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Livelihood Diversification of Farm Households and Its Impact on Cultivated Land Utilization in Agro-pastoral Ecologically-vulnerable Areas in the Northern China

LIU Haiyan, HAO Haiguang, HU Xujun, DU Leshan, ZHANG Zhe, LI Yuanyuan

(*State Key Laboratory of Environmental Criteria and Risk Assessment*, *Chinese Research Academy of Environmental Sciences*, *Beijing* 100012, *China*)

Abstract: The relationship between livelihood diversification of farm households and cultivated land utilization has become a core research topic related to global environmental change. Agro-pastoral ecologically-vulnerable areas face challenges such as insufficient ecosystem conservation, low agricultural production, and weak economies. In this study, 215 farm households from Zhengxiangbai Banner, Taibus Banner, and Duolun County of Inner Mongolia were surveyed. The sustainable livelihoods framework of the United Kingdom (UK) Department for International Development (DFID) was used to measure the livelihood capital of these farm households. A one-way analysis of variance (ANOVA) was applied to examine the differences in the livelihood capital of different types households, and a correlation analysis was applied to analyze its impact on cultivated land utilization. Results showed that households with non-farming activities accounted for 64.7% of the total surveyed households, and non-farming employment was becoming more prevalent. Physical and financial capital was the driving factors for livelihood diversity. Each livelihood capital had key factors that affected household farmland use behaviors, such as the age of householder, the labor ratio, proportion of income, farmland scale, number of machines, and these had a significantly positive or negative influence on farmland use. Full-time farming households were more likely to transfer the land into cultivation and invest more labor, while non-farming households with high income were likely to transfer farmland out and invest more money to develop efficient farming or improve the employment skills. The results of this study suggest that policy-makers need to fully consider livelihood changes of local households. It is effective to strengthen labor training, create farmland market and improve the efficiency of farmland utilization. We hope to achieve a win-win scenario to improve local economies and ecosystem conservation.

Keywords: agro-pastoral ecologically-vulnerable areas; livelihood diversification; cultivated land utilization; ecosystem conservation

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1 Introduction

China has one of the largest total areas of the most vulnerable ecological habitat types in the world (MEE, 2008). The environments of these ecologically vulnerable areas are extremely sensitive to disturbances. Livelihood choices, including livelihood diversification and cultivated land utilization, are important factors that can affect these ecologically-vulnerable areas (Hao et al., 2017). Livelihood diversification of farm households has become an acute social phenomenon in China, which has changed the social, economic, and ecological

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Corresponding author: HAO Haiguang. E-mail: haohg@craes.org.cn

environment in rural areas (Yan et al., 2010a; 2010b; Wang and Yang, 2012; Zhang et al., 2018). Two typical behaviors of farmland use (transfer and intensity) affect the development of agriculture. The welfare of farmers largely depends on ecosystems service, especially land resources (Costanza et al., 2017; Wang et al., 2017; Malmborg et al., 2018; Everard et al., 2019). It has been confirmed that livelihood diversification leads to high incomes, and off-farm households are able to reduce natural resource reliance, thereby alleviating the pressure on farmland for contributing to local environmental and economic health (Hao et al., 2015a; Peng et al., 2017; Dong et al., 2019; Liu and Wang, 2019). Therefore, farmland use and household livelihoods are different reflections of farmer decision-making processes in response to social, economic, family, institutional, and other environmental changes (Xie and Jiang, 2016; Dib et al., 2018; Yang et al., 2018).

As a consequence, joint research on household livelihoods and farmland use has become a hot topic in global geography and ecological research (Hua and Squires, 2015; Makita, 2016; Sherren et al., 2016; Kassie, 2017). The existing research has demonstrated that the process of livelihood differentiation is closely related to farmland use changes (Hao et al., 2017; Li and Li, 2017). With the development of urbanization and industrialization in China, farm households will develop into large-scale farming households, professional farming households, part-time or non-farming households in the future (Mirzabaev et al., 2015; Ito et al., 2016). Households in agro-pastoral areas are divided into full-time farming, agro-pastoral farming, and part-time farming according to the distribution of labor and farmland use status (Zhu et al., 2010). Currently, there are many explanations for the impact of livelihood diversification on farmland use behaviors (Hao et al., 2015b; Makita, 2016; Kasaaie, 2017). Mostly, livelihood diversification would promote farmland transfer (Tan et al., 2006). But sometimes, farmers may choose to expand their management scale instead of transferring their farmland out with the non-farming income, especially in the eastern China (Tang et al., 2013). The livelihood diversification influence farmland use intensity by three patterns: an increasing investment in farmland because of increasing income (Bhandari, 2013; Li et al., 2017), a reducing concerns on farmland because of the non-farming employment (Shao, 2014), and a differentiated investment because of the different sources of livelihood (Nyanga et al., 2016; Sherren et al., 2016; Hao et al., 2017; Li et al., 2017).

Moreover, additional research has revealed that livelihood capital is a key driving factor of farmland use changes (Hao et al., 2015a; 2015b). The sustainable livelihoods framework proposed by the United Kingdom's (UK) Department for International Development (DFID) showed that the livelihood parameter contains human capital, physical capital, natural capital, financial capital, and social capital (DFID, 1999). Livelihood capital is the tangible and intangible assets of the farmers (Kibria et al., 2018), which impact the strategies and actions of farming households. It is necessary to accurately quantify livelihood capital to identify the future development of farm households (Yan et al., 2010b; Wan et al., 2018). This framework provides a new perspective for identifying household livelihood trends and differentiating their types. The quantitative analysis of livelihood capital has great significance to study livelihood strategies and their farmland use strategies (He et al., 2013; Wan et al., 2018). Indicators in each capital, such as share of non-farming income, cultivated land area, the number of non-farming laborers, are influencing factors for households to transfer cultivated land or change investment on farmland (Schilling et al., 2014; Shao, 2014; Dib et al., 2018). Some households prefer to lease part of their cultivated land or conversely expand farmland scale because of the increasing financial capital, the rich natural capital, or the limited human capital (Alary et al., 2014; Nyanga et al., 2016; Sherren et al., 2016).

