



Household livelihood change under the rocky desertification control project in karst areas, Southwest China



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ABSTRACT

The Rocky Desertification Control Project (RDCP) has become an important government measure to prevent soil erosion, restore vegetation, and pull farmers out of poverty in the karst areas of Southwest China. In order to understand the impact of the RDCP on households' livelihoods, we surveyed 150 households and collected a total of 117 valid questionnaires in 2013 to analyze the impact of the RDCP on their livelihoods and their livelihood response of the project. The results showed that RDCP significantly improved the process of household livelihood diversity and non-agriculturalization, and a distinct non-agricultural transfer of the rural labor force appeared after the RDCP implementation, characterized mainly by off-farm employment. But RDCP has no direct or significant impact on the increase of households' income which is primarily due to off-farm employment income. Although farmers emphasized on earning profits in the short run when they choose alternative livelihoods in the future, their choices are significantly impacted by the individual conditions. Furthermore, 38.5% of the households considered returning to agricultural production. Besides, households' concern on ecological environment is positively related with their dependence on environmental resources. To prevent a return to agriculture, it is important to develop compensation policies, to create new jobs, and to provide job training to help households construct new alternatives to returning to old livelihoods.

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1. Introduction

The rate at which anthropogenic activities are adversely affecting the environment is increasing. The impact thus far has been significant, and a sustainable coordinated development of humans and the environment has become a common goal worldwide (Li et al., 2011; Sachs and Reid, 2006; Robinson, 2009; Prosdocimi et al., 2016). China has made great achievements in economic development while environmental problems have become increasingly prominent, especially in ecologically fragile areas, such as desertification and karst rocky desertification (RD). The desertification occurs mainly in arid and semi-arid area in Northwest China with an area of $261.16 \times 10^4 \text{ km}^2$ in 2015 (The State Forestry Administration, 2015). Whereas the RD mainly distributes in subtropical humid areas in karst areas in Southwest China including

parts of the provinces of Guizhou, Yunnan, Sichuan, Guangxi, Guangdong, Hunan, Hubei, and Chongqing city (Fig. 2).

Karst rocky desertification is a term used to characterize the processes that transform a karst area covered by vegetation and soil into a rocky landscape almost devoid of all soil and vegetation (Yuan, 1997). The latest RD monitored results show that there is a RD area of $1200.02 \times 10^4 \text{ ha}$ and potential rocky desertification area of $1331.8 \times 10^4 \text{ ha}$ (The State Forestry Administration, 2012). At present, the RD research in China mainly concentrated on the spatial distribution (Bai et al., 2013), the classification and gradation (Xu et al., 2015), the driving factors (Xu and Zhang, 2014; Jiang et al., 2014; Yan and Cai, 2015), the evolution process, and the ecological and economic effects of RDCP (Xie et al., 2015; Peng et al., 2014; Xiong et al., 2012; Yue et al., 2012). However, the relationship between RD governance and household livelihood has not been fully considered in the background of multi-scale human-environment system previously.

The karst rocky desertification area is one of the poorest and most economically backward regions in the country where farmers live in poverty and their livelihoods heavily depend on environmental resources (Jiang et al., 2014; Su, 2012; Zhang et al., 2016),

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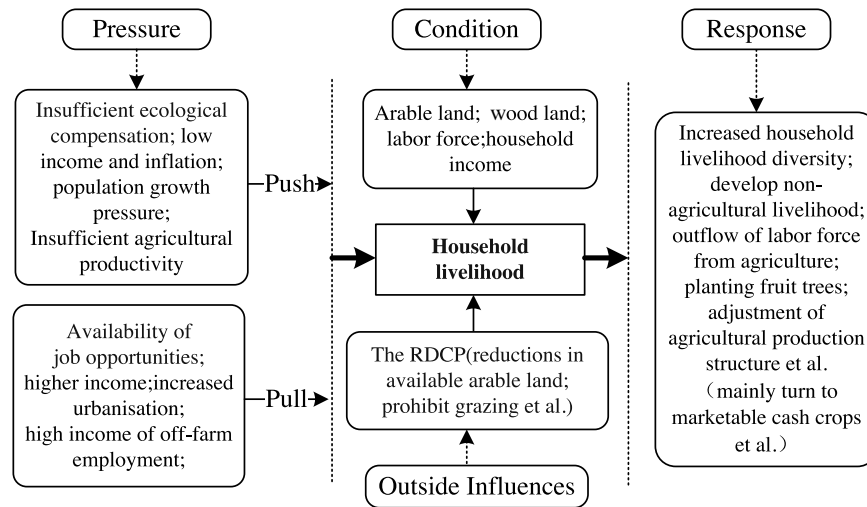


Fig. 1. Analysis framework of household livelihood changes in response to the RDCP.

