SUPPORTING INFORMATION

Impacts of Conservation and Human Development Policy across Stakeholders and Scales

S1 Ankang Municipality

Ankang is typical of western China, with its conflict between nature conservation and poverty alleviation. 92.5% of Ankang Municipality is steeply mountainous, prone to frequent natural disasters, such as flooding, landslides, debris flow, etc. that result in severe economic losses every year. Farmland is very limited and accounted for only 21% of Ankang Municipality in 2010. Moreover, farmland with slope <15% accounted for only 41% of the total farmland in Ankang Municipality 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.

With its mountainous areas, Ankang Municipality is not only an ecologically fragile area, but also a typically poor area. Ankang has a large population in poverty and was designated as one of the 18 Nationally Contiguous Poor Areas at the National Poverty Alleviation Conference in November 2011 by the Chinese central government. Restricted by the limitation of farmland as well as the eco-conservation policy for ‘send clean water to Beijing’, poverty alleviation is one of the great challenges for the local government (Source: Bureau of land and resources of Ankang Municipality (2010), General planning for land use in Ankang Municipality 2006-2020.).

S2 Description of the Relocation and Settlement Program of Southern Shaanxi Province (RSP) – implementation of program

In order to avoid natural disasters (e.g., geological disaster, flooding disaster), restore key ecosystem services such as erosion control, flood mitigation, water purification for downstream drinking, irrigation and hydropower, and carbon sequestration, and to improve human well-being generally, Shaanxi Province, including Ankang, Shangluo and Hanyang, initiated the RSP in 2011 – the largest resettlement project in the history of modern China (Fig. S1). Offering direct financial assistance and other incentives, the government aims to relocate, on a voluntary basis, 2.4 million people over 10 years in 28 counties of these three municipalities – a quarter of their total population. There are five types of relocation (geologic disaster avoidance relocation, flooding disaster avoidance relocation, poverty alleviation relocation, ecological restoration relocation, and engineering project relocation), together called “disaster avoidance relocation”. Ecological relocation, which aims to reduce the impacts of human activities in nature reserves, historic reservation areas, ecologically fragile and sensitive areas, has significant impacts on the South-to-North Water Transfer Project (SNWTP) because Ankang is the water source area of the Middle Route of SNWTP.

Fig. S1. Location of the RSP implementation areas in southern Shaanxi Province.

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 that are 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 far away from a main road; (v) those located inside nature reserves, historic reservation areas, 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 that depends on the willingness and the availability of land in the community to which they relocate. In centralized relocation, households within a village all move together to another location. This new location depends on preferences of village residents and on the availability of land.

Unlike several earlier examples in China of forced relocation (e.g., Three Gorges Dam), the RSP is designed to be a voluntary program, and many measures have been put in place to support voluntary participation so that people will choose to relocate (e.g., increased subsidy for poor households, creation of job opportunities, flexibility in relocation area). From the viewpoint of the government, implementation has so far honored the voluntary nature of the Program. Its purpose is to help people in ‘dwelling securely and becoming rich step-by-step’, the great challenges faced by government. The government relocation subsidy partially covers the cost of new housing. There is no compensation for assets left behind in the mountainous area. However, the government provides assistance to help the relocating households get new jobs, such as by providing recruiting information, paying for new skill training, and providing small loans for self-employment. According to our survey data and informal conversations, lots of households choose to relocate due to (i) the high risk of injury and (further) impoverishment associated with the high frequency and severity of natural disasters in the region; and (ii) the perception that life in urban areas is far better, with much more rapid development and new opportunities for themselves and their children, than life in the mountainous rural areas. There is a frequently stated sense that there is no hope of life improving to match conditions in urban areas in this region in the foreseeable future.

Generally, the RSP appears to be successful in terms of the attitudes, life condition changes, and security of relocated households. Our household survey explored the attitudes of those who chose to move: 77% of the relocated households expressed satisfaction with the Program, and only 3% indicated that they were not satisfied. Moreover, 36% of relocated households reported an income increase and only 12% reported a decrease after participation.

S3 *South–to-North Water Transfer Project (SNWTP)*

The South-to–North Water Transfer Project is a multi-decade infrastructure project for the People's Republic of China to ultimately channel 44.8 billion cubic meters of fresh water annually from the Yangtze River in southern China to the more arid north through three canal systems: the Eastern Route, through the course of the Grand Canal; the Middle Route, flowing from the upper reaches of the Han River (a tributary of the Yangtze River) to Beijing and three other provinces or direct-controlled municipalities; and the Western Route, which goes from three tributaries of the Yangtze River near the Bayankala Mountains to many provinces, including Qinghai, Gansu, Shaanxi, Shanxi, Inner Mongolia and Ningxia. Construction of the Eastern Route was completed, and water transfer began in 2013. Construction of the Middle Route is also complete, and water transfer was in a pilot phase until October 2014. The Western Route is still under feasibility study and construction has not yet begun (http://www.nsbd.gov.cn/). Ankang Municipality is located in the water source area of the Middle Route of SNWTP (Fig. 1).

S4 LULC of RSP scenarios for 2015 and 2020

In Ankang Municipality, the RSP involves 226 thousand rural households (ca. 450,000 local residents during 2011-2015 and ca. 427,000 more during 2016-2020). In order to analyze the impacts of the Program on ecosystem services, we obtained the

LULC maps for RSP planning scenarios in 2015 and 2020 by means of the following steps (Fig. S2):

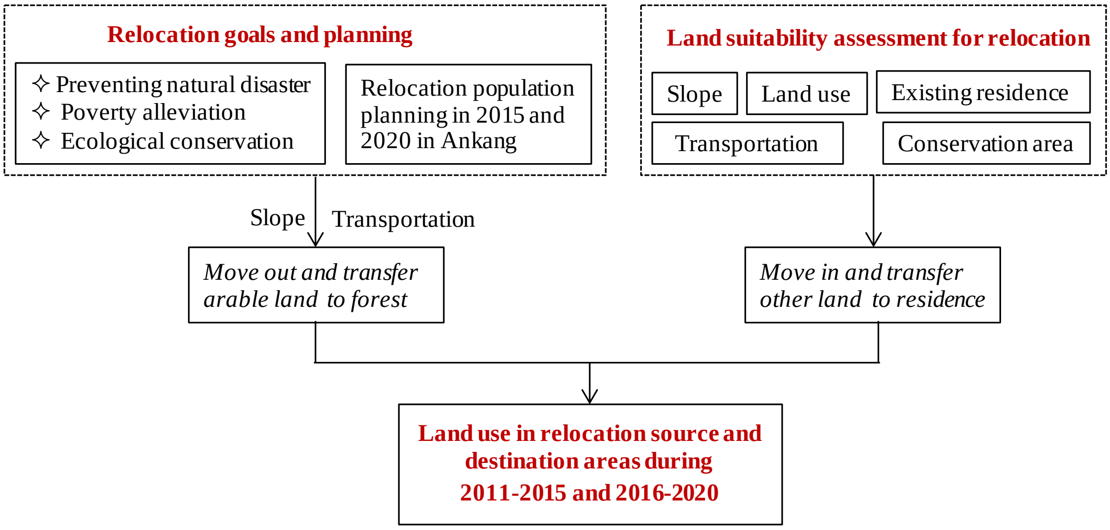

Fig. S2. Land use planning procedure for RSP implementation during 2011-2015 and 2016-2020.