The agro-pastoral belt of ecologically vulnerable areas in the northern China is characterized by poor local economies and serious environmental problems. Furthermore, to improve farming household livelihoods, it is necessary to formulate effective policies for farmland use and ecological protection. Previous studies have established a foundation to investigate the driving forces, changing in land use behaviors and ecological effects leading from livelihood differentiation, but were lack of comprehensive analysis. In this study, we synthesized a number of previous studies and established the main line of 'farm household livelihood differentiation-farmland utilization decision-farmland use change-ecological protection effect'. Accordingly, we analyzed the evolution of households' livelihood by quantifying

livelihood capital, and researched its impact on farmland use behaviors from land scale and investment. We discussed the effects of changes in household livelihood and land use behaviors on the local ecological environment and rural socio-economic development. Based on previous research, the Zhengxiangbai Banner, Taibus Banner, and Duolun County of Inner Mongolia, China were chosen as study areas. The Shannon-Wiener index, a one-way ANOVA, and a correlation analysis were then applied to analyze the relationship between livelihood types and land utilization. Farmland transfer behavior (farmland transfer in and out) and farmland use intensity (labor intensity and capital intensity) were selected as indicators. The results will provide an academic basis for ecosystem protection and agricultural development policies in ecologically vulnerable areas.

2 Materials and Methods

2.1 Study area

Zhengxiangbai Banner, Taibus Banner, and Duolun County are situated in the south-central area of the Inner Mongolia Autonomous Region of China (Fig. 1). This region is located in the northern foothills of Yinshan Mountain and the southern edge of the Hunshandake sandy land. The average altitude is 1400 m and covers an area of 13 400 km^2. This region has a mid-temperate semiarid continental climate, with frequent droughts. Average annual precipitation is approximately 400 mm, 75% of which falls between July and September. The annual average temperature is 1.9℃. The land is covered by grass, cultivated land, forest, unused land, water, and construction land. The entire population was approximately 370 000 in 2017, with approximately 294 000 living in rural areas, accounting for 79.5% of the total. In 2017, the first, second, and third industry GDPs of the study area were 2.93, 6.54, and 5.23 billion, respectively. Grain crops in the study area include wheat, corn, naked oats, and potatoes, and the main livestock products are cattle, sheep, and camels.

The agro-pastoral areas are important part of the 'three barriers and two zones' and they ensure China's ecological security (Hao et al., 2015b). During the last ten years, the cultivated land of Inner Mongolia underwent an extreme change in agro-pastoral areas, with many people becoming dependent on the land (Tian et al., 2018). These three areas are key ecological functional zones related to the Hunshandake desertification, and the agricultural use of natural resources has had a major impact on the ecological environment. This has improved the well-being of farmers and is directly related to the level of ecological security in the region and even for the country. Due to long-term unreasonable resource exploitation, low vegetation coverage, land desertification, and other ecological problems in the study area, the area has been listed as an 'ecologically-vulnerable key area of desert grassland reclamation and desertification in the northern foothills of Yinshan

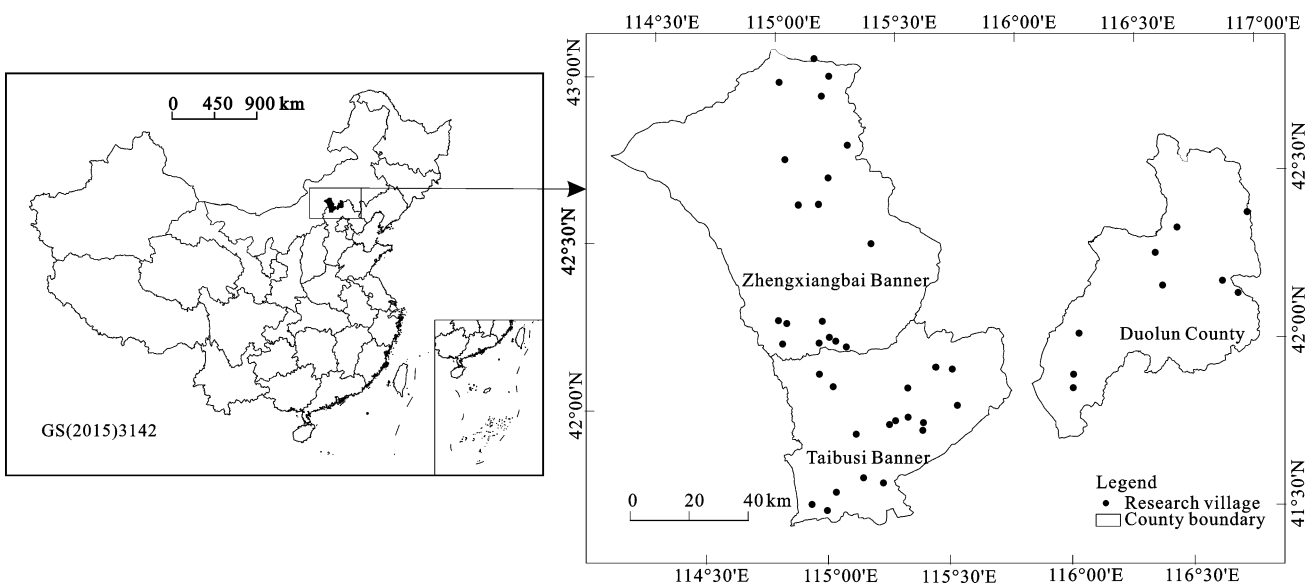

Fig. 1 Location of study area and distribution of sample villages

Mountain' in the 'agro-pastoral and ecologically-vulnerable areas in northern China' (MEE, 2008). Much of ecological protection projects in the study area have been funded by the national and local government, and there are great opportunities due to the constantly regulated land market and the highly valued environment. But these areas face enormous challenges, such as the imperfect policies and laws related to agricultural lands and the lack of research regarding environmental impacts and land management (Hua and Squires, 2015). These three counties were chosen as the study areas due to their location, important ecological functions, the constantly changing lifestyles and farmland uses of the area farmers, the importance and urgency of ecological protection, and the need for development strategies in these areas.