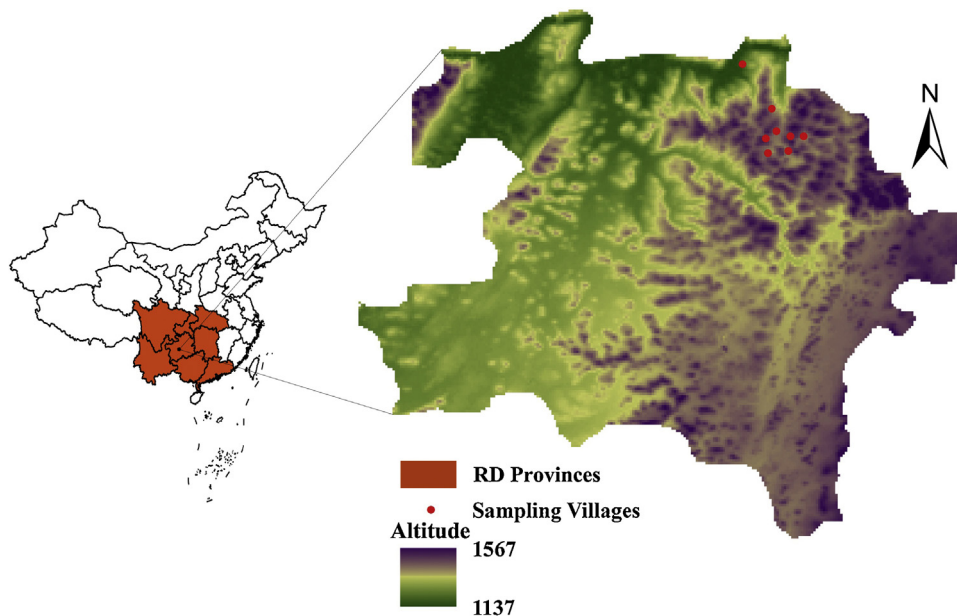


Fig. 2. The distribution provinces of Rocky Desertification in China and Geographic location of the study site.

and irrational human activities caused serious RD (Jiang et al., 2014; Zhang et al., 2016). To curb RD, the Chinese government has implemented the RDCP. The government invested 3 billion RMB (Chinese Yuan) in 100 pilot counties in the first stage of the RDCP between 2007 and 2008 (Jiang et al., 2010). The RDCP aims to prevent soil erosion, restore vegetation and alleviate poverty. The main measures are returning farmland to forests, planting fruit trees and timber forest and enclosing the hills to allow natural reforestation. In the RDCP, farmers were mainly compensated with free nursery stocks and grass seeds provided by the government. The farmers were employed to plant and offered a one-time labor remuneration of 600 RMB for one mu of land (one mu = 1/15 hm²), but there was no uniform standard for counties. After planting, the farmers managed the land independently and the income generated went solely to the farmers; there was no other direct compensation.

Studies of non-karst areas in China have shown that ecological restoration projects, such as Sloping Land Conversion Program (SLCP), helped alleviate poverty (Bennett, 2008; Cao, 2011; Cao et al., 2009a; Li et al., 2011; Uchida et al., 2007). However, the main

effects of poverty alleviation were achieved through alternative off-farm income sources rather than through ecological compensation (Lin and Yao, 2014; Yin et al., 2014), though some farmers eventually reclaimed the cultivated land in cases where the compensation didn't fully cover their loss from banned activities (Cao et al., 2010b; Cao et al., 2009b; Uchida et al., 2007), and the farmers lacked alternative livelihoods. This in turn caused further environmental deterioration. An example of such a failure in China is the Three-North Shelter Forest Program, where the survival rate of forest was only 15% (Li and Hu, 2001; Su, 2004). So the program did not inhibit desertification or the increase of land degradation (Cao et al., 2010a; Cao, 2012; Yang et al., 2005).

