Impacts of conservation and human development policy across stakeholders and scales

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Ideally, both ecosystem service and human development policies should improve human well-being through the conservation of ecosystems that provide valuable services. However, program costs and benefits to multiple stakeholders, and how they change through time, are rarely carefully analyzed. We examine one of China's new ecosystem service protection and human development policies: the Relocation and Settlement Program of Southern Shaanxi Province (RSP), which pays households who opt voluntarily to resettle from mountainous areas. The RSP aims to reduce disaster risk, restore important ecosystem services, and improve human well-being. We use household surveys and biophysical data in an integrated economic cost–benefit analysis for multiple stakeholders. We project that the RSP will result in positive net benefits to the municipal government, and to cross-region and global beneficiaries over the long run along with environment improvement, including improved water quality, soil erosion control, and carbon sequestration. However, there are significant short-run relocation costs for local residents so that poor households may have difficulty participating because they lack the resources to pay the initial costs of relocation. Greater subsidies and subsequent supports after relocation are necessary to reduce the payback period of resettled households in the long run. Compensation from downstream beneficiaries for improved water and from carbon trades could be channeled into reducing relocation costs for the poor and sharing the burden of RSP implementation. The effectiveness of the RSP could also be greatly strengthened by early investment in developing human capital and environment-friendly jobs and establishing long-term mechanisms for securing program goals. These challenges and potential solutions pervade ecosystem service efforts globally.

human well-being | payment for ecosystem services | social–ecological systems | relocation | sustainable household livelihoods

China is in a period of intense policy innovation to achieve sustainable development by harmonizing economic development with nature and transforming itself into the "ecological civilization of the 21st century" (1, 2). A major new policy involves zoning the country to protect and restore the most vital natural capital assets—spanning 28% of the nation's land area—which are crucial contributors to flood mitigation, sandstorm control, water resources, soil fertility, climate stability, and biodiversity (3). Key questions in China are, who are the potential winners and losers, and can policies be designed to promote both natural capital and human well-being across diverse stakeholders and through time?

Ecosystem services are generated and supplied to beneficiaries across a range of ecological and institutional scales. Stakeholders can have very different perspectives on the values of ecosystem services and, by extension, the impacts of policy (e.g., ref. 4). These differences arise from the nature of a stakeholder's role(s) in the system, such as whether they are suppliers or beneficiaries, or both; how their income-generating and livelihood activities affect the provision of different services; whether institutions exist through which beneficiaries compensate suppliers for services; stakeholders' specific livelihood opportunities and capacity to change; and rapidity of change in the system, such as in resource use, property rights, migration, and the local influence of global actors (5–9).

Ideally, linked conservation and human development policies would be designed, evaluated, and adaptively improved using rigorous biophysical and socioeconomic analysis of impacts on ecosystems and their services, and on the livelihoods and well-being of diverse stakeholders (10). In practice, this is extremely challenging and is rarely done (1, 11). With recent advances in knowledge and approaches, however, it is now realistic to apply integrated approaches to do such analyses.

To address devastating environmental crises and to improve human well-being, China is implementing multiple regional and national conservation policies. One such policy, the Relocation and Settlement Program of Southern Shaanxi Province (RSP or "Program"), pays people to move voluntarily from ecologically

Significance

Understanding costs and benefits to multiple stakeholders, and how they change through time, is essential to designing effective conservation and human development policies. Where, when, and to whom benefits are delivered are rarely analyzed, however. We examine one of China's conservation–development policies—the Relocation and Settlement Program of Shaanxi Province (RSP)—drawing insights of broad relevance. Although the RSP benefits the municipal government, downstream water consumers, and global beneficiaries, the short-run costs to local households and the municipal government greatly exceed these benefits. Moreover, poor households are unable to pay the upfront costs and have difficulty participating. The RSP is well designed to reduce local ecological pressure and enhance human development, but its effectiveness could be strengthened in key ways.

