Development and testing of a sustainable environmental restoration policy on eradicating the poverty trap in China's Changting County

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It is widely accepted that environmental degradation and poverty are linked and that conservation and poverty reduction should be tackled together. However, success with integrated strategies has been elusive. Here, we present the results of a study that illustrates how development that combines environmental and economic perspectives and that provides appropriate compensation to affected populations can improve both nature and society, thereby eradicating the "poverty trap." The results show that if we cannot improve the livelihood of local residents, we will be unable to restore degraded environments when state-owned property is transferred to private ownership to encourage better management by residents. In contrast, measures to eliminate poverty, combined with the development of green enterprises that improve the livelihoods of private land owners in the long term, is the precondition for successful ecological restoration.

environmental conservation | environmental policy | payment for ecosystem service | property rights

By the start of the 21st century, growing understanding of the relationship between environmental conservation and poverty reduction led to a remarkable degree of international agreement on the urgency of eliminating poverty as part of any conservation policy (1–3). Sustainable development, meaning economic growth that is environmentally sound, is a practical necessity (4). Unfortunately, global environmental problems often affect the resource base of the world's poorest people most severely (5). The interaction of poverty and environmental degradation is often invoked in the form of a vicious circle known as the "poverty trap," in which poverty leads to environmental degradation and environmental degradation deepens poverty (6). This trap locks populations in developing regions into a situation with a narrower margin for survival, increased vulnerability to natural hazards, and increasing fragility of the ecosystems on which the residents depend (7). All of these factors are exacerbated by a lack of capital or technological investment, a lack of work skills among residents, inadequate education, and poor governance (8). The vulnerability of these populations may be further exacerbated by unjust or ineffective policies (9–10).

The links between biodiversity and livelihoods, and between conservation and poverty reduction, are dynamic and locally specific (3). Therefore, conservation and development projects must be able to achieve both ecological and social progress without detracting from their primary objectives. However, whereas "win−win" projects that achieve both conservation and economic gains are a commendable goal, they are not easy to attain (3, 10). To escape the poverty trap, both internal work (the effort of the local residents) and external aid (capital investment, skills and education development, advantageous policies, etc.) are necessary (11). But determining how much aid to provide and what approach can use the external aid most efficiently represent an elusive solution and a difficult balance to achieve. A recent analysis of World Bank projects with the objectives of alleviating poverty and protecting biodiversity revealed that only 16% made major progress on both objectives (10).

Payment for ecosystem service programs use a combination of market and institutional incentives to meet both environmental and poverty alleviation objectives (11–13). However, the problem of achieving an optimal design squarely confronts the reality that conservation is far from always a win-win situation: the implications for the rural poor are not always positive. In fact, activities that are desirable from the point of view of society are often unattractive to the farmers, loggers, fishers, and others who manage ecosystems directly (14–17). Thus, policymakers in developing countries must wrestle with the dual objectives of reducing poverty and increasing the flow of ecosystem services from rural areas occupied by small-scale agriculturalists and other users of local ecosystem resources (18).

To test the efficacy and sustainability of such interactions when a whole community is mobilized to pursue a well-articulated poverty reduction and environmental restoration strategy (19), we have been performing an experiment with a soil- and water-conservation project in China's Changting County since 2000. In the present paper, our goals were to evaluate the potential links between environmental policy and environmental and social sustainability by presenting an approach that combines the need to protect both nature and society. This approach provides a good example of how to improve the benefits of environmental restoration while simultaneously protecting the livelihoods of those who are most directly affected by the program. Our study had the major objective of comparing the effectiveness of subsidy programs that promote environmental restoration with and without additional measures taken to ensure the livelihoods of the residents will be protected when the subsidies end.

For political and practical reasons, it was not possible to establish formal "control" villages in this study. Instead, we assessed the project's impact by means of rigorous before-and-after comparisons and have also provided evidence from other villages that did not originally participate in the new project to serve as a standard of comparison. Because the new approach described in this paper targeted all villages in Changting County that were experiencing severe soil erosion, the comparison villages were located in areas with less severe environmental damage than the study area.

The Impact of Property Rights Reform on Vegetation Cover and Forested Land. Changting County is located in western Fujian Province (25°18′40″ to 26°02′05″N, 116°00′45″ to 116°39′20″E).