The area of afforestation is increasing as a result of the RDCP (The State Forestry Administration, 2012), but whether or not farmers will return to environmentally damaging agricultural practices after the RDCP mainly depends on whether the farmers change their livelihoods and land use practices. Only if the old livelihood model is changed, will the driving factors that damage the environment be eliminated. Therefore, the key to a successful RDCP is

the knowledge of what impacts farmers' livelihoods so that appropriate strategies can be developed to help farmers out of poverty alongside restoration strategies. This study focused on the impacts of the RDCP on farmers' livelihoods and how farmers responded to the RDCP and whether these policies could potentially contribute to improving household livelihoods. It aimed to provide a case study of a major environmental remediation policy in karst area that is ecologically, socially, and economically successful.

2. Analysis framework

In this paper, households refer to those whose livelihoods mainly rely on agricultural production to make a living. The livelihood system is an open, dynamic, balanced system where people obtain income through livelihood activities and maintain family life and reproduction through consumption. It has the ability to adjust and restore itself and produces an adaptive response to external stress. The types of livelihoods, such as livestock breeding and planting crops, have different adaptive responses to environmental stress (Djouidi et al., 2013). Whether the farmers adopt response strategies under external stress depends on livelihood types, regional or social background, and the local economy.

Therefore, we established the Condition-Pressure-Response analysis framework (Fig. 1) for household livelihood changes based on the Pressure-State-Response and Pull-Push theory for population mobility. In this framework, *condition* mainly refers to production capitals such as farmland, labor force, and agricultural development status; *pressure* refers to the factors that cause the deterioration in conditions and changes in old livelihoods, such as the reduction of arable land, a decline in agricultural earnings caused by drought, rural unemployment, and urban employment opportunities with higher incomes. According to the different roles in farmers' livelihood transformation, the factors are divided into "push" factors and "pull" factors (Fig. 1); *response* refers to the farmers' adaptive responses to conditions and pressures, such as diversified livelihoods and non-agricultural livelihoods. Moreover, *path dependence* (Freier et al., 2012; Jiang et al., 2012) causes farmers to maintain existing livelihoods. After considering the risks, households will strive to maintain their livelihoods in dynamic equilibrium when confronted with slow changes (modeled by *condition* and *pressure*), which may undermine their ability to make a living.

However, the dynamic equilibrium of the household livelihood system is broken when a strong outside influence like the RDCP is exerted, and farmers attempt to recombine their livelihood capitals so as to establish a new equilibrium (Fig. 1). This analysis framework clearly describes the processes involved in changes in household livelihoods and reveals the impacts of the RDCP on livelihoods as well as farmers' adaptive response to the RDCP, thus providing a new analytical viewpoint for eliminating the adverse effects of the RDCP, for improving relevant follow-up safeguard measures, and for properly guiding the reconstruction and development of household livelihoods.

3. Material and methods

3.1. Data collection

Seven natural villages covered by the RDCP in Puding County (105°27'14"–105°59'02"E, 26°10'28"–26°31'47"N), Guizhou Province, Southwest China were selected at random: Dazhai, Duimen, Xiaojing, Shanshulin, Diangang, Changsuoshai, and Shiren (Fig. 2). The RDCP took effect in the selected villages in November 2011. We randomly selected these villages without any attempt to bias the selection by choosing a representative range of

socio-economic conditions, except for the fact that they all were located in the peak cluster depression areas.

In order to improve the efficiency of the investigation, we conducted a field investigation of the study sites before the formal design of questions for the questionnaire. The main tools for quantitative data collection were household questionnaires, participatory rural appraisal, interviews with villagers, and village cadre symposiums. In each village, 15–20 households covered by the RDCP were randomly selected. The questions were answered by the head of the household, and additional information was provided by other family members. At the same time, we conducted face-to-face interviews with village leaders to identify the natural, economic, and population conditions of villages. As supplementary reference to the questionnaire, we carried out open-ended interviews on topics of interest to farmers such as existing policies of the RDCP implementation and their relative compensation.