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fragile, steep, remote mountain areas to towns or plains, to restore ecosystems, critical ecosystem services (e.g., water purification, flood control, landscape stabilization), alleviate poverty, and enhance livelihood security. Similar to other ecosystem service investment projects worldwide, multiple stakeholders, including local households, governments, and regional beneficiaries of ecosystem services, are involved in the RSP. One of the greatest challenges is how to address the interests and livelihoods of different stakeholders to achieve sustainability goals.

In this article, we use the RSP in Ankang Municipality, a primary water source conservation area for the South-to-North Water Transfer Project (SNWTP)—the largest water transfer project in the world—as a case to explore the costs and benefits for multiple stakeholders. We first identify the expected impacts of the RSP on land use and land cover (LULC). Second, we use household survey data from RSP participants and nonparticipants to better understand the immediate impacts of the Program on household well-being and livelihood activities, and its potential influences on the environment. Finally, we analyze changes in the costs and benefits that reveal how the RSP is likely to affect different stakeholders in the short and long term.

Background

Ankang Municipality. Ankang Municipality is located in the south of Shaanxi Province in the Qinling Mountains, on the upper reaches of the Han River, a major branch of the Yangtze River (Fig. 1 and *SI Appendix*, section S1). Ankang Municipality comprises nine counties, together spanning 23,534 km^2. The permanent resident population is 2.63 million, one-third of whom are below the poverty line (354 USD per capita per y; 1 USD = 6.5 CNY in 2011). The per-capita annual income of urban and rural residents, in absolute terms and relative to national average urban and rural income levels, is 2,672 USD (80%) and 770 USD (72%), respectively (12).

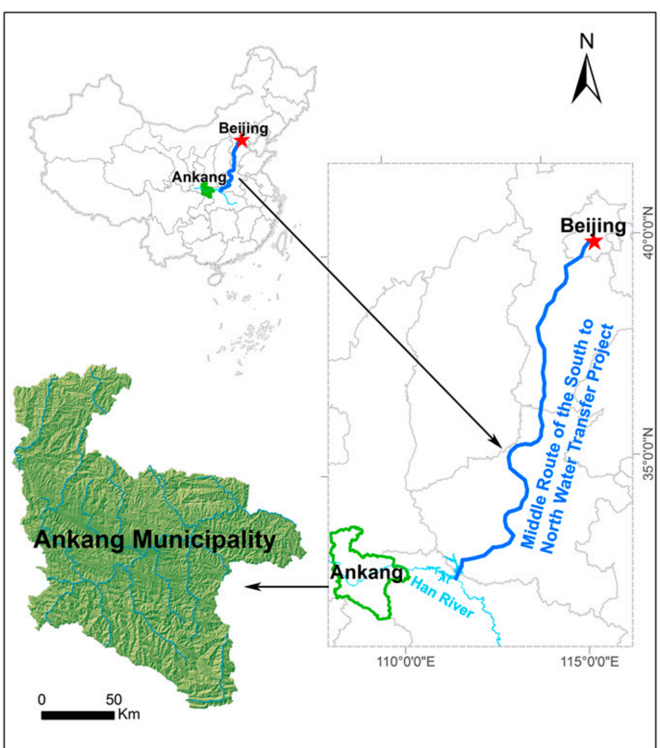

Fig. 1. Ankang Municipality is located in the upstream of the Han River and is the water source conservation area of the Middle Route of the SNWTP (*SI Appendix*, section S3).

Ankang is an important water resource conservation area for the SNWTP. The 340-km section of the Han River in Ankang Municipality provides average annual runoff of 1.07×10^{10} m^3. Ankang Municipality accounts for 60% of the water resources in Shaanxi Province (12).

Relocation and Settlement Program Planning. Ankang Municipality faces severe challenges in reducing disaster risk and improving human well-being, together with its neighboring municipalities of Shangluo and Hanzhong (*SI Appendix*, Fig. S1). In total, 92.5% of Ankang Municipality is steeply mountainous, prone to frequent floods, landslides, debris flow, etc., that result in severe economic losses every year (13). From the viewpoint of the provincial government, relocating people who live in vulnerable mountain villages, with poor access to basic facilities, is the most effective way to improve livelihoods. Thus, to avoid natural disasters, 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 initiated the RSP in 2011—the largest resettlement project in the history of modern China.