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Table 1. The changes in vegetation cover, forest cover, and soil erosion in Changting County between 1985 and 1995

	1985	1995	Change, %
Vegetation cover, %	64	62	−3.13*
Forest cover, %	65	63	−3.08*
Area in which soil erosion was occurring, km^2	974.60	747.33	−23.32*
(1) Light soil erosion (<2,500 t km^{-2} yr^{-1}), km^2	594.73	483.32	−18.73*
(2) Moderate soil erosion (2,500 to 5,000 t km^{-2} yr^{-1}), km^2	207.13	58.21	−71.90**
(3) Heavy soil erosion (5,000 to 8,000 t km^{-2} yr^{-1}), km^2	117.13	93.71	−19.99*
(4) Severe soil erosion (>8,000 t km^{-2} yr^{-1}), km^2	55.80	112.09	100.88**
Vegetation species, no. per ha	81	80	−1.23 ns

Notes: Differences between the 1995 and 1985 values were compared using the *F*-test: ns, not significant; *, $P < 0.05$; **, $P < 0.01$.

Historically, the county has had good vegetation cover because of the high mean precipitation (1730.4 mm yr^{-1}) and warm annual temperature (a mean of 18.3 °C and a minimum temperature of 7.9 °C) (20). However, a half-century period of forest exploitation, combined with monoculture planting, has led to large decreases in species diversity and vegetation cover, increasing the frequency and scale of water erosion of soil and the severity of floods, all leading to degradation of the county's forests and landscape (21–22). The size of the area experiencing serious erosion increased by 5.1% annually, from 47,870 ha in 1966 to 97,470 ha in 1985 (20).

To alleviate this land degradation, the county's government reformed property rights for forested land starting in 1985, with ownership of 90% of forested lands allocated to individual farmers. Unfortunately, the county's impoverished farmers did not protect the trees as the government had expected; instead they harvested the wood that now belonged to them so they could sell the wood or use it as fuel. The government's policy thus failed to prevent environmental damage and actually led to rapid decreases in vegetation cover and a serious increase in soil erosion (21). Because the government required farmers to plant trees every year (without providing any compensation), the area experiencing soil erosion had decreased by 23.3% by 1995 (Table 1), but the area experiencing severe soil erosion (>8000 t km^{-2} yr^{-1}) increased by more than 100%, reaching a total of 112.1 km^2 in a period of only 10 years (22). During the same period, vegetation cover and forest cover both decreased by 2% of the total area despite the planting program (Table 1), and degradation of the landscape worsened (supporting information (SI) Fig. S1, top).

Test of a New Conservation Policy. Because the original policy was not working, the county's government began testing a new development policy in 2000 that was designed to promote both environmental conservation and poverty reduction. The policy provided annual compensation of RMB 10 million (US$1 equaled approximately RMB 8.27 in 2000) from the province's budget in areas that were experiencing the heaviest soil erosion. The program focused on 4 towns: Cewu, Hetian, Sanzhou, and Zhuotian (23). Under this policy, the farmers received living subsidies that compensated them for abandoning the harvesting of forests (i.e., reimbursement for their loss of access to the wood) and for their efforts in ecosystem restoration.

To compensate residents for their lost ability to harvest trees for fuel, subsidies were provided amounting to RMB 0.04 per lump of coal (25% of the local cost) for farmers who stopped cutting vegetation within 3 years and replaced their fuel wood consumption with coal consumption, and facilities were set up to produce this coal (Fig. S2). To move the farmers away from a form of forestry that focused on harvesting fuel wood, the government also encouraged the construction of infrastructure for the production and use of methane-generation facilities for every household by providing compensation ranging from RMB 1000 for <8 m^3 of capacity to RMB 1500 for >8 m^3 of capacity (Fig. S3). To increase the net income of farmers and encourage them to use organic fertilizers to improve plant growth, the government encouraged the planting of fruit trees by providing compensation of RMB 1500/ha. (This had the additional benefit of providing an incentive for farmers to protect the trees since, unlike forest tree species, the continuing presence of the fruit trees provided an ongoing source of food and cash income.) To encourage the raising of pigs and fish on this land, compensation of RMB 100 for each additional pig and RMB 15 000 for each 1-ha fish pond was provided (Fig. S4). In the study area, the fish ponds were intended to both encourage water conservation and provide a source of nutrition and income for residents. The government also paid farmers RMB 30/day for planting trees or forage vegetation and provided tree seedlings or the seeds of forage species at no cost (Fig. S5). To reduce the cost of this program and improve the environmental restoration, the government encouraged the transfer of land ownership to residents who were willing to plant trees and prohibited tree harvesting in all natural forests—with the exception of low-lying wasteland in hilly terrain where fruit trees could be planted (24).