2.2 Data collection

Farm household surveys were conducted from August to September 2016. Using the stratified multi-stage sampling method, according to differences in natural environmental conditions, economic development levels, land quality, and livelihood strategies, the surveys were conducted at the county, township, and village levels. Research sites included 44 villages in the three counties, indicated in Fig. 1. Ten farm householders in each administrative village were randomly interviewed to conduct the questionnaire survey. A total of 215 sample rural households were selected, with 85 in Taibus Banner, 56 in Zhengxiangbai Banner, and 74 in Duolun County. The Department of Rural Surveys of the National Bureau of Statistics formed the basis for this research. The questions were primarily related to the resources at their disposal, and to the farmland use practices they used in 2016. The content of the questionnaire included: 1) basic household information, such as the number in the labor force, their occupations, and the age of the household occupants; 2) the status of non-farming employment, such as the number of family members engaged in non-farming work, the types of jobs they are involved in, and their incomes; 3) family livestock husbandry information, such as the number of livestock and income from livestock husbandry; and 4) family managed farmland information, such as the amount of cultivated land, crop planting machinery, agricultural inputs, and yields. According to the actual situation of farmers in the survey area, people over age 60 but under 80 yr old were included in the family labor force.

2.3 Methods

2.3.1 Classification of household livelihoods

Household incomes were primarily from four sources: crops, livestock rearing, non-farming employment, and other activities. As income can represent both the economic situation and employment (Zhang et al., 2008), the farm households were divided into full-time farming households, I part-time farming households, II part-time farming households, and non-farming households in different regions according to the share of non-farming income. The proportions of income from non-farming employment to the total income were less than 10% for full-time farming households, more than 10% and less than 50% for I part-time farming households, more than 50% and less than 90% for II part-time farming households, and equal to or greater than 90% for non-farming households.

2.3.2 Livelihood diversity index

The Shannon-Wiener index was applied to describe the diversification of farming household livelihoods (Wang et al., 2017). The calculation formula is

$$H = -\sum_{i}^{n}\left(P_i \times \log_2 P_i\right) \tag{1}$$

where H is the livelihood diversity index; i is the income type, n is the number of income types, and P_i is the share of different income type, such as the share of cropping income, the share of livestock rearing income, the share of non-farming employment, and the share of other income. These income data were collected using the questionnaire survey. Generally speaking, the more the income source types, the larger the H. The Shannon-Wiener Index is generally used to measure species diversity. The higher the index, the higher the biodiversity and the more stable the ecosystem. It was chosen to measure the livelihood diversity according to the formula calculation method for its equal applicability. Previous studies have measured the extent of household livelihoods using the inverse Herfindahl-Hirschman Index (Kassie, 2017), which measures economic business competition. By comparing the two above, the Shannon Wiener Index was more suitable for judging the stability of livelihood diversity.

2.3.3 Livelihood capital framework

Based on the sustainable livelihood framework (DFID,

1999), the household livelihoods in this study consisted of five dimensions: human capital, physical capital, natural capital, financial capital, and the livelihood diversity index. The proportions of household laborers, education levels, and age of the householders were used to measure the human capital (Bhandari, 2013). The number of rooms and machines were used to measure the physical capital (Li et al., 2017). The area of cultivated land, the cultivated land per labor force, and the farmland size per plot were used to measure the natural capital (Jain et al., 2015). The annual income of the household and the income per labor force were used to measure the financial capital (Su et al., 2016). Currently, the indicators used to represent social capital include the number of relatives, family talented people, participation in social activities and organizations, and similar factors (Xu and Yue, 2012). Due to the large subjectivity involved in the social capital indicator selection, quantification, and weighting, this study excluded the social capital (Paul et al., 2016).

2.3.4 Interpretation model of household livelihood diversification

Through SPSS22.0, linear regression analysis was carried out based on the impact factors of the livelihood diversification. The model used the 'livelihood diversity index' as a dependent variable to analyze the possible reasons for livelihood diversification (Wang et al., 2017). The calculation formula is

$$H = \beta_0 + \sum_{i}^{n} \beta_i X_i + \varepsilon \quad (2)$$

where H is the livelihood diversity index, which is the explained variable. i is indicators of household characteristic index, n is the number of indicators, X_i refers to explanatory variable, which mainly includes indicators related to farmers' livelihood capital, β_i is the coefficient for X_i, β_0 is the parameter and ε is the error term.

2.3.5 Quantitative description of farmland use status

Production scale and factor input are two important aspects of farmland use. Therefore, the farmland use of farming households was measured using two aspects in this study: farmland transfer and farmland use intensity. Farmland transfer is further divided into land transfer in and out of cultivation areas, and farmland use intensity is further divided into labor intensity and capital intensity according to different factor inputs (Hao et al., 2015b). In this study, we chosen the farmland rent in and lease out as the farmland transfer in and out to analyze the difference in land demand of different livelihood households. If the farmer rent in farmland, it is expressed as 1, otherwise it is 0. The same goes for farmland lease out. Due to the fact that the labor price is difficult to calculate, the amount of time labor input per unit of area (d/ha) was used to calculate the cultivated land use labor intensity. The cultivated land use capital intensity refers to the value of physical and monetary input per unit of area yuan (RMB)/ha, that is CNY/ha.

2.3.6 One-way ANOVA and correlation analysis

The SNK-q test in one-way AVOVA was applied to analyze significant differences in farm household livelihood capital and cultivated land use indicators. A correlation analysis was used to determine whether there was a significant relationship between livelihood type, livelihood diversity index, and farmland use behavior.

3 Results

3.1 Comparison of livelihood characteristics of different livelihood-oriented households

According to survey data, the non-farming income of study area is between 0–96.7%. The number of full-time farming households, I part-time farming households, II part-time farming households, and non-farming households was 76, 44, 53 and 42. And the last three types in total accounted for 64.7% of surveyed farm households (Table 1).