Offering direct financial assistance and other incentives, the provincial government aims to relocate, on a voluntary basis, 2.4 million people over 10 y in 28 counties of these three municipalities—a quarter of their total population. Eligible households will be given financial assistance to move from steep, remote locations to safer places with better access to public services (*SI Appendix*, section S2). In Ankang Municipality, the Program involves ~226,000 rural households (450,000 individual residents during 2011–2015 and another ~427,000 during 2016–2020).

The Program is tied to the Middle Route of the SNWTP (*SI Appendix*, section S3), designed to deliver high-quality fresh water to arid North China by reducing soil erosion and nutrient runoff into the Han River. Controversy has arisen in relation to past relocation programs, especially the Three Gorges Dam displacement and resettlement (14, 15). In response and in contrast to the Three Gorges Dam project, this resettlement project is expected to be voluntary, relocates people locally, and aims to improve human well-being and vital ecosystem services locally, regionally, and globally (*SI Appendix*, section S2).

A Framework for Analyzing Policy Impacts Across Stakeholders and Scales. To reduce vulnerability and increase resilience and well-being in the social–ecological system of Ankang, the RSP will affect significant land use and land cover changes, not only in the migration areas but also in the relocation areas. These will impact the production and delivery of multiple ecosystem services and their stakeholders across multiple (local, regional, and global) scales. Simultaneously, the livelihoods of migration householders will also change with RSP implementation. Furthermore, all of these impacts will change with time. To guide and improve the Program, it is vital to assess its impacts on and the distribution of costs and benefits to different groups through time (Fig. 2).

Results

Impacts of Relocation Project on LULC. Significant LULC changes resulting from the RSP involve two primary conversions. The largest in terms of area is from farmland to forests, and the other is from gently sloping grassland and bare (rocky/sandy) land to urban land (Fig. 3). According to Program plans, by 2015 9.3% of farmland will be converted to forest, whereas 3.5% of grassland and 16.9% of bare land will be converted to urban land (Fig. 3 and *SI Appendix*, Fig. S4). By 2020, a total of 16.9% of farmland will be converted to forest, whereas 12.7% of grassland and

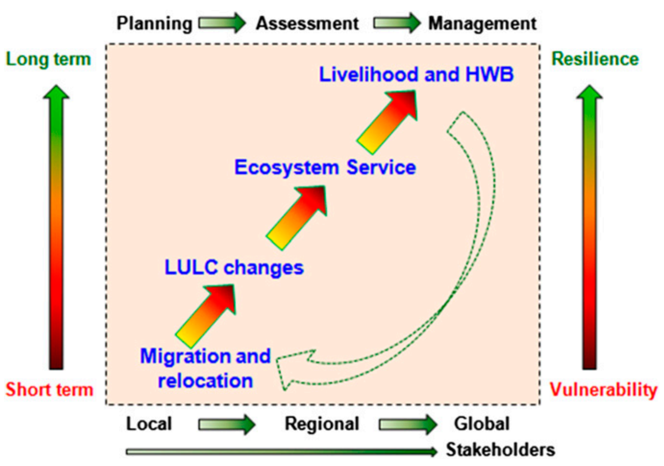

Fig. 2. Our framework for assessing the RSP. LULC and HWB denote land use and land cover, and human wellbeing, respectively.

16.9% of bare land will be converted to urban uses (Fig. 3 and *SI Appendix*, Fig. S4).