After 8 years of this experiment, the environment and various socioeconomic factors in the project area have improved greatly. Compared with 1999 (Table 2), the area experiencing soil erosion has decreased by 37.7%, and the area of land experiencing heavy soil erosion (5000 to 8000 t km^{-2} yr^{-1}) has decreased by 53.6%. Moreover, these decreases were significantly greater ($P < 0.001$) than the decreases reported in the area outside of the program. As a result, total soil erosion decreased by 68.3%. The number of plant species in areas affected by the project has increased from a mean of 6 species per ha to 38 species where logging was prohibited, which is a significantly greater increase than the increase reported outside of the program area, which had a larger biodiversity at the start of the study period ($P < 0.001$). During the same period, vegetation cover has increased to 75% in 2007, from only 42% in 1999, indicating rapid improvement of the landscape (Fig. S1, bottom), and this increase was also significantly higher than that outside of the program area ($P < 0.001$). Although the results in Table 2 suggest that environmental conditions outside the study area were better than those inside the study area at the end of the study period, this does not mean that the new approach was less effective than the approach being used outside the study area. The 4 towns in our study area were specifically chosen for the new approach because they represented the most severe environmental damage in Changting County. As a result, the improvement in environmental conditions, not the final levels of the parameters in Table 2, should be used to judge the success of the new approach.

From 2000 through 2007, 6,340 methane-generation facilities were built in the project area. Government encouragement of a "green vocation" (i.e., working in soil- and water-conservation projects and participating in the development of environmen-

Table 2. Environmental improvements in Changting Country as a result of the new soil- and water-conservation project

	In the project area		Outside the project area		Change (%)	
	1999	2007	1999	2007	In project area	Outside of project area
Vegetation cover, %	42	75***	73	84	78.57	15.07***
Forest cover, %	45	62***	71	82	37.78	15.49**
Area in which soil erosion was occurring, km^2	382	238**	355.7	196.5	–37.70	−44.76 ns
(1) Light soil erosion (<2,500 t km^{-2} yr^{-1})	235	130**	244.3	115	–44.68	−52.92 ns
(2) Moderate soil erosion (2,500 to 5,000 t km^{-2} yr^{-1})	45	70***	13.8	53.6	55.56	288.40**
(3) Heavy soil erosion (5,000 to 8,000 t km^{-2} yr^{-1})	69	32***	17.7	22.8	–53.62	28.81***
(4) Severe soil erosion (>8,000 t km^{-2} yr^{-1})	33	6***	79.9	5.3	–81.82	−93.36 ns
Total soil erosion (Mt yr^{-1} yr^{-1})	306	97*	57.98	19.26	–68.30	−66.78 ns
Erosion modulus, t/km^2	8,000	4100**	1630	980	−48.75	−39.87 ns
Runoff proportion, % of precipitation	65	28***	0.38	0.26	–56.92	−31.58 ns
Vegetation species, no. per ha	6	38***	72	83	533.33	15.28***

Notes: Levels of significance represent differences between 2007 and 1999 within the project area, and the difference between the change (%) inside the project area and the change (%) outside the project area using the F-test: ns, not significant; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

tally sustainable projects such as fruit tree orchards) also increased employment in the project area by 8,012 workers (an increase of 12.4% in the total workforce) and increased net farmer income by RMB 407/year (an 11.2% increase over the mean net income before the new project) in 2007 (Table 3). This increase in net income was provided by the planting of fruit trees, raising of pigs, and water-conservation activities, which accounted for 0.3, 63.6, and 36.1% of the increase, respectively.