We mainly investigated the influence on households' livelihoods and the adaptive response strategies the farmers took after the RDCP implementation. The survey collected information on key elements of households including household farmland area, income change and its causes, the quantity and variation of labor, livelihood changes, and changes in farmers' knowledge of karst ecosystem services and environment. Every question in the questionnaire had several choices, but only one could be chosen except when explicitly stated otherwise such as questions about source of income, factors affecting income, and likely future livelihoods, where multiple selections could be made. In addition, we prepared some open-ended questions concerning future livelihood patterns and their degree of difficulty in an attempt to further examine the impacts of the RDCP on household livelihood variation. Through field investigation and random questionnaires in households taking place between July 16 and August 1, 2013, a total of 117 valid questionnaires were selected for our research (150 questionnaires were collected in total) and those that contained incomplete responses were excluded.

We deemed the survey data to be accurate and reliable for the following reasons. First of all, households from the chosen villages were engaged in limited types of economic activities. They mainly relied on agricultural production and had limited sources of income. Second, the data were collected in short intervals; the RDCP was implemented in the study site in November 2011 and the data were collected in July 2013. The annual income data included the income data of 2011 and 2012, near to the RDCP implementation time. Third, the questions were answered by the heads of households with supplementary information provided by other family members to correct errors and fill in gaps. All questionnaires were strictly screened and unqualified questionnaires including incomplete ones were excluded. Finally, the amount of farmland owned by households was allotted by the government based on population, and the seedlings and tree-planting wages provided by the RDCP were based on the area of covered farmland.

3.2. Calculation formulas

To understand the difference in impacts of the RDCP on different types of household livelihood and the opinions of farmers with regard to environmental protection, we developed two indices, livelihood diversity index and knowledge index, which were calculated by Formulas (1) and (2), respectively.

The Livelihood Diversity Index (LDI) (1), V was introduced in order to depict the degree of livelihood diversity. That is, every means of livelihood was given the value 1; for example, in a household engaged in two livelihoods, livestock breeding and crop planting, the livelihood diversity index V would be 2. Single-business households were given a LDI of 1 while multi-business households were given a LDI greater than 1. Single-business house-

holds refer to farmers engaged in agriculture-based livelihoods. Multi-business households refer to farmers engaged in two or more livelihoods.

$$V = 1/n \times \sum_{i=1}^n d_i \quad (1)$$

where d_i is the LDI of the order of i household, n is the number of households and V is the LDI of the region.

The Knowledge Index (KI) (2). E was introduced to identify the understanding of households with different livelihoods with respect to the environment, karst ecosystem service value, and the RDCP. E can be calculated according to quantitative measure indices and their values (Table 1).

$$E_j = 1/n \times \sum_{i=1}^n h_{i,j} \quad (2)$$

where E_j is the overall knowledge index, n is the number of households, $h_{i,j}$ is the knowledge value of index j for household i ; j is one of the quantitative measure indices for knowledge of environment, which includes knowledge of environmental quality, knowledge of karst ecosystem services, knowledge of the RDCP, knowledge of income changes impacted by the RDCP, and knowledge of livelihood changes impacted by the RDCP.

4. Results

4.1. Changes in livelihood conditions

Overall, the impact of the RDCP was greater on single-business households than that on multi-business households. There was a clear decline in arable land owned by the farmers, declining by 2.33 mu from 4.69 mu to 2.36 mu per household in 2011, among which the average arable land of multi-business households and single-business households declined from 4.35 mu to 2.02 mu, and from 5.04 mu to 2.71 mu in 2011, respectively (Table 2). The farmland reduction did not decrease over time and the land covered by the RDCP was prohibited from being farmed after implementation. As a whole, the labor force dropped from 2.67 to 2.27 per household from 2011 to 2013, among which the average labor force of single-business households and multi-business households dropped from 2.84 to 2.26 and 2.53 to 2.29, respectively (Table 2). The labor force of single-business households declined more than that of multi-business households. Household income increased overall from 10,094.4 RMB to 16,142.6 RMB between 2011 and 2012, an increase of 59.9%. The income and income growth rate of multi-business households were higher than those of single-business households, and the income gap between the two types of households expanded from 1415.81 before the RDCP to 3759.2 RMB after the RDCP from 2011 to 2012 (Table 2).