Fig. 2 showed that the total number of laborers was 477. The non-farming laborers ratio of the four households types was 9.6%, 54.2%, 65.9%, 78.2%. The I part-time farming households, II part-time farming households and non-farming households invested more than half of the laborers into non-farming work. And in the full-time farming households, 82.9% of them did not involve in the non-farming work at all based on survey

Table 1 The division of household livelihood type and the status of classification

Household type	Proportion of non-farming income (%)	Number	Proportion (%)
Full-time farming households	0–10	76	35.3
I part-time farming households	10–50	44	20.5
II part-time farming households	50–90	53	24.7
Non-farming households	≥90	42	19.5

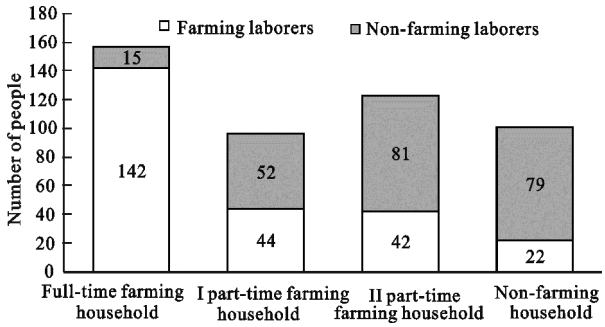

Fig. 2 Status of laborer distribution in each type of household livelihood

data. Also in the non-farming households 35.7% of them were completely out of agricultural activity. The total number of non-farming laborers was 227 distributed in 152 households, and 70.7% of surveyed farm households had non-farm laborers. The number of non-farming laborers accounted for 47.6% of all farm laborers. All above, more and more laborers are participating in non-farming employments in order to improve their quality of life during the differentiation of livelihoods. The phenomenon of non-farming employment was becoming more and more common.

Based on the DFID's sustainable livelihoods framework, the characteristics of households livelihoods were analyzed (Table 2), and the following results were obtained: 1) in terms of human capital, 63.8% of the householders were over 50 years old. Among them, 83.8% had an education level of or under junior high school, indicating a low education level in the study area. 2) In terms of natural capital, the total actual farmland of the farming households ranged from 0.06 to 6.00 ha, the farmland per laborer was between 0.01 and 3.00 ha, and the farmland size per plot was 0.03–3.60 ha. 3) In terms of physical capital, every household had two tile-roofed rooms and two adobes. And they had 2.22 agricultural machines including two tractors and two or more small pumps. 4) In terms of financial capital, the annual total income of the farming households ranged from 1000 to 200 000 CNY. The per capita income was lower than the national annual per capita income of 21 966 CNY. So economic development was an important issue in China that urgently needs to be solved, especially in ecologically-vulnerable areas.

Table 2 Comparison of different farm household livelihoods

Livelihood capital	Household characteristic index	Mean	Households				Significance
			Full-time farming households	I Part-time farming households	II Part-time farming households	Non-farming households	
Human capital	Share of laborers	0.82	0.81^{a}	0.79^{a}	0.86^{a}	0.81^{a}	0.471
	Age of householder(1)	4.73	4.97^{a}	4.64^{ab}	4.71^{ab}	4.40^{b}	0.035^{*}
	Education level of householder(2)	1.80	1.66^{a}	1.89^{a}	1.78^{a}	1.98^{a}	0.178
Natural capital	Cultivated land (ha)	1.45	1.56^{a}	1.96^{a}	1.28^{ab}	0.96^{b}	0.001^{**}
	Cultivated land per laborer (ha)	0.68	0.77^{a}	0.91^{a}	0.55^{b}	0.44^{b}	0.000^{***}
	Farmland size per plot (ha)	0.58	0.46^{a}	0.47^{ab}	0.78^{c}	0.66^{bc}	0.000^{***}
Physical capital	Agricultural machinery (3)	2.22	2.16^{a}	1.97^{a}	2.22^{a}	2.64^{b}	0.000^{***}
	Rooms(4)	3.37	3.08^{a}	3.63^{ab}	2.82^{a}	4.38^{b}	0.002^{**}
Financial capital	Total income (CNY)	31796	18804^{a}	31586^{b}	31037^{b}	57754^{c}	0.001^{**}
	Income per laborer (CNY)	10758	6326^{a}	10954^{b}	10376^{b}	19485^{c}	0.001^{**}
	Livelihood diversity index	0.95	0.42^{a}	1.62^{d}	1.24^{c}	0.87^{b}	0.001^{**}

Notes: (1)A householder age under 26 years old was defined to be 1, 26–31 years old was defined to be 2, 32–41 years old was defined to be 3, 42–51 years old was defined to be 4, 52–61 years old was defined to be 5, and over 61 years old was defined to be 6. (2) A householder educational level included 'primary school and below' 'junior middle school' 'senior high school' and 'junior college and above' and was defined to be 1, 2, 3, and 4, respectively. (3) Agricultural machinery included tractors and small pumps. The value of a tractor was 1, and the value of a small pump was 0.5. (4) The types of family rooms included brick houses and soil houses. The value of a brick house was 1, and the value of a soil house was 0.5. ***, ** and * denote the correlation significance at the 0.001, 0.01 level and 0.05 level (2-tailed), respectively. Letter a, b, c, d means that in the same line if two number did not contain the same letter, there was a significant difference between them. CNY is Chinese yuan (RMB)

A one-way ANOVA analysis was used to compare the livelihood characteristics of different households from five aspects using livelihood capitals and the livelihood diversity index. There was no significant difference among the different types households in share of laborers and the education level of householder. The results showed that the age of a full-time farming householder was significantly higher than that of a non-farming householder ($P < 0.05$). The cultivated land, cultivated land per laborer, and farmland size per plot showed significant differences among the four types of farming households ($P < 0.01$). The actual cultivated land and the farmland per laborer for non-farming household were significantly lower than those of full-time farming households ($P < 0.01$). The natural capital of part-time farming household was higher than others. The agricultural machinery of non-farming households were significantly more than the other three types of farming households ($P < 0.001$). The rooms of non-farming households were significantly more than the full-time and II part-time farming household ($P < 0.01$). The total income and per capita income of the four types of farming households were significantly different and decreased from non-farming to I part-time farming to II part-time farming to full-time farming households ($P < 0.01$). This result indicated that livelihood diversification has led to a significant change of incomes. Non-farming households had relatively high physical capital and financial capital.

There were significant differences in the livelihood diversity index among the different types of farming households ($P < 0.01$). The part-time farming household had significantly higher livelihood diversity index than others. Considering both the livelihood capital and the livelihood diversity index, full-time farming households had a relatively higher livelihood risk because of their lowest livelihood diversity index and the relatively lower livelihood capital.

