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RESEARCH ARTICLE

Feedback effect of crop raiding in payments for ecosystem services

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Abstract Payments for ecosystem services (PES) may alter dynamics in coupled human and natural systems, producing reciprocal feedback effects on socioeconomic and environmental outcomes. As forests recover following China's two nation-wide PES programs, wildlife-related crop raiding has been increasingly affecting rural people's livelihoods. We evaluate the feedback effect of crop raiding on people's intention to convert their cropland plots into forests under different PES program scenarios in the Tianma National Nature Reserve. Increases in crop raiding, conservation payment amounts, and program duration significantly increased local people's intention to enroll their cropland plots in future PES programs. Our results suggest that a substantial portion of economic benefit from the current PES programs was offset by the feedback effect of crop raiding promoted by these programs. Therefore, such complex human–environment interactions should be incorporated into the design and evaluation of China's PES practices and other PES programs around the world.

Keywords Complex human–environment interactions · Ecological Welfare Forest Program · Grain-to-Green Program · Human livelihoods · Stated choice · Tianma National Nature Reserve

INTRODUCTION

Human conversion of natural landscapes to monocultures and urban areas has often resulted in ecosystem degradation and biodiversity loss globally (Foley et al. 2005; Green et al. 2005). Governments, conservation organizations, and the private sector have invested billions of dollars to counter this trend (McCarthy et al. 2012), but current conservation investments are far below the requirements for conserving ecosystems (Watson et al. 2014). The conservation challenges created by these investment shortfalls can be compounded by indirect and inefficient use of resources (Ferraro and Kiss 2002). Indirect conservation interventions, such as stimulating community economies, encouraging community-based natural resources management, redirecting labor and capital from activities that harm ecosystems, and providing social benefits to communities are commonly employed, but the effectiveness of these interventions is still an open question (Ferraro and Hanauer 2014). Given the limited availability of conservation resources, the effectiveness of conservation investments have been of great concern to conservation practitioners (Baylis et al. 2016).

In order to improve the effectiveness of conservation investments, Payments for Ecosystem Services (PES) have been increasingly implemented as a form of direct conservation investment around the world (OECD 1997, Wunder 2008). Under PES schemes, economic incentives are provided to landholders for shifting ecosystem management in order to produce desired ecosystem functions and processes, which may provide or secure ecosystem services such as carbon sequestration, watershed protection, and biodiversity conservation (Wunder 2007; Chen et al. 2010). PES should at least overcome landholders' opportunity costs (i.e., landholders' costs of forgoing alternative uses of land) in order to attract participation. Such opportunity costs are likely to vary among different landholders (Ferraro 2008). Although the opportunity costs of landholders are usually not publically observable, they are often correlated with the location and features of the land (Ferraro 2003; Khanna et al. 2003; Messer 2006; Alix-Garcia et al. 2008), household characteristics of landholders (Cooper and Osborn 1998; Zbinden and Lee 2005), as well as rental rates of PES programs (Babcock et al. 1997;

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Yang et al. 2005), which are often recognized as determinants of PES participation. PES often produce substantial ecological and socioeconomic effects, which may in turn affect PES participation.

The ecological outcomes of PES schemes are often measured through land use and land cover changes. For instance, by the end of 2005, about 14.5 million ha of land was protected by the U.S. Conservation Reserve Program (Claassen et al. 2008). In the European Union, an afforestation scheme was implemented as a major PES program, which reforested around 930 thousand ha of land by 1997 (OECD 1997). Costa Rica's Pagos de Servicios Ambientales (PSA) program for both reforestation and forest conservation had protected about 600 thousand ha of land by the end of 2008 (Arriagada et al. 2012). Different PES programs often aim to improve different types of ecological benefits, including reduced soil and wind erosion (Osborn et al. 1993), watershed protection (Asquith et al. 2008; Pagiola 2008), ecosystem restoration (Sierra and Russman 2006; Wunder and Alban 2008), and biodiversity conservation (Johnson and Schwartz 1993; McMaster and Davis 2001).