(i) Identify the relocated population through RSP planning. We use an estimate from the Program of the total number of people who will move from mountainous areas to urban areas for the periods 2011-2015 and 2016-2020. We assume that 20% of this total moves each year in each of the five-year periods.

(ii) Identify the farmland area that will be transferred to forest according to average arable area per capita (data from "Household Livelihood Survey") and the relocating population (data from RSP planning). We convert population to an amount of land to be converted from farmland to forest in the mountainous areas using the amount of arable area per capita that we obtain from the survey. We use the following rules to choose which lands switch from farmland to forest: a) in 2015 we take all land with slope > 30%, which equals the total number of targeted hectares, b) in 2020 we take all land with slope between 25% and 30% and that is more than 3.5 km away from a main road. These details are described in Table S1. A total of 460 km^2 and 372 km^2 farmland were transferred to forest during 2011-2015 and 2016-2020.

Table S1 Description of LULC changes in terms of relocation planning in 2015 and 2020

Scenarios	Previous residence area	Relocation area
2015	Arable land with slope> 30%	✧ Land with suitability grade V for construction + Bare land ✧ Land with suitability grade V for construction + Grassland less than 1.2 km from urban land, less than 1.5 km away from a main road
2020	Arable land with slope between 25% and 30%, at a distance more than 3.5 km away from main road	✧ Land with suitability grade V for construction + Bare land ✧ Land with suitability grade V for construction + Grassland with less than 2 km from urban land, less than 1.5 km away from a main road ✧ Land with suitability grade V for construction + Grassland with slope <15%, 2-3 km distance away from the urban land and 1.5 km away from a main road, from urban land

(iii) Assess the land's suitability for relocation according to land-use types, slope, distance from main road, distance from urban land, and distance from a nature reserve (Table S2). Assessment indicators and grades for relocation land suitability were identified through RSP planning.

Table S2 Assessment indicators and grades for relocation land suitability

Types	Factors	Grades	Score
Natural factors	Slope (°)	0-8	5
		8-15	4
		15-25	3
		25-30	2
		>30	0
Social-ecological factors	Distance from main road (km)	<1.5	5
		1.5-2.5	4
		2.5-3.5	3
		3.5-5.0	2
		>5.0	0
	Distance from urban land (km)	<1.2	5
		1.2-2.0	4
		2.0-3.0	3
		3.0-4.0	2
		>4.0	1
	Land use types	Bare land	5
		Shrub, Grassland	4
		Forest	3
		Farm land	2
		Wetland, Urban	0
	Distance from nature reserve (km)	>1	5
		0.8-1	4
		0.5-0.8	3
		0-0.5	2
		Within nature reserve	0

(iv) Identify the location of farmland that will be transferred to forest in land-use maps, according to slope and distance from places convenient for human activity (Fig. S3). Usually, there are two methods for land suitability grade calculation: geometric mean and weighting sums of assessment factors. In this study we used a geometric mean to calculate land suitability grades according previous studies (1, 2). Land suitability grade for relocation were identified by the following formula: $G = \sqrt[5]{S \cdot D_R \cdot D_U \cdot LULC \cdot D_{NR}}$, where G is the land suitability grade for relocation, S is the slope, D_R is the distance from main road, D_U is the distance from urban land, LULC is land use and land cover type and D_{NR} is the distance from a nature reserve.

Finally, we get the suitability grades I (0), II (0-2.5), III (2.5-3.5), IV (3.5-4.5) and V (4.5-5) (Fig. S3).

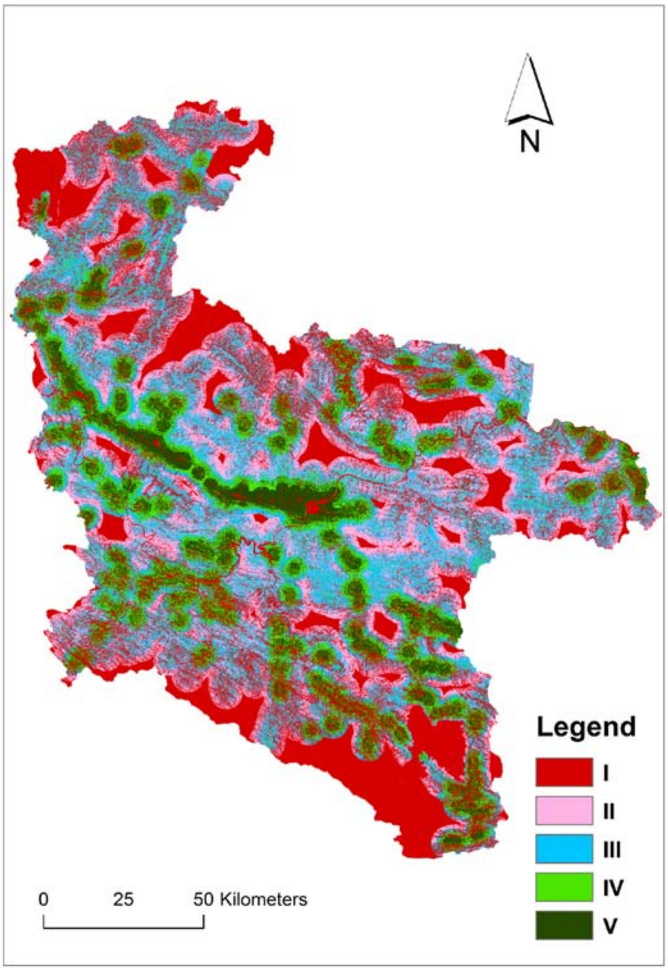

Fig. S3. Land suitability grade for relocation.

(v) Identify the land where the relocation can be arranged by land-suitability assessment (Table S1) through the RSP planning (relocation population and goals). Relocation will increase the area of urban land. The increased amount of urban land was found by multiplying the population relocating to the urban area by the average area of urban land per capita. In 2015, we selected land for urban expansion that had suitability grade V for construction and was bare land or grassland less than 1.2 km from a main road (and described in Table S1). In 2020 we use similar conditions, as spelled out in Table S1.

