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RESEARCH ARTICLE

Using the green purchase method to help farmers escape the poverty trap in semiarid China

Shixiong Cao[1] · Xinyi Zheng[2] · Li Chen[1] · Hua Ma[3] · Jiangzhou Xia[4]

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Abstract People who live in ecologically fragile environments face both poverty and environmental degradation, which reinforce each other and create a "poverty trap." Traditional ecological restoration projects focus only on ecological measures, and thus ignore the livelihoods of local residents. Those projects therefore fail to solve the poverty trap. In addition, project subsidies to residents typically end when the projects end, thus forcing residents to return to their old way of life and reversing the gains from the projects. To break this cycle, we performed a study in China's Yanan City, in Shaanxi Province, to promote a new "green purchase" method for implementing sustainable economic activities that bring residents ongoing earnings without harming the environment. This method involves the construction of terraced fields, establishment of fruit tree orchards, implementation of grazing restrictions, and ecological migration. We found that the method was ecologically effective, as it increased Yanan's vegetation cover by 0.89% annually since 1999, which is twice the rate for Shaanxi Province.

Keywords Ecological restoration · Green purchase · Livelihood · Poverty · Win-win strategy · Environmental policy · Socioeconomic development

1 Introduction

Humans who live in ecologically fragile areas face the double challenge of environmental degradation and poverty, which are invariably linked and mutually reinforcing, thereby creating what has been called the "poverty trap" (Serageldin 2002; Sietz et al. 2011). The Food and Agriculture Organization (FAO) of the United Nations and the World Bank have worked with governments around the world for a long time in an effort to solve this problem (FAO 2016; World Bank 2015). However, traditional ecological restoration projects have typically focused solely on the influence of natural factors while neglecting socioeconomic factors (Beddington et al. 2007; Castilla and Defeo 2005; Sachs and Reid 2006). Impressive initial achievements have been reported (e.g., Zhang et al. 2010). However, after the projects finish, funding disappears and residents sink back into poverty, which forces them to return to their old practices (which were often responsible for ecological degradation), thereby creating a vicious circle in which poverty leads to ecological degradation that further deepens poverty. The heart of this problem is that the projects do not establish ecologically and economically sustainable industries that will provide alternatives to unsustainable practices by improving the long-term livelihoods of residents (Gong et al. 2011). Monitoring data indicate that only 16% of the ecological restoration projects subsidized by the World Bank have accomplished both their environmental and socioeconomic goals (State Forestry Administration, 1985-2015; World Bank 2015).

✉ Shixiong Cao
shixiongcao@126.com

1 School of Economics, Minzu University of China, No. 27 Zhongguancun South Street, Haidian District, Beijing 100081, People's Republic of China

2 College of Economic Management, Beijing Forestry University, No. 35, Qinghuadong Road, Haidian District, Beijing 100083, People's Republic of China

3 Nanning Water Conservancy Bureau, No. 36 Youai North Road, Nanning 530001, People's Republic of China

4 State Key Laboratory of Earth Surface Processes and Resource Ecology, Future Earth Research Institute, Beijing Normal University, Beijing 100875, People's Republic of China

Since 1999, China's government has implemented heavily funded nationwide ecological restoration policies such as the Grain for Green Project and the Natural Forest Conservation Project (Chang et al. 2011; Gauvin et al. 2010). These are an improvement over older projects, which were often based on a single government expenditure in response to a perceived emergency rather than an ongoing, long-term solution, but the newer projects have proven to be equally unsustainable (Cao et al. 2009b). The problem has been that project planners have failed to fully account for the influence of their projects on the livelihoods of the residents who are affected by these projects (Gauvin et al. 2010). In the Grain for Green Project, for instance, local residents received economic compensation for their loss of income caused by obeying grazing restrictions in degraded land and instead performing afforestation or grassland restoration activities to restore this land; however, no training or job creation programs were included in the project and no new industries were created, so this approach forced residents to return to their old, unsustainable activities when the compensation payments ended. As a result, the project only accomplished 20% of its economic development goals (Groom et al. 2010; State Forestry Administration, 1985-2015).

