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Research, part of a Special Feature on Telecoupling: A New Frontier for Global Sustainability

Feedback of telecoupling: the case of a payments for ecosystem services program

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ABSTRACT. Around the globe, previously isolated rural areas are increasingly connected with other distant places (e.g., cities) by telecouplings (i.e., environmental and socioeconomic interactions over distances) such as payments for ecosystem services (PES) programs, labor migration, and tourism. Although many studies have estimated impacts of telecouplings in rural areas, little is known about how these impacts might in turn affect telecouplings themselves through feedbacks. Using household survey data collected in China's Wolong Nature Reserve for giant pandas (*Ailuropoda melanoleuca*), we evaluated an unexpected impact of the telecoupling of the Grain to Green Program (GTGP)—one of the largest PES programs in the world. This impact may trigger a feedback that can strengthen the GTGP in the future. A previous study in Wolong found that afforestation on marginal cropland promoted by the GTGP has significantly intensified crop damage by wildlife on nearby remaining cropland. We evaluated how this change might in turn affect the GTGP by estimating the impact of crop damage induced by the current GTGP on local households' willingness to participate in possible future GTGP. Our results show that due to the impact of the current GTGP on crop damage, local households may enroll 10.4% more cropland that is close to the afforested lands in future GTGP, which suggests a positive feedback that will strengthen the influences of the GTGP in Wolong and beyond. Our study highlights that local human–nature interactions driven by telecouplings, such as human–wildlife conflicts, may trigger feedbacks that affect telecouplings themselves. With improved understanding of telecouplings' feedbacks, scientists, policy-makers, and conservation practitioners can better anticipate the complex interactions among different places and design effective conservation strategies for achieving sustainability objectives such as those set by the United Nations' Sustainable Development Goals.

Key Words: *conservation; ecosystem services; feedback; giant panda; telecoupling; Wolong*

INTRODUCTION

Since the beginning of human history, telecouplings—socioeconomic and/or environmental interactions over long distances (Liu et al. 2013*a*)—have significantly shaped the Earth (Eakin et al. 2014). With the rapid development and expansion of transportation, information, and communication technologies, telecouplings have been occurring at much larger scales and a much faster pace than ever before (Liu et al. 2013*a*). Even previously isolated rural areas have been increasingly connected with distant places like urban centers through telecouplings such as payments for ecosystem services (PES) programs, labor migration, and tourism (Kramer et al. 2009, Liu et al. 2015).

As different parts of the world are increasingly interconnected, many key issues of our time are profoundly shaped by telecouplings, such as global land use change (Verburg et al. 2013, Bruckner et al. 2015), urbanization (Alberti 2015, Fang and Ren 2017), trade impacts (Sun et al. 2017), wildlife conservation (Wang and Liu 2016, Hulina et al. 2017), international economic development (Galaz et al. 2015, Yang et al. 2016*a*), water scarcity (Yang et al. 2016*b*), energy security (Fang et al. 2016), species invasion (Liu et al. 2014), and forest sustainability (Liu 2014). On the one hand, some issues have been exacerbated by telecouplings. A striking example involves species invasion, the second leading cause of biodiversity loss (Kohli et al. 2009). Both incidentally and deliberately, humans have been redistributing an ever-increasing array of species across the world through migration, transport, and commerce, which has drastically increased the homogeneity of world biota and the economic damage to many related industries (Mack et al. 2000). On the other hand, some telecouplings offer unique tools to address these issues and drive human–nature interactions toward sustainability. For example, PES has been widely used in recent decades as a promising tool to reconcile the conflicting demands of socioeconomic development and ecosystem conservation (Naeem et al. 2015). Through PES programs, beneficiaries of ecosystem services offer incentives (e.g., cash, grain) to users of natural resources who are often long distances away (e.g., farmers in rural areas) for activities that can enhance the provision of ecosystem services, such as cropland retirement (Engel et al. 2008, Liu et al. 2013*b*). Given the great importance of telecouplings, understanding their complex effects has become a practical need to achieve sustainability objectives such as those targeted by the United Nations' Sustainable Development Goals (United Nations 2015).