4.2. Changes in household livelihood types

The household livelihood diversity index increased by 44.6% from 1.39 to 2.01 from 2011 to 2013. The proportion of multi-business households significantly increased from 36.75% to 76.92% with a significant decline of 40.17% in the proportion of single-business households from 2011 to 2013. Moreover, the transition to non-agricultural livelihoods was significant and consisted of off-farm employment, planting fruit trees and timber forest, and small business (Fig. 3). The household livelihoods were mainly made up of planting crops, off-farm employment, and livestock breeding, accounting for 95.6% before implementing the RDCP. The proportion of planting crops fell by 26.5% while the proportion of off-farm employment livelihoods significantly increased by 24.3% from 2011

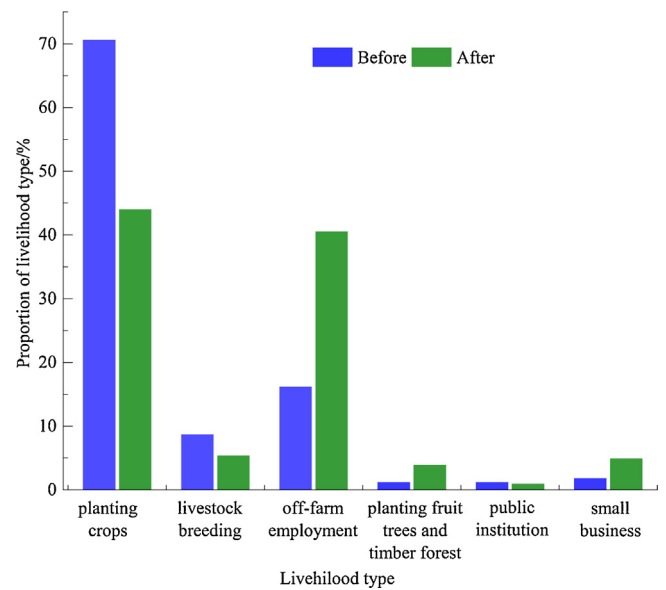


Fig. 3. The changes of households' livelihood composition before and after the RDCP.

to 2013 after the RDCP. There was a little increase in the proportion of farmers engaged in planting fruit trees and timber forest and small business while there was a slight decline in livestock breeding (Fig. 3).

4.3. Response of livelihood strategies

Livelihoods from planting crops and off-farm employment accounted for the largest proportion after the RDCP implementation at 84.7% of all livelihoods (Fig. 3). After the RDCP, the proportion of agriculture-based livelihoods (planting crops) significantly decreased from 70.6% to 44.1%, while the proportion of off-farm employment and small business increased; off-farm employment had a particularly notable increase from 16.3% to 40.6% between 2011 and 2013 (Fig. 3). The proportion of livestock breeding and planting of fruit trees and timber forest was small with a decline in livestock breeding and an increase in the planting of fruit trees and timber forest after the RDCP (Fig. 3). Among the livelihoods, farmers expected to be engaged in after implementation of the RDCP, off-farm employment and planting fruit trees and timber forest had the highest proportions, 36.3% and 25%, respectively (Fig. 4). The proportion of off-farm employment slightly declined when compared to the existing proportion of farmers engaged in off-farm employment (40.6%) (Fig. 3), but fruit trees and timber forest planting increased by 21.5%. The proportion of fruit tree and timber forest planting and livestock breeding accounted for 38.5% of future livelihood in total, close to that of the off-farm employment (Fig. 4).

The RDCP promoted the transition to non-agricultural livelihoods, but it had different impacts on households who were engaged in different types of livelihoods. The income source variation index and livelihood variation index of multi-business households were 1.28 and 1.31 respectively in 2013, higher than those of single-business households (Table 3). This is because after the RDCP was implemented, household livelihood diversity improved and the proportion of single-business households declined significantly by 40.17%, while the number of multi-business households increased 109.3% from 2011 to 2013 (Table 2 and Table 3).

Table 1
Quantitative measure indices and their values for households' knowledge index (KI).

Indices	the meaning of indices' evaluation	Indices' scores
Knowledge of environmental quality	Value of environmental quality	excellent = 4; fine = 3; modest = 2; poor = 1
Knowledge of karst ecosystem services	Value of the karst ecosystem service	familiar = 3; know = 2; not know but hear of = 1; never heard of = 0
Knowledge of the RDCP	The importance of the RDCP	very important = 3; fairly important = 2; not important = 1; never heard of = 0
Knowledge of income source variation	How the RDCP impacts changes in income source	large = 2; moderate = 1; almost none = 0
Knowledge of livelihood variation	How the RDCP impacts changes in livelihood	large = 2; moderate = 1; almost none = 0

Table 2
Household livelihood changes before and after the RDCP.