Finally, based on the actual land use in 2010, we obtained the LULC maps for RSP planning in 2015 and 2020 in Ankang Municipality (Fig. S4 and Table S3). We developed land-use change scenarios only for the periods 2011-2015 and 2016-2020. In our analysis, there is no land-use change after 2020.

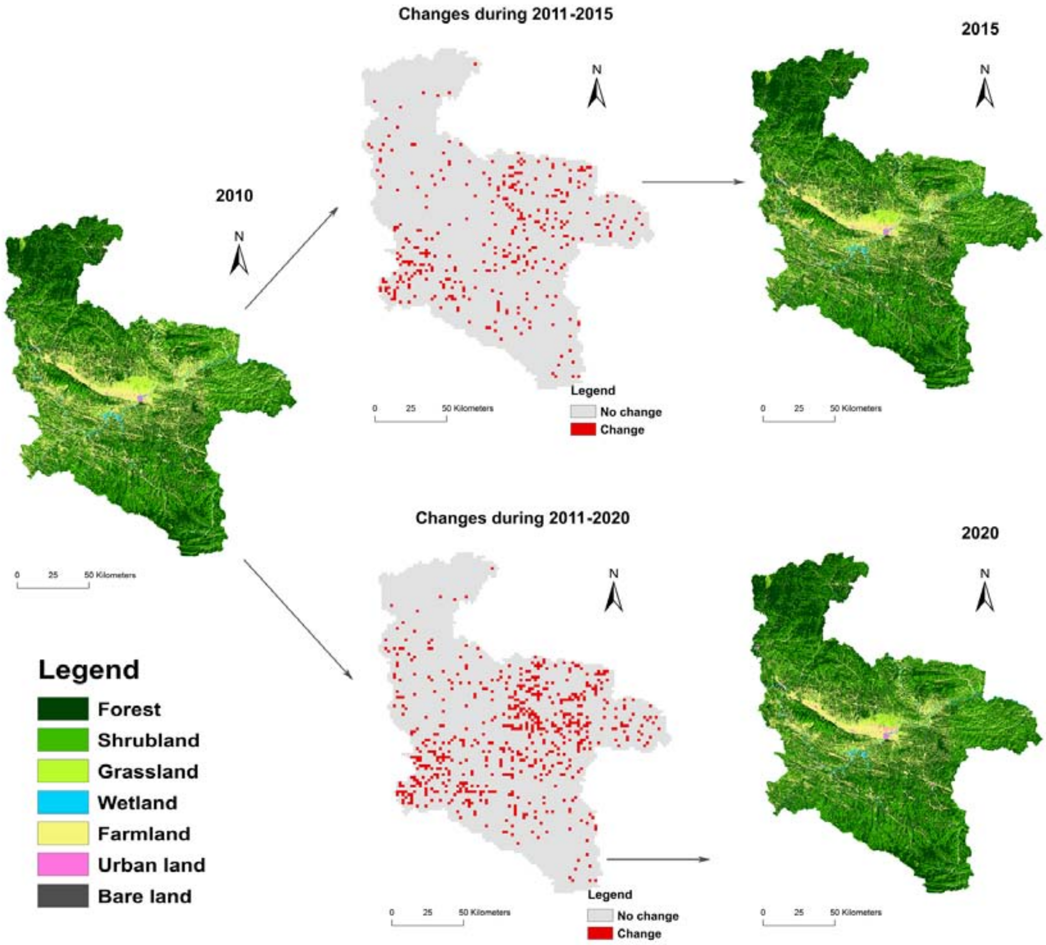

Fig. S4. LULC changes under RSP planning in 2015 and 2020.

Table S3 LULC in 2010 and RSP planning scenarios for 2015 and 2020 (km^2)

Year	Forest	Shrub	Grassland	Wetland	Farmland	Urban land	Bare land
2010	11,264	6,843	180	212	4,929	69	51
2015	11,724	6,843	174	212	4,469	84	42
2020	12,096	6,843	157	212	4,097	101	42
LULC changes (2011-2015)	460	0	-6	0	-460	15	-9
LULC changes (2016-2020)	372	0	-17	0	-372	17	0

S5 Ecosystem service assessment

(i) Water purification and sediment retention.

We assessed ecosystems services (ES) of water purification and sediment retention based on actual land use in 2010 and RSP planning scenarios for 2015 and 2020, using InVEST models (Integrated Valuation of Ecosystem Services and Tradeoffs) (3).

Water purification. The nutrient retention model quantifies the contribution of vegetation and soil to purifying water. First we used the water yield model to estimate annual average runoff from each parcel. We then used this model to estimate total nitrogen and phosphorus exported to streams (kg yr^{-1}).

Sediment retention. The sediment retention model uses the Universal Soil Loss Equation (USLE). We estimated erosion as tons per year of sediment load, based on geomorphology, climate, vegetation and management practices.

Parameter identification. Previous research results were used for the parameters of the water purification model, as well as the sediment retention model. The parameters used in InVEST models are as follows:

Biophysical table: The Biophysical Table of the InVEST User's Guide contains data on water quality and sediment retention parameters, as attributes of each LULC used in the tools. Parameters in the table are largely based on research studies in local places. Thus, we chose parameter values from a lot of papers that provide observation-based parameters for in Ankang Municipality and/or other places like Ankang to show differences resulting from different LULC. For example, forest and shrubland perform better water purification than other ecosystems; farmland and urban land make higher contributions to eutrophication; forest functions better at sediment retention than other LULC types. The parameters in this table play a key role in the modeling output.

The evapotranspiration coefficient (etk): Etk is used to obtain actual evapotranspiration which is based on alfalfa (or grass). All the coefficients are multiplied by 1,000, so the values are integers ranging between 1 and 1,500 according to the data provided by FAO (http://www.fao.org/docrep/X0490E/x0490e0b.htm#annual crops) and Chinese researchers (Table S4).

Table S4 The evapotranspiration coefficient (etk) for each LULC category

LULC_category ID	LULC Category	Etk	Source
1	Forest	1,200	(4)
2	Shrub land	1,100	(4)
3	Grassland	800	(4)
4	Wetland	1,000	(4)

5	Farmland	800	(4)
6	Urban land	1	(4)
7	Bare land	1	(4)

Root_depth: Maximum root depth for vegetated land use classes (Table S5).