Over the past decades, much progress has been made in understanding impacts of telecouplings under systems frameworks such as coupled human and natural systems (Liu et al. 2007*b*), coupled human–landscape systems (Werner and McNamara 2007), or coupled social-ecological systems (Walker et al. 2004, Ostrom 2009). In them, telecouplings were usually treated as static external drivers with the assumptions that external drivers affect local couplings (human–nature interactions at the local scale) (Mena et al. 2006). However, as the effects of telecouplings on local couplings accumulate, feedbacks may emerge and strengthen or weaken telecouplings themselves (Liu et al. 2013*a*). A typical example might be nature-based tourism, which has been widely incorporated into integrated conservation and development projects (ICDPs) as a tool to achieve social and environmental sustainability in many

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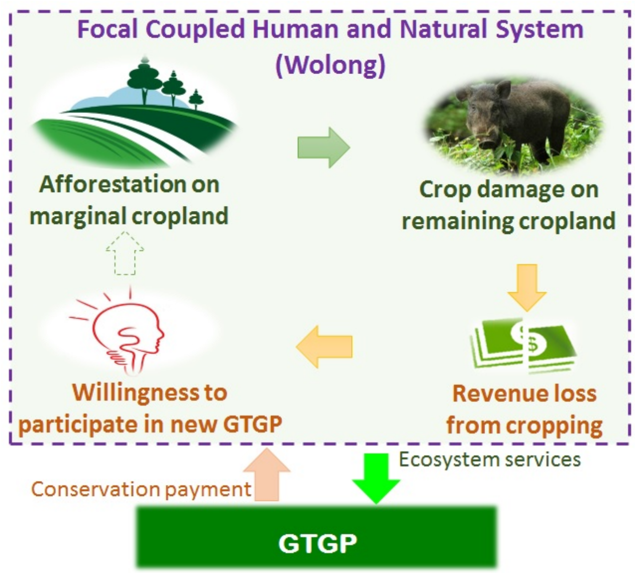
biodiverse rural areas (Liu et al. 2012). However, as tourism life cycle theory (Butler 1980) predicts, local demand for economic growth may interact with outside capital markets that are looking for high-volume businesses, and thereby drive local tourism development beyond the carrying capacity of the local environment (Liu et al. 2012). When the negative environmental effects of tourism accumulate and become manifest, tourist visitation may decline rapidly and cause devastating effects on local livelihoods, thereby defeating the ICDPs' sustainability goals. Therefore, understanding telecouplings' feedbacks is critical for the design and management of telecouplings. Ignoring them may lead to biased estimates of the long-term effects of telecouplings and generate unexpected outcomes (Liu et al. 2007*a*, Hull et al. 2015).

However, empirical and quantitative knowledge of how impacts of telecouplings might trigger feedbacks that affect telecouplings themselves has remained rare in existing literature. To address this important knowledge gap, we used household data collected in China's Wolong Nature Reserve (Wolong) for giant pandas (*Ailuropoda melanoleuca*) to empirically evaluate a change in behavioral intention inspired by the Grain to Green Program (GTGP) in China that may create feedbacks affecting the GTGP itself (State Forestry Administration 2010). The GTGP is a national PES program that was initiated in the late 1990s and is one of the largest PES programs in the world. By the end of 2014, the program had converted about 9.27 million hectares of cropland from more than 30 million households to forestland or grassland (Liu et al. 2008, Wu 2015). Evidence shows that the current GTGP has generated substantial socioecological effects in China and constitutes an important telecoupling that links the program's target areas to other places (Liu et al. 2008, 2015). Through the GTGP, participating households received payments from distant places (as represented by the Chinese government in Beijing) to convert their cropland to forestland or grassland (Chen et al. 2012*b*). In return, many other places have benefited from this program as the outflows of ecosystem services from the program's target areas have been enhanced. For example, many of the program's target areas are located upstream of the Yangtze River, the third longest river in the world (Sun et al. 2016). Previous studies have shown that afforestation promoted by the GTGP has increased the capacity of soil and water retention of the land (Ouyang et al. 2016, Rodríguez et al. 2016) and thus mitigated flooding risk downstream. To enhance gains from the GTGP, the Chinese government has been planning a new round of GTGP to enroll more cropland in the near future (State Forestry Administration 2014).

