

REPORT

The impact on rural livelihoods and ecosystem services of a major relocation and settlement program: A case in Shaanxi, China

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Abstract China's largest-ever resettlement program is underway, aiming to restore ecosystems and lift ecosystem service providers out of the poverty trap and into sustainable livelihoods. We examine the impact of the relocation and settlement program (RSP) to date, reporting on an ecosystem services (ES) assessment and a 1400-household survey. The RSP generally achieves the goals of ES increase and livelihood restore. In biophysical terms, the RSP improves water quality, sediment retention, and carbon sequestration. In social terms, resettled households so far report transformation of livelihoods activities from traditional inefficient agricultural and forest production to non-farm activities. Increased income contributes to decrease the poverty rate and improve resettled households' living condition and standard. Meanwhile, the RSP decreases households' dependence on ES in terms of provisioning services. Difficulty and challenge also showed up subsequently after relocation. A major current challenge is to enable poorer households to move, while providing greater follow-up support to relocated households. While the program is unique to China, it illuminates widespread opportunities for addressing environmental and poverty-related concerns in a rapidly changing world.

Keywords Ankang prefecture · Ecosystem services · Human development · Relocation and settlement · Rural household · Sustainable livelihoods

INTRODUCTION

In order to mitigate natural disasters caused by ecosystem degradation, to restore vital ecosystem services and to improve human well-being, Shaanxi Province, China initiated the Relocation and Settlement Program (RSP) in 2011—the largest resettlement program in the history of China. It plans to move 2.4 million people from 28 counties in three prefectures over 10 years. These people live in steep mountainous areas that are prone to landslides and flooding and where poverty is widespread. This relocation program is tied to China's massive South-to-North Water Transfer Project. This project is designed to deliver high-quality water to arid North China by reducing the amount of highly erodible farmland and agricultural runoff into the nearby source, the Danjiangkou Reservoir. While attracting much attention in terms of scale, budget, and duration, doubts have also been raised in the context of past relocation programs, especially the Three Gorges Dam resettlement, which moved 1.5 million people to make way for major hydro-electric infrastructure and resulted in serious problems, in part because people were forced to move (Li et al. 2001; Duan and Steil 2003). Although the number of people to be relocated is far larger than in the Three Gorges Dam resettlement, this program is voluntary, and is designed to improve the well-being of both the people and ecosystems involved.

In the second half of the twentieth century, more than 45 million people were displaced by development programs in China (Fuggle et al. 2000; Stanley 2004). Since the turn of the century, two main types of relocation constitute the majority of resettlement in China. These are ecological resettlements, like the Three-River Headwater Region relocation (Rogers and Wang 2006; Wang et al. 2010), and poverty alleviation resettlements (Xue et al. 2013),

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respectively. Most often, the kinds of programs proposed fulfill dual purposes by considering the characteristics of Coupled Human and Natural Systems (CHANS) (Liu et al. 2007). Firstly, there was serious environmental degradation and crises along with China's economic growth during the past decades (Liu and Diamond 2008). Secondly, after implementing several rounds of the poverty alleviation policies from the central government to local governments, the poverty reduction rates were decreasing; meanwhile, the cost per capita was increasing and a higher proportion of the population was at risk of falling back below the poverty line (Shi and Zheng 2010). From 2001 to 2015, over 6.8 million poor people have been resettled. According to the National Development and Reform Commission (NDRC), this aim will rise to 10 million in the forthcoming "The 13th Five-year National Plan (2016–2020)." Most of these individuals belong to the impoverished populations that are mainly located in remote and environmentally fragile areas (Xue et al. 2013). Physical relocation of the rural poor away from these "dead corners" has become an attractive option for reducing rural poverty. The expanding use of resettlement as a tool for addressing environmental and poverty-related concerns calls for further research into the impact on both the environment and the local populations.

However, in theory and in practice, resolving the vexing dilemma between environmental protection and livelihood improvement is neither new nor easy to resolve (Cernea and Schmidt-Soltau 2003). Since the surge of attention to ecosystem services (ES) in the 1990s (Daily 1997; MA 2005), there has been a strong focus on the dual goals of poverty alleviation and ecological conservation, for example, through payments for ecosystem services (PES) policies (Pagiola et al. 2005; Daily and Matson 2008). In contrast to China's other eco-compensation policies (Liu and Diamond 2008; Wang et al. 2010), the RSP is far larger than a single-payment scheme for ES conservation; it represents a new paradigm for integrating conservation and human development for the long term. It is a bold attempt to halt and reverse environmental destruction, while at the same time promoting human development in ecologically fragile regions. Specifically, the government aims to lift ES providers out of the poverty trap and into newly opened non-farming sectors, thereby reconciling conservation and poverty alleviation (Ouyang et al. 1999; Zheng et al. 2013). The success and wider applicability of this approach hinges on achieving the double sustainability of improving both ES and local livelihoods (Cernea and Schmidt-Soltau 2003; Daily et al. 2013; Li et al. 2015).

Previous studies paid much attention to the observed impacts of resettlement programs in terms of the environmental issues (carrying ability, water quality, fisheries, sediment flows in the river and geological instability, and

so on) and the population issues (health risk, land and other resources, food security, plus food production, and income levels). While all studies mentioned above contributed significantly to understanding the social–ecological impacts of resettlement in China, most of them are limited and restricted to relatively small temporal or spatial extents. Even fewer studies combine these two aspects together by approaching the resettlement as a process with multiple outcomes. However, it is not effective to study human and natural systems separately when addressing social–ecological and human–environment interactions (Liu et al. 2007). Though our previous study (Li et al. 2015) evaluated the policy efficiency by combining the two aspects together and considered the RSP program as a whole system, it however emphasized on ES and the main thread was the generation and delivery of ES at different scales and time periods. Additionally, much less is known about how people, those whose livelihoods are affected by resettlement programs, adapt or try to adapt to their new location and what factors enable them to restore their livelihoods, or prevent them from doing so. Moreover, quantitative analyses of resettlement, which complement the more qualitative sociological and anthropological research efforts to better understand the patterns and trends of this complex issue, are needed.