Household Livelihood Changes During the Initial Program Year. We explore how the RSP impacts livelihoods in two dimensions: changes in flow variables and changes in stock variables. We report these changes with propensity score-matching (PSM) techniques, which pair each treated observation (relocation household) with a similar control observation (nonrelocation household) on the basis of their propensity scores. We interpret the difference in outcomes for these matched households as the average effect of treatment on the treated (ATT) (*SI Appendix*, section S6). The RSP is projected to increase per-capita income, the proportion of rural–urban migration remittance income, clean energy utilization, and housing value and quality, and to decrease agro-forestry, fuel wood utilization, natural disaster losses, and the poverty rate (Table 1). On a less positive note, the Program increased per-capita loans and decreased per-capita land area and savings (Table 1).

Benefit–Cost Dynamics of Multiple Stakeholders. The household survey has limited value for assessing the long-term societal impacts of the program, because it provides information only on households and only during the initial program year. We therefore also estimated the net benefits and their changes through time to multiple stakeholders. For a household participating in the resettlement program, the upfront cost of relocation is much higher than the one-time subsidy payment from the government. Therefore, moving might not bring any net benefit to the households in the short term (Fig. 4*A*). Furthermore, poor households may be blocked from relocation because they lack the resources to pay the upfront costs (see *SI Appendix*, sections S7 and S8, for detailed analysis of different scenarios). In the long run, however, easy access to roads, transportation, education, communications, and markets would make households economically better off. We estimate how an increase in subsidy or income would allow households to be better off in the future, yielding positive present value of net benefits. In particular, we project that the total household expenses associated with resettlement will be paid off either with an increase of 13,000 USD of subsidy or 1,500 USD of annual income (*SI Appendix*, sections S7 and S8).

The local government also incurs significant upfront costs and will face a 942 million USD shortfall in present value terms by the end of 2020 (*SI Appendix*, sections S7 and S8). The future benefits eventually make the present value of net benefits positive, but the payback period for the local government is expected to extend 15 y after the end of the Program (Fig. 4*B*).

The Program also greatly benefits downstream water-receiving areas of the SNWTP: an estimated total of 6 million USD in avoided water purification and sediment removal costs during 2011–2020 and an estimated 1.85 million USD in further avoided costs annually thereafter. Meanwhile, the RSP will also contribute a total of 35 million USD from 2011 to 2020 and then 9 million USD per year to global beneficiaries of carbon sequestration (*SI Appendix*, section S7, and Fig. 4 *C* and *D*).

Many of the variables in this analysis are subject to considerable uncertainty, including parameters for biophysical assessment of ecosystem services and the prices for economic valuation. To understand how uncertainty affects the results, we considered a range of values for key variables. We find that results for net benefits are sensitive to variability in the cost of housing and the social discount rate. Lower housing costs can tip the scales so that households have positive net benefits from relocation both in the short run and long run. Moreover, a lower discount rate also reduces the payback period compared with a higher discount rate. However, variation in water purification, soil erosion control, and carbon sequestration have only minor effects on the results (*SI Appendix*, section S8).

Discussion

Ecosystem service benefits, and their distribution to beneficiaries, remain poorly understood components of measurement and monitoring programs (16). Quantifying the distribution of benefits requires an in-depth understanding of socioecological systems (8). By using a socioecological systems approach (17, 18) (Fig. 2), we identify the benefits associated with a bundle of interacting services (e.g., water purification, disaster risk reduction, carbon sequestration) and examine how these benefits flow to different stakeholder groups (different local household groups, the local municipal government, downstream water resource users, and global beneficiaries) (Fig. 4). These stakeholders include funding providers, ecosystem service providers, and ecosystem service beneficiaries. Not only household incentives, but also incentives at local, regional, national, and global scales, are essential to the success of conservation efforts, because governments often make large-scale natural resource decisions affecting conservation (19), and households interact with ecosystems directly.