Table S5 Root depth for each LULC category

LULC_category ID	LULC Category	Root_depth	Source
1	Forest	7,000	(5)
2	Shrub land	5,100	(5)
3	Grassland	5,600	(5)
4	Wetland	1,000	(5)
5	Farmland	2,100	(5)
6	Urban land	1	(3)
7	Bare land	1	(3)

The nutrient loading (load_n/loand_p): we chose research on related places to get well approximated parameters for our study area (Table S6).

Table S6 The nutrient loading for each LULC category

LULC_category ID	LULC Category	Load_n	Load_p	Source
1	Forest	4,800	300	(6, 7)
2	Shrub land	3,500	350	(6, 7)
3	Grassland	5,000	330	(7)
4	Wetland	2,000	350	(3, 7)
5	Farmland	300,000	3,000	(7)
6	Urban land	13,800	1,800	(8)
7	Bare land	880	10	(6)

Cover and management factor for the USLE (usle_c), management practice factor for the USLE (usle_p): These two factors are the important in the USLE model (Table S7).

Table S7 Cover and management factor for each LULC category

LULC_category ID	LULC Category	Usle_c	Usle_p	Source
1	Forest	3	1,000	(9-13)
2	Shrub land	4	1,000	(9-13)
3	Grassland	40	1,000	(9-13)
4	Wetland	1	1,000	(9-13)
5	Farmland	250	300	(9-13)
6	Urban land	1	1,000	(9-13)
7	Bare land	1,000	1,000	(9-13)

(ii) Carbon sequestration estimation

The carbon sink in China's terrestrial ecosystems, such as forests, shrubs, grassland and soils of croplands, represents considerable potential for a mitigation approach (14). Recently, the carbon sink of China was estimated with different methods and a net sink of 190-260 Tg yr^{-1} was suggested (15). Some of these increases in the carbon stock of ecosystems might be sustained for about 20 to 50 years (16, 17). In Ankang Municipality, as a result of the Sloping Land Conversion Program (i.e., conversion of annual cropland to forest and perennial grassland) from the beginning of this century (18), the carbon pools of the soils suffering from serious erosion and the newly restored vegetation, are far less than their maximum values, and thus the carbon sequestration function of the ecosystems will last for quite a long time.

Based on the above background, we estimate total carbon sequestration over different LULC types each year. The amount of carbon stored in above-ground and below-ground biomass and soil depends primarily on LULC (e.g., forest, shrub land, grassland), as well as land management. As we lacked data on age class and species distribution of forests, we assumed that land use and land management in each grid cell had existed for a period long enough for the ecosystems to reach a relatively steady carbon sequestration rate. Generally, each LULC type would sequester carbon at a steady rate. Then the annual sequestration estimation can be reported as tons of carbon sequestered, and the final carbon sequestration status of different LULC type under different scenarios compared. Based on previous studies, the carbon sequestration rates of steady-state levels for different LULC types in Ankang Municipality are estimated (Table S8). We recognize that the availability of data to describe carbon sequestration more precisely could improve our analysis; however, the simple proxies that were chosen were sufficient to meet our research goals.

Table S8 Carbon sequestration rate for each LULC category

LULC_category ID	LULC Category	Carbon sequestration rate	Source
1	Forest	4.57	(19)
2	Shrub land	2.47	(19)
3	Grassland	0.33	(20)
4	Wetland	0	(21)
5	Farmland	0.05	(22, 23)
6	Urban land	0	(21)
7	Bare land	0	(21)

S6 Livelihood change estimation

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, and to interpret 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 enables relocation households to be compared to non-relocation households that are similar in terms of their observed characteristics, thereby correcting to some extent for self-selection to relocate, conditional on these observables. In this article, we extend the PSM approach to analysis of the impacts of relocation and the subsequent effects on livelihood in Ankang Municipality.

PSM applied here consists of the following steps. First, we estimate a Probit regression model of the treatment variable; that is, the households participating in the RSP. In Table S6, we present the result of Probit regression of the probability of relocation based on observable characteristics of the household. We consider households' demographic characteristics (including household size and structure), livelihood assets (human assets and social assets), as well as the policy characteristic (whether they participate in the Sloping Lands Conversion Program) to be determinants of participation in the Program (*See Table S9*). Second, the parameters of the Probit model are used to calculate the propensity score, that is, the predicted probability of participating in the Program 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. We interpret the difference in outcomes for these matched households as the average treatment effect of the treated (ATT). We obtain robust standard errors using bootstrapping methods that resample observations from the original data with replacement K times (K=500 times). Here, the sample drawn during each replication is a bootstrap sample clustered by village. Each time, it conducts a calculation of the average treatment effect of the treated (ATT_1, ATT_2, ……,ATT_K,). Then we obtain the standard errors by calculating the standard deviation of each ATT value. To further identify the heterogeneity of the outcomes, we also conduct PSM estimation by different relocation groups (Table S10).

Table S9 Definitions and descriptive information of the determinants of participation in the RSP

Variables	Definitions and descriptions	M	SD	Probit	SE
Demographic characteristics					
Household size	Total number of people in the household (person)	3.66	1.56	0.13***	0.03
Elders	Whether the household has a family member that is older than 65 years old (0, 1)	0.35	0.48	0.3***	0.09
Children	Whether the household has a family member that is younger than 15 years old (0, 1)	0.42	0.49	0.06	0.09
Livelihood assets					
Credit access	Whether the household has borrowed money from a bank or other credit/loan institution (0, 1)	0.26	0.44	0.61***	0.09
Village cadres	Whether family members or relatives are village cadres or government officers (0, 1)	0.25	0.43	-0.17*	0.10
Skills	Whether family members have some non-farm income generation skills, like bee-keeping, craftsmanship or other skilled activities that bring income (0, 1)	0.26	0.44	0.18**	0.09
Highest education	The highest education year of the family members (year)	8.73	3.29	-0.03**	0.02
Special experience	Whether family members have some special experience, such as military service or government job that also enhances the social network and gives an advantage in rural regions (0, 1)	0.12	0.33	0.3**	0.12
Policys					
SLCP	Whether the household takes part in the Sloping Land Conservation Program. (0, 1)	0.81	0.39	0.29**	0.11
Constant		/	/	-1.42***	0.16
Pseudo R^2		/	/	0.09	/
LR $chi^2(10)$		/	/	133.8***	/

Note: M, SD, SE denote mean value, standard deviation and standard errors, respectively; *, ** and *** denote differences that are significant at $p<0.1$, $p<0.05$ and $p<0.01$, respectively.