Discussion

Environmental goals cannot be achieved without some type of economic development that provides a livelihood to the people affected by the program. Without such support, poor people will circumvent environmental restrictions in their desperation for land, food, and sustenance (4). The result is a poverty trap in which poverty, environmental degradation, and poor governance are all mutually reinforcing (25). Investing in environmental assets and management are vital to the implementation of cost-effective and equitable strategies to achieve national goals for relief from poverty (4). Our results demonstrate that the net income of residents was increased by the development of green enterprises and the replacement of fuel wood by methane generation and purchased coal. Although environmental improvement was also observed outside the project area (Table 2), and the improvement was in some cases comparable to that inside the project area (e.g., total soil erosion decreased by comparable amounts), there was an important difference. Outside the project area, funding for environmental remediation was short-term and was only provided for remediation activities. As a result, the funding will end once the planned remediation is complete. Previous research (26) has shown that under these circumstances, residents are likely to return to their previous activities when they can no longer survive solely on the government subsidies, thereby eliminating any gains from the project. In contrast, the residents of the project area have built infrastructure that will continue to provide income (such as fruit orchards, fish ponds, and livestock-raising facilities) or to reduce their costs (e.g., the methane generators) even after government subsidies end. This greatly increases the likelihood that the environmental improvements will be sustainable.

It is essential to understand that the concept of "property" ownership involves more than just the physical piece of land; it is also the right to the benefit stream from that property and that right is only secure if others respect the owner's right (27) and if the stream can be sustained in the future. The landowner is free to use the owned resource (and all of the goods and services it provides) in accordance with his or her own volition—and even to destroy it—as long as no legal regulations restrict this liberty (27). However, so long as the resource provides a sufficient stream of benefits to its owner, there is a strong incentive to protect those benefits by using the resource sustainably. In contrast, where the resource provides insufficient benefits, landowners may be forced to transform the resource toward agriculture or other intensive forms of resource extraction that may be unsustainable but that nonetheless meet the owner's immediate need to survive (28). As a result, giving local managers

Table 3. Economic improvements in Changting Country as a result of the new soil- and water-conservation project

	2000	2001	2002	2003	2004	2005	2006	2007	Total
Methane-generation facilities added	2,013	552	795	851	1003	704	422	—	6340
Number of workers employed in soil and water conservation, thousand	5.7	6.1	7.5	8.1	10.3	11.2	12.9	12.9	—
Fruit tree area (includes tea plantations), km^2	3.5	2.0	2.1	3.1	6.0	4.5	3.2	—	24.4
(1) Income, thousand RMB	—	—	—	79	123	170	478	749	1599
(2) Net income, thousand RMB	—	—	—	39	61	85	239	374	798
Sales of pigs (thousand yr^{-1})	388	424	473	523	565	629	645	674	4362
(1) Income, million RMB	271	442	494	545	590	656	715	943	4656
(2) Net income, million RMB	54	60	67	74	80	89	97	97	675
Water conservation activities (e.g., aquaculture)									
(1) Income, million RMB	20.1	25.1	30.2	35.2	40.3	45.4	50.4	55.4	302.1
(2) Net income, million RMB	20.0	25.0	30.0	35.1	40.1	45.1	50.1	55.1	300.7
Net income provided by soil and water conservation activities (RMB $person^{-1}$ yr^{-1})	198	228	260	292	322	359	395	407	—

property rights over their ecosystem may not be sufficient to protect that ecosystem, as they may be forced by the necessity to survive to adopt unsustainable alternative land uses with immediate perceived benefits (29). Thus, property rights by themselves can have either positive or negative impacts on an environmental conservation strategy. To ensure that the impacts are predominantly positive, planners must find a way to encourage sustainable use by providing economically adequate alternatives to unsustainable use. In the present study, planners attempted to both alleviate poverty in the long term and remediate the environment. The results revealed that both objectives can be achieved when the conflict between environmental protection and the needs of the poor is addressed. Policy makers must understand that the need to survive and the right to survival supersede all other rights. For a development strategy to be effective and sustainable, it must therefore eliminate poverty in the long term.

Policy makers seeking financial incentives that will sustainably increase the flows of ecosystem services must consider where to focus their attention and what collection of incentives can effectively achieve the policy objectives (18). For policies and projects to be effective, they must be scientifically appropriate, but they also require long-term support from the participants and from others who are affected by the policies (30). Even when conservation projects have been able to change local resource-use strategies in the short-term, interventions rarely altered the incentives that prompted local resource users to degrade habitats in the first place (28). One reason for the success of the project described in this paper is that it no longer relies on short-term incentives; for example, payments to plant trees will encourage reforestation as long as the payments continue, but when the payments end residents are likely to return to their old habits of cutting the trees unsustainably to provide fuel wood (26). In contrast, the new project encourages the planting of fruit trees that will provide greater benefits while the trees are alive (i.e., fruits that can be used for food and for sale to generate income) than if the trees were harvested for fuel wood. Similarly, by paying residents to establish pig farms and fish ponds, the project creates a sustainable long-term industry that will provide a livelihood to residents without damaging their environment. These green industries also provide sufficient income that farmers can purchase supplies (such as coal). Other aspects of the project provide infrastructure that can sustainably produce replacements for environmentally damaging activities, such as methane production that reduces the need for fuel wood. This greatly reduces the risk that residents will need to return to forest harvesting just to provide fuel.