In this study, we evaluated the feedback of the GTGP by estimating the influence of crop damage induced by the current GTGP on local households' willingness to participate in possible future GTGP, an impact that may trigger feedback of the GTGP. A previous study in Wolong found that afforestation on marginal cropland promoted by the GTGP has significantly increased the crop damage by wildlife on nearby remaining cultivated cropland. This is because participating households tend to enroll their land that is close to forest edges in the GTGP as those croplands are often susceptible to crop damage by wild animals (e.g., wild boar [*Sus scrofa*]) and typically have a low yield (Chen et al. 2010). However, afforestation on cropland that is close to forests may create new habitat for crop raiders and displace crop damage that was previously borne by former cropland that is now enrolled in the GTGP (GTGP lands) to nearby remaining cropland, resulting in more crop damage there. Since the revenue from remaining cropland may decrease due to this impact, we hypothesize that households may be more willing to enroll remaining cropland in future GTGP, thereby stimulating a positive feedback that will get more cropland enrolled and strengthen the associated flows between Wolong and other places (e.g., inflow of conservation payments and outflow of ecosystem services) (Fig. 1).

Fig. 1. Conceptual model of the feedback effect of the Grain to Green Program (GTGP) in Wolong. Through GTGP, other distant places (as represented by the Chinese government in Beijing) paid local farmers for converting their marginal cropland to forestland to secure the provision of ecosystem services. However, afforestation on marginal cropland significantly increased crop damage on nearby remaining cropland in Wolong, and reduced the revenue local households obtained from the affected cropland. This in turn increased local households' willingness to enroll remaining cropland in possible future GTGP and will strengthen the effects of GTGP (e.g., outflows of ecosystem services to other places) in Wolong and beyond if a new round of GTGP is implemented in the future.

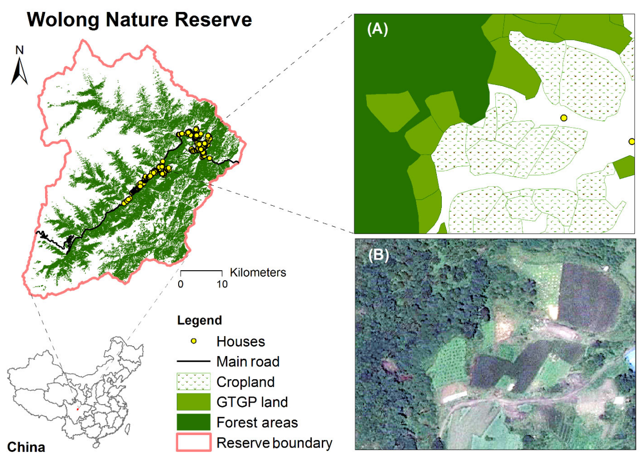


METHODS

Study area

Wolong is a flagship protected area in Southwest China (Fig. 2) and is part of the UNESCO World Heritage system (World Heritage Convention 2016). The reserve is characterized by high biological diversity and provides sanctuary to about 10% of the total wild giant panda population (Liu et al. 2016*a*). Wolong was first established as a national nature reserve in 1963 and was expanded to its current size of 200,000 ha in 1975 (Wolong Nature Reserve 2005). The reserve is managed by the Wolong Administration Bureau and is home to about 5300 residents, most of whom are farmers (Liu et al. 2016*a*). Before 2000, Wolong was a remote area with limited connections to the outside world (An et al. 2001). Most local residents were involved primarily in subsistence-based agricultural activities, such as growing potatoes and corn (Hull et al. 2011). Despite the status of being a nature reserve, the establishment and expansion of the reserve did not mitigate the degradation of panda habitat inside its borders (Liu et al. 2001). As the population size and number of households rapidly increased, human activities, such as farmland expansion, fuelwood collection, and timber harvesting, had caused serious degradation of panda habitat before the early 2000s (Liu et al. 2001, Yang et al. 2013).

Fig. 2. Wolong Nature Reserve in Southwest China. Panel (A) shows the digitized information of the distribution of cropland enrolled in the Grain to Green Program (GTGP) (GTGP land) and remaining cropland in a sample area of Wolong. Panel (B) shows the corresponding Google Earth imagery of this sample area.



In response to this critical issue, a series of conservation programs were implemented, including the GTGP (Yang 2013). In Wolong, GTGP enrollment began in 2000, and additional contracts were signed in 2001 and 2003. Under the GTGP, local households received government payments at an annual rate of about 240 yuan per mu (1 USD = 6.6 yuan as of June 2016; 1 mu = 0.067 ha) for 16 years for converting their cropland to forestland and keeping it forested (Yang et al. 2013). In total, 367.3 ha of cropland (57% of the total) from 969 households (97% of the total) was converted to forestland from 2000 to 2003. In Wolong, cropland parcels close to the forest are often susceptible to crop damage by wild animals, such as wild boar, sambar deer (*Rusa unicolor*), and hedgehog (*Erinaceinae*). Therefore, these parcels can generate less economic benefit than cropland farther from the forest, and they constitute most of the cropland enrolled in the GTGP (Chen et al. 2010).