Table S10. Impact of RSP on different relocation groups based on the criteria by which they qualify for the Program

Livelihoods	PSM (DA)		PSM (ER)		PSM (PA)	
	ATT	t	ATT	t	ATT	T
Flow variable (annual)						
Per capita income (exclude subsidy, yuan yr^{-1})	527	(1.35)	-889	(-1.82)*	1,323	(3.29)***
Per capita expenditure (exclude housing cost, yuan yr^{-1})	1,681	(3.61)***	700	(1.12)	1,243	(1.61)
Proportion of agro-forestry planting income (0-1)	0.01	(0.19)	0.18	(2.41)**	-0.14	(-2.71)***
Proportion of remittance (rural-urban migration) income (0-1)	-0.03	(-0.68)	-0.05	(-0.71)	0.11	(1.96)**
Agro-forestry planting participation (0,1)	-0.03	(-1.16)	0.02	(0.58)	-0.07	(-1.80)*
Fuel wood utilization (0,1)	-0.14	(-2)*	0.1	(1.41)	-0.21	(-3.15)***
Coal gas and biogas utilization (0,1)	0.29	(3.99)***	-0.27	(-2.88)***	0.19	(2.54)**
Poverty rate (0-1)	-0.13	(-1.93)*	-0.19	(-2.35)**	-0.17	(-2.49)**
Stock variable						
Land area per capita (hectare per capita)	-0.25	(-1.64)	-0.09	(-0.67)	-0.18	(-0.97)
Saving (0,1)	-0.05	(-0.93)	0.03	(-1.01)	-0.14	(-2.32)**
Per capita loan (yuan per person)	4,387	(4.31)***	-1,032	(-1.16)	3,742	(3.58)***
House value rank (1,3)	0.58	(4.66)**	1.08	(7.73)***	0.55	(4.33)***
House quality rank (1,3)	0.22	(2.27)**	0.83	(6.42)***	0.42	(4.48)***

Note: t-stats are shown in parentheses. *, ** and *** denote the differences are significant at p<0.1, p<0.05 and p<0.01, respectively. PA: poverty alleviation; DA: disaster avoidance; ER: ecological restoration

To examine the matching results of the sample, as well as to illustrate the rationality of using PSM, we compare both the propensity score density of the control and treatment groups by matching. The density graphs are in Fig. S5.

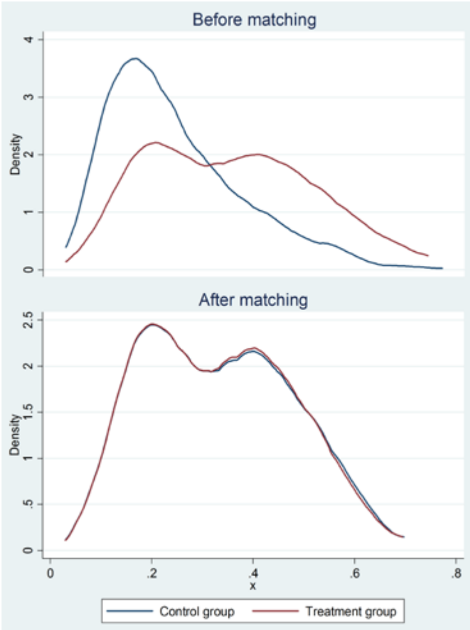

Fig. S5. Matching result of samples.

Table S11 Balancing test for matching, based on propensity score

Variable	Sample	Mean Treated	Mean Control	%bias	%reduct bias	t-test t	t-test p>t
Household size	Unmatched	4.1532	3.4843	44		6.85	0.000
	Matched	4.0135	4	0.9	98	0.11	0.909
Credit access	Unmatched	0.43544	0.20489	50.9		8.27	0.000
	Matched	0.23232	0.20875	5.5	22.5	0.69	0. 489
Skills	Unmatched	0.32132	0.2305	20.4		3.24	0.001
	Matched	0.29966	0.3165	-3.8	81.5	-0.44	0.657
Highest education	Unmatched	9.1171	8.7206	13		1.96	0.050
	Matched	9.0909	9.0909	0.0	100	-0.00	1.00
Special experience	Unmatched	0.17417	0.10827	19.0		3.08	0.002
	Matched	0.14815	0.13805	2.9	84.7	0.35	0.726
SLCP	Unmatched	0.89189	0.80326	24.8		3.66	0.000
	Matched	0.87879	0.88889	-2.8	88.6	-0.38	0.701
Elders	Unmatched	0.40841	0.27939	27.4		4.33	0.000
	Matched	0.38384	0.34343	8.6	68.7	1.02	0.307
Children	Unmatched	0.5045	0.39814	21.5		3.34	0.001
	Matched	0.48485	0.52862	-8.8	58.8	-1.07	0.287

Before matching, there is a significant difference between the control group and treatment group. If we directly compared the difference in livelihoods between these two, the estimate would be biased. However, after matching, the distributions of control and treatment groups are extremely close to one another, which indicates a good matching result (Fig. S5). We also present the balancing test for matching based on propensity score (Table S11).

S7 Cost-benefit analysis (CBA)

A.Costs and benefits for multiple stakeholders

We use cost-benefit analysis to give assessments for stakeholders involved in the RSP system, including local resettled households, local government, downstream water resource users, as well as global beneficiaries. For the whole RSP system, the cost consists of two parts, namely the costs experienced by resettled households ($C_{households}$) and the costs experienced by the Ankang government ($C_{government}$); The benefit includes the benefits experienced by resettled households ($B_{households}$), the Ankang Municipal government ($B_{government}$), downstream water resource users of the Middle Route of the SNWTP ($B_{downstream}$), and global beneficiaries (of carbon sequestration) (B_{global}). The detailed parameters are as follows:

Local resettled households.

For the resettled households, the total cost is a sum of the expenses of all resettled households, denoted as:

$$C_{households}=\sum(C_{house}+C_{consumption}),$$

where C_{house} is the cost of new house construction for an average (representative) resettled household, $C_{consumption}$ is the increased living expenses (daily consumption), which mainly refers to the recurring living expenses of a household, including food, clothing, energy utility, telecommunication fee, cash gift spending, medical costs, education, as well as other normal living expenditures.

The total benefit of resettled households is the sum of direct and indirect gains of all resettled households, denoted as:

$$B_{households}=\sum(B_{subsidy}+B_{income}+B_{security}),$$

where $B_{subsidy}$, B_{income}, $B_{security}$, are the representative family's relocation subsidy from government, change in income after relocation, and improved security resulting from the decrease of disaster risk, respectively. Here we didn't include the benefit of amenity value from the improvement in living conditions and conveniences, such as easy access to roads, transportation, education, communication and markets, because our available data on these are not reliable (given the early timing of our survey). Although these benefits are real for the relocation households (24), we simplified the cost-benefit analysis model to make more conservative estimates. We will modify this model by including the amenity value after acquiring more reliable data in future surveys.