From our readings on this subject, we believe that the problem lies in focusing on a single objective (ecological restoration or socioeconomic development) rather than combining both objectives to create a result that will be sustainable in the long term and that offers a chance to escape the poverty trap. To test this hypothesis, we have cooperated with the Yanan Municipal Government since 1999 in an experimental demonstration-scale study in a semiarid region of China that relies on the "green purchase" approach (i.e., paying those who are affected by a program to protect their environment), in which ecological restoration is implemented in a way that achieves a win-win solution and mitigates or eliminates the poverty trap.

2 Materials and methods

2.1 Restoration and development strategies for Yanan City

The goal of this study was to find ways to prevent and remediate the ecological degradation associated with farming, while simultaneously improving food production through the use of improved agricultural techniques. We therefore looked for restoration and development strategies based on a green purchase approach that would provide financial benefits for local residents while protecting the local environment. Specifically, we found ways to reform local farming and grazing methods, as these activities were responsible for most of the income of local residents.

The first key component of this approach was to build terraced fields in areas that had been formerly managed as sloping fields and that therefore experienced unacceptably high rates of soil erosion caused by wind and running water. Specifically, the government provided funding to build 0.2-ha terraced fields for each farmer to replace the former 0.6-ha sloping fields (Fig. 1a); this approach was accepted because the grain output of the terraces was expected to be three to five times that of the former sloping fields.

Second, we vigorously promoted the establishment of fruit tree plantations to produce fruits such as apples, pears, and apricots to increase farmer income (Fig. 1b). We selected species that were adapted to the local hydrological conditions so that the trees would survive and produce long-term benefits for the residents. The area of these orchards increased by more than 129×10^3 ha between 1999 and 2012, and generated more than 29×10^6 RMB of income for the farmers (State Forestry Administration, 1985-2015). Sales of this fruit accounted for 66.9% of total rural income. As a result of this and other changes, per capita farmer income increased from 2438 RMB in 1999 to 6180 RMB in 2014 (Statistical Bureau of China, 1985–2015).

A third key approach was to encourage ecological restoration by natural processes (i.e., rather than by planting of new vegetation). This was done by implementing grazing exclusion in degraded areas. Overgrazing is a key human disturbance that is responsible for vegetation degradation and, if allowed to continue, can prevent sustainable development. In contrast, implementing the protection policy decreased the number of grazing animals in Yanan City from 3.797×10^6 in 1999 to 1.877×10^6 in 2014 (Statistical Bureau of China, 1985–2015). As a result, substantial forest recovery occurred (Fig. 1c).

Our fourth key strategy was to promote ecological migration. Residents who live in regions with a fragile environment that has low vegetation cover typically find that the environment provides insufficient resources for all inhabitants. In such cases, it is necessary to relocate these residents to areas that can sustain them. Thus, we encouraged rural residents to move to cities (Fig. 1d), where economic opportunities were much improved. As a result, 244.8×10^3 residents (17.5% of the rural population of Yanan City in 1999) moved to cities or rural areas adjacent to cities. To prevent conflict with residents who might be unwilling to migrate, the provincial government offered vocational training (e.g., training in literacy and other skills required by the rapidly growing urban manufacturing sector) to these migrants and guaranteed employment opportunities; for those who lost the ability to work (e.g., due to age or injury), the government provided a subsidy of 300 RMB per month. The combination of training in work skills and an income subsidy persuaded many residents to move away from places with a fragile environment, thereby reducing the pressure on the environment.

Fig. 1 Examples of the consequences of the new "green purchase" approach in China's Yanan City. **a** Terraced fields were constructed to replace the former fields on sloping sites. **b** Highly productive apple orchards were established in the terraced land. **c** Prevention of overgrazing contributed to strong recovery of the protected forest by natural processes, without requiring tree planting or other interventions. **d** Ecological migration was encouraged so that rural residents would move to cities or areas adjacent to cities, where they built new houses and found jobs that earned them more income

2.2 Study area and methods

Yanan City is located in northern Shaanxi Province, bordered by Gansu Province to the west and Shanxi Province to the east, across the Yellow River. Situated in the middle reaches of the Yellow River, Yanan City's terrain is dominated by a mixture of plateaus and hills. Based on local meteorological records from 1950 to 2015, the mean annual temperature is 9.6 °C, with mean monthly temperatures ranging from a minimum of −11 °C in January to a maximum of 28.2 °C in August. The annual mean precipitation is 500 mm, with 81.4% of the precipitation falling during the growing season. The natural vegetation type of Yanan City is broadleaved deciduous forest, and the soil is a dark loess.

