classes based on the dissimilarity of observed samples in many variables. The K-means clustering method randomly selects K points from the sample data as the initial cluster center according to the characteristics of the sample rural households, calculates the distance between each sample and the cluster center, and then assigns the sample to the nearest cluster. The class is where the center is located. It calculates the average value of the data objects of each newly formed cluster to get the new cluster center. If there is no change in the adjacent two cluster centers, it means that the sample adjustment is over, and the clustering criterion function converges; otherwise, the sample will be adjusted, modified to the cluster center, and perform the next iteration until all samples are correctly classified. If the cluster center does not change, the clustering criterion function converges. Then the clustering is completed, and the cluster category is obtained.

The cluster analysis method provides a convenient and intuitive grouping method for the sample rural households to identify themselves, which is meaningful for objectively explaining the different types of livelihood patterns of local rural households. The outcomes of K-means cluster analysis show that the livelihood patterns of the sample rural households can be divided into five categories with obvious characteristics in particular.

Pattern 1: The main production is sugar cane, tea and coffee. There are 18 rural households in this category, accounting for 4.46% of the sample rural households. The per capita land area of each household is the largest, reaching 70.93 mu, of which the per capita cash crop planting area is 45.84 mu, accounting for 64.62% of the land area, and the per capita grain crop planting area is only 18.82 mu. The crop farming varieties of cash crops are

mainly concentrated in sugarcane, tea and coffee. The planting area per household is 20 mu, 11.44 mu and 6.21 mu respectively. A small amount of rubber is also planted, and the rubber planting area is small. In terms of animal husbandry, pigs and chickens are of a large raising volume, with an average of 7.06 chickens and 31.06 pigs per household. In terms of non-agricultural activities, there are a small number of rural households who go out for work. According to statistics, the per capita net income of rural households in this category is 14,918.75 yuan, which is quite high, and their livelihood behaviors are diversified.

Table 8 *Cluster analysis of the livelihood patterns of rural households in mountainous areas patterns in 2020*

Variable	Pattern1	Pattern2	Pattern3	Pattern4	Pattern5	Overall
Grain crop planting area	18.82	4.03	17.58	15.48	11.55	12.56
Cash crop planting area	45.84	52.10	16.52	8.73	8.35	14.85
Number of pigs raised	7.06	2.83	12.00	8.06	6.02	6.63
Number of cattle raised	0.61	1.05	0.68	1.01	1.12	1.04
Number of chickens raised	31.06	13.35	108.42	28.36	3.29	17.79
Tea planting area	11.44	0.08	6.15	2.22	2.08	2.53
Sugarcane planting area	20.00	0.00	8.11	2.97	3.17	3.78
Coffee planting area	6.21	0.65	0.42	1.56	1.65	1.67
Rubber planting area	1.00	50.53	0.16	0.91	0.92	5.80
Other activities	0.00	0.05	0.16	0.00	0.05	0.04
Non-agricultural day laborers	0.00	0.00	0.05	0.07	0.06	0.05
Long-term migrant workers	0.17	0.05	0.21	0.22	0.22	0.20
Other activities	0.17	0.00	0.00	0.04	0.05	0.05
Other variables：						
Number of rural households	18	40	19	118	209	404
Proportion of rural households	4.46	9.90	4.70	29.21	51.73	100
Per capita net income	14918.75	20321.76	7853.41	7137.35	5563.22	8008.77

Note: *The per capita net income is the per capita net income of rural households in 2020.*

Pattern 2: The main production is rubber. There are 40 rural households in this category, accounting for 9.9% of the sample rural households. The land area per household is 52.21 mu, of which the planting area of cash crops per household is 52.10 mu. The main variety of cash crop is rubber. The rubber planting area per household is as high as 50.53 mu, accounting for 96.78% of the land area of rural households. At the same time, a small amount of tea and coffee are planted. But the planting area is very small. In terms of animal

husbandry, compared with other types, the number of animal husbandry is the least. Among them, each peasant raises 2.83 pigs and 13.35 chickens per household. In terms of non-agricultural activities, the number of rural households engaging in non-agricultural activities is very small. The per capita net income in this category of rural households is the highest among the sample rural households, with a per capita net income of 20,321.76 yuan, and the main source of income is rubber. It should be added that the average planting altitude in this category is 905.32 meters, and the geographical location and climate are suitable for rubber planting.