However, afforestation on these marginal croplands significantly increased crop damage on nearby remaining cropland in Wolong (Fig. 1). A previous study in Wolong estimated the impact of the GTGP on crop damage and found that 64% of observed cropland damage on remaining cropland was attributable to the afforestation promoted by the GTGP (Yang 2018). Most (88%) of the GTGP-induced crop damage occurred on cropland within close range (< 10 m) of GTGP lands. In this range, the GTGP caused about an 18.9% increase in yield loss due to wildlife damage (Yang 2018).

This study benefits from the rich research conducted over the past two decades in the reserve (e.g., Liu et al. 1999, An et al. 2006, Linderman et al. 2006, Tuanmu et al. 2011, Chen et al. 2012*b*, Yang et al. 2015, Tuanmu et al. 2016). The accumulated knowledge from previous studies lays a good foundation for the systematic design of this study, such as the selection of model variables. As a typical coupled human and natural system, findings and methods developed in the reserve have been applied to many other parts of the world (e.g., Liu et al. 2003, Xu et al. 2006, Yu and Liu 2007, Bawa et al. 2010, Chen et al. 2010, 2011, Liu and Raven 2010, Vina et al. 2010, Tuanmu et al. 2012, An et al. 2014, Bradbury et al. 2014). It is our hope that insights from this study (e.g., feedback mechanisms and management implications) will be similarly useful for research and management in many other areas around the world.

Data collection

We conducted a household survey in Wolong from July to August 2015. Household heads or their spouses were chosen as interviewees because they are the main decision-makers in the households and are familiar with household affairs. We iteratively pretested our survey instrument using one-on-one interviews with 33 local households randomly chosen from the 2012 Wolong Household Registration list. After the pretest, we randomly selected 255 other households for the finalized survey. However, six households did not have eligible interviewees because the household heads or their spouses were not available during our survey period, and four households declined to participate, which resulted in 245 interviewees (21% of the total households in the reserve) and a 96% response rate.

We collected information on household socioeconomic and demographic conditions (e.g., each household member's age, education, occupation, and income sources). Since cropland characteristics may also affect households' willingness to participate in future GTGP, we also collected information on croplands owned by each surveyed household. On Google Earth Imagery of Wolong (Fig. 2), with the interviewees' help, we digitized the boundary of all cropland parcels owned by each surveyed household. For each cropland parcel, we recorded related information about its characteristics (e.g., distance to the main road in the reserve and yield loss due to wildlife damage).

To query the interviewees' participation willingness (i.e., whether or not to enroll some or all of their remaining cropland in possible future GTGP), the survey included a set of stated choice questions to elicit choices households make under different hypothesized scenarios. The proposed scenarios consisted of three attributes: crop damage intensity, payment level of future GTGP, and social norm. Crop damage intensity was defined as the proportional yield loss in a cropland parcel due to wildlife damage. The social norm was defined as the proportion of neighborhood households that will participate in future GTGP. Each of these attributes had three possible levels. The crop damage intensity ranged from 10% to 50% with an interval of 20%. These damage intensity levels used in the scenarios were determined based mainly on the crop damage intensities of cropland parcels close to the forest edge (< 10 m) as reported by interviewees in the pretest. These levels roughly corresponded to the 25th, 50th, and 75th percentiles of the reported damage intensities. The payment levels of future GTGP were 500 yuan, 1000 yuan, or 1500 yuan per mu per year. They roughly corresponded to the expected economic returns from 1 mu of cropland with high, medium, and low productivity in Wolong as reported by households in our pretest. These payments are higher than the current payment of the GTGP because cropland productivity and crop price have been increasing in China over past years. The survey explained that all payments would last for a fixed period of eight years in all scenarios. For the social norm, interviewees were told that either 0%, 33%, or 66% of households in the same group (the smallest administrative unit in rural China) would participate in future GTGP. We used these three levels because they worked well in our pretest as variation in the responses could be observed across these three levels. There were 26 groups in Wolong, and each group contained from 14 to 89 households, for a total of 1156 households.