The population of Yanan City in 2015 was 2.23×10^6, which included 1.915×10^6 rural residents. The land area is 3.704×10^6 ha (Note that in China, unlike in the West, a "city" includes both the built-up urban area and the large surrounding rural area that lies within the city's administrative boundary.) The livestock population of Yanan City in 2015 was 1.88×10^6. Agricultural production and other economic activities earned residents a per capita annual income of 6180 RMB in 2014. Starting in 1999, our green purchase approach was implemented primarily by means of the construction of terraced fields to replace the former sloping fields, which experienced unacceptably high rates of soil erosion, leading to impoverished soils with low agricultural yields. In addition, farmers were encouraged to establish fruit orchards and protect existing forests to allow natural recovery. Finally, ecological migration of rural residents to a city was encouraged by providing training and urban employment, as well as a monthly income subsidy for those who could no longer work. Yanan City was the first place in China to participate in the Grain for Green Project, the Natural Forest Conservation Project, and the Three North Shelterbelt Development Project. Our approach was added to these national-scale projects.

Our primary data sources were satellite images and data from the Yanan Statistical Yearbook (Statistical Bureau of Yanan 1985–2015). To determine the influences of our new approach on vegetation cover, which we used as a proxy for ecological restoration, we obtained satellite normalized-difference vegetation index (NDVI) data with 8-km spatial resolution from the Global Land Cover Facility (http://glcf.umd.edu/data/ndvi/). To provide full spatial and temporal coverage of our study area, we combined AVHRR and EOS data. To account for the different image resolutions (4 and 1 km, respectively), we transformed the EOS data from 2000 to 2010 to have the same resolution as the AVHRR data from 1983 to 2006, with each AVHRR pixel comprising a 16 × 16 grid of EOS pixels (Feng et al. 2015). We then used spline-based interpolation to convert the 8-km NDVI pixels to the 4-km AVHRR pixels. To account for temporal discrepancies, we calculated the weighted mean value of the EOS pixels for the two halves of each month, since the AVHRR satellite captures data only once every 15 days. These weighted means were chosen to represent the mean NDVI in each month, and the values that we analyzed to determine the degree of recovery were the maximum NDVI values in each year. Since the EOS satellite stopped providing data in 2012, we lost this source of NDVI data. The result was data for a 29-year study period, which ran from 1983 to 2012 and provided an adequate amount of data (17 years before and 12 years after implementation of our new approach).

To support our analysis, we acquired data from annual statistical reports on the natural and socioeconomic factors that potentially affected vegetation cover in the study area. We obtained data on the following statistical indices: (1) rural social development indices: the rural population, rural labor force, the lengths of roads and railways, and the area of mine greening (i.e., afforested areas at mining sites); (2) rural economic development indices: agricultural GDP, agricultural income, rural per capita income, rural per capita net income, the cultivated area, the sown area, the multiple-cropping index (i.e., the proportion of the total planted area cultivated with more than one crop), farmland area, total grain yield, grain yield per unit area, and number of livestock; (3) environmental policy indices: area of hilly terrain in which grazing was forbidden, area of natural forest protected to allow its recovery in hilly terrain, area of artificial afforestation, area of grass planting, area in which farmland was converted to forest, and investment in ecological projects; (4) climate and environmental indices: annual mean temperature, annual mean precipitation, extreme temperatures, the cumulative temperatures above 0 and 10 °C, total solar radiation, depth to the water table, and surface water capacity (i.e., water retention to a depth of 30 cm).

To account for differences in the units of measurement, we used the annual rate of change in each index to discern the most critical factors and their contribution to NDVI change. We used the 2011 version of the STATA software (http://www.stata.com/) to calculate multiple-regression coefficients for all factors that were significantly related to changes in NDVI and used the Breusch-Godfrey LM test to eliminate correlated variables that would bias the results through multicollinearity. Ultimately, we retained the following variables: for natural variables, the annual mean temperature and annual mean precipitation; for socioeconomic variables, the rural population, rural per capita net income, cultivated area, area of sloping land in which grazing was forbidden and natural recovery was pursued, afforestation area, the lengths of roads and railways, and the area of mines that underwent greening. We used the following regression equation form:

$$y_{it} = a + bx_{it} + u_{it} \quad (1)$$

where y_{it} represents the NDVI value in year t (where the standardized value for that year represents the percent change in the variable compared with the previous year) for area i, x_{it} is the corresponding influence factor for variable x, u_{it} is the error term, and a and b are regression coefficients.