Integrating multiple stakeholders in policy design can also help to realize multidimensional policy targets such as ecosystem

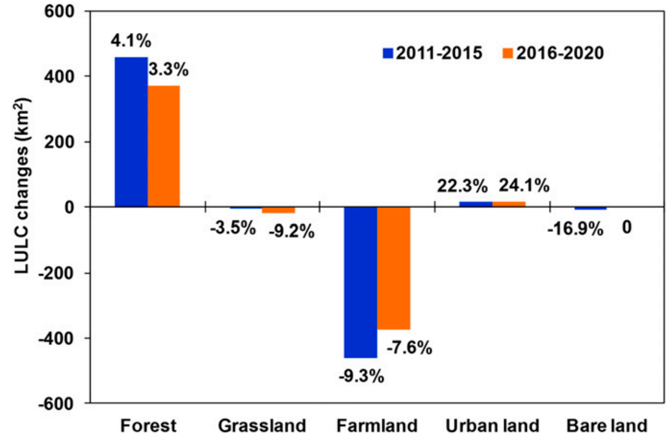

Fig. 3. LULC changes under RSP planning scenarios during 2011–2015 and 2016–2020. The percentages refer to changes compared with the areas of the indicated land uses at the start of each subperiod.

Table 1. Impacts of the RSP on local residents' livelihoods during the initial year

Livelihoods	PSM	
	ATT	t
Flow variables, annual		
Total income; exclude subsidy, $\$\cdot y^{-1}$	290	(2.17)**
Per-capita income; exclude subsidy, $\$\cdot y^{-1}$	90	(2.55)**
Total expenditure; exclude housing cost, $\$\cdot y^{-1}$	233	(1.67)*
Per-capita expenditure; exclude housing, $\$\cdot y^{-1}$	90	(1.8)*
Proportion of agro-forestry planting income, 0–1	−0.07	(−2.35)**
Proportion of (rural–urban migration) remittance income, 0–1	0.15	(2.9)*
Agro-forestry planting participation; 0, 1	−0.05	(−2.24)**
Fuel wood utilization; 0, 1	−0.08	(−1.68)*
Coal gas and biogas utilization; 0, 1	0.09	(2.39)**
Disaster loss; disaster suffering sample, $\$\cdot y^{-1}$	−1,497	(−2.77)***
Poverty rate, 0–1	−0.06	(−1.71)*
Stock variables		
Land area per capita, hectare per capita	−0.27	(−3.02)***
Saving; 0, 1	−0.07	(−1.83)*
Per-capita loan, $ per capita	320	(3.48)***
House value rank, 1–3	0.24	(4.21)***
House quality rank, 1–3	0.56	(8.24)***

Note: t statistics are shown in parentheses. *, **, and *** denote significant differences at $P < 0.1$, $P < 0.05$, and $P < 0.01$, respectively. Variables refer to an entire household, unless otherwise indicated.

service restoration, poverty alleviation, and security improvement (20), through diversifying the types of stakeholders who benefit from ecosystem services and increasing investments in natural capital conservation and restoration (21). For example, payment for ecosystem service (PES) schemes, designed to increase investment in natural capital, could be implemented between Ankang and beneficiaries of the RSP, including downstream water resource users and global beneficiaries of carbon sequestration (Fig. 4).

Policy decisions are often evaluated through cost–benefit assessments, which can help make ecosystem service research operational (22). Conservation is most likely to succeed when benefits outweigh costs for all relevant decision makers (19). Understanding costs—including land prices, government investments, and opportunity costs—will help in allocating scarce resources most efficiently (23). Understanding benefits of ecosystem services such as flood control, water purification, and carbon sequestration from forests will assist in estimating the economic value of lands identified for conservation and identifying who may be willing to pay for these services (24).

Our analysis reveals not only the net benefits to different groups of stakeholders but also changes in net benefits over time. For local households, the cost initially exceeds the benefits. Reaching the break-even point in the near term hinges on either increasing household income, through improved livelihood opportunity, or providing higher government subsidy after relocation (Fig. 4*A* and *SI Appendix*, section S8). Moreover, easy access to roads, transportation, education, communications, and markets will make local households economically better off in the long term. For the local government, the total cost also initially exceeds the benefit and involves a 15-y payback period after the implementation of program (Fig. 4*B*). For downstream water resource users and also global beneficiaries, the net benefits start positive and increase through time. The results provide a metric for evaluating the effectiveness of ecosystem service conservation projects and various policy objectives by integrating into decision making the value of ecosystem services and other benefits and costs in both the short term and long term for different stakeholders.