$C_{households}$: The total cost to local resettled households is the sum of the expenses of all resettled households. For an average household: (i) the total expense of building a new home in the resettling community is a single payment once they participate in the RSP. From the resettled household sample, we collected data on the total expense of building a new house in the resettling community. Then we calculated the mean value of the expense, which is about 136,000 yuan; (ii) we used PSM to calculate the impact of the RSP on households' daily consumption (excluding the total expense of housing). Our estimate shows that the Program significantly affects the resettled households' daily consumption by an increase of 1,515 yuan per yr.

$B_{households}$: The total benefit to resettled households is the sum of direct and indirect gains of all resettled households. (i) Once a household participates in the RSP, it will be subsidized by the government for relocation. According to the relocation planning and policy, the one-time subsidy standard is 30,000 yuan per household which will be directly deposited to the participant's bank account. This benefit to households is also the cost to the government. (ii) To assess the variation in households' incomes after the RSP, we used PSM to estimate the change in income after participation in the Program, which is about 1,885 yuan per yr. (iii) Implementation of the RSP benefits local residents by reducing losses from disaster. During the household survey, we investigated the disaster-suffering households, recording their loss of production and property caused by natural disasters during the previous year. To calculate this disaster-reduction benefit, we first sum the total loss caused by disasters which includes the loss of agro-forestry planting income, loss of cultivation income, and loss of property. Using the disaster-suffering sample, we then used PSM to estimate the change in total loss between the resettled households and non-resettled households caused by the RSP. Then we calculate the $B_{security}$ by using the value of the change (9,731 yuan) multiplied by the proportion of disaster–suffering households in the resettled households (13.6%). Our estimate of $B_{security}$ is 1,323 yuan per yr.

Local government.

For the Ankang government, the total cost is denoted:

$$C_{government} = \sum_{i=1}^{3} \sum_{j=1}^{7} C_{ij} ,$$

i indicates the three non-overlapping classes by which relocation households receive voluntary assistance, namely disaster relocation, poverty alleviation relocation, and ecological relocation respectively. j indicates the focus of associated government investments, namely new home construction, public infrastructure, industrial development, human capacity building, public services, ecological restoration mostly for erosion control (and associated disaster risk reduction, water purification, and carbon sequestration), and land improvement (for construction and farming), respectively (Data source: "Planning of relocation in Ankang Municipality from 2011-2020"). The $B_{subsidy}$ of family's relocation subsidy from government should be treated as the cost of government. Here, it belongs to the 'new home construction' cost in the *j* item.

The benefit to the Ankang Municipal government ($B_{government}$) is denoted as the following:

$$B_{government}=B_{disaster}+B_{poverty}+B_{purify1}+B_{erosion1},$$

where $B_{disaster}$, $B_{poverty}$, $B_{purify1}$, $B_{erosion1}$ are the benefits of disaster risk reduction, poverty alleviation, water purification and erosion control, respectively.

$C_{government}$: According to RSP planning, the total investments budgeted for new house construction are 3.72 billion yuan at the first stage and 3.52 billion yuan at the second stage; 2.3 billion yuan at the first stage and 1.8 billion yuan at the second stage in public infrastructure; 0.58 billion yuan at the first stage and 0.55 billion yuan at the second stage in industrial development; 0.12 billion yuan at the first stage and 0.11 billion yuan at the second stage in human capacity building; 2.1 billion yuan at the first stage and 1.7 billion yuan at the second stage in public services; 0.23 billion yuan at the first stage and 0.22 billion yuan at the second stage in ecological restoration; 0.5 billion at the first stage and 0.4 billion at the second stage in land improvement). According to the RSP planning of Ankang Municipality, the total number of households (population) to be relocated is ca. 226,000 (877,000) from 2011-2020. The proportionality coefficient of each relocation group is 32.4% for disaster relocation, 31% for poverty alleviation relocation and 36.7% for ecological relocation. For the poverty relocation group, an extra 0.23 (2011-2015) and 0.22 (2016-2020) billion yuan in subsidies will be invested in new house construction.

For the first stage (2011-2015), the total number of households (population) to be relocated is ca. 116,000 (450,000). For the second stage (2016-2020), the total number of households (population) to be relocated is ca. 110,000 (427,000). Therefore, we distribute the total investments in each of the items at different stages according to different proportionality coefficients and then multiply these investments by the appropriate proportionality coefficient for the relocation population at the different stages.

$B_{government}$: To estimate $B_{government}$, (i) we first used the official statistical data from Ankang Municipal Government to sum the total fiscal expenditure of annual disaster relief from 2007 to 2011 in Ankang Municipality. Then we calculated the mean value and used it as the benefit of disaster relief reduction expected from the RSP, which is approximately 370 million yuan per yr ($B_{disaster}$).

(ii) We used the official data on total financial poverty-alleviation investment in a whole year divided by the total population in poverty to calculate the per capita investment on poverty alleviation. Then we multiplied the per-capita investment in poverty alleviation by the total population of the poverty-alleviation group of the RSP to estimate the total benefit of poverty alleviation resulting from the Program. In practice, because of the adjustment of the national official poverty line standard in

2011, we used the available official data in 2013 instead. The total financial poverty alleviation investment was 3.9 billion yuan, and the total poverty population was 0.9 million. Our estimate is that the per capita poverty-alleviation investment is about 4,300 yuan per year. To calculate the $B_{poverty}$, we then multiplied 4,300 by the total population of the poverty alleviation group of the Program.

(iii) As to $B_{purify1}$, based on the ES provision in terms of total nitrogen (TN) retention (122 tons for 2011-2015 and 200 tons for 2011-2020) and total phosphorus (TP) retention (19 tons for 2011-2015 and 30 tons for 2011-2020), we calculated the total water purification benefit of the RSP by first distributing the amounts of total phosphorus and total nitrogen retention into each year during the Program and then multiplying the unit cost of TN and TP treatment, which are 9,150 yuan per ton and 50,000 yuan per ton, respectively (25, 26). To estimate the $B_{purify1}$, we multiplied the relevant benefits of water purification by the water sharing coefficient, which is 5.24% (27).

(iv) Based on the ES provision of soil erosion regulation (297,220 tons for 2011-2015 and 890,162 tons for 2011-2020), we estimated the erosion control benefit of the Program by using the soil bulk density as 1.29t m^{-3} (28), the dredging efficiency as 2.6 m^3 per day per capita (29) and the payment for a construction worker as 120 yuan per day (Household survey data). Then we estimated $B_{erosion1}$ by using the calculated unit cost of soil erosion control (35.8 yuan per ton) multiplied by the soil erosion control service sharing coefficients of Ankang Municipality (45%) (30).

Downstream water resource users.