To clarify whether socioeconomic or natural factors contributed most to the increase of NDVI in Yanan, we developed a contribution model to identify the main reasons for that growth. In this analysis, we accounted for the impacts of the following four new approaches: building terraced fields, the construction of fruit orchards, grazing restrictions in degraded land, and ecological migration of rural residents to cities. We used the following contribution model:

$$\mathrm{Con}_j = \frac{|SCV_j|}{\sum_1^j |SCV_j|} \quad (2)$$

where Con_j represents the contribution of influence factor j, and SCV_j is the coefficient for influencing factor j after standardizing the value of the factor (Feng et al. 2015). Values for the climate variables (temperature and precipitation) were obtained from the China Climate Yearbook (State Climate Administration 1985–2015).

3 Results and discussion

3.1 NDVI changes in Yanan City and Shaanxi Province

From 1984 to 1999, the period before the implementation of our program, the normalized-difference vegetation index (NDVI) for Shaanxi Province (excluding Yanan City) increased by an average of 0.17% annually, which was more than twice the rate of 0.07% for Yanan City. In contrast, Yanan's NDVI increased by 0.89% per year after implementation of the new program in 1999 (an increase of more than one order of magnitude compared with the previous rate), and this was twice the rate (0.45%) for the rest of Shaanxi Province (Fig. 2).

Despite similar climatic conditions in Yanan City and the other regions of Shaanxi Province, Yanan City's NDVI growth rate was twice that of the surrounding areas. This is likely to be because the other areas of Shaanxi Province only implemented the programs imposed by the central and provincial governments (e.g., Grain for Green), which included agricultural development policies (e.g., subsidies and a price support system for grain production) implemented by China's Ministry of Agriculture and the agriculture department of Shaanxi Province. In contrast, Yanan City also implemented the new green purchase approach described in this paper, which accounted for both environmental and socioeconomic factors.

Our research demonstrated that the green purchase approach greatly improved NDVI growth and growth of rural income compared with the simplistic measures of the central and provincial governments, which focused on ecological measures and neglected measures to improve local livelihoods in the long term

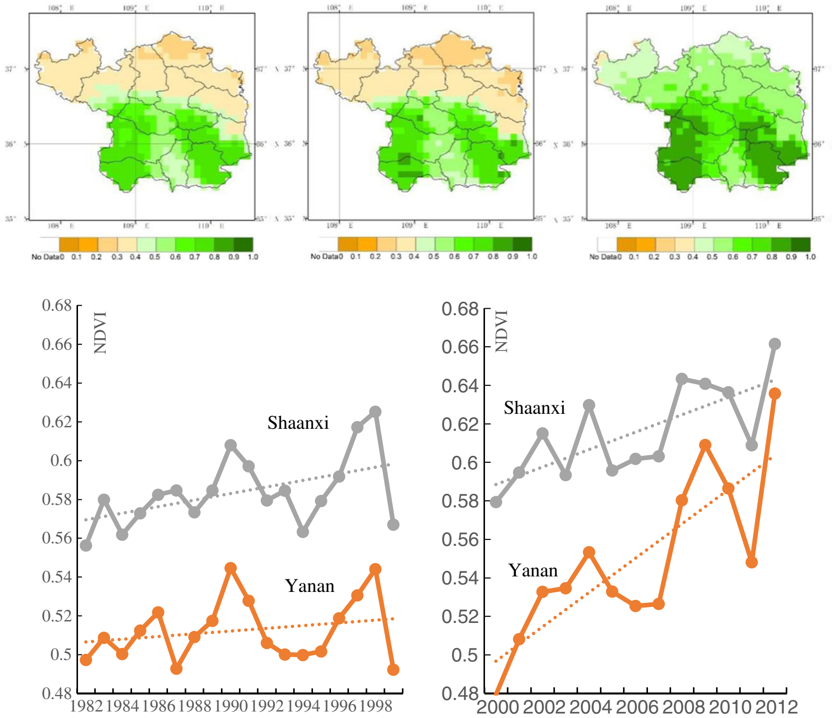

Fig. 2 NDVI in Yanan City from (*left*) 1984 to (*middle*) 1999 and (*right*) 2012. Changes in NDVI in Yanan City and the other regions of Shaanxi Province from 1982 to 1999 and from 2000 to 2012 (*bottom*). The regressions for the NDVI change in Yanan City and Shaanxi Province from 1982 to 1999 were not statistically significant; the regressions from 2000 to 2012 were both statistically significant ($p < 0.01$)