Given that each of the three scenario attributes had three possible levels, there were 27 (3×3×3) possible combinations of them, and correspondingly, 27 different possible stated-choice questions. However, it was generally impractical to ask each household all the 27 questions. Instead, we chose nine combinations of these attribute levels based on main-effects design, as suggested by Louviere et al. (2000). This subset of attribute combinations maintains the independent variation among these three attributes required to capture their main effect on households' participation willingness. Before the face-to-face interview with each household, three choice questions were randomly drawn without replacement from the nine questions. For each choice question, an interviewee was shown the level of crop damage by wild animals, the payment and the social norm specified by the scenario, and was asked whether he or she will participate in future GTGP under those conditions.

Modeling household willingness to participate in future Grain to Green Program

Since households' actual behavior of participating in future GTGP cannot be observed currently, we used households' willingness to participate as an indicator of the actual behavior. As suggested by the theories of reasoned action and planned behavior (Ajzen 1985, Fishbein and Ajzen 2011), willingness or intention is often the strongest predictor of actual behavior. For example, the observed amount of cropland that households re-enrolled in the Conservation Reserve Program in 2001 in the United States was close to that predicted based on survey data on households' stated willingness to participate, which was collected in 1993 (Cooper and Osborn 1998). In other contexts, such as purchase decisions, some literature indicated that stated and actual choices are highly correlated (e.g., Loureiro et al. 2003). In this study, we estimated the effect of crop damage by wildlife on farmers' willingness to participate in possible future GTGP by using the stated choice method (Louviere et al. 2000). This method is a standard procedure used in social sciences to elicit particular actions in response to a set of conditions that modify human agency (Louviere et al. 2000), and has been successfully used in Wolong to investigate the likelihood of re-enrollment of cropland in the GTGP (Chen et al. 2009).

We built a stated choice model to relate the attributes of scenarios (i.e., crop damage intensity, payment level, and social norm) presented in the stated choice questions to households' willingness to participate in future GTGP. Characteristics of the interviewees, their households, and their remaining cropland might also affect interviewees' choices. We thus included a set of variables that described these characteristics in the stated choice model as covariates (Table 1). As mentioned, we asked each interviewee three stated-choice questions, thereby observing three choices for each household. Therefore, the expected number of observations was 735 (245×3). However, there were 13 cases where our interviewees found it is hard to make a choice (i.e., decide to participate or not) in the presented scenarios and responded "not sure." These observations were excluded from our modeling analysis, which resulted in 722 observations for our analysis.

In each of the finalized observations, a household either is or is not willing to participate in future GTGP (i.e., willing to enroll cropland in the program) under a hypothesized scenario and yields a discrete dependent variable for our model. We assumed that farmers are willing to participate in future GTGP if the utility of participating in the program is greater than not participating. That is, $U_i^1 > U_i^0$, where U_i^1 and U_i^0 are the utilities of participating and not participating for household i, respectively. The utility function $U(\cdot)$ is unobservable; however, there is a probability of participating $\Pr(Y_i = 1) = \Pr(U_i^1 > U_i^0)$, where $Y_i = 1$ if the plan was to participate and 0 otherwise, and a farmer's participation plan under the hypothesized scenario, Y_i, can be observed. Empirically, the program participation willingness under different scenarios was modeled with a random-effects probit model (Wooldridge 2010) (Eq.1):

$$\Pr(participate_{ij} = 1 | P_i, H_i, C_i, S_{ij}, \mu_i) = \Phi(P_i\alpha + H_i\beta + C_i\gamma + S_{ij}\delta + \mu_{i)} \quad (1)$$

where $\Pr(participate_{ij} = 1)$ is the probability the ith household plans to participate in future GTGP under the jth scenario; $\Phi(\cdot)$ is the cumulative normal distribution; P_i represents the personal traits of the interviewee from the ith household; H_i represents household economic and demographic conditions of the ith household; C_i represents the characteristics of the cropland parcels owned by the ith household; S_{ij} is the attributes of the jth scenario that household i is exposed to; α, β, γ, and δ are parameter vectors associated with factors that describe personal traits of interviewees, the household's socioeconomic conditions, features of the household's cropland, and scenario attributes, respectively; and μ_i represents the unobserved random effects associated with the ith household to account for the panel nature of the data. In the probit model, the marginal effects of explanatory variables are obtained from the formula shown in Eq. 2:

$$\frac{\partial \Pr(participate=1)}{\partial X} = \varphi(X\beta)\beta \quad (2)$$

where X represents all explanatory variables, $\varphi(\cdot)$ is the standard normal density function, and the derivative is calculated at the mean of the explanatory variables. The marginal effect indicates the change in the participation probability associated with a marginal change in an attribute. For large changes in an attribute, the participation probability can be evaluated using Eq. 1 to

Table 1. Descriptive statistics of variables that were used to construct the stated choice model (GTGP: Grain to Green Program).