Therefore, one objective of this study is to explore the process of change and adaptation after the resettlement, with a particular focus on livelihood assets, strategies, and outcomes. A second objective is to shed light on the general impact of resettlement programs on ES. We first use land use and land cover (LULC) data to assess ES change on a macro scale, and also use household survey data to assess the households' dependence on ES. Thereafter, adopting the Sustainable Livelihoods Framework (SLF) as an analytical framework (DFID 1999), we use household survey data and econometric approaches to identify those changes in livelihood assets and strategies that helped households rehabilitate their livelihood after resettlement. The identification of these factors is important for improving the planning of resettlement programs in the future, and for identifying policy interventions that may help reduce the adverse impacts of resettlement.

MATERIALS AND METHODS

Study area

This study focuses on the prefecture of Ankang, one of the three prefectures involved in the RSP, located in the southern province of Shaanxi at the northern base of the Daba Mountains and south of the Qinling Mountains on the upper stream of the Han River. This river is the largest

tributary of the Yangtze River and is also the main water source for the middle route of the South-to-North Water Transfer Project, the largest water transfer project in the world (Fig. 1). 92.5% of the Ankang region is steeply mountainous, and prone to frequent natural disasters, such as flooding, landslides, debris flow, that result in severe economic losses every year. Farmland is very limited and accounted for only 21% of Ankang in 2010. Moreover, farmland with slope <15% accounted for only 41% of the total farmland in Ankang in 2010. Most of the farmland has low productivity due to low soil fertility. Sloping farmland contributes greatly to geological disasters and severe soil erosion. Ankang has historically been a disaster-prone area (mostly floods and landslides) and disaster relief and

prevention are major concerns for local governments. Since 1980, the reasons for relocation have expanded to include poverty alleviation and environmental protection.

The Ankang prefecture typifies much of western China, with serious short-term conflicts between conservation and livelihood activities of the poor. With mountains covering most of the region, Ankang is not only an ecologically fragile area, but also a typically poor area. Nine of Ankang's ten counties are states designated as poor or extremely poor; therefore, Ankang was designated as one of the 18 Nationally Contiguous Poor Areas by the central government at the National Poverty Alleviation Conference in November 2011. Restricted by the limitation of farmland as well as the eco-conservation policy of “send



Fig. 1 Ankang Prefecture (23 534 km²) in Shaanxi Province. The blue line between Ankang and Beijing in the China map is the Middle Route of the South-to-North Water Transfer Project (SNWTP)



Fig. 2 Scenes of the areas surveyed: **a** Road damaged by landslide; **b, c** Surveying rural household members in the original community. **d** New homes, with power lines and light poles in the background

clean water to Beijing,” poverty alleviation is one of the great challenges for the local government. Among the 2.63 million permanent resident population of Ankang prefecture, people living below the poverty line account for one-third (354 USD per capita per y; 1 USD = 6.5 CNY in 2011, at the start of the RSP). The RSP is now underway to move 226 thousand rural households (876 thousand local residents) from very remote and steep mountainous areas of the Ankang prefecture to safer places with better access to public services (Fig. 2).

There are several standards that determine eligibility for the RSP. Households or villages that meet the following criteria are eligible: (i) those threatened by geological disaster, flooding, or other natural disasters; (ii) those far away from the center of the administrative village, with poor infrastructure and production conditions, and low development potential; (iii) those that have small population size as well as low income; (iv) those located in a remote mountainous area with inconvenient transportation, such as being more than 5 km away from a main road; and

(v) those located inside nature reserves, historic reservation areas, and ecologically fragile and sensitive areas. Households that meet the eligibility criteria described above can choose to relocate. They may select one of three relocation modes: relocation to an urban area, scattered relocation, or centralized relocation. Households that choose to relocate to an urban area are free to choose any urban area. In scattered relocation, households move to another rural area, depending on the willingness of the local population and the availability of land in the community in which they relocate. In centralized relocation, households within a village all move together to another location. The move to this new location depends on preferences of village residents and on the availability of land.

Ecosystem service assessment

The RSP will lead to significant LULC changes, not only in the origin areas but also in the relocation areas. These will impact the production and delivery of multiple ES and their

stakeholders, such as the local households and downstream water resource users. To assess the impacts of the RSP on ecological systems, the ES (closely connected with the well-being of these stakeholders), including sediment retention, nitrogen and phosphorus purification as well as carbon sequestration, were assessed in this study. We assessed the impact of the RSP on ES by using the following procedures: (i) Identified the RSP planning scenarios, namely, the RSP that involves 226 thousand rural households (ca. 450 000 local residents during 2011–2015 and ca. 427 000 more during 2016–2020). (ii) Obtained the LULC maps for RSP planning in 2015 and 2020 in the Ankang Municipality based on the LULC data in 2010 and RSP planning scenarios for the periods 2011–2015 and 2016–2020 by using land-suitability assessment methods. (iii) Assessed ecosystem services of water purification and sediment retention based on actual land use in 2010 and RSP planning scenarios for 2015 and 2020, using InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) models. InVEST quantifies and maps ecosystem services provided by an existing landscape or under future scenarios (Sharp et al. 2015). We also assessed carbon sequestration services of each LULC type. The main parameters for InVEST model running and carbon sequestration service assessment are described in detail in our previous study (Li et al. 2015).

The reference study used the index of dependence on ecosystem services (IDES) proposed by Yang et al. (2013) to quantify the relocation households’ dependence on ecosystem services. The overall index of human dependence on ecosystem services is defined as the ratio of net benefits obtained from ecosystems to the absolute value of

total net benefits that derived from ecosystems and other socioeconomic activities (e.g., migrant work, and small business unrelated to ES). In addition to the overall index, a sub-index can be calculated for each category of ES (MA 2005).