(Ginkel et al. 2013). Ecosystems respond to complex interactions among natural and socioeconomic factors (Feng et al. 2015). It is therefore necessary to comprehensively account for both natural and socioeconomic factors to achieve ecological restoration targets and sustain these conditions in the long term (Plagányi et al. 2013; Stringer and Dougill 2013). The subsidies provided under the traditional government projects do not represent a long-term source of income for farmers who are displaced by these programs, and when the subsidies end, their only option is to return to their old practices (e.g., to return to farming in sloping fields), thereby eliminating the gains from the projects (Qu et al. 2011). Under the central government's programs, farmers were asked to plant trees rather than cut them down, and as a result, the programs eliminated both the traditional source of income (grazing or farming in the afforested land) and a potential new source of income (harvesting as the trees matured). Although it is essential to protect regional vegetation (Enfors 2013), the need to care for the new trees until they develop into a mature forest creates large direct expenses for the farmers in the form of tending costs and large indirect costs in terms of the income they lose after abandoning their former activities (Cao et al. 2009b).

3.2 Relative contributions of the green purchase strategies to NDVI growth

The contribution model (Eq. 2) revealed the relative impacts of the various green purchase strategies on NDVI growth in Yanan City. Building terraced fields accounted for 14.6% of the increase in NDVI, versus 5.6% for the construction of fruit orchards, 16.7% for grazing restrictions in degraded land, and 5.8% for ecological migration of rural residents to cities (Table 1). These four strategies therefore accounted for a total of 42.7% of the NDVI change in Yanan City. The remainder of the change was caused by population growth and government programs such as Grain for Green. After adjusting values to 2014 values using the central government's published inflation published mean inflation rate for the study period, the increase in annual rural net income in Yanan City from 1999 to 2014 was 3742 RMB, versus only 2962 RMB for Shaanxi Province, excluding Yanan City. The income increase from the fruit orchards accounted for 66.9% of the increase in rural net income (which contributed 23.6% of the NDVI increase). Thus, our proposed green purchase strategies clearly played an important role in the NDVI growth.

The implementation of grazing exclusion in degraded areas accounted for the largest proportion of the increase of NDVI growth. This approach, which relies on natural recovery processes that can operate once the pressure from grazing has been relieved, plays an important role in ecological restoration. The natural restoration process also reduces the restoration cost compared with afforestation. Building terraced fields was the second-most-important factor that played a role in ecological restoration because it can reduce soil erosion

Table 1 The contribution of each factor to the changes in NDVI since 1999 in Yanan City

	R^2	Contribution (%)
Decrease of rural population	0.743**	5.77
Increase of rural net income	0.331*	23.63
Increase in area of farmland (terraces)	0.647**	14.62
Increase in fruit orchard area	0.612**	5.62
Increase in the area with restricted grazing	0.628**	16.68
Increase in area of afforestation	0.513**	12.11
Increase in lengths of roads and railways, and in the area of greened mines	0.691**	13.31
Increase in mean annual temperature	0.678**	2.89
Increase in annual precipitation	0.043 ns	5.36

Significance levels: **1%, *5%
ns not significant

caused by wind and running water; as a result, it reduces additional degradation by retaining fertile soil and that, in turn, helps degraded vegetation to recover. Local technicians teach farmers how to build the terraced fields, which occupy a smaller area but are far more productive than the area of sloping fields they replaced; the increased productivity, combined with more economically valuable crops such as apple trees, increases farmer income while also increasing the vegetation cover. Ecological migration also plays an important role because it resolves the contradiction between the need of humans to live and the need to reduce the pressure on degraded natural areas; because the migration is voluntary, and provides training, employment opportunities, and financial support for those who cannot work, it is more effective than forced migration policies that do not provide this support. As a result of these beneficial effects, the green purchases described in this paper accounted for nearly half of the NDVI growth in Yanan City while simultaneously increasing the income of local farmers by 153% since 1999. These results demonstrate that strategies focused on restoring the ecological balance do not have to sacrifice economic goals; instead, they can find a win-win path that arouses the enthusiasm of local farmers to participate in efforts to preserve the ecological environment. Our strategies conform with this goal, and the present results confirm that they are effective and efficient.