The present study shows how it may be possible to resolve the dilemma (31) of how to devise effective conservation policies that also protect the livelihood of the affected populations and encourage them to continue participating in the project. Although direct payments are expected to be cost-effective ways to meet environmental and development goals (32), they often lack long-term sustainability (26). The elimination of poverty and the preservation of ecosystems are 2 distinct objectives. Each may be driven by different moral agendas, but there is considerable overlap in practice (3). Considering both the environmental and human aspects of development by providing appropriate long-term measures by which those affected by the plan can escape the poverty trap thus appears to be an effective way to improve both nature and society.

Methods

To examine the environmental and economic improvements that resulted from the project described in this paper, we selected 5 representative villages in the 4 towns (Cewu, Hetian, Sanzhou, and Zhuotian) targeted by Changting County's new project. Because of the different land-use types in the study area, we randomly established three to eight 1.0-ha plots at each village. Our total sample size was thus 20 villages ($= 4$ towns $\times$ 5 villages), with 3 to 8 plots per village, in the project area. To provide a basis for comparison, we also obtained data from 14 towns outside the project area after our study of the new project was complete, with 5 villages per town and 3 to 8 plots per village. The residents outside the project area received payments only for remediation projects, not to create long-term trees such as fruit trees or infrastructure such as fish ponds or pig barns.

To assess forest cover, we used a steel tape (Fig. S6) to measure the crowns of 20 randomly selected trees of each species in each plot during the middle of the growing season of each year (between the last 10 days of June and the end of August) and used this data to determine crown area. We measured the maximum and minimum crown radii, modeled the crown as an ellipse—with these radii representing the semimajor and semiminor axes—and calculated the mean canopy area for each species using geometric mean values to account for extreme values. Tree cover (the proportion of the total site area accounted for by a vertical projection of the elliptical crowns of the trees) was calculated by multiplying the mean crown area of the trees in a plot by the number of trees in that plot, then dividing this total by the total plot area. We performed this analysis for each tree species in the study plots and combined these percentages to produce an overall forest cover value. Canopies that overlapped were combined and treated as a single canopy to avoid double-counting of crown area; that is, we calculated the total crown area as if the 2 trees were a single tree then divided the resulting crown area by 2 to produce a mean value per stem.

In addition, we performed line-intersect sampling using two 10-m transects at right angles to each other to survey nontree vegetation; in forest plots, we used 3 randomly located 4-m^2 circular quadrants. We measured the vegetation cover in the project plots by means of line-intersect sampling in each plot using a 10-m transect perpendicular to the edges of the plots. We identified every species of plant in these transects every year at the same time (between the last 10 days of June and the end of August). To describe vegetation species diversity in the study plots (Fig. S6), samples of all plant species were collected annually from each plot in August. The samples were brought to Fujian Normal University if their identity needed to be confirmed.

To monitor soil erosion at each of the selected 90 representative villages, the Water and Soil Conservation Bureau of Changting County established 12 sand sedimentation ponds (run-off ponds) at representative plots (Fig. S7). To do so, we selected 20-*m* long by 5-*m* wide observation sections along the slopes in each test plot and constructed a stone and concrete sand sedimentation pond with 15-m^3 capacity at the bottom of the slope. The quantity of run-off was measured in each pond after a rain. In addition, all of the soil was removed from the bottom of each pond 24 h after the rain, and 3 random samples of this soil were dried for 12 h at 105 °C, and were then weighed to determine the quantity of soil eroded by the rain. Downstream of the project area, a monitoring station was established to monitor run-off and soil erosion. The quantity of run-off was measured every 2 h, and water samples were taken every 12 h to measure the sediment produced by soil erosion (Fig. S8).

The incomes of households in the study area were monitored by the Monitoring Station for the Soil and Water Conservation and the Statistics Bureau of Changting County. We used the SPSS software (SPSS Inc.) to compare data between households inside and outside the project area using the *F* test. We used post hoc tests to identify significant differences among means.

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