The impacts of PES schemes on human livelihoods have been mixed. While PES may reduce some income-generation activities, such as logging and the extraction of forest products for subsistence use, PES may create new opportunities in tree plantations, tourism development, and monitoring compliance with PES contracts, which can lead to more stable and diversified incomes (Grieg-Gran et al. 2005; Pattanayak et al. 2010). Studies suggest PES can be important in poverty alleviation as the location of environmentally sensitive land often coincides with areas of poverty, and income from PES can serve as a safety net for people in poverty (Wunder 2008; Song et al. 2014). Further, PES may increase landholders' land-tenure security when property rights are allocated during PES enrollment, and increase human and social capital when internal organization is improved through PES implementation (Pattanayak et al. 2010). PES may also have impacts on land and labor markets because land enrollment in PES may reduce the supply of agricultural land and release labor from agriculture (Wunder 2008).

Research exploring the efficacy and efficiency of PES has typically focused on the ecological or socioeconomic effects of PES without considering their complex interactions (Pattanayak et al. 2010). Components in coupled human and natural systems (CHANS) often interact to produce feedback effects among human and natural systems (Liu et al. 2007; Hull et al. 2015). One potential feedback from natural system to human system is crop raiding, which is especially pronounced in and around many of the world's protected areas, such as in Uganda (Naughton-Treves 1998; Wallace and Hill 2012), Indonesia (Linkie et al. 2007), and European countries (Schley and Roper 2003). Human land-use practices affect habitat of many wildlife species, resulting in changes in the extent and spatial distribution of crop raiding (Naughton-Treves 1998; Tweheyo et al. 2005; Morzillo et al. 2014). Studies also suggest crop raiding can substantially influence the economic value of crop production and long-term land-use practices, resulting in a feedback effect (Hill et al. 2002; Mackenzie 2012). Effective conservation through PES requires understanding of the complex interactions among socioeconomic, demographic, and environmental components in CHANS.

The present study aims to evaluate the feedback effects of China's nation-wide PES programs, the Grain-to-Green Program (GTGP), and the Ecological Welfare Forest Program (EWFP), on how rural people respond to PES (Fig. 1). As forests recover following the implementation of these programs, crop raiding by wildlife has been increasing in many places in China (Liu et al. 2009; Sun et al. 2015). Increased crop raiding due to the GTGP and the EWFP may reduce returns from agriculture and decrease the opportunity costs of enrolling in PES programs. Thus crop raiding may serve as an important feedback impacting future land-use decisions of rural people (Fig. 1). In order to evaluate this complex CHANS context for PES, we first demonstrated the implementation of the GTGP and the EWFP was related to increased forest cover and increased perceptions of crop raiding among local people. We then tested the hypothesis that wildlife crop raiding was positively related to local people's intention to enroll their cropland in a PES program while controlling for household socioeconomic characteristics and land plot features that may also predict land enrollment. As China has been expanding the implementation of the GTGP, this study can provide important implications for PES practice throughout the nation and provide insight for similar programs around the world.

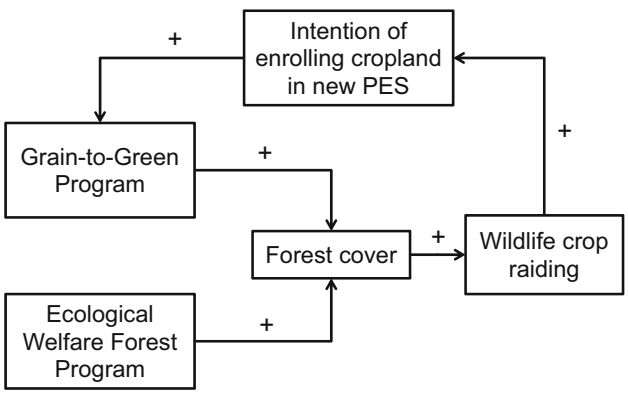

Fig. 1 Interrelationships among PES programs, wildlife crop raiding, and the intention of enrollment in new PES programs