Livelihood assessment

Sustainable livelihoods framework

Following previous studies (DFID 1999; Wilmsen et al. 2011a, b; Kabra and Mahalwal 2014), this study uses the SLF as an organizing framework to provide a micro-level perspective on the effects of the RSP (Fig. 3). The SLF is a tool developed to facilitate a broad and systematic understanding of the various factors that constrain or enhance livelihood opportunities and the interrelationships between these factors (Krantz 2001). More specifically, it explores the strategies, assets, context and underlying policies, institutions or processes that underpin sustainable livelihood outcomes (Scoones 1998). In this study, the SLF can provide important methodological advantages over a micro-level perspective for rapid appraisal of overall impacts of displacement on the resettlement populations. This allows for a comprehensive inventory of assets and livelihood changes due to displacement, while enabling researchers to explore the linkages between change of assets, emergence of new opportunities, and the resultant changes in livelihood outcomes such as food security, income, and vulnerability (Kabra and Mahalwal 2014).

This study focuses on five main classes of assets that represent households’ capability to attain self-development

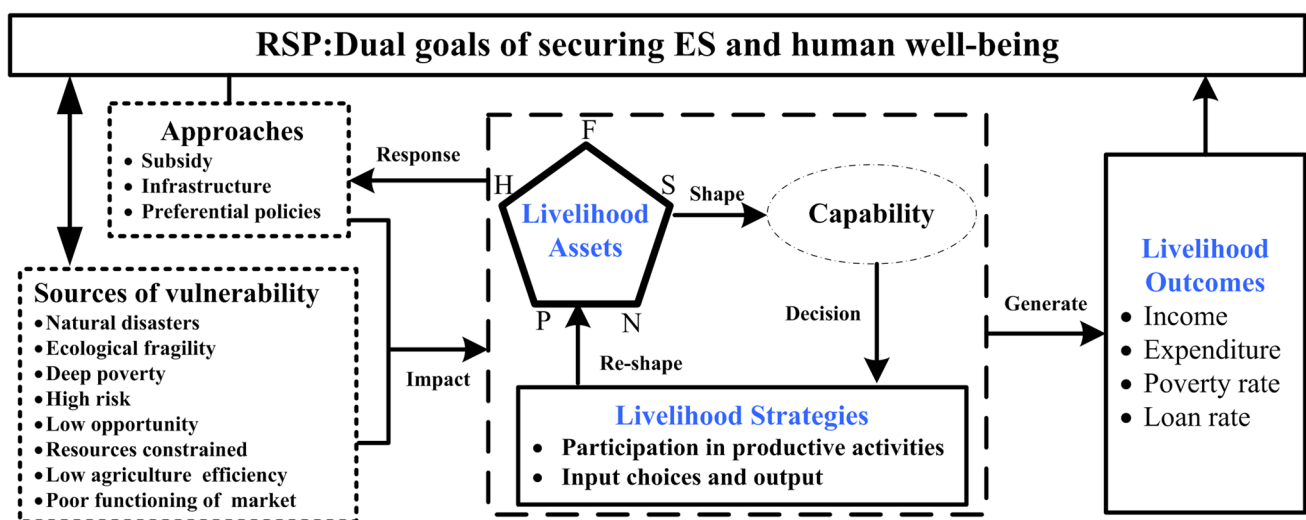


Fig. 3 A livelihoods framework for assessing the impact of the Relocation and Settlement Program of Southern Shaanxi Province (RSP). Livelihood assets include five capital stocks, physical (P), human (H), financial (F), social (S), and natural (N)

(Bebbington 1999), including natural assets, physical assets, human assets, financial assets, and social assets. Although some of these assets do not satisfy the orthodox economic definition of capital assets, all five are useful for understanding the construction of households' livelihood strategies (Ellis 2000). Different livelihood activities and choices result in different outcomes. The outcomes here include both objective and subjective aspects, where the objective outcomes include households' income, expenditure, poverty rate, and the indebtedness. The subjective outcomes mainly include the resettlers' cognition, attitude, and evaluation of their post-relocation life.

Household surveys

The data used in this study come from the Households' Livelihood and Eco-environment Survey conducted by the Institute for Population and Development Studies of Xi'an Jiaotong University. The survey includes questionnaires for rural households and communities, and some semi-structured individual interviews and focus groups, as follows. First, we selected five focal counties (out of nine) in the Ankang prefecture according to their GDP: one from the first rank (3 counties); one from the third rank (3 counties); and three from the middle rank (3 counties). Second, in each selected focal county, we selected three townships for detailed study. All selected townships satisfy the criteria of having resettling communities, natural reserves, and PES policies. Then, a total of 25 administrative villages were selected as the sample target; among which 15 were randomly chosen and 10 were new villages for relocating people. Fourth, villager groups were randomly chosen within the 25 target villages. Finally, all the rural households inside sampled groups were surveyed. The head of the households (hereafter referred to as householder), or a family member over 18 years old, were asked to complete a questionnaire.

In total, 1570 questionnaires were distributed. 1404 valid questionnaires were collected, including 408 relocation households and 996 non-relocation households. The questionnaire focused on the household-level: (i) demographic characteristics; (ii) livelihood assets (natural, human, financial, physical, and social capital); (iii) livelihood activities (e.g., crop and forestry production, rural-urban cyclic migration, local non-farm enterprise); (iv) labor allocation; and (v) consumption and expenditure. After excluding samples with missing or extreme values, we included 1306 samples in the analysis as a whole, comprising 361 households relocated from mountainous regions (HHr,sc, relocation, settling community); 202 households that chose to remain in communities from

which people are moving (HHn,oc, non-relocation, original community); and 493 original households in the communities where migrants are settled (HHn,sc, non-relocation, settling community) as well as 250 samples that could not be placed into any of these three categories.