Types		Farmland area per household /mu	Income per household /RMB	The amount of labor per household	LDI	The number of households	Proportion%
Before the RDCP	Multi-business	4.35	10802.3	2.53	--	43	36.75
	Single-business	5.04	9386.49	2.84	--	74	63.25
	Overall	4.69	10094.4	2.67	1.39	117	100
After the RDCP	Multi-business	2.02	18022.2	2.29	--	90	76.92
	Single-business	2.71	14263.0	2.26	--	27	23.08
	Overall	2.36	16142.6	2.27	2.01	117	100

Table 3
Households' KI before and after the RDCP.

Types		Environmental quality	Karst ecosystem services	The RDCP	Income source variation	Livelihood variation
Before the RDCP	Multi-business	2.16	1.2	2.49	--	--
	Single-business	1.92	1.26	2.39	--	--
	Overall	2.04	1.23	2.44	--	--
After the RDCP	Multi-business	2.0	1.21	2.46	1.28	1.31
	Single-business	2.04	1.33	2.33	1.15	1.15
	Overall	2.02	1.27	2.39	1.22	1.23

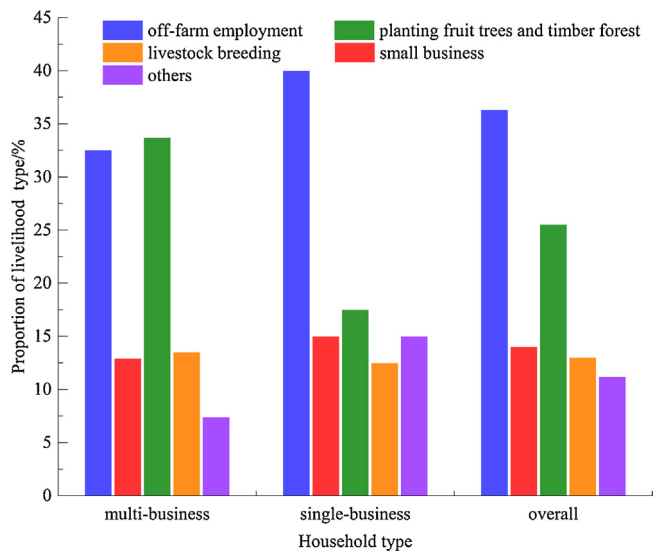


Fig. 4. Composition of future livelihoods that different types of households expect to be engaged in after the RDCP.

4.4. Changes in knowledge index

Generally speaking, there was no significant impact on households' knowledge of environmental ecology after the RDCP implementation with only a slight decline from 2011 to 2013 (Table 3). However, households' knowledge of karst ecosystem services gradually increased, particularly among single-business households.

5. Discussion

5.1. Mechanism of household livelihoods response

The household livelihood diversity significantly improved after RDCP. The RDCP triggered off-farm employment to deal with the impact of itself as an alternative livelihood. Under the influence of external "pull" factor of high income of off-farm employment, a majority of farmers had a strong motive for off-farm employment before implementing the RDCP. Meanwhile, the internal "push" factors of the decline of farmland and ban on grazing caused RDCP triggered non-agricultural livelihood transformation. The result showed that as an internal "push" factor, the RDCP promoted notable outflow of the labor force and non-agricultural transfer of household livelihoods characterized by off-farm employment.

There is a phenomenon of a notable increase in the proportion of off-farm employment after the RDCP. The internal "push" factors are the decline in the amount of farmland and the agricultural labor force caused by RDCP. Both reduced almost at the same time and the reason was that the farmland was evenly allotted according to population size and the market trading of farmland was prohibited. The reduction of farmland brought down the demand of agricultural production for labor and thus caused the surplus agricultural labor, providing a foundation for transition of the rural labor into non-agricultural labor. Meanwhile, China has become a "world factory" with a high demand for its labor force without requirement of high educational level, and off-farm employment income is higher than that of agricultural production, which is the most important external "pull" factor.