An important aspect of policy assessment is understanding how changes in human well-being may influence governance and policy and, consequently, ecosystems and the provision of services (4). In our study, we found that the RSP has multiple impacts on the well-being of local households. The Program improves income, living conditions, and security (Table 1). However, we also found that participants in the Program lost land resources and savings, and have more loans (Table 1). Furthermore, in the short term, poor households with higher housing investment may have difficulty participating because the upfront cost (shortfall) is too high (see *SI Appendix*, section S8, for details). Subsequently, these changes in human well-being can lead to new, unpredictable impacts on destination ecosystems (e.g., converting forest to farmland), on whether participation is voluntary, and on the efficiency of the RSP (e.g., with participants potentially moving back to original areas or falling into impoverishment again). Over the long term, the improvement of human well-being depends heavily on successful transformation of livelihoods through voluntary participation. Our results emphasize the importance of integrating human well-being changes into program assessment.

Our study has some key limitations. First, we conducted the household survey just months after the RSP was implemented in Ankang in 2011. Within such a short time window, the longer term effects of the Program on household livelihoods could not be revealed, especially the potential economic benefit from easy access to roads, transportation, education, communication, and markets. Our predictions, however, include that of the benefits to households of relocating, which may underestimate the net benefits to households. We are conducting a follow-up survey to monitor the dynamics of households' livelihoods over the longer term. Second, our estimate of household net benefit is conservative and simple because we excluded the amenity benefit from the improvement of living conditions and access in the cost–benefit analysis model, because our early survey could not yield credible data on this. We will include this value and improve the cost–benefit analysis model in future study. Third, we treat households as identical (average household), but the survey shows that there is tremendous variation among households. This variation can have important effects—especially on who chooses to participate. There are unobservable household traits that could influence participation and produce bias in evaluating program impact.

To achieve multiwin results and multiscale sustainability, we make the following suggestions.

First, subsequent supporting programs should follow up. "Moving out" is just the first step, not the final aim of the RSP. More attention should be paid to implementing the subsequent supporting programs after moving out, such as investing in capacity building and environment-friendly job opportunities. In China, ecomigration and resettlement face great challenges in providing new housing and livelihood opportunities in urban areas (25). Our results show that, although the income-based poverty rate is reduced immediately after relocation, the resettled households face a heavy burden of loans and reduced savings (Table 1). To shorten the payback period and to avoid potential problems that might cause a household to move back to the original area or fall into impoverishment again (26), capacity building (such as knowledge and skill development, technology training, public service development, institution building) as well as creating environment-friendly job opportunities (such as national handicrafts, ecotourism, ecoagriculture) are very important (27).

Second, programs should establish direct financial compensation from ecosystem service beneficiaries to ecosystem service suppliers. As an important water source conservation area, Ankang plays a key role in water provision, water purification, and erosion control (Fig. 4). However, there is no direct PES program between Ankang and downstream water-receiving areas, which increases the risks of ecosystem degradation and reduced ecosystem service supply from Ankang Municipality. Corresponding financial compensation, including for carbon sequestration, would strengthen the impact of the RSP on poverty alleviation and livelihood improvement in Ankang Municipality. Each household has its specific perspective on the value of relocation, and these perceptions of the net benefits of relocation will directly influence the effectiveness of the RSP and the sustainability of the social–ecological system, especially after the one-time governmental subsidy has ended. With the compensation, local government could establish financial assistance mechanisms for the relocation households to secure program goals over the long term.

Our analysis emphasizes several important aspects of policy design and assessment. First, integrating multiple stakeholders into the assessment is crucial for ecosystem service conservation and human development policy design. Second, dynamic cost–benefit analyses of multiple stakeholders can help decision makers understand when and to whom ecosystem services are delivered, and how to design policies to ensure that net benefits are positive for all stakeholders. Finally, integrating household well-being into conservation policy can help to increase policy sustainability and prevent unexpected and undesired ecological consequences (4).