Statistical analysis

By comparing the differences among these groups, the effects of the RSP on households' livelihoods were further estimated. We first used Analysis of Variance (ANOVA) to compare differences in livelihood assets, livelihood strategies, and outcomes among the three groups. Then, the effect (average treatment effect, ATT) of the RSP on the households' livelihoods for both relocation households and non-relocation households is determined, employing 'Propensity Score Matching' (PSM). PSM controls for self-selection, based on observables, without relying on strong distributional assumptions (Rosenbaum and Rubin 1983). PSM estimators have been developed to correct for non-random selection and to pair each treated observation (relocation households) with a similar control observation (non-relocation households) on the basis of their propensity scores. This allows us to conquer the shortfall of cross-sectional data for interpretation of the outcome of the control observation as the counterfactual outcome of the treated observation in the absence of treatment. Matching on the basis of the propensity score enabled the relocated to be compared to non-relocated households that are otherwise similar in terms of their observed characteristics, thereby correcting for self-selection of relocation, conditional on those observables.

PSM applied here consists of the following steps: First, a Probit regression model of the treatment variable (Table S1) is estimated, that is, the households participating in RSP. Second, the parameters of the Probit model are used to calculate the propensity score; that is, the predicted probability of participating in the RSP for each household, based on the observed characteristics included in the model. Third, using the estimated propensity score, each relocation household is matched with the nearest non-relocation household, using the "nearest neighbor" matching procedure with replacement. Fourth, once a relocation household has been matched with the nearest non-relocation household, the observed livelihood of the latter is imputed for the former.

To examine the matching results of the sample, as well as to illustrate the rationality of using PSM, we compared both the propensity score density of the control and treatment groups by matching. The density graphs are presented in Figure S1.

RESULTS

Impact of resettlement programs on ecosystem services

ES assessment: macro scale

With the implementation of resettlement during 2011–2020, significant LULC changes took place. The largest were in terms of area from farmland to forests, and the other is from gently sloping grassland and bare (rocky/sandy) land to urban land (Li et al. 2015). The LULC changes led to changes of ecosystem services. According to the program plans, by 2020 5% of sediment retention, 7% of total nitrogen retention, 8% of total phosphorus retention, and 6% in carbon sequestration will be increased in comparison with those in 2010 (Fig. 4). As one of the most important water sources of the South-to-North Water Transfer Project, the RSP of Ankang brings significant benefits to downstream water-receiving areas.

ES assessment: household scale

From Table 1, it can be seen that the comparative analysis found that there are significant differences in the overall IDES among the three groups. The average IDES of HHr,sc is dramatically less than that of the other groups. Meanwhile, the sub-index of provisioning services, which account for most of the IDES, also showed the same trend. The PSM estimation confirmed that the RSP had a significant effect in decreasing the households' dependence on ES, especially on the provisioning services. The relocation households made less use of ES after relocation.

Table 1 ANOVA and PSM estimation of households' dependence on ecosystem services

	ANOVA			Sig.	PSM	
	HHn, oc	HHr, sc	HHn, sc		ATT	t
Indices						
Provisioning services	0.53	0.38	0.51	***	-0.09	(-3.31)***
Regulating services	0.09	0.07	0.07	ns	-0.01	(-0.71)
Cultural services	0.05	0.06	0.07	ns	-0.01	(-0.40)
IDES	0.68	0.52	0.67	***	-0.12	(-4.05)***

t statistics are shown in parentheses

IDES index of dependence on ecosystem services

*, **, and *** denote differences that are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels, respectively

Impact of RSP on livelihoods

Basic information of the household

Basic information covered the age and educational background of the householder, the number of family members, and income earners in the family (Fig. 5). The age of the householders fell within a normal distribution, with ages from 40 to 49 making up the largest group, which was 31.13%. Householders who were younger than 30 years made up the smallest segment, which was only 3.56%. This is almost the same as the general situation in rural China; householders of the age from 30 to 60 being the major part.

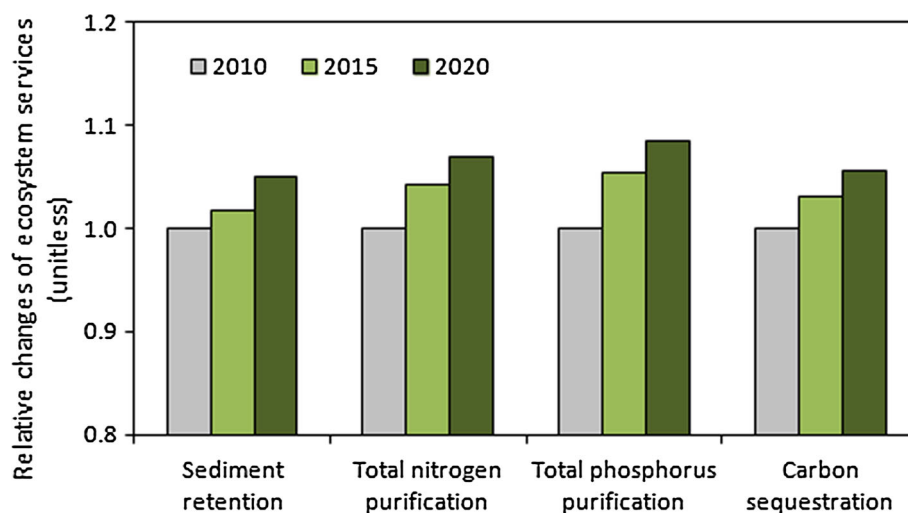


Fig. 4 Projected relative changes in ecosystem services over implementation of the Relocation and Settlement Program (RSP) over 2011–2020