MATERIALS AND METHODS

Background and the study site

China has been implementing a few nation-wide PES programs, including the GTGP and the EWFP, with huge investments. The GTGP has been implemented since 2002 for soil and water conservation through conversion of croplands on steep slopes or otherwise ecologically sensitive areas into forests and grassland (Liu et al. 2008). Although the program targets cropland with slopes above 15 degrees in northwest China and above 25 degrees elsewhere in China, some cropland with slopes below the thresholds was enrolled during the program implementation (Uchida et al. 2005; Chen et al. 2009a). Participants received 3150 and 2100 yuan/ha/year (1 USD $\approx$ 6 yuan in 2013) for enrolled cropland in the upper reaches of the Yangtze River Basin and in the middle-upper reaches of the Yellow River Basin, respectively, plus 300 yuan/ha/year of living allowance. The duration of the payment was 2, 5, and 8 years for land that was converted into grassland, 'economic forests' (e.g., walnuts), and 'ecological forests' (e.g., sweetgum, poplar), respectively. In addition, a one-time subsidy of 750 yuan/ha for seeds or seedlings was also provided. After the initial GTGP contracts matured, the program was extended for another 8 years, but at half of the initial payment rate, while maintaining the 300 yuan/ha/year of living allowance. The GTGP has already converted 9.06 million ha of cropland into forests or grassland (State Forestry Administration of China 2015). As a result, the GTGP has produced substantial ecological benefits including increased forest cover, reduced water surface runoff, soil erosion, river sedimentation, nutrient loss, and desertification (Liu et al. 2008).

The EWFP has been implemented since 2001 to conserve ecologically significant forest in order to maintain and improve ecosystem services and promote forest regeneration (Dai et al. 2009; Jiang et al. 2012). Economic incentives are provided to forest enterprises, rural communities, and individual households to shift their roles from timber harvesting to forest conservation and management. Participating households receive a payment that has been increased from 75 yuan/ha/year in 2001 to more than 100 yuan/ha/year in 2010, although the specific implementation and payments in different regions are typically unique (Jiang et al. 2012). The protected forest area under the EWFP has expanded from 13 million ha in 2001 to 105 million ha in 2007. By the end of 2009, the Chinese government had invested a total of 22 thousand million yuan in the EWFP (Jiang et al. 2012).

Our study site is the Tiantangzhai Township (115°39′–115°53′E, 31°9′–31°17′N, Fig. 2) within China's Tianma National Nature Reserve. The reserve was initially established as a provincial-level nature reserve in 1982 in Anhui Province, and was expanded to 289 km^2 in 1990 for the protection of the subtropical natural forest ecosystem. Tianma Nature Reserve provides critical habitat for more than 2000 wildlife species, including about 185 vertebrate species and 1881 higher plant species (Zhong 2006). Tiantangzhai Township accounts for about 65% of the reserve's area, and more than 90% of the human residents in the reserve were located within the Tiantangzhai Township. Local people in Tiantangzhai conduct diverse economic activities, such as farming, fuelwood and food collection from forests, and tourism-related businesses.

The GTGP has been implemented in Tiantangzhai since 2002, and has converted a total of 103.3 ha of cropland into forests. Although 25 degrees in slope was suggested as a criterion for enrollment in the GTGP at the nation-level, only about 2% of land plots that were enrolled in the GTGP in Tiantangzhai have slopes greater than 25 degrees. In addition, the government had identified areas of land plots that were eligible for enrollment in the GTGP based on two additional conditions. First, the eligible land could not be "basic cropland" that usually has better crop yield than other land plots. Second, because the quota for enrollment in the GTGP was limited, eligible land plots had to be located in government identified areas that tended to form forests instead of small isolated patches. A total of 753 out of about 4369 households in Tiantangzhai were enrolled in the GTGP. The EWFP has been implemented in Tiantangzhai since 2001. Almost all households in the township enrolled in the EWFP. Under EWFP contracts, each household was responsible for managing its forest parcels to prevent illegal logging. As compensation, each household receives a payment at 131 yuan/ha/year. Our field observations suggest the EWFP has substantially reduced illegal logging in the natural forests.

Analysis of satellite imagery showed a total of about 3% net forest loss in Tiantangzhai between 1992 and 2002, which occurred after the reserve was expanded to the current extent. This trend was reversed to forest recovery after the implementation of the GTGP and the EWFP. From 2002 to 2013, there was about 14% net forest recovery (Zhang 2014). Although many factors may affect forest cover change, the implementation of the GTGP and the EWFP was considered the major reason for the forest transition in Tiantangzhai and many other places across China (Viña et al. 2011; Chen et al. 2014). In Tiantangzhai, land that has been enrolled in the GTGP accounted for only about 2% of the increased forest area between 2002 and 2013, and all other forests are protected through the EWFP, suggesting that most of the forest increase can be attributed to the EWFP.