The household income increased after the RDCP. But the increased income was mainly derived from off-farm employment, especially for single-business households. The RDCP triggered a

significant non-agricultural outflow of the agricultural labor force, mainly characterized by off-farm employment. It is consistent with studies of the SLCP in the Loess Plateau region (Lin and Yao, 2014; Yao et al., 2010; Yin et al., 2014; Zhen et al., 2014). However, some studies indicated that there was no apparent transfer of the labor force into off-farm work after the SLCP (Uchida et al., 2007), which is because the SLCP offered higher compensation and the rural surplus labor force has not been absorbed by China's less-developed economy in 2003. This also implies that ecological restoration policies must be made matching macro socio-economic circumstances. Meanwhile, Giger et al. (2015) studied sustainable land management technologies in many countries and concluded that economic factors were key determinants of farmers' decisions and behaviours.

The impact of the RDCP on multi-business household livelihoods is less than that on single-business households. Multi-business households are less affected by the reduction in farmland and policies such as the ban on grazing. The reason is that they have more diversified sources of income and do not rely only on a single agricultural income. The research on forest degradation and rural poverty questionnaires in Iran also showed that the poor households' income was more from livelihoods which were only dependent on agriculture (Soltani et al., 2012). In detail the income gap between single-business households and multi-business households gradually increased. There are two reasons of the increased income gap. On the one hand, multi-business households make the change of livelihoods more likely to be realized. Because multi-business households had congenital advantages over single-business household in some aspects, such as rich social network et al. Previous research has shown that personal experiences and social networks had an important impact on farmers' ability to develop new livelihoods (Hunter et al., 2013). On the other hand, the RDCP does not allow farmers to graze on mountains or to cut forests and firewood, which also had certain negative effects on household livelihood, especially on single-business households mainly engaged in the agriculture-based livelihood.

5.2. Household livelihood selection

The farmers pursue short-term benefits and low risk when they select alternative livelihoods. Compared with small business and planting fruit trees and timber forest, the off-farm employment requires little prior investment and has low risk, so off-farm employment became the farmers' first choice for an alternative livelihood (Table 2 and Fig. 3). In composition of household livelihood changes, there was only a slight decline in the proportion of livestock breeding with the improvement of households' diversified livelihoods. The main reason is that farmers chose mixed strategy in livelihoods based on livelihood security. Soltani et al.'s (2012) research on relationship between forest degradation and household livelihood strategies in Iran also showed that most households (64%) chose mixed livelihood strategies. Moreover, the ban on grazing and the non-agricultural livelihoods that led to the reduction in the demand of animal power for agricultural production had a negative impact on the livestock breeding.

Small business is a local activity and plays a better driving role among the farmers, but it needs a certain amount of money and management ability, so it only increased by 3% (Fig. 3). Lack of capital and technology (Gray and Mueller, 2012; Mortreux and Barnett, 2009), and poor low levels of market integration between sending and receiving areas (Morrissey, 2013) were important factors limiting farmers in small business. The above situation also appeared in ecological restoration projects in semiarid regions in Zambia (Customer Unity And Trust Society-International Lusaka, 2013) and Kenya (Recha et al., 2015); besides, their farmers' poor education blocked the promotion of new technologies.

Planting fruit trees and timber forest takes a long time from cultivation to generating stable economic benefits and requires certain production management technologies and a market environment with relatively stable prices. In addition, the RDCP supporting and safeguard policies are imperfect, especially the lack of long-term support policy guiding farmers in transitioning to alternative livelihoods. A study of Soil Conservation Project in Tanzania showed that long-term investment significantly contributed to the success of the project (Ligonja and Shrestha, 2015).

The farmers selected alternative livelihoods considering long-term benefits of alternative livelihoods with increasing age and physical decline as well. From the composition of future alternative livelihoods the farmers expect to be engaged in after RDCP (Fig. 4), there is a slight decline in off-farm employment and a significant increase in fruit tree and timber forest planting. We suggest that based on long-term considerations for the future, the farmers may return to the countryside when they become less competitive in the labor market with age and physical decline, and the return is also affected by the fluctuation of China's economic growth rate. Besides, for the purposes of vegetation recovery and helping farmers alleviate poverty, the government gave priority to supporting the construction of alternative livelihoods, mainly with the planting of fruit trees and timber forest, which had a higher added economic benefits compared with the agricultural products, and suitable nature environmental conditions.