3.2 Driving indicators of livelihood diversification

As the Table 3 showed, the livelihood diversity index had a significantly positive correlation with the agricultural machinery ($P < 0.001$), total income ($P < 0.001$) and share of non-farming income ($P < 0.01$). So the physical capital and financial capital were the main factors for livelihood diversification. Therefore, in the early stage farmers mainly focused on farmland for livelihood. With the rich physical capital, the household would be more inclined to engage in the agricultural work using existing agricultural production tools. Mechanical brings out the release of labor and farmers begin to focus on other livelihood strategy, which promotes the part-time farming proportion. If the household had more non-farming income, they would focus on the non-farming work, promoting the formation of non-farming employment (Table 3).

3.3 Impact of household livelihoods on farmland transfers

Among our survey, 54.9% of the total households transferred cultivated land, which changed the area and quality of the farmland. Approximately 57 households transferred in cultivated land, 79 households transferred out cultivated land, and 18 households both transferred their cultivated land in and out. Among the 118 households, the area of farmland transfer in from 0.33 to 8.80 ha, and the area of farmland transfer out range from 0.05 to 6.6 ha. These results indicate that farmland transfer is quite usual in the study area.

According to the correlation between farmland transfer strategies and livelihood capital (Table 4), the proportion of farming labor and share of farming income had significantly positive correlation with the farmland

Table 3 The liner correlation analysis results for livelihood diversification of farm household

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	*Sig.*
	B	Std. Error	Beta		
(Constant)	0.313	0.615	–	0.508	0.612
Share of laborers	0.025	0.516	0.010	0.048	0.962
Share of non-farming laborers	0.206	0.368	0.135	0.560	0.576
Education level of householder	–0.017	0.039	–0.025	–0.454	0.651
Age of householder	0.027	0.037	0.051	0.732	0.465
Cultivated land	0.021	0.119	0.048	0.180	0.857
Cultivated land per laborer	0.020	0.255	0.021	0.078	0.938
Farmland size per plot	–0.016	0.066	–0.014	–0.243	0.808
Agricultural machinery	0.064	0.049	–0.074	–1.297	0.000***
Rooms	0.006	0.014	0.024	0.452	0.652
Total income	0.144	0.021	3.383	5.815	0.000***
Share of non-farming income	0.521	0.184	0.365	2.831	0.005**

Notes: ***, ** denote the correlation significance at the 0.001, 0.01 level (2-tailed), respectively

Table 4 Correlation analysis between cultivated land transfer decisions and livelihood characteristics

Livelihood capital	Character indexes of farming household	Farmland transfer in	Farmland transfer out
Human capital	Proportion of farming laborers	0.212**	–0.333**
	Proportion of non-farming laborers	–0.234**	0.296**
	Age of householder	–0.067	–0.006
	Education level of householder	0.089	–0.01
Physical capital	Rooms	0.03	0.09
	Agricultural machinery	–0.209**	0.058
Financial capital	Share of farming income	0.271**	–0.286**
	Share of non-farming income	–0.171*	0.315**
Natural capital	Cultivated land per laborer	–0.528**	0.169*
	Farmland size per plot	–0.201**	0.084

Notes: ** and * denote the correlation significance at the 0.01 level and 0.05 level (2-tailed), respectively

transfer in ($P < 0.01$), and cultivated land per laborer had a significantly negative correlation with the farmland transfer in ($P < 0.01$). There was a significantly negative correlation between the farmland size per plot and farmland transfer in ($P < 0.01$). There was a significant negative correlation between agricultural machinery and their willingness to transfer land into cultivation. In this study, farming households with large amounts of agricultural machinery had a lower willingness to transfer land into cultivation. This was probably due to the use of machinery to make up for labor shortages or to further liberate labor by purchasing machinery for them to be involved in non-farming employment.

A one-way ANOVA was used to analyze the cultivated land transfer conditions of different types of households. Fig. 3 shows a significant difference ($P < 0.01$) between full-time farming households and non-farming households about farmland transfer in. There were significant differences in farmland transfer out among full-time farming households, II part-time farming households, and non-farming households ($P < 0.05$), and cultivated land transfers decreased in the order from full-time farming households, I part-time farming households, II part-time farming households, and non-farming households (Fig. 3). This is consistent with reality. The phenomenon that full-time farming households transfer farmland in order to produce large-scale operations occurs in all agricultural- dominated areas, not just the study area. The three counties showed a significant difference in farmland transfer. The full-farming and I part-time farming household between three counties had no significant difference about farmland transfer in. The II part-time farming and non- farming households of Zhengxiangbai Banner had a significant higher rate of transfer in farmland than the same types of other counties. At the same time, the rate of farmland transfer out of the part-time households in Zhengxiangbai Banner was significantly lower than the same types of other counties.

3.4 Impact of household livelihoods on farmland use intensity

In the collected data, the maximum farmland use labor intensity of households was 360.0 d/ha; the minimum was 42.8 d/ha; and the mean was 124.8 d/ha. It was higher than that of the national three main grain crops (80.0 d/ha) and national farming (74.9 d/ha). The maximum of the farmland use capital intensity was 25 024 CNY/ha; the minimum was 111 CNY/ha; and the mean was 2611 CNY/ha. It was much lower than the amount of capital investment in the three main national grain crops (3537 CNY/ha) and national farming (3450 CNY/ha) in 2016①. This indicates that households tended to invest labor in the study area at levels comparable to the nationwide values.

According to the correlation between farmland use intensity and household livelihood capital, the age of the householder had a positive correlation with labor intensity ($P < 0.01$), since households with older householders usually managed their farmland in traditional ways. The cultivated land per laborer and farmland size per plot were both negatively related to farmland use intensity significantly ($P < 0.01$). There was a negative significant correlation between farmland per laborer and labor intensity, which was in accordance with the actual situation. The age of the householder and the number of agricultural machines had significantly negative correlation with capital intensity ($P < 0.01$). And the share of farming income was positively correlated to money investment ($P < 0.01$). This meant that households with higher farming incomes would increase their capital investment on farmland. The more agricultural machinery a household owned, the more likely that cost of using the machinery and capital investment would be reduced (Table 5).