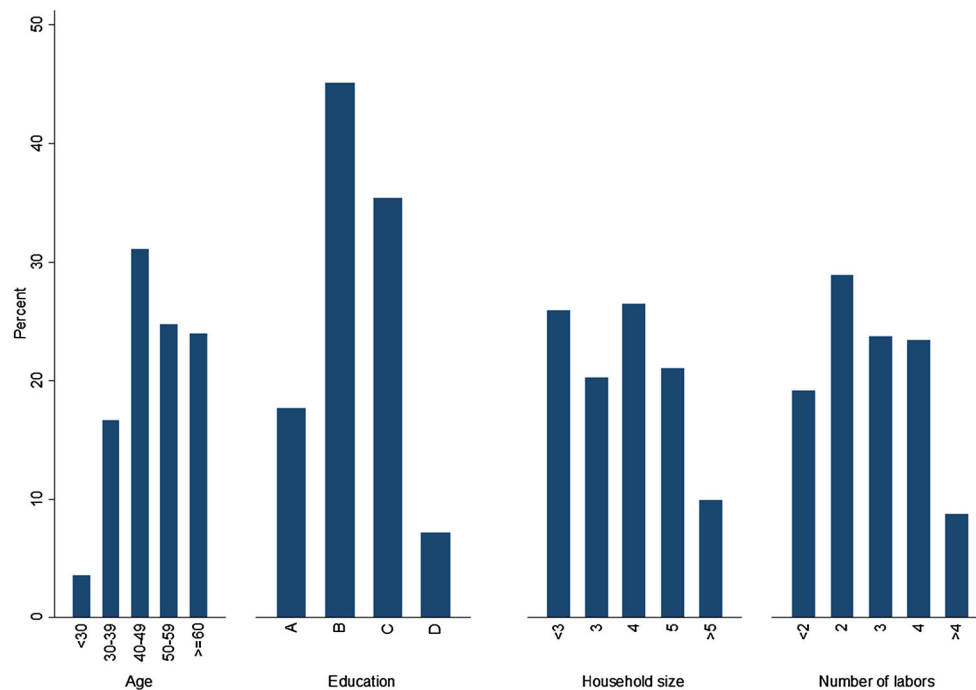


Fig. 5 Basic information about the investigated householders

Significant differences existed in the educational background of householders. The majority of householders (42.88%) had only elementary education. The higher the educational level, the lower the percentage of householders in the category, with only 6.77% of householders having an educational level higher than high school. Only 16.74% of householders had an educational level lower than elementary school. This situation mirrors the educational level of the poverty population in many Contiguous Poor Areas of western China. Most families included in this study (25.5%) consisted of four members, and 27.85% had two income earners. However, the household size also showed a decreasing trend, mirroring the development of China's economy due to aging populations, lower fertility rates, higher per capita income, and so on (Liu et al. 2003), as well as the stationary older adults left behind in their rural communities (Wu et al. 2015).

Livelihood assets

In explaining the differences among these three groups of households (Table S2), one may ask whether these differences already existed before participation in the relocation or were caused by the program. Based on the convertibility and acquisition of livelihood assets, this study considers both exogenous and endogenous indicators. The exogenous indicators comprise those that are constrained and easily influenced by relocation, such as land area, house value, amount and value of production tools, savings, and

telephone bills. The endogenous indicators are pre-existing and not affected by relocation, such as highest education, special experience, number of laborers, skills, and credit access in a household.

We drew radar maps to illustrate the differences among the three household groups (Fig. 6). HHr,sc has the most endogenous assets, while HHn,oc has the least (b). For the exogenous indicators (a), however, we found significant differences among the three household groups, which might reflect the influence of RSP. After relocation, the amount and value of production tools and also telephone bills increase due to greater accessibility to public services, such as roads and telecommunication. Meanwhile, a family's savings might also be consumed during the construction of a new house, reflected in an increase in 'house value.'

Among these assets, the most important is land area, which decreases markedly among HHr,sc. First, the number of farm plots with less than a 25-degree slope, and with a proper soil layer and water source for irrigation is very limited in Ankang. Second, farmland redistribution in the resettling community is very difficult because the local farmers are reluctant to share resources with new, resettled neighbors (Appendix S1).

Livelihood activities and participation

This study focuses on HHr,sc by first comparing the livelihood choices among the three groups, and then uses

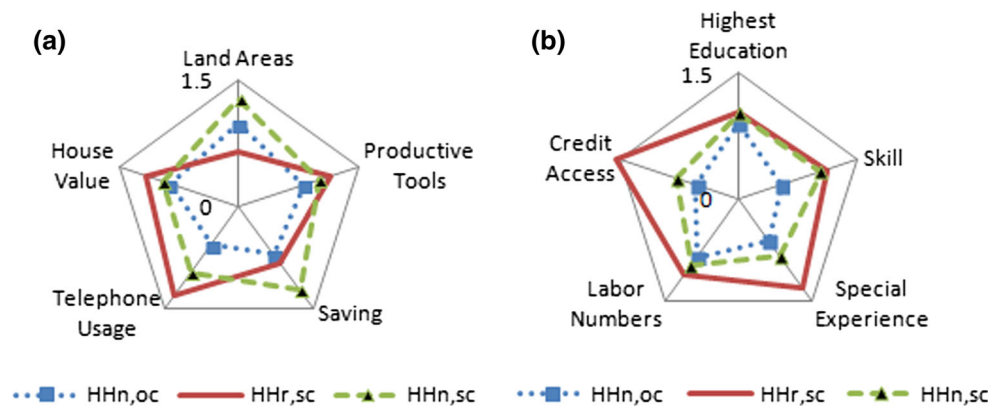


Fig. 6 Radar maps of asset indicators in the three surveyed household groups, used to assess the effects of the Relocation and Settlement Program on livelihoods: Households relocating from the deep mountains (HHr,sc, relocation, settling community); HHs choosing to remain in communities from which people are moving (HHn,oc, non-relocation, original community); and original HHs in the communities where people are settling (HHn,sc, non-relocation, settling community). HHs remaining in communities from which people are moving are the poorest, and least able to move, by both **a** exogenous indicators and **b** endogenous indicators

PSM to estimate the ATT of the RSP on these activities (Table 2). Although there is low agricultural efficiency due to the steep slopes and thin soil in these ecologically fragile mountain areas, the rural households still rely heavily on traditional agriculture for food security. However, from the PSM estimation, there seems to be a reduction in agriculture (cultivation and forestry) and livestock activities after participation in the RSP. The RSP has a significant negative effect on the proportion of households participating in agricultural (−7%) and livestock (−13%) work. Along with the decrease in farmland area, relocation households also decrease their use of both farmyard manure (−5%) and chemical fertilizer (−11%).