Pattern 3: The main production is grain and cash crops plus a large scale of animal husbandry. There are 19 rural households in this category, accounting for 4.7% of the rural households under survey. The per capita land area of each household is 40.65 mu, of which the planting area of grain crops is 17.58 mu, and the planting area of cash crops is 16.52 mu. Among them, the cash crops are mainly sugar cane and tea, and the planting area accounts for 37.22% and 49.09% of the planting area of cash crops respectively. In addition, the proportion of coffee and rubber planting is very small. In terms of animal husbandry, pigs and chickens are the main products. Compared with other livelihood patterns, households in this category have the largest scale of pigs and chickens, with an average of 12 pigs and 108.42 chickens per household. In terms of non-agricultural activities, some rural households engaging in other business activities, such as short-term non-agricultural labors and long-term migrant workers, and the proportion of rural households engaging in non-agricultural activities is significantly higher than that of Pattern 1 and Pattern 2. The per capita net income of rural households in this category is 7853.41 yuan, which is slightly lower than the overall average income among the five livelihood patterns.

Pattern 4: The main production is grain crops, plus a large scale of animal husbandry. There are 118 rural households in this category, accounting for 29.21% of the rural households under survey. The per capita land area of each household is 29.01 mu, of which the planting area of grain crops is 15.48 mu, accounting for 53.36% of the land area, while the planting area of cash crops is about half of the planting area of grain crops, which is 8.73 mu. The main varieties of cash crops are tea, coffee, sugarcane and rubber, and the proportion of each variety is relatively average. In terms of animal husbandry, rural households in this category own a relatively large scale, around 8.06 pigs and 28.36 chickens per household. In terms of non-agricultural activities, the number of migrant laborers in households in this category is larger in number than that of other types, with an average of 0.22 long-term migrant workers and 0.07 short-term non-agricultural labors. The per capita net income in this category of rural households is 7137.35 yuan, which is low among the five livelihood patterns.

Pattern 5: The main production is rain crops plus migrant worker activities. There are 209 rural households in this category, accounting for 51.73% of the rural households under survey. Peasants in this category own the smallest amount of land, with an average household of 24.06 mu, of which the planting area of grain crops is 11.55 mu, while the planting area of cash crops is only 8.35 mu. In terms of animal husbandry, pigs and cattle are mainly raised, but compared with other patterns, their raising scale is small. In terms of non-agricultural

activities, more rural households engage in non-agricultural activities. It can be found that the land area, grain crop planting area, cash crop planting area and the number of animals in this category are all lower than those of the rest four patterns, but the number of labors who go out for work is significantly higher than that of the rest four patterns. The per capita net income of this category is 5563.22 yuan, the least among the five livelihood patterns.

4.2 Optimal livelihood pattern identification method

Random dominance will prioritize the livelihood patterns of rural households in mountainous areas, assuming livelihood pattern i and livelihood pattern j, if $D_i^{(s)}(x) \le D_j^{(s)}(x)$ for all x, and there is at least one point of x for which the inequality is strictly true. Then the livelihood pattern i dominates the livelihood pattern j in order. Among them $D_k^{(s)}(x) = \int_{-\infty}^{x} D_k^{(s-1)}(t)dt$, (k=i, j; s>1); $D_k^{(1)}(x) = F_k(x)$, $F_k(x)$ is the distribution function. That is, if for all x, the distribution function $F_i(x)$ of livelihood pattern i is lower than the distribution function $F_j(x)$ of livelihood pattern j. It shows that the first-order occupation of the livelihood patterns of rural households in mountainous areas pattern i is better than that of livelihood pattern j, even if the return rate of livelihood pattern j is higher than that of livelihood pattern i in a certain state, but for each return level x, the return rate of livelihood pattern i is less than x. The probabilities are lower than the probability that the livelihood pattern j is less than x and when it is $D_i^{(2)}(x) \le D_j^{(2)}(x)$, it means that the second-order proportion of the livelihood pattern i of rural households in mountainous areas is better than that of livelihood pattern j.