① These data come from a compilation of national agricultural product costs and income data for 2017

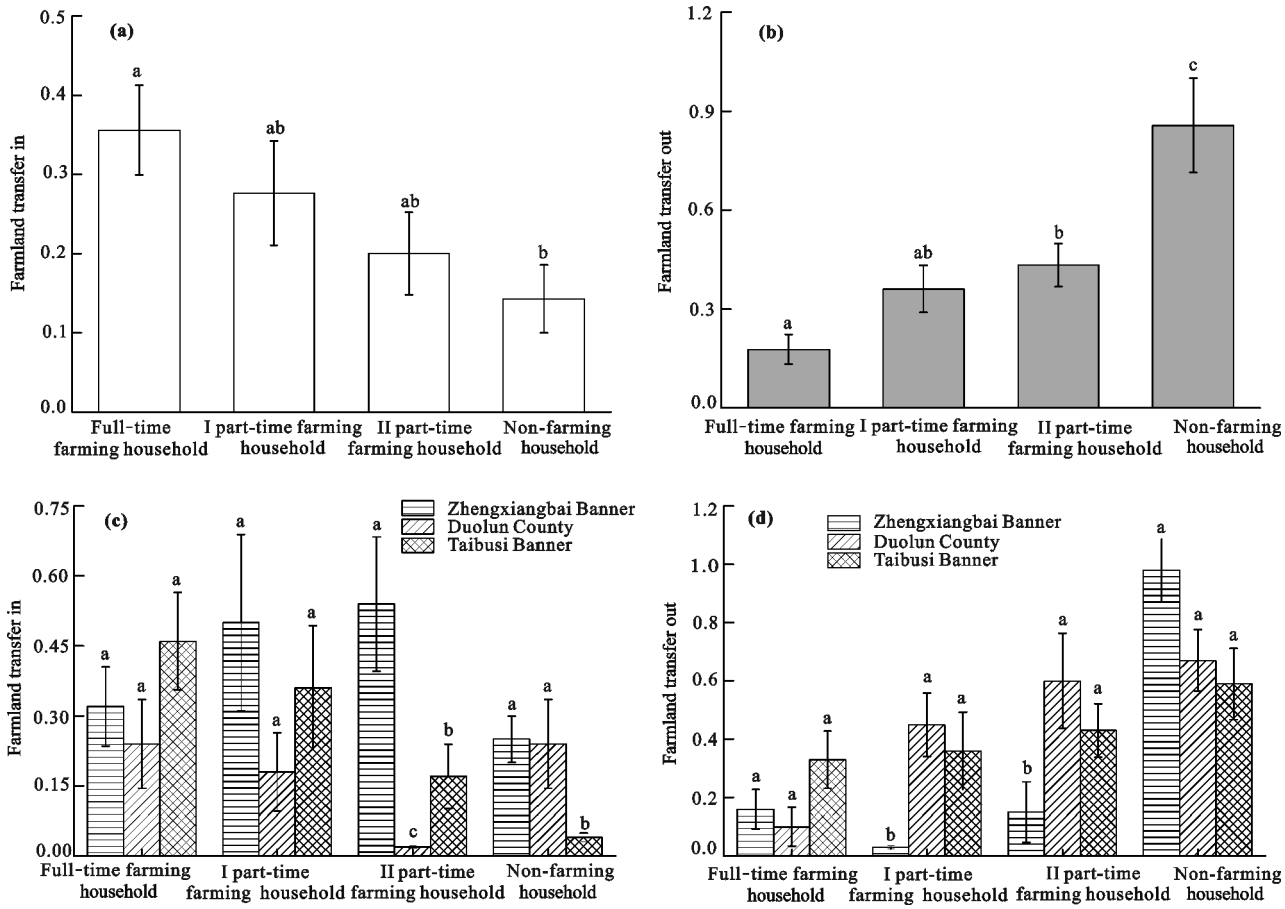

Fig. 3 Variance analysis of cultivated land transfer of different households. Different letters denote a correlation significance level of 0.05. If the different type households did not contain the same small letters, the difference between them was significant. (a), (b) indicated the farmland transfer behaviors from different livelihood household. (c), (d) indicated the farmland transfer behaviors of different livelihood household from three counties

Table 5 Correlation analysis between cultivated land use intensity and livelihood characteristics

Livelihood capital	Character indexes of farming household	Labor intensity	Capital intensity
Human capital	Proportion of farming laborers	0.060	–0.068
	Proportion of non-farming laborers	–0.068	0.050
	Age of householder	0.176**	–0.229**
	Education level of householder	0.008	0.088
Physical capital	Rooms	–0.058	0.067
	Agricultural machinery	0.108	–0.193**
Financial capital	Share of farming income	0.078	0.230**
	Share of non-farming income	–0.119	–0.031
Natural capital	Cultivated land per laborer	–0.507**	0.058
	Farmland size per plot	–0.376**	0.023

Notes: ** denotes the correlation significance at the 0.01 level (2-tailed)

A one-way ANOVA was used to analyze the labor intensity and capital intensity of cultivated land use of the different types of households. The results showed that there was no significant difference among the four types of farming households in their labor intensity, but their capital intensity showed significant differences ($P < 0.05$) (Fig. 4). However, laborers of full-time farming households were primarily allocated to farming practice for their livelihood, and their farmland use labor intensity and capital intensity were relatively higher but not significantly. In contrast, households whose incomes were primarily derived from non-farming employment had more financial capital, and these households primarily allocated laborers in non-farm activities, which led to a lower farmland use labor intensity and significantly higher capital intensity, as shown in Fig. 4. According to the