Besides agriculture, rural–urban cyclic migration becomes the most important livelihood activity in the HHr,sc group. Based on the PSM estimation, the RSP does not significantly increase households' probability of participating in rural–urban cyclic migration. Thus one may speculate that a high proportion of rural–urban cyclic migration already existed before the RSP, as is generally the case all across China (Li et al. 2012). Therefore, it is suspected that participation in the RSP hinges on household's financial ability, because households participating in rural–urban cyclic migration from such poor, remote areas are usually wealthier than the non-participants (Tang et al. 2005).

Inputs and outputs

Despite a reduction in agricultural participation, HHr,sc conduct more collective and cost-efficient agricultural activity than before, even if their farmland area is reduced. The farmland allocated to new settlers typically has very thin soil, comprising small stones and sand. To make up for this, HHr,sc always use more labor, chemical fertilizer and

material inputs than HHn,oc, which is consistent with the PSM estimate that the RSP has significant positive effects on both the average input of labor and chemical fertilizer. Correspondingly on the output side, the average unit agricultural income increases by 2378 yuan per hectare.

The analysis did not fully verify the hypothesis that the RSP stimulates participation in rural–urban cyclic migration. This is because the PSM estimation did not show a significant positive effect on participation in rural–urban cyclic migration, or total number of migrants, although the proportion of HHr,sc participating in such migration is significantly higher than in the other groups. Based on its destination and distance of migration, such rural–urban cyclic migration may be divided into two modes; local migration and out-migration. Local migration refers to short distance migration, where the migrants find non-farm work inside their province and often close to their hometown. Out-migration refers to a long distance move, where the migrants seek non-farm jobs outside their province, mostly in big cities. From the inputs and outputs, one might, however, speculate that the RSP augments the shift of surplus labor from agriculture and livestock activities to rural–urban cyclic migration, especially local migration. More specifically, the proportions of participants in local migration (+8%) and out-migration (−9%) show opposing changes after relocation.

It thus appears that, given participation in rural–urban cyclic migration activities, the migration households adjust their strategy by transferring out-migrant family members to local migrants after relocation (Appendix S2). This can explain a 17% (significant) increase in local migrants, although there is no significant effect on out-migrants. As an integral feature of the migration system in China, the remittances occur largely because migration diversifies the household income portfolio and helps finance household

Table 2 ANOVA and PSM estimation of households' livelihood strategies and outcomes

Livelihood strategies and outcomes	HHn, oc	HHr, sc	HHn,sc	Sig.	ATT	t
Activities participation choice						
Agricultural work	0.94	0.88	0.90	ns	−0.05	(−2.95)**
Livestock	0.75	0.59	0.59	***	−0.13	(−3.49)**
Non-farm self-employment	0.09	0.10	0.12	ns	−0.01	(−0.28)
Rural–urban cyclic migration	0.55	0.64	0.54	**	0.01	(0.25)
Input and output						
Agriculture						
Utilization of farmyard manure	0.91	0.66	0.74	***	−0.05	(−2.25)**
Utilization of chemical fertilizer	0.96	0.78	0.84	***	−0.11	(−3.45)**
Avg. labor input (day/hectare)	127.46	207.91	149.4	***	53.13	(38.06)**
Avg. fertilizer (yuan/hectare)	274.63	447.76	298.51	**	138.06	(43.28)**
Avg. material (yuan/hectare)	482.84	825.07	502.54	**	274.63	(22.84)
Avg. income (yuan/hectare)	2441.64	7558.21	7246.12	***	2378.21	(28.96)*
Rural–urban migration						
Migration types						
Within local county	0.16	0.27	0.21	**	0.08	(1.99)*
Out of county	0.89	0.75	0.82	***	−0.09	(−2.24)**
Migrants (migration HHs)	1.35	1.54	1.39	**	0.10	(1.34)
Local (local migration HHs)	1.16	1.31	1.17	ns	0.17	(1.82)*
Out (out-migration HHs)	1.3	1.56	1.38	***	0.08	(0.96)
Remittance (migration HHs)	5801.78	9461.77	8228.01	***	2195.96	(2.16)**
Local (local migration HHs)	7572.22	7730.15	7246.49	ns	1226.66	(0.71)
Out (out-migration HHs)	5135	9652.62	8070.90	***	758.51	(0.66)
Per capita (Migration HHs)	4529.61	6794.22	6139.78	**	1515.07	(1.96)*
Income						
Total income	13 871.62	26 945.19	20 886.05	***	5074.96	(2.35)**
Agricultural	3839.16	8422.29	9518.51	***	−836.56	(−0.54)
Livestock	2091.93	1616.85	1241.98	**	−83.81	(−0.33)
Non-farm	2527.22	3531.68	3284.80	ns	303.22	(0.25)
Remittance	3216.83	6028.27	4475.76	*	1337.78	(1.83)*
Subsidy	1367.01	5089.35	1207.61	***	3799.52	(8.93)**
Other	829.45	2138.79	1056.04	*	794.21	(2.23)**
Per capita	4646.68	6876.93	6575.57	***	1490.98	(2.63)**
Cash income	9950.16	21 521.06	14 706.66	***	5855.42	(2.92)**
Cash proportion	0.57	0.76	0.66	***	0.10	(4.02)**
Expenditure						
Total expenditure	11 023.83	39 454.83	18 810.87	***	18 805.33	(5.59)**
House and durables	1542.22	19 371.29	2730.24	***	16 412.60	(5.45)**
Food	2425.20	6752.88	6103.08	***	285.77	(0.67)
Education	1310.89	2533.66	1975.69	**	213.24	(0.55)
Medical	1552.92	2985.70	2006.99	***	901.70	(2.20)**
Energy	826.01	957.01	1068.83	*	−74.40	(−0.83)
Social network	1592.68	4071.90	3027.51	***	917.48	(2.37)**
Productive input	1212.23	699.29	691.59	**	−82.45	(−0.61)
Per capita	3809.42	10 276.96	5570.70	***	5247.66	(4.75)**
Poverty rate	0.36	0.27	0.30	*	−0.07	(−1.79)*

Table 2 continued

Livelihood strategies and outcomes				Sig.		
	HHn, oc	HHr, sc	HHn,sc		ATT	t
Loan	4850.49	14 596.41	4053.54	***	6326.04	(2.93)**
Loan rate	0.24	0.44	0.26	***	0.06	(1.72)*

t statistics are shown in parentheses

HHs households

*, **, and *** denote differences that are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels, respectively

expenditures. Furthermore, both the total remittance and per capita remittance increase very significantly after relocation (by 2195 yuan and 1515 yuan, respectively). Based on the PSM estimation, neither the increases in local remittances nor out-remittances are significant; therefore, local migration contributes more to the trend of increasing total remittances than does out-migration.