Meanwhile, livelihood path dependence is also an important reason why farmers tend to choose to plant fruit trees and timber forest as a future alternative livelihood. But it is worth noting that the farmers' spontaneous livelihood construction often only considers self-interest at the expense of the environment. The existing environmental situation shows that the farmers' reclamation often leads to failure in environmental engineering, resulting in the degradation of the environment again due to the lack of alternative livelihoods after compensation (Cao et al., 2009b; Komarek et al., 2014; Salafsky and Wollenberg, 2000).

5.3. Household livelihood and environment

Livelihood diversity helps reduce households' dependence on environmental resources, thereby helping environment restoration. Off-farm employment causes the outflow of the rural population and reduces regional population and environmental pressures, which is beneficial for maintaining RDCP achievements. This conclusion is consistent with the results of the study on ecological restoration in the Wuyi Mountain Area, Fujian, China (Wang et al., 2011), as well as the studies on combating desertification in Asia, Africa and the rest of the world (Heshmati and Squires, 2013). As an external "pull" factor, the rapid development of China's overall economy effectively promotes the non-agricultural transfer of the rural labor force and improvement of household livelihoods, so as to indirectly facilitate the restoration of the ecological environment.

The degree of farmers' concern and knowledge of environment depends more on the impacts the environment has on themselves. The more dependent they were, the higher the KI. The reduction in households' KI is mainly caused by less dependence on environmental resources after the improvement of livelihood diversity. As shown in Table 3, the farmers' knowledge of the karst ecosystem services increased after the RDCP implementation, particularly among single-business households. This is because single-business households are mainly engaged in agriculture-based livelihoods and have higher dependence on environmental resources, and their residential energy resources mainly come from firewood cutting. Besides, regional culture has important impacts on ecological restoration. Traditional cultures of Miao nationality in Tangan in Guizhou forbid cutting wood. Whereas, farmers in Blue Nile basin

in Egypt were reluctant to construct ecological restoration projects because of the religious views (Ayele et al., 2016).

5.4. Suggestions on the RDCP supporting policies

Based on the aforementioned lessons, we believe that the key to success of rocky desertification control is the realization of farmers' livelihood diversity. The control of desertification involved economic, social and environmental factors (Heshmati and Squires, 2013) and the farmers' livelihood transformation is affected by regional resources, national-regional situation and farmers' own conditions, hence it is necessary to get multi-faceted supports in finance, policies, market information, education and technology.

Therefore, we suggest that three supporting policies should be taken by the RDCP: (1) Technical training and employment information should be provided to improve the competitiveness of the rural labor force in the labor market and accelerate the non-agricultural transfer of rural labor to reduce the population pressures on the environment. (2) The breeding of economic crops (such as fruit trees and timber forest) in karst areas should be increased to create a new agricultural development pattern that cultivates alternative industries for rural economic development, new jobs, and new rural policies benefited farmers should be created to provide farmers with diversified alternative livelihood choices. (3) The compensation standard of the RDCP should be improved and appropriately increased with the development and inflation of socio-economy to reduce the motivation of farmers to destroy the environment again. Meanwhile, the success of rocky desertification control should be linked to the ecological compensation standard so as to improve the initiative of the farmers participating in rocky desertification control and their attention to maintaining its achievements.

6. Conclusions

The RDCP has substantially and positively affected land use and improved ecological environment in karst areas in Southwest China by simultaneously retiring degraded land and increasing vegetation covers. Through the analysis of our case study results, we may draw the following conclusions: (1) Household livelihood diversity significantly improved after the RDCP, which promoted notable outflow of the labor force and non-agricultural transfer of household livelihoods characterized by off-farm employment. But the RDCP has no direct or significant impact on the increase of farmers' income which is mainly from off-farm employment. (2) Farmers tended to pursue short-term benefits and low risks when they selected alternative livelihoods; meanwhile, they took long-term benefits into consideration of future livelihoods with increasing age and physical decline as well. (3) The farmers' knowledge of environment was mainly affected by how much the farmers depended on environmental resources.

In addition, this study was carried out at the micro-level, and it may prove difficult to generalize results and make policy recommendations to the region as a whole. Study of a larger area might reveal more diversified livelihood strategies; however, micro-level studies have certain advantages such as keen attention to detail, which can often be ignored in large-scale studies. Moreover, because the interval between the study period and the time of the RDCP implementation was small, changes in future households' diversified livelihoods and non-agricultural livelihoods need to be further studied.

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