Variables	Description	Mean (SD)
Outcome		
Participation	Whether the household is willing to participate in the future GTGP in the hypothesized scenario: Yes: 1; No: 0	0.63 (0.48)
Scenario attributes		
Crop damage intensity	The crop damage intensity assumed in the hypothesized scenario	0.29 (0.16)
Program payment	The payment level of the future GTGP assumed in the hypothesized scenario (yuan)	1005.54 (408.78)
Social norm	The percentage of the household's neighbors' plan to participate in the future GTGP assumed in the hypothesized scenario	0.34 (0.27)
Characteristics of interviewee		
Gender	The gender of the interviewee: Male: 1; Female: 0	0.60 (0.49)
Age	The age of the interviewee (year)	50.34 (12.66)
On-farm laborer	Whether the main income activity the interviewee is involved in is farming: Yes: 1; No: 0	0.62 (0.47)
Household demographic and economic conditions		
Household size	The number of members in the household	4.48 (1.41)
Education	The average education level of household members (year)	6.56 (2.65)
Stable off-farm employment	The number of household members with an off-farm job that will last at least 1 year	0.74 (0.89)
Farming income	The log-transformed income obtained from agricultural production (yuan)	7.15 (3.82)
Income	The log-transformed gross household income (yuan)	10.89 (0.88)
Characteristics of cropland parcels owned by the household		
Cropland area	The total area of the household's remaining cropland (mu)	3.03 (3.33)
Cropland renting	Whether the household has cropland currently rented to other households: Yes: 1; No: 0	0.17 (0.38)
Max distance to road	The maximum distance of the cropland parcels owned by the household to the main road (m)	404.11 (536.79)

[†] The observation unit is individual hypothesized scenario.
[‡] Sample size = 722
[§] 1 mu = 0.067 hectares
[|] 1 USD = 6.6 yuan as of June 2016

predict the change. With the estimated model, we can also evaluate how much the crop damage that was induced by previous GTGP enrollments will affect future GTGP enrollments.

RESULTS

Crop damage had significant ($P < 0.001$) positive effects on local households' willingness to participate (i.e., enroll some or all of their remaining cropland) in future GTGP (Table 2). It was estimated that an additional 1% increase in crop damage intensity increased the interviewees' participation probability by 0.55 percentage points on average. Combined with the previous study result that the GTGP has increased the crop damage intensity that has occurred on cropland close to the afforested lands (< 10 m) by 18.9%, the impact of this crop damage intensity change on households' willingness to participate in future GTGP would be 10.4%. This result indicates that, holding everything else the same, the current GTGP may cause an additional 10.4% of cropland in the nearby range (distance to afforested lands < 10 m) to be enrolled in future GTGP.

The payment level of future GTGP and the social norm also had a significant ($P < 0.001$) positive influence on interviewees' willingness to participate in future GTGP (Table 2). On average, an additional 100 yuan in the payment of future GTGP will increase the probability of participation by 4.2 percentage points. An additional 1% increase in the proportion of neighboring households planning to participate will increase the interviewee's willingness to participate by 0.42 percentage points. In other words, people's willingness to participate in future GTGP can be significantly affected by the participation decisions of their neighbors, and tends to conform to the majority.

Households' willingness to participate in future GTGP was also influenced by characteristics of households and their cropland (Table 2). Both household size and household members' average education had a significant negative effect ($P < 0.05$) on the participation probability. It was estimated that one additional member in the household reduced the participation probability by 2.5 percentage points, and one more year of education reduced households' participation probability by 1.5 percentage points. Stable off-farm employment (off-farm employment that will last at least one year) significantly increased participation probability ($P < 0.05$); one more member with stable employment increased the participation probability by 4.4 percentage points. Households that currently rent cropland to others had significantly higher ($P < 0.001$) willingness to participate in future GTGP. Compared with other households, their probability of participating in future GTGP was about 14 percentage points higher. Households with cropland far from the main road in the reserve were more likely to participate in future GTGP. An additional 1 km from the main road increased households' participation probability in future GTGP by 9 percentage points ($P < 0.05$). Interviewees' personal traits, including gender, age, and occupation (as measured by whether their main income activity involves farming activities), did not show significant influence on household willingness to participate in future GTGP ($P > 0.1$).