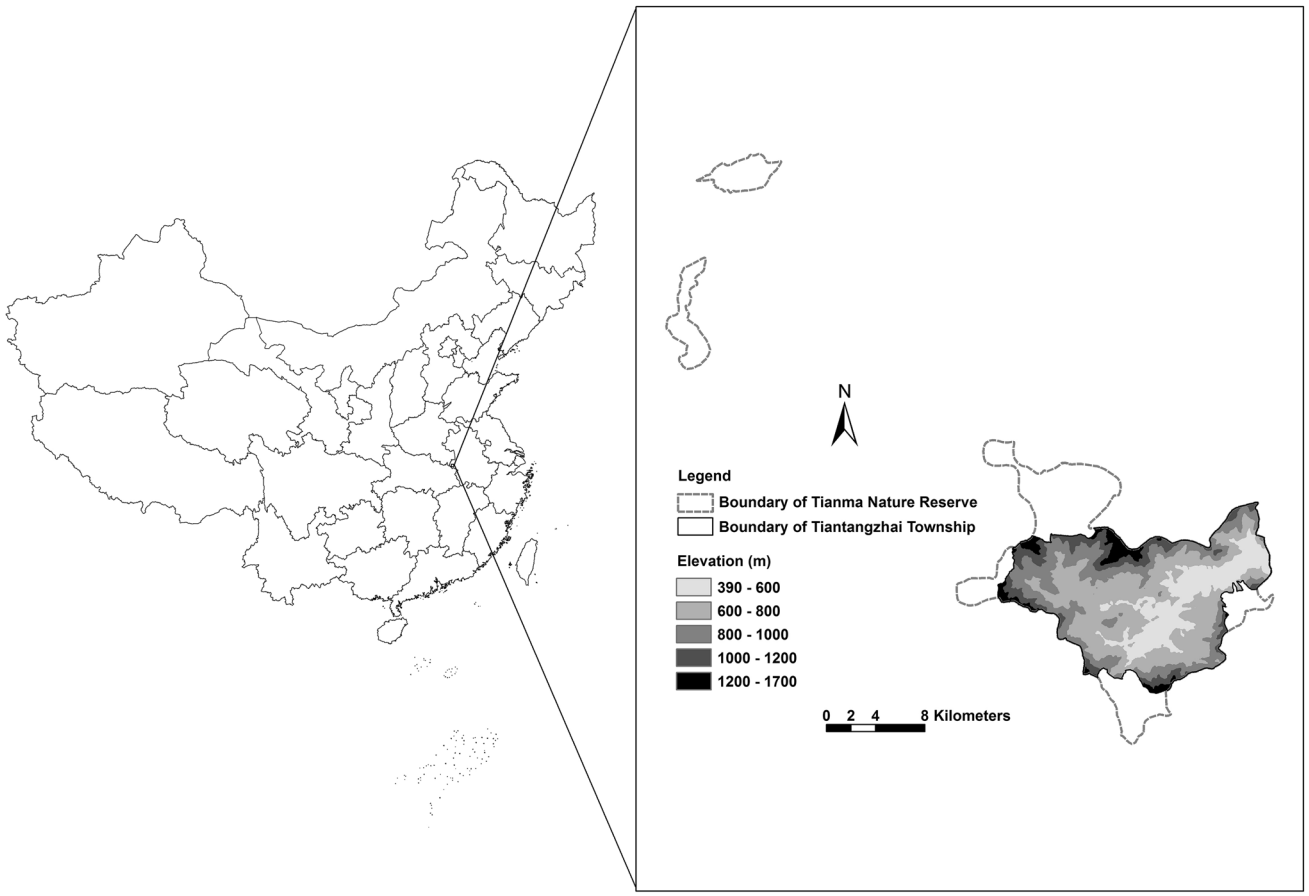

Fig. 2 Location and elevation levels of Tiantangzhai Township within Tianma National Nature Reserve

Household survey

Household surveys with local households in Tiantangzhai were conducted in the summer of 2013. We randomly selected 139 and 111 households who had and had not enrolled in the GTGP, respectively, from the government's record of households. We selected household head or their spouses as our interviewees. If neither of the spouses were at home, we interviewed the adult at home who managed the day-to-day household affairs. We collected demographic information on individual household members, household socioeconomic conditions, and GTGP participation of households. We also measured the locations of cropland plots for all surveyed households using a GPS receiver. The extent of crop raiding at each land plot was reported by our respondents as the percentage of crop loss from crop raiding by wild animals. Biophysical features of land plots were measured by combining GPS data with digital elevation model data, and were processed in a geographic information system (ArcGIS 10.1, Environmental Systems Research Institute, Redlands, California).