For the downstream water resource users in the receiving area of the Middle Route of the SNWTP, there are only benefits involved in our analysis. The total benefit ($B_{downstream}$) is the avoided costs of water purification thanks to receiving relatively nutrient- and sediment-free water through implementation of the Program. The value of improved water quality ($B_{purify2}$) and sediment retention ($B_{erosion2}$) due to the implementation of the RSP is as follows:

$$B_{downstream} = B_{purify2} + B_{erosion2},$$

$$B_{purify2} = (P_{TN} * E_{TN} + P_{TP} * E_{TP}),$$

where P_{TN} and P_{TP} are the cost of TN treatment (kg yr^{-1}) and the cost of TP treatment (kg yr^{-1}), respectively; E_{TN} and E_{TP} are the change in export of TN (kg yr^{-1}) and change in export of TP (kg yr^{-1}), respectively.

P_{TN} and P_{TP}: We used the cost of TN and TP treatment as 9,150 yuan per ton and 50,000 yuan per ton, respectively, which were identified by Wang et al. (25) and Nian et al. (26).

E_{TN} and E_{TP}: We used InVEST models to estimate total nitrogen and total phosphorus exported to streams, and their changes due to RSP implementation. For Ankang Municipality and the downstream water resource users, the proportions of water resource utilization were 5.24% and 31.59%, respectively (27, 31), which were also used as the benefit coefficients of water purification services for Ankang Municipality and the downstream water resource users.

We estimated $B_{erosion2}$ by using the average value of the calculated unit cost of soil erosion control (35.78 yuan t^{-1} for artificial price (Survey data) and 9.53 yuan t^{-1} for machine price (http://www.doc88.com/p-8929990788995.html)) multiplied by the soil erosion control service sharing coefficients of downstream water resource users (55%) (30).

Global beneficiaries

For global beneficiaries, the benefit refers to the increased carbon sequestration service from implementation of the Program. According to the ES provision of carbon sequestration (207,831 tons during 2011-2015 and 375,681 tons during 2011-2020), we estimated the benefit by multiplying this by the price of carbon sequestration in China. There are two widely used methods for estimating the carbon price: the carbon exchange price and the afforestation cost method. In this study, we used the average value of the two prices (43 yuan t^{-1} and 267 yuan t^{-1}) to estimate the value range of carbon sequestration, where 43 yuan t^{-1} was the average price of carbon exchange in 7 carbon markets of China (http://www.tanpaifang.com/tanshichang/201406/2133972.html) and 267 yuan t^{-1} was the average carbon sequestration price in China identified by the afforestation cost method (32-35).

B. Cost and benefit variation across time

Present value calculation

We developed land-use change scenarios only for the periods 2011-2015 and 2016-2020. In our analysis, there is no land-use change after 2020. However, benefits and costs continue to accrue each year. We use a capital equivalent calculation to make the cost and benefit comparable at the same time point (36). Theoretically, either future value equivalent or present value equivalent method could be adopted (37). In practice, we use an 8% social discount rate to calculate the present value of each stakeholder and the whole RSP system at a beginning time (2011) (38-40).

The Present value (P) of a single payment/benefit (A) at a comparable time point is denoted as the following: $P=A(1+i)^{-t}$, where the $(1+i)^{-t}$ is the duplicated rate present value coefficient. Here P is the present value, i is the social discount rate, t is the period to be calculated. We used the present value to calculate the corresponding equivalent cost-benefit of each stakeholder across the time period.

Specifically, for the recurring cost/benefit (considered as an annuity), we adopted the present value of annuity as follow: $S=A[1-(1+i)^{-t}]/i$, where A is the annuity (annual cost or benefit), $[1- (1+i)^{-t}]/i$ is the ordinary annuity coefficient.

To calculate the payback period of program, we used the Net Present Value (NPV) denoted as follows:

$$NPV = \sum_{1}^{t} (B-C)/(1+i)^t$$

Here, B-C is the net benefit (NB) of each stakeholder. The payback period is the time at which the NPV equals 0.

S8 Uncertainty analysis

There are uncertainties in both the biophysical assessment of ecosystem services and in the various values that we use in the model. Here we included a range of values for various key parameters to better account for uncertainty. We focused our analysis of uncertainty on factors that were both important (i.e., the range of reasonable parameter values could have a large impact on results), and for which we had a clear method for establishing a reasonable range of parameter values. Water purification service benefits make up a very small percentage of the total benefits, so we did not include uncertainty analysis of this service.

(i) Soil erosion

We use a range of values for soil erosion control services, reflecting the difference between labor cost and machinery cost (35.78 yuan to 9.53 yuan). As to the shared responsibility of damage for related beneficiaries, we adopt a 45% distribution coefficient for local government (Ankang Municipality) and 55% for the downstream water resource users (30). For Ankang Municipality, the value of soil erosion control service has little impact on the net benefit to the Ankang Municipal Government. Whether the value of soil erosion control services is calculated by using machinery costs (high) or labor prices (low), for Ankang Municipal Government the payback period is expected to last until 2035.

However, the soil erosion control service has a large impact on the net benefit of downstream water resource users. We provided a range of soil erosion control service for downstream water resource users to show the uncertainty of their net benefits (Fig. S6).

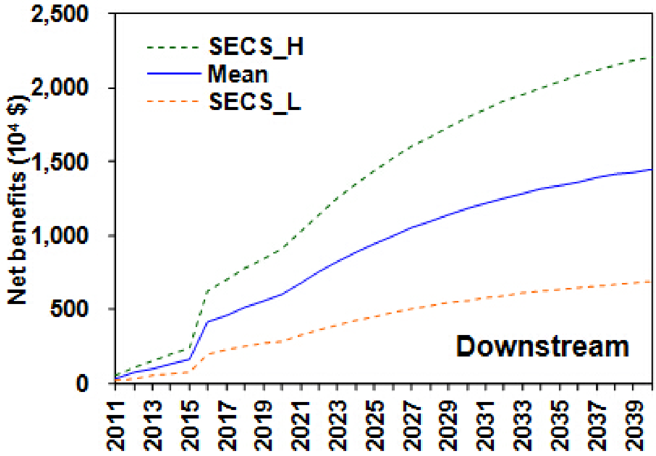

Fig. S6. Impacts of the value of soil erosion control service on the net benefits for downstream water resource users.

Note: SECS_H, SECS_L mean Soil Erosion Control Service with High Price and Soil Erosion Control Service with Low Price, respectively.