Table 2. Estimation of model coefficients for scenario attributes and other characteristics and their marginal effect on the households' willingness to participate in future Grain to Green Programs.

Independent variables	Coefficients	Standard Error	Marginal Effects
Crop damage intensity	1.97 ***	0.333	0.55***
Program payment	0.0015 ***	0.0014	0.00042***
Social norm	1.50 ***	0.204	0.42***
Gender	0.096	0.121	0.027
Age	0.003	0.0046	0.0009
On-farm laborer	0.228	0.139	0.063
Household size	- 0.090 *	0.047	- 0.025 *
Education	- 0.054 *	0.026	- 0.015 *
Stable off-farm employment	0.157 *	0.074	0.044 *
Farming income	0.021	0.017	0.006
Income	0.038	0.074	0.011
Cropland area	- 0.027	0.02	- 0.008
Cropland renting	0.514 ***	0.15	0.143***
Max distance to road	0.0003 **	0.0001	0.00009 **
Constant	- 2.554	0.795	

Significance: * $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$; two-tailed tests
Sample size = 722

DISCUSSION

Our results suggest that, among the socioeconomic and biophysical factors considered at the household level, crop damage occurring on households' remaining cropland has significant influences on their willingness to enroll the land in future GTGP. Combined with the impact of GTGP on crop damage found in previous research, our study shows that the implementation of the current GTGP can prompt more cropland to be enrolled in the future, a positive feedback that strengthens the GTGP's effects. Households that had no enrollment plan initially may change their minds as increasing crop damage occurs on their remaining cropland due to the current GTGP. Although this willingness change occurred locally, it may generate impacts on places far away. For example, as more land is enrolled and becomes vegetated, outflows of some critical ecosystem services (e.g., clean water and air) will increase and help address the shortage crisis of ecosystem services in other parts of China, especially in urban areas where the demand for ecosystem services often goes beyond the local provision capacity (Liu et al. 2016*b*). Conservation planners may leverage this feedback and implement the GTGP round-by-round to increase the enrollment of cropland.

In modeling households' participation willingness, we found that households with stable off-farm income are more likely to enroll their remaining cropland in future GTGP. As tourism in Wolong has been recovering from the devastating impacts of the 2008 Wenchuan earthquake (Zhao 2017), tourism development may bring many off-farm employment opportunities for local people and prompt more cropland to be enrolled and converted to forestland. However, to fulfill this potential of tourism, sound development planning and management are indispensable. He et al. (2008) found that only a small share (< 5%) of revenue from tourism development in Wolong before the earthquake went to local inhabitants because they often have poor education and lack relevant skills to be involved in tourism activities. Therefore, management interventions that help overcome these barriers (e.g., providing training to local households to develop related skills) should be considered to increase the benefits households could obtain from tourism development in the future. In addition, tourism is not completely eco-friendly, and its development should avoid the occurrence of potential negative feedback (i.e., poorly planned tourism development compromising ecosystem health, which in turn harms tourism development in the long run). For example, the design of tourism facilities (e.g., hiking trails) should avoid the core habitat of giant pandas, and the activities of visitors should be regulated to mitigate the negative impacts (e.g., noise pollution) on wildlife health.