Respondents were asked about whether or not they would enroll each of their existing cropland plots in a few proposed PES program scenarios that were similar to the GTGP. The proposed program scenarios consisted of two attributes: conservation payment and program duration. Each attribute could take three values. Possible values for the annual conservation payment were 1500, 4500, and 7500 yuan/ha. Both the medium and high payment levels were higher than the established GTGP payment because the opportunity costs for retiring existing cropland tend to be much higher than those of the land that was previously enrolled in the GTGP. Possible values for the duration of proposed program scenarios were 3, 6, and 10 years. Each respondent received three program scenarios that were randomly chosen and randomly ordered from nine possible combinations of attribute values.

Statistical analysis

Because our surveyed households were selected using a stratified random sampling approach where GTGP participation status was used to define strata, GTGP participants had a higher chance of being selected in the sample than non-participants. Therefore, observations were weighted in our regression analysis where weight is defined as the

reciprocal of the probability that households were selected in the sample. Both conservation payment and duration of PES programs were treated as continuous variables as it is common in stated choice models to treat attributes as continuous variables to allow inferences at attribute levels other than the design levels (Louviere et al. 2000). Empirically, the enrollment under different program scenarios was modeled with a random-effects probit model to control for the correlations among responses to different program scenarios of the same respondent (Wooldridge 2002). The marginal effects of independent variables were also estimated to make the effects of different variables comparable.

RESULTS

Our household survey respondents reported dramatic increases in crop raiding after the implementation of these PES programs. When respondents were asked their perceptions on the level of crop raiding in a five-level Likert scale from none to very serious, only 31% of our respondents felt crop raiding was serious or very serious in 2002, whereas 56% considered it as serious or very serious in 2012. In addition, 25% of our respondents felt crop raiding was none or light in 2002, whereas only 6% believed crop raiding was none or light in 2012. These results suggest as forest cover increased due to the EWFP and the GTGP, many wildlife populations rebounded and crop raiding increased in Tiantangzhai.

Summary statistics of household-level variables for our surveyed households are presented in Table 1. About 56% of our surveyed households participated in the GTGP. These households had an average of 4.5 household members. Household income was dominated by off-farm income within Tiantangzhai and through labor migration outside Tiantangzhai, which accounted for 51% and 39% of total household income, respectively. Farming income accounted for less than 10% of total household income. Each household had about a quarter ha of cropland on average (Table 1). Household heads averaged 52 years old, and had about 7 years of education. Land features of cropland plots for all surveyed households are summarized in Table 2. These households owned a total of 969 cropland plots. On average, there was about 10% of crop loss from crop raiding by wild animals. The average area of each cropland plot was 0.08 ha. The average walking distance from each cropland plot to its corresponding household was approximately 10 min. These cropland plots had an average elevation of 644 m, and an average slope of 9.63 degrees. Most of these cropland plots were south-facing (Table 2).

Table 1 Summary statistics of household-level variables of respondents (n = 250)

Variables	Description	Mean	SD
GTGP participation	Participation in the GTGP (participant = 1, non-participant = 0)	0.56	0.50
Household size	Number of people in the household	4.54	1.46
Farming income	In 1000 yuan	3.00	8.58
Off-farm income	In 1000 yuan	29.07	36.17
Cropland	Amount of cropland under cultivation (in ha)	0.26	0.19
Age	Age of household head in 2013 (in years)	52.44	9.62
Education	Education level of household head (in years)	6.95	2.71

The estimated effects of program scenario attributes, land plot features, and household characteristics on respondents' intention to enroll in a proposed PES program are presented in Table 3. Both conservation payment and duration of proposed PES program scenario had significant impacts on the respondents' intention of enrolling their cropland plots. It was estimated that an additional 1000 yuan/ha of conservation payment increased the probability of enrolling in a PES program by 0.6%. An additional year duration of a PES program increased the probability of enrollment by 0.2%. The proportion of cropland plots that was raided by wild animals had a significant positive effect on the enrollment. An additional 10% of wildlife-related crop raiding in a plot increased the probability of enrolling it by 