(ii) Carbon sequestration benefits

To assess carbon sequestration rates, we use parameters from the regions that share similar climate and similar vegetation types with Ankang. There is considerable uncertainty about the appropriate carbon sequestration service value to use. Estimates of the social cost of carbon vary widely (e.g. 41) and these also differ from current prices on carbon markets. We chose to use two prices relevant for China that span a range of reasonable values. First, we use the average price from seven carbon markets in China (http://www.tanpaifang.com/tanshichang/201406/2133972.html), which is 43 yuan t^{-1}, or 6.61 USD t^{-1}. We also use a price of 267 yuan t^{-1}, USD 41.08 t^{-1}, which is the average cost per ton for afforestation projects in China (35-38). For global carbon sequestration, the different prices have a large impact on the net benefit. We provided a range of carbon sequestration service for global beneficiary to show the uncertainty of their net benefits (Fig. S7).

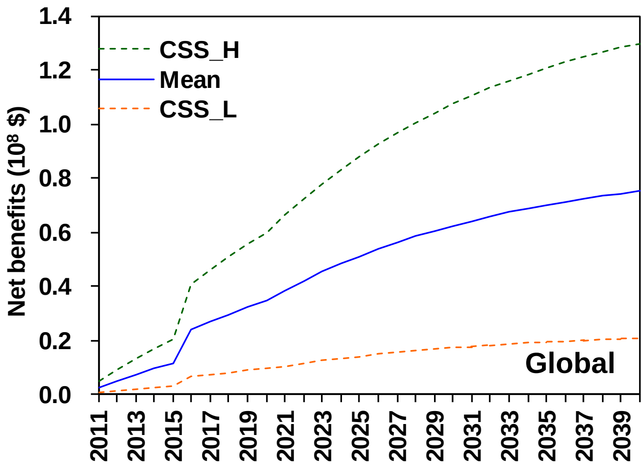

Fig. S7. Impacts of the value of carbon sequestration on the net benefits for global beneficiaries.

Note: CSS_H, CSS_L mean Carbon Sequestration Service with High Price (USD 41.08/ ton) and Carbon Sequestration Service with Low Price (USD 6.61/ ton), respectively.

(iii) Housing costs

We adopt mean values to calculate the costs and benefits of households in the main manuscript. Here, to explore uncertainty, we set the ranges of housing cost by using mean value plus/minus two standard deviations (S.D.).

For the low housing cost curve, the initial benefit is higher than the initial cost. For the high housing cost curve, the payback period may never come up (Fig. S8). Therefore, the poor group might be blocked from the Program by up-front costs.

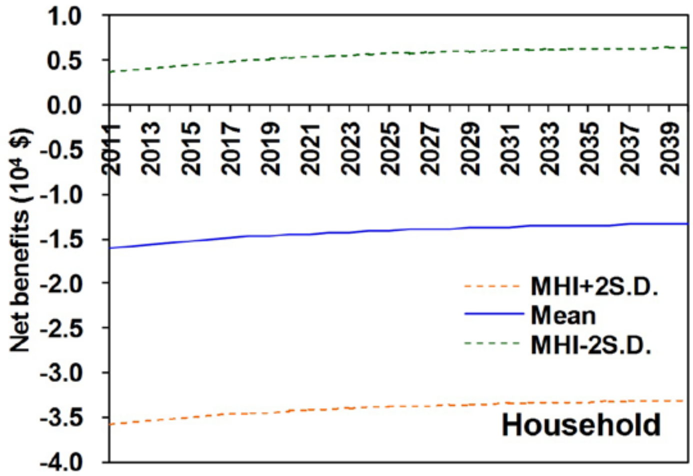

Fig. S8. Impacts of housing investment on net benefits for households.

Note: MHI means Mean Housing Investment.

(iv) Social discount rate

We also conduct an uncertainty analysis by adopting different social discount rates. With a lower discount rate, the payback period will be shorter. With a higher discount rate, the payback period will be longer. Here we first calculate the necessary subsidy to households to make them as well off by moving: 1) Costs for a new house are 136,000 yuan, the subsidy is 30,000 yuan, so the net cost of moving is 106,000 yuan; 2) the annual costs from higher consumption are 1,515 yuan; 3) the annual benefits from higher income and more security are 3,208 yuan in total (1,885 + 1,323); 4) the annual net benefits are 1,693 yuan (3208 – 1515); 5) the present value of 1,693 forever into the future discounted at 8% is 21,163 (1693/0.08); 6) subtracting this value from the one-time cost of 106,000 gives a value of 84,838 yuan. Therefore the necessary increase in the subsidy to households to realize payback in the long term is about 84,838 yuan. The same goes for the calculation of necessary increase of annual income, it is 8,672 yuan at 8% discount rate. After that, we calculate the subsidy value and income value at 5% discount rate. Here we present the payback condition for an average household and payback period for Ankang Municipality at 5% and 8% social discount rates (Table S12).

Table S12 Payback condition and payback period with different social discount rates

Stakeholders	8%	5%
Average household (payback conditions)	84,838 yuan (subsidy) 8,672 yuan (income)	72,140 yuan (subsidy) 5492 (income)
Ankang Municipality (payback period)	2035	2030

Note: Subsidy indicates the increase of subsidy; income indicates the increase of annual income.

For a single household, especially low-income rural households, we also explore a higher discount rate at 10% (Fig. S9).

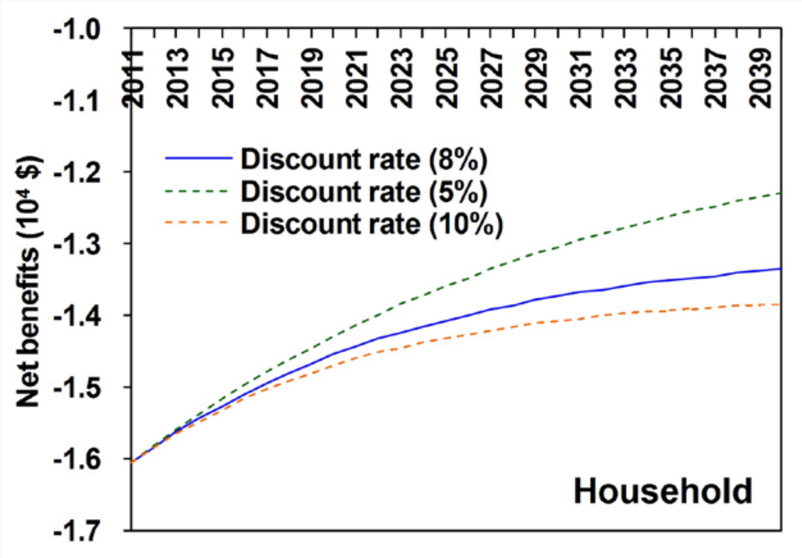

Fig. S9. Impacts of social discount rate on the net benefits for households.

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