4.3 Assessment of the optimal livelihood pattern of rural households

Five livelihood patterns are obtained by K-means cluster analysis method, and the dominance of five different livelihood patterns can be determined simply by the income obtained by rural households based on the livelihood pattern. Comparing the per capita net income of rural households in the five livelihood patterns, it was identified that the per capita net income of pattern 1 is 14,918.75 yuan, pattern 2 20,321.76 yuan, pattern 3 7,853.41 yuan, pattern 4 7137.35 yuan, and pattern 5 5563.22 yuan. A significant difference test was conducted on the per capita net income of each livelihood pattern, and the outcomes demonstrate that the income level of pattern 2 is the highest, and the income level of pattern 5 is the lowest. There is no significant difference in per capita net income between Pattern 2 and Pattern 1, and their income is significantly higher at the 1% level than the other three patterns. There is no significant difference between Pattern 4 and Pattern 3, and they are significantly higher at the 5% level than Pattern 5.

Further, a random dominance analysis was conducted to test the differences in income generated by different livelihood patterns. The cumulative distribution density of income for each livelihood pattern is plotted in shown in Figure 7. Assuming that these distribution densities are very close to the income distributions of each livelihood pattern, the random

dominance of the income distributions of different livelihood patterns can be tested. A livelihood pattern is first-order stochastic superiority over another if and only if, at each possible income level, the livelihood pattern is of a lower cumulative density, reflecting its higher probability of earning income (Whitmore, 1978). Using this criterion, the first-order random predominance pattern is better than the other livelihood patterns based on the cultivation of cash crops, the planted varieties based on rubber, and the production of sugarcane, coffee and tea. The order of first-order random dominance is as follows: rubber production is dominant; sugarcane, tea and coffee production is dominant; both grain and cash crops are given equal attention, and animal husbandry scale is large; grain crops are mainly planted, and animal husbandry scale is relatively large; grain crops are mainly planted, and there are more migrant workers. The second-order dominance test found that rural households are risk-averse and are not inclined to choose a higher income livelihood pattern, but the livelihood pattern mainly based on rubber production and sugar cane, coffee and tea production is still more than the other three types of livelihoods.

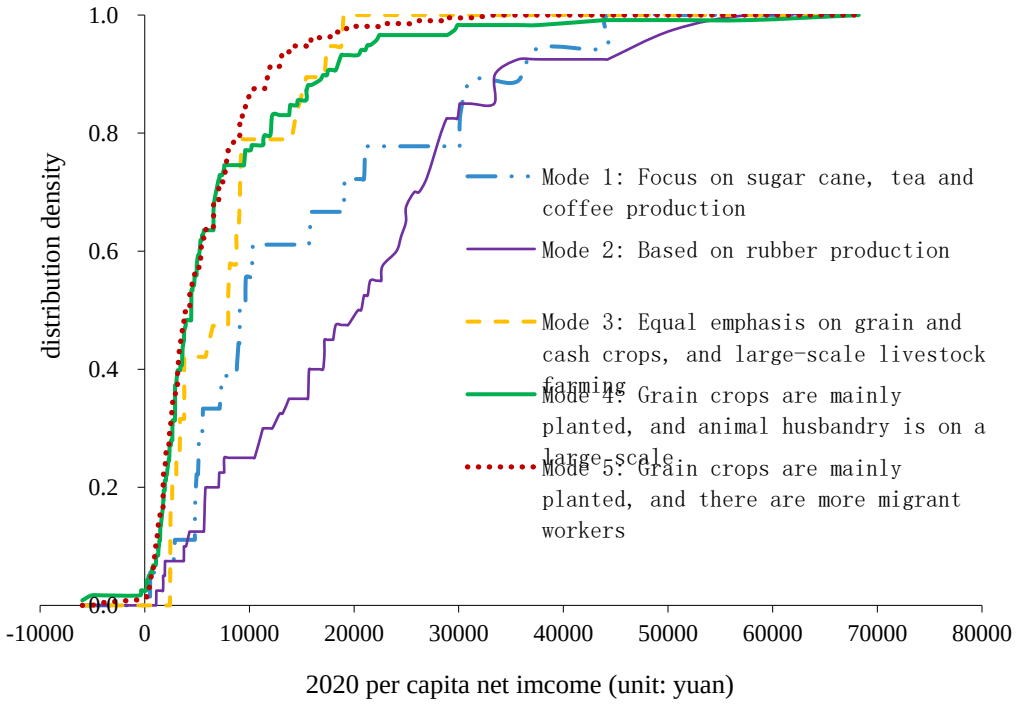

Figure 7 *Cumulative distribution of per capita net income of rural households with different livelihood patterns in 2020*