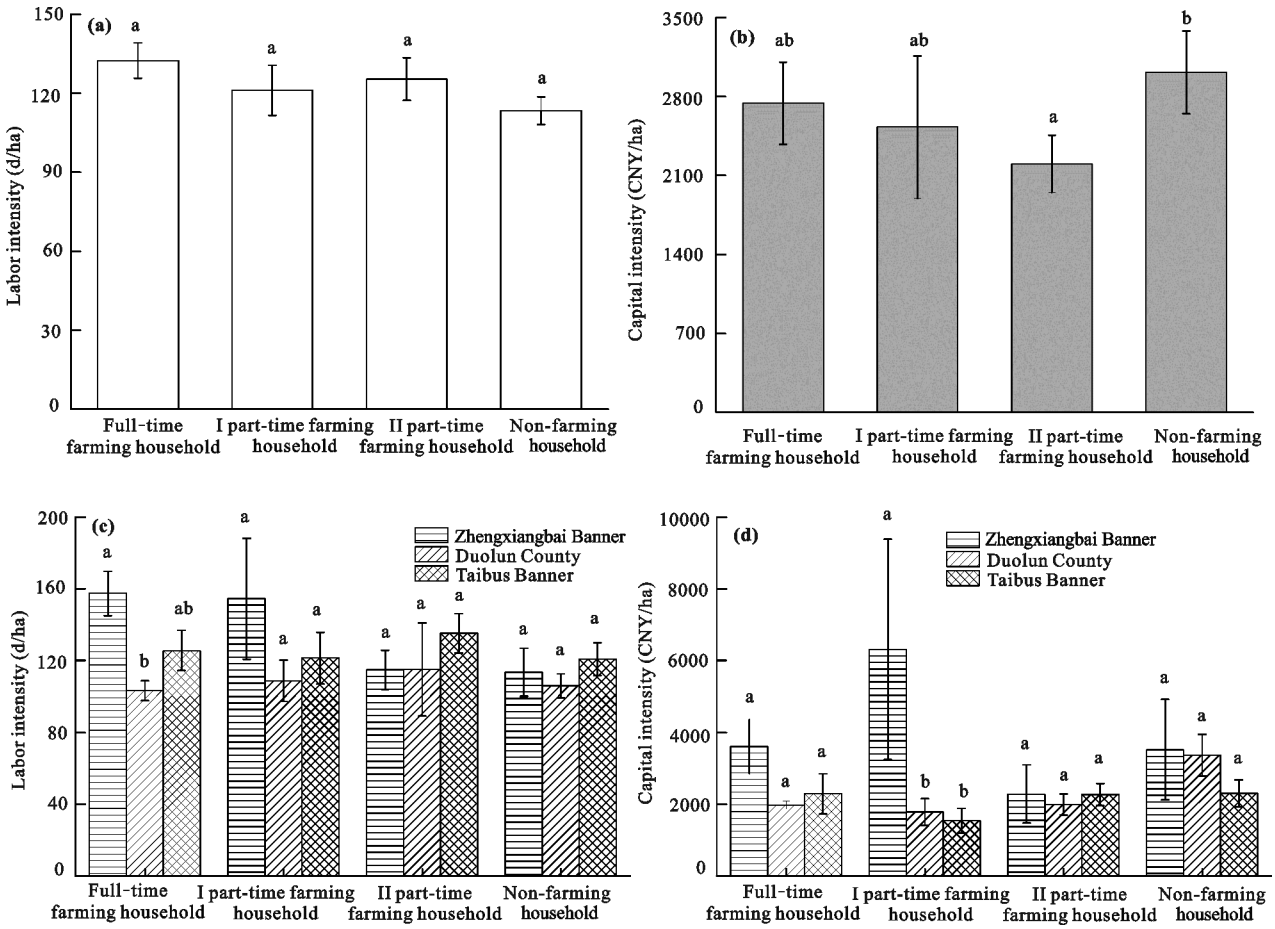

Fig. 4 Variance analysis of the farmland use intensity of different households. Different letters denote a correlation significance level of 0.05. If the different type households did not contain the same small letters, the difference between them was significant. (a), (b) indicated the labor intensity and capital intensity from different livelihood household. (c), (d) indicated the labor intensity and capital intensity of different livelihood households from three counties

analysis of the relationship between livelihood differentiation and farmland intensification in the three counties, we found that Zhengxiangbai Banner's investment in farmland was higher than the other two counties, especially for full-time farming and I part-time farming households.

4 Discussion

4.1 Driving effect of livelihood capitals on diversification

Rural households adopt a highly diverse livelihood to generate income, which allowed them to deal with market stress and natural disasters (Nguyen et al., 2019). Six determinants of livelihood diversification are recognized: seasonality, risk strategies, labor markets, credit market, asset strategies and coping behavior and adaptation (Ellis 2000a; 2000b). The studies of Bhandari (2013), Wang et al. (2016), Salazar et al. (2018), and Wan et al. (2018) revealed that labor decrease, farmland scale, amount of machinery, and income change could promote household diversification to different types. In our study, the physical and financial capital was the key driving factors of livelihood diversity, which subordinate to the asset strategies. And our study found that part-time and non-farming household had higher physical and financial capital than full-time farming households. The reason was that the existing farmland did not require too much labor in farmland management with the increasing production technology and factors of labor substitution. As a result, labor switch to other forms of employment, increasing the livelihood diversity. The part-time farming households have enough ma-

chines and farmland, and at the same time the non-farming employment bring more income, promoting the transition from part-time to non-farming household. The Bhandari (2013) study showed and confirmed that the non-farming employment significantly and positively influences the livelihood diversification in a village community of Nepal.

4.2 Main factors for farmland transfer from livelihood capital

In this study, households with more non-farming labor, more non-farming income, and more cultivated land per laborer tended to transfer out of farmland. Similar results were also appeared in the river basins of U.S. counties (Bhandari, 2013), the Miyun Reservoir watershed (Peng et al., 2017; Wang et al., 2017) and the Loess Plateau (Li et al., 2017). Non-farming labor and income bring diversity livelihood way, and broaden the revenue channels, leading the farmland transfer out. Non-farming work opportunities are consistently the key reasons for cultivated land transfer. Similarly, the cultivated land per laborer reflected the matching degree between the cultivated land management scale and the number of household laborers. Households who transferred out farmland can release labor. But there was an opposite case in the agricultural counties of Sichuan Province, where farmers with higher non-farming income would likely to transfer in farmland for the simultaneous development of both agriculture and non-agriculture (Shao, 2014). The different results between agro-pastoral areas and agricultural counties decided by the dependence on the farmland or the local economic development level. In our study, households with less agricultural machinery and smaller farmland sizes per plot were willing to transfer land into cultivation. Big Farmland size per plot and little agricultural machinery indicates farmland fragmentation. Farmland transfer will promote farmland scale management (Li and Li, 2018) and increase product efficiency (Schilling et al., 2014; Orea et al., 2015). Currently, with the development of agricultural technology and labor structure adjustment in China, households are tending to use machinery to save labor. So no matter transferring out farmland for labor migrated or transferring in farmland for labor-saving production, households can get a rational distribution of labor and a continuous improvement in household incomes in the agro-pastoral areas.