Within the 25 provinces in China where the GTGP was implemented, the magnitude of the program's feedback may vary substantially due to the high biological and socioeconomic heterogeneities. For example, unlike Wolong, populations of wild animals that damage crops in some areas may be small. Afforestation on cropland in these regions may generate little influence on crop damage on remaining cropland, thereby little impact on households' willingness to participate in future GTGP. In addition, compensation policies may exist in some areas to cover the loss from wildlife damage, or preventive measures (e.g., building fences) may have been taken by local households to reduce wildlife damage. If effectively implemented, these strategies may substantially reduce households' willingness to enroll their land in conservation programs and thus the magnitude of the feedback of the GTGP. However, previous studies indicate that compensation schemes can be subject to factors like corruption, shortage of funding, and difficulties with handling large numbers of wildlife damage cases (Nyhus et al. 2005, Storie and Bell 2016). In Wolong, 98% of our interviewees said they had never received any compensation for wildlife damage from local government, though they had reported their cases. Preventative measures may also have some limitations. The common preventive measures in Wolong include building fences, tying dogs to stakes at the edge of cropland, and sending a member to frequently patrol cropland during seasons when damage is most likely to occur (e.g., summer when corn and potato mature). However, these measures are either costly (e.g., building and maintaining iron fences or sending a household member to patrol cropland) or have low efficiency (e.g., building a simple wooden fence or tying their dogs to stakes at the edge of cropland). Due to these factors, enrolling cropland in the GTGP should be considered as an option for local households in Wolong and perhaps in many other places to address the wildlife damage issue. Otherwise, as losses due to wildlife damage increase, local people may grow to view wildlife and conservation projects negatively.

Although our analysis is restricted to the GTGP in China, similar feedback may exist in other parts of the world. For instance, converting marginal cropland to other types of vegetation land covers (e.g., forest or grassland) has been widely promoted by conservation efforts in other regions around the world, such as the Conservation Reserve Program in the United States (USDA 2016), the Common Agricultural Policy in Europe (European

Commission 2013), and the Protective Afforestation Program in the Russian Federation (Kulik et al. 2015). Like the feedback of the GTGP, these conservation efforts may cause more crop damage on remaining cropland and make the remaining cropland more likely to be enrolled in these or other similar programs in the future.

Besides conservation programs, the dynamics of other types of telecouplings may also be affected by similar feedbacks. For instance, as globalization continues, the stunning rural–urban disparity in many developing countries (e.g., China, Zambia, and Brazil) attracts millions of farmers from rural areas to work in cities every year (Rush 2011, Lucas 2016). In many rural areas, the rapid increase in labor migration has significantly reduced the negative impacts of human activities (e.g., farming and fuelwood collection) on local wildlife habitats (Klooster 2003, Kramer et al. 2009, Xiao 2011, Chen et al. 2012*a*). This may facilitate the propagation of wildlife populations (e.g., wild boar) that cause crop damage, which in turn may discourage rural households from farming activities and ultimately prompt more rural farmers to out-migrate to work in cities.

Since interactions often exist among different types of telecouplings, a better understanding of the feedback of the GTGP may also help explain or predict the dynamics of other telecouplings. For example, like many other farming areas, Wolong sells agricultural products to other places (e.g., cities like Dujiangyan) while buying industrial products (e.g., fertilizer and plastic film) from elsewhere (Liu et al. 2015). As more cropland is enrolled in future GTGP due to the program's feedback, the outflows of agricultural products and inflows of related industrial products may decrease, thus weakening the telecouplings of trades of agricultural and industrial products between Wolong and other places. Tourism development in Wolong may also be affected by the feedback of the GTGP. Laborers released from farming activities in Wolong may participate in tourism activities, such as operating a restaurant or guest house (Yang et al. 2018). This in turn will increase the accommodation capacities of Wolong and facilitate tourism development. At a large scale, this positive feedback of the GTGP in China's rural areas may increase the import of agricultural products from other countries because less land might be available for domestic food production in the future. This in turn may have socioeconomic and environmental impacts in exporting countries, such as increasing farming revenue and stimulating the conversion of forestland to farmland.

CONCLUSION

In response to unprecedented ecological degradation, PES programs have been widely leveraged as a conservation tool to enhance the outflows of ecosystem services from many rural areas to other places, and constitute an important telecoupling (Naeem et al. 2015). However, as the effects of PES programs on human–nature interactions in target areas accumulate, feedback may emerge. In this study, we found that the intensified human–wildlife conflicts due to the GTGP discouraged farmers from continuing farming activities and increased their willingness to enroll their remaining cropland in possible future GTGP, thereby strengthening the influences of the program within and beyond the target areas in the future. Our findings emphasize that evaluation of PES programs and other telecouplings should properly consider their feedbacks to better understand and anticipate the long-term effects of telecouplings. Future interdisciplinary studies are needed to accumulate empirical evidence across space and time to produce generalizable results on telecouplings' feedbacks that are applicable under different contexts. Armed with such knowledge, scientists, policy-makers, and conservation practitioners would be better equipped to design effective strategies for managing telecouplings among distant places and achieving the United Nations' Sustainable Development Goals in a telecoupled world.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/10140

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