Income and expenditure

Table 1 shows that both the total and average income and also expenditure of HHr,sc are much higher than that of the other two household groups', especially HHn,oc. Moreover, further PSM estimations of households' income and expenditure portfolio confirm these significant differences, providing evidence that the RSP is bringing about significant increases in both.

We first compared the differences in each category and income item, and then estimated the effect of participating in the RSP on the changes of each income item. Both the comparison and estimation show that remittances, subsidies, and other income in the HHr,sc group are higher than in other groups, and that participation in relocation contributes to these increases. As an important cash source, state subsidizes specific qualified group in the following items, grain production, convert farmland to forestry, ecological forest, forest ranger, relocation and settlement, minimum living guarantee household, and the disabled. Moreover, remittances, subsidies, and other income constitute all sources of cash income, which explains the significant increases in both cash income level and cash proportion in total income after relocation (+5855 yuan, +10%). Although the income from agriculture and livestock has decreased, the PSM estimation shows that the decrease is not significant.

There are contrasting differences for each expenditure item among the three groups. HHr,sc spend more on housing, food, education, medical, and social network construction and maintenance than others. Especially when it comes to housing and durables, HHr,sc's expenditure is much higher than that of the other two groups. The

presumption that participation in the RSP leads to these increases in expenditures is confirmed by the PSM estimation results: households participating in the RSP increase their expenditures on house construction, education, medical, and social networking. One can also speculate that, through the RSP, HHr,sc begin to realize that social capitals are more important in order to cope with liquidity squeeze or provide aid in daily life after settling in new environment, so it is worth spending more on them; thus the total expenditure level is significantly increased.

Poverty rate and loans

The poverty rate of HHr,sc is the lowest. The RSP has a significant positive effect on reducing the poverty rate, namely by 7%. By comparing total income and expenditure, this study finds a massive gap in the HHr,sc group. Moreover, the PSM result shows that the increase in total income due to participation in the RSP is much less than the total expenditure after relocation. To smooth consumption in the short term, most of the households participating in the program turn to their relatives and friends for financial assistance (Fig. S2). This also explains the significant difference in regard to loans between HHr,sc and others, as well as the significant increases in both loan amount (+6326 yuan) and loan rate (+6%) after relocation.

Subjective evaluation of quality of life after relocation

Table 3 shows the subjective evaluation of quality of life after relocation among HHr,sc. Most of the resettlers gave a high evaluation of the RSP. Based on the survey, 84.7% of the relocation households considered that the RSP brought more benefit than loss during implementation. More than 62% of the respondents expressed that their family is quite satisfied with the RSP, almost 19% gave a medium evaluation and less than 20% of the respondents were not satisfied with the RSP. In regard to their lives in the past 1 year before the survey, 30% indicated that there was no difference compared to before. More than 56% rated their lives as satisfactory, while less than 14%

Table 3 Subjective evaluation of the quality of life after relocation

Items/extent	1	2	3	4	5
a. Relocation brings (%)	84.71	10.62	4.67		
1. More benefit than loss					
2. Same benefit and loss					
3. Less benefit than loss					
b. Difficulties and problems after relocation (%)	60	15	10	9	6
Pressure of loan refund					
Loss of agricultural and livestock incomes					
Decrease of farmland access					
Shortage of public services					
Fewer job opportunities					
c. Overall evaluation of the RSP	3.41	15.78	18.98	49.47	12.37
d. Overall evaluation of the quality of life in past year	4.04	9.57	30.00	44.68	11.70
e. Evaluation of adaption after resettlement					
Adaption of customs and habits	4.48	4.48	16.84	48.83	25.37
Adaption of production	4.47	12.34	28.72	42.77	11.7
The effect of relocation on family income	10.43	17.02	24.04	30.85	17.66
Satisfaction with current income	13.4	18.7	34.26	26.38	7.23
Confidence with increasing future income	6.4	10.23	20.26	40.72	22.39
Satisfaction with new house	4.48	7.68	17.27	42.22	28.36
Satisfaction with redistribution of farmland	12.02	13.09	39.27	28.54	7.01
Satisfaction with new neighborhood relationships	0.85	2.77	15.78	49.47	31.13
Evaluation of local original residents' hospitality	1.92	3.41	21.75	49.04	23.88
Missing the old friends	16.63	19.4	22.6	29.64	11.73
Missing the old place	25	18.80	16.67	26.07	13.46

1–5 in a and b indicate the corresponding choices; for the other items, it indicates the extent from low to high

indicated that there were not satisfied with their lives during the past year. The survey indicated that the greatest difficulty and biggest problem to be conquered after relocation was the pressure of loan refund (60%), followed by the loss of agricultural and livestock income (15%), decrease of farmland access (10%), shortage of public services (9%), and fewer job opportunities (6%). HHr,sc who were satisfied with the RSP making up the largest share (61.84%). Less than 1/5 indicated that they were not satisfied with the RSP. 56.38% HHr,sc gave a high evaluation of the past year of their lives after resettlement, while 30% of HHr,sc indicated that there was no change. 13.61% of the HHr,sc expressed that they were not satisfied.