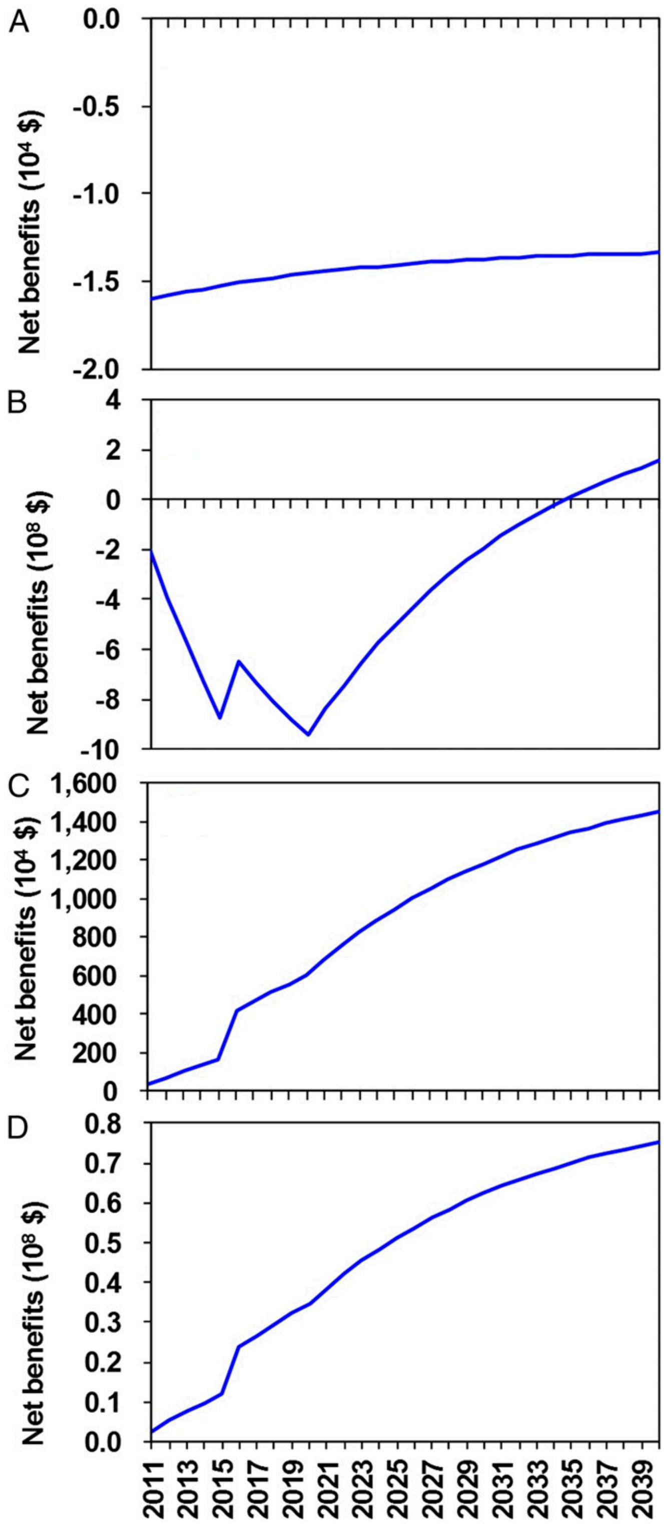

Fig. 4. Discounted net benefit curves of multiple stakeholders across different periods for (*A*) a single resettled household, (*B*) the Ankang municipal government, (*C*) water-receiving areas of the Middle Route of the SNWTP, and (*D*) global beneficiaries.

Methods

LULC Changes. LULC data for 2010 originates in Thematic Mapper images (30 × 30-m resolution), from the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences. We classified LULC into seven types: forest, shrub land, grassland, wetland, farmland, urban land, and bare (rocky/sandy) land. Based on actual land use in 2010, we projected LULC for 2015 and 2020 according to RSP planning scenarios (*SI Appendix*, section S4).