3.3 Win-win path to escape the poverty trap

After implementation of the green purchase strategies in Yanan City, local ecological restoration has accelerated, and Yanan City now has twice the rate of increase that has been recorded in other areas of Shaanxi Province (Fig. 2). In addition, the rural net income in Yanan City increased to 1.26 times the level in the rest of the province, and the increase is likely to be sustainable because our new approach was designed to remain viable in the long term. The observed environmental improvement and increase in farmer income suggest that our proposed approach has high potential to help rural residents escape the poverty trap in this semiarid region of China.

Preventing behaviors that cause environmental damage is a direct way to promote ecological restoration (Brown et al. 2014). However, environmentally unfriendly production modes persist when they provide economic benefits for residents that cannot be obtained in other ways (Gray and Moseley 2005). Farmers lack the technology and funds to implement more environmentally friendly methods, such as the construction of terraced fields to decrease soil erosion (Long et al. 2006; Spiertz 2012). Thus, when the government forbids them to grow crops in sloping fields, farmers see a reduction in crop yield (due to the decreased area of fields they are allowed to cultivate) without any offsetting income to replace their loss (Jayne et al. 2014). The construction of terraced fields solved this problem by improving crop yield in a smaller area while using a more ecologically sustainable form of cultivation. However, the monthly subsidy of 300 RMB that was provided to ecological migrants who are unable to work has become inadequate due to high rates of inflation, and must be increased rapidly to maintain their ability to survive in the cities where they now live (Cao et al. 2009a). If this is not done, many of the migrants will be forced to return to their farms and engage in activities that may be ecologically damaging (Gong et al. 2011). Our results showed that planting of ecologically appropriate fruit tree species rather than forest vegetation that provides no immediate economic benefits can greatly and sustainably increase farmer income (Gong et al. 2011; Reij et al. 2005).

Ecological migration is a potentially effective and rapid solution to solve some of the problems of people who live in environmentally fragile places. However, planners of this approach must respect the human rights of displaced citizens before, during, and after the migration process (Reuveny 2008). In particular, they must take measures to provide migrants with support and social insurance so that they can find new sources of income that guarantee their livelihoods. The present results suggest that our proposed new approach was effective because it simultaneously improved environmental conditions through green purchases and met the needs of those who were displaced by the program. However, because of the relatively short duration of our study (13 years), it will be necessary to continue monitoring Yanan City and its surrounding areas to detect signs of problems (such as the abovementioned inadequacy of the 300 RMB income supplement), thereby allowing a response before the problems become serious.

Gray and Moseley (2005) noted that the goals of ecological restoration and socioeconomic development are to simultaneously protect the environment (thereby increasing ecological sustainability) and improve the livelihoods of inhabitants of the region affected by a program (thereby increasing socioeconomic sustainability). This approach ensures that mitigating poverty will not have dramatic negative consequences for future generations (Cao et al. 2009a). Such programs have traditionally failed to achieve ecological restoration targets because they ignored the right of poor rural residents to earn a living (Zhang et al. 2013). However, if protecting the environment can also increase rural net income, as in the present study, farmers will be glad to participate in long-term ecological protection (Gray and Moseley 2005). In the long run, only policies that provide local residents with at least as much income as they earned unsustainably before implementation of the new approach are likely to achieve their goals (Comim et al. 2009).

4 Conclusions

It is humanity's duty to protect the ecological environment that is the basis of humanity's social and economic activities. In addition to the ethics of protecting the environment for its own sake, we must also seek ways to improve the lives of humans. Consequently, ecological restoration or protection projects must seek ways to balance environmental protection with socioeconomic development. Focusing on only one of these goals is unlikely to achieve sustainable development. Although our results seem likely to be applicable in many other parts of the world, and particularly in arid or semiarid regions of developing countries, they can only be extended to other areas with considerable caution. Natural conditions, human cultures, and the conditions for socioeconomic development will vary from place to place, and these variations will affect the outcome of such projects by changing the key factors that control these outcomes. As a result, researchers, planners, and managers will need to carefully identify the key factors that affect a project's success and create comprehensive measures based on these factors to ensure that the affected people have a chance to escape the poverty trap.

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Author contributions S. Cao designed the research; L. Chen, H. Ma, and J. Xia analyzed the data; and S. Cao and X. Zheng wrote the paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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