Regarding the evaluation of adaption after resettlement, the majority of HHr,sc expressed relative positive attitudes in terms of the adaption of production mode, customs, and habits, life in their new house. They were also happy with neighborhood relationships in new community and the hospitality of the local original residents, but missed their old place (44%) and friends (36%). As to the family income, a larger part of HHr,sc indicated that the RSP had a significant impact on their income, and 1/3 of HHr,sc were not satisfied with their current income. However, more than 63% of the respondents felt confident in increasing future income. Additionally, more than 1/4 of HHr,sc were not satisfied with the redistribution of farmland in the new community. Due to the scarcity of farmland, most of the collective resettlement HHr,sc could not be allocated enough farmland in the resettlement community. Therefore, they had to rely more on non-farm work, especially by circular out-migration to urban areas.

CONCLUSION

The government's growing largesse towards this ecological conservation and human development initiative is encouraging but also challenging. The RSP meets the strong desire of people who live under extremely harsh conditions. Most of the HHr,sc consider the RSP brings more benefit than loss. At the beginning, voluntary participation resulted in wealthy households who can afford the cost of relocation and participating first (Tang et al. 2005). Thus the impoverishment risks identified by Cernea (2000a, b) cannot be fully confirmed in this study. However, the interventional poverty risks still exist if the major problems encountered during the implementation of the RSP hamper resettlement and diminish the opportunity for subsequent development (De Sherbinin et al. 2011; Yan et al. 2011), because of landlessness, indebtedness, and lack of job opportunities.

Generally speaking, the RSP achieves the goals of ES increase, IDES decrease, and livelihood restoration. With the changes in livelihood assets during relocation, the relocation households transformed livelihood activities from traditional inefficient agricultural and forest production to non-farm activities. In addition, the increased income after relocation not only contributed to the decrease of poverty rate, but also led to the improvement of relocation households' living condition and standard. As each coin has two sides, difficulty and challenge also showed up subsequently after relocation, such as the increasing expenditure, decreasing agricultural and forest incomes, pressure of loan refund, social network rebuilt, and so on. Although the relocation households are facing new concern in the new environment, very few household denied the

benefit from RSP and less than 5% considered the relocation brings less benefit than loss. Meanwhile, this study's ES and livelihood results corroborate each other to some extent. Over the long term, with the return of the resettled households' steep farmland to forest, sediment retention and carbon sequestration benefits should steadily increase. Correspondingly, resettled households' reduced participation in agriculture, as well as the reduced utilization of chemical fertilizer in the destination community, leads to decreased regional nitrogen and phosphorus export.

Moreover, the RSP enhanced participants' livelihoods, no matter what their previous economic status was. First and foremost, general satisfaction with living conditions improved significantly. It also became easier to access public facilities and services than before. Along with the RSP, many rural–urban cyclic migration households adjusted their strategy by shifting out-migration to local migration, because there were more local job opportunities due to local government investments in infrastructure construction. These non-farm job opportunities and the subsequent growth of income improved rural household's welfare. This indicates that the nearby relocation as well as a transitional period will help households to buffer the change in production mode and to rebuild their livelihoods, thereby enhancing the adaptability in new environment.

Living standards and conditions, while vastly improved after relocation, remain problematic. Even with government subsidies in term of relocation and settlement, the enormous cost of relocation is still a major challenge. To relocate, most households have to take loans after spending the family's savings. To pay off debt as soon as possible, relocation households rely more on rural–urban cyclic migration work than before (Fig. S2). Especially when the one-time relocation subsidy ceases after relocation, cash sources will become constrained, which will subsequently reduce households' ability to cope with impoverishment risks and shocks. In addition, though spending on social networks after relocation may be helpful in the households' new communities, sometimes this kind of expenditure may just be status-oriented, excessive consumption. Although most of the relocated households' farmland in the original community was supposed to be returned to forest after relocation, they may delay this return and still use it for cultivation after the transitional period if there is no farmland available in resettling communities, or new livelihood opportunities in the future. This great challenge to ecological recovery will then be the responsibility of the local government.

To better achieve the planned goals and avoid this vexing dilemma, it is essential to develop new strategies to overcome these shortcomings in the next phases of the RSP. First, the central government should propose and facilitate the establishment of direct PES scheme from

water-receiving areas in North China to the RSP area in order to ensure positive short- and long-term ES and human well-being outcomes. In this context, exploring and setting up a certain Eco-Fund could be a novel approach by converting the value of ES from the sending area to economic benefits with the generation of ES year by year. Through the market-oriented mechanisms, it will raise money from the interprovincial beneficiary to provide continuous payment for the ES providers in RSP area. Second, new standards for displacement compensation must continue to be explored and further supported in order to encourage those remaining to participate in RSP, especially for those living in the worst situations. Third, it will be necessary to extend the duration of subsidies and to further diversify funding channels, especially to encourage multiple social participants, such as the large enterprise, charity organization, and explore market-oriented business operation model. Fourth, in terms of the redistribution and sharing of farmland in these settlement areas, an innovative incentive policy portfolio is needed in order to establish a fair balance between residents and the resettled. Fifth, more attention should be given to training in off-farm skills to help the relocation households find non-farm jobs when migrating out to urban areas. For people who prefer non-farm livelihoods in the new communities, investments in development of replacement industries should be increased and financial credit provided for local non-farm self-employment so as to guarantee long-term sources of income for the resettled people. Finally, it is necessary to further complete and fully implement the social insurance system in countryside and take targeted measures for each individual household with different requirements. Although government has already established the New Rural Cooperative Medical System (NCMS) throughout the country, poverty caused by illness is still very common. Therefore, special attention should be paid to the poverty relocation households. It is quite essential to increase both the compensation standard and subsidy individual payment. As education was considered to be the most effective and reliable approach, it is the right time to popularize the free education in the RSP area because Shaanxi Province has already been pioneering by implementing the 13 year of free education in the urban area since 2016. Moreover, in these disaster-prone areas, it would be better to introduce the policy-oriented agricultural and endowment insurance to strengthen households' resistance of the natural disasters. To smooth the relocation households' income during the first phase of livelihood restoration in the resettlement areas, unemployment insurance would be helpful to cope with temporary suspension. In that case, provincial government is responsible to take the lead to establish certain insurance with the local enterprise by referring the urban unemployment insurance.

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