Ecosystem Service Assessment. We 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 Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) models (28). InVEST quantifies and maps ecosystem services provided by an existing landscape or under future scenarios (29) (*SI Appendix*, section S5). We also assessed carbon sequestration services for each LULC type (*SI Appendix*, section S5).

Household Livelihood Survey. In November and December of 2011, we conducted a household survey concerning rural households' livelihoods and the environment in Ankang Municipality. The survey included questionnaires for rural households and communities, and some semistructured individual interviews and focus groups, as follows. First, we selected five focal counties (of nine) in Ankang Municipality according to their gross domestic product in 2010: Hanbin from the top group (first), Ziyang, Shiquan, and Pingli from the middle (ranked four, five, and six, respectively), and Ningshan from the bottom (ninth). Second, in each focal county, we selected three townships for detailed study. All selected townships had resettling communities, nature reserves, and payment for ecosystem service (PES) policies. Then, 25 villages were selected: 15 were randomly chosen; 10 were new villages for relocating people. Fourth, villager groups were randomly chosen within the 25 survey villages. Finally, all of the rural households in the sampled village groups were surveyed, and the head of household, or a family member over 18 y old, was asked to complete a questionnaire.

We issued a total of 1,570 questionnaires, of which 1,410 (89.8%) were returned, and, of these, 1,404 (99.6%) were valid. The questionnaire focused on the household level: (*i*) social and demographic features, (*ii*) livelihood assets (natural, financial, social, physical, and human capital), (*iii*) livelihood activities (e.g., crop production, forestry, local nonfarm enterprise, rural–urban migration, etc.), (*iv*) labor time, and (*v*) consumption and expenditure.

Methods for Estimating Livelihood Changes. To evaluate the impacts of the relocation project on household livelihoods, we used PSM (30). Formally, the ATT was estimated as follows:

$$ATT = E\{E[Y_{1i}|D_i = 1, p(X_i)] - E[Y_{0i}|D_i = 0, p(X_i)]|D_i = 1\}.$$

Y_{1i} and Y_{0i} are the potential outcomes in the two counterfactual situations of treatment (relocation) and control (nonrelocation). D_i represents whether the household is a participant (i = 1) or not (i = 0). $p(X_i)$ is the conditional probability of participating in RSP given pretreatment characteristics of households. The SEs were obtained using bootstrapping methods (*SI Appendix*, section S6).

Cost–Benefit Analysis of Multiple Stakeholders. We conducted a cost–benefit analysis of the RSP by estimating the costs and benefits for each stakeholder involved in the RSP system, including local resettled households, local government, downstream water resource users, global beneficiaries, as well as the whole program (*SI Appendix*, section S7). (*i*) For local resettled households, the total costs ($C_{households}$) include the cost of new house construction and increase in living expenses (daily consumption). The total benefits ($B_{households}$) include the single family's relocation subsidy from government, change in income after relocation, and disaster reduction resulting from the decrease of disaster risk, respectively (*SI Appendix*, section S7). (*ii*) For the Ankang municipal government, the total cost ($C_{government}$) is the sum of the total investment in three relocation classes, namely disaster relocation, poverty alleviation relocation, and ecological relocation, respectively. The total benefits ($B_{government}$) are the decreased investment in disaster risk reduction, poverty alleviation, and water purification and erosion control, respectively, which resulted from the Program. (*iii*) For downstream water resource users, 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 (31) (*SI Appendix*, section S7). (*iv*) For global beneficiaries, the total benefit (B_{global}) is the value of increased carbon sequestration service resulting from implementation of the Program.

Methods for Estimating Benefit–Cost Changes. Using the biophysical data and household survey, we examine the net present value of the relocation program across multiple stakeholders as well as different time periods (2011–2020, after 2020), using an 8% social discount rate (*SI Appendix*, section S7).

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