4.3 Main factors for farmland use intensity from livelihood capital

In our study, the age of householder significantly influence the labor input and capital investment. Old householders usually adopt traditional farming methods and they cannot accept new things easily. These results are supported by some findings that younger householders were more willing to withdraw time and labor from the farmland (Kilgore and Snyder, 2016; Zhao et al., 2016). Full-time farming household with older householder tend to invest in labor in farmland with traditional farming method, may leading to the low income. In this investigation the small farmland size per plot limited the machinery, increasing the labor consumption, which was reflected in the current reality. The less agricultural machinery and higher farming income promoted the large capital intensity. Households with fewer machines may have to invest more money in mechanical purchases and labor employment, as confirmed by the research of Shao (2014). When farming income becomes the primary source of livelihood, farmers will invest more money in agricultural practices to obtain greater benefits. Li et al. (2017) found in their study of the Loess Plateau that full-time farming households will put 60% of their income into chemical fertilizers, necessary materials, and even into expanding the farmland area. Our results indicated that, in agro-pastoral areas, most households with different livelihood capital decided to use labor-saving machinery to replace labor, and the labor transfer will further affect farmland use intensity.

4.4 Farmland use behavior of different livelihood-oriented households

There were significant differences in the farmland use behavior among different livelihood-oriented households. Full-time farming households were more disposed to transfer the farmland into cultivation and depended on farmland as the main source of household income. The more diverse the household's livelihood, the less the demand for farmland. The labor intensity did not show significantly different, showing that the labor was better deployed. The non-farming household had higher financial capital, and their income may be invested in agricultural machinery and equipment improvements (Alary et al., 2014; Udmale et al., 2014).

The results showed that farmland transfer due to livelihood differentiation was significantly different from full-time farming and part-time farming to non-farming, but farmland use intensity did not vary significantly. Therefore, this indicates that the dependence on the farmland will gradually decrease, but farmers will not completely withdraw from the farmland. The transfer in rate of cultivated land and capital intensity of part-time farming household from Zhengxiangbai Banner was significantly higher than other counties. In recent years, Zhengxiangbai Banner has a more mature farmland transfer environment and policy than the two other counties, and it will be an opportunity to improve farmers' benefits from green agriculture by farmland transferring in and money investment. In northern China and other regions around the world, ecosystem resources can enhance household welfare, so people never lose their focus on the farmland (Costanza et al., 2017; Dib et al., 2018; Hao et al., 2018; Collins et al., 2019). A healthy and moderate dependence on farmland and resources can bring out sustainable supply such as the food and energy (Liu and Wang, 2019), and living improvements (Everard et al., 2018). However, excessive dependence can lead to depletion of resources and environmental degradation, which in turn affect the sustainability of household livelihoods (Mirzabaev et al., 2015; Sandhage-Hofmann et al., 2015; Ito et al., 2016).

4.5 Policy implications of ecological protection and rural economic development

Typically, an agro-pastoral farming system is a crop-livestock mix. Therefore, off-farm employment is suitable for small farmland holders with a few animals, and they can lessen farming to reduce resource dependence and increase household welfare (Peng et al., 2017; Wang et al., 2017). Those with large areas of farmland need to learn rational farmland management for sustainable development (Flannery et al., 2015; Mikulcak et al., 2015; Garibaldi et al., 2017) with the long-term goal of achieving ecological stability and economic development (Travers et al., 2015; Vincent and Fleury, 2015). In this study, farmland transfer changed significantly, which was helpful to alleviate farmland pressure and improve agricultural efficiency. Therefore, under the limited natural capital, the enhancement of human, physical, and financial capital is extremely beneficial to reduce livelihood risk and improve land ecosystem security (Li et al., 2017). So the government should improve the farmland use rights transfer system and create a healthy market to promote large scale and modern farmland management (Hua and Squires, 2015; Zhang et al., 2018). Also they can strengthen farmers' training and financial invest, achieve 'labor transfer' to reduce farmland dependence and enhance farming efficiency. Furthermore, these policies can encourage households to adopt ecologically and economically balanced farming modes for soil conservation, and even improve their welfare (Kassie, 2017; Li and Li, 2017; Wang et al., 2017).

5 Conclusions

This study provides a basic foundation for how to improve economy and ecological protection in agro-pastoral areas. The intermediate links that affect both household livelihoods and farmland use strategies were selected for the study. This study quantified the livelihood capital based on the DFID's sustainable livelihood framework to describe the livelihood status of farm households. The households were then classified according to their non-farming income. Based on this, the impact of household livelihoods on farmland transfer and farmland use intensity was investigated.

An important conclusion was that in this study area, livelihood diversification of farming households was universal. Physical and financial capital were the driving factors for livelihood diversity. It was found that each livelihood capital had key factors that affected farmland transfer and farmland intensity of household. Factors that positively or negatively affected farmland use behaviors of farming household, including income, the education level of householders, the scale of cultivated land, number of agricultural machines and so on. Full-time farming households were highly dependent on farmland, and they tended to transfer the land into cultivation and invest more labor into their cultivated land. However, non-farming households tended to transfer farmland out. In addition, their high financial capital contributes to the high capital intensity, releasing laborers to non-farming employment.

In the future, households may gravitate to two poles: large farming households or non-farming households. To alleviate the dependence on natural resources and create high-quality living conditions, policy makers

need to comprehensively consider the livelihood characteristics of different farming households and their farmland use status. Governments can formulate differentiated policies to encourage the labor transfer, farmland contracting rights, optimization of farming methods, and other strategies. Increasing the financial subsidies and arranging technology training are effective and sustainable strategies. These approaches will hopefully contribute to achieving a win-win development scenario of sustainable livelihoods, ecosystem conservation, and stable agricultural production.

Currently, this research data did not include natural and social conditions such as the social economy, market environment, and government policies. Therefore, further research should expand the survey area and consider more factors. Furthermore, we will make an in-depth and comprehensive analysis of household livelihood changes and farmland use decision-making behaviors.

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