5. Discussion and Conclusion

The livelihood pattern is the transformation process of the livelihood of rural households. According to the production structure of rural households, this research divided the livelihood patterns of rural households in mountainous areas in Yunnan of the past ten years into 6 categories and 11 sub-categories of “part-time households with partial cash crop farming”, “pure cash crop rural households”, “pure animal husbandry households” and “pure non-agricultural households”. Rural households make corresponding choices of livelihood

behaviors according to their resource endowments and it is these choices of livelihood behaviors that make the livelihood patterns of the households under survey more diverse. However, at the same time, because rural households are far away from the market and the transportation is inconvenient, their farming activities and non-agricultural activities are restricted, making it difficult for them to further expand their livelihoods.

In the process of transforming the livelihood patterns of rural households, rural households have gradually increased the farming of high-yield cash crops, increased commercial animal husbandry activities and increased labor input in non-agricultural activities, which has promoted the improvement of rural households' income levels. The changes in the housing area, wall materials, and toilet types in the houses of rural households have reflect that the living conditions of rural households have been greatly improved after the transformation of their livelihood patterns, and their welfare level has been improved. The decline of food self-sufficiency in rural households also reflects the adjustment of the structure of rural households in the process of transformation.

Then, in the identification of the optimal livelihood pattern of rural households, this research has identified that in terms of the livelihood pattern with the main production of cash crops of rubber, sugarcane, coffee and tea, one cash crop is randomly chosen as the dominating crop. Moreover, it proves that cash crop farming has a greater influence over the transformation of the livelihood of the rural households under survey.

The development of mountainous areas and improvement of the income of rural households in mountainous areas has received extensive attention worldwide and there are numerous relevant studies. Although researchers have put forward a series of countermeasures, this issue has not been effectively solved, and the status of development in mountainous areas and the low-income growth of rural households is still severe. Most of the current measures are developed based on the macro background analysis of mountainous areas, which is a typical "top-down" policy-making process. To promote the effective development of mountainous areas, it is necessary to analyze the livelihoods of rural households in specific regions, comprehensively consider the "natural ecological niche" and "agricultural adaptation mechanism" of the development of mountainous areas, and develop "bottom-up" development measures.

This research on the livelihood patterns of rural households in mountainous areas included a direct analysis on the livelihood patterns of rural households in mountainous areas. From the perspective of sustainable livelihood patterns, this research analyzed on the five livelihood resources owned by rural households and the specific issues based on the perspective of their livelihood resources. Based on security, livelihood risks, and alternative livelihood perspectives, this research analyzed the livelihood patterns of rural households in mountainous areas, and also involved specific rural households' land use and the livelihood pattern transformation of rural households in mountainous areas. These studies have simply analyzed the livelihood patterns of rural households in mountainous areas resources and livelihood patterns, and have combined various livelihood resources such as the analysis of land resource and the transformation of their livelihoods. In addition, the research objects

included rural households, landless rural households, rural households whose farmland returned to the forest, rural households whose farmland returned to wetland, etc. It is not difficult to find that the researches on the livelihood patterns of rural households in mountainous areas at home and abroad have only included a few research objects to cover a wide range of content. It is not difficult to find that the research on the livelihood of rural households still needs in-depth analysis from multiple perspectives, especially the livelihood pattern transformation of rural households. Rural households will continue to restructure and reconstruct their resources according to their own resources in the process of development. Whether it is for returning farmland to forests, returning farmland to wetlands, or becoming landless, their production resource will always change. In the process of maintaining their own livelihood, they will adjust their livelihood pattern according to their own livelihood resource. In decision-making, some rural households need to rearrange their resource portfolios, and some rural households need to rebuild their livelihood resource to maintain their livelihoods, which all involve the transformation of the livelihood patterns of rural households in mountainous areas. Therefore, it is necessary to study the characterization of the livelihood patterns of rural households in mountainous areas and their transformation, especially for the livelihood transformation of rural households in mountainous areas in China. At present, relevant research generally focuses on the description of the transformation process using sociological methods, and few studies have focused on the micro-survey data of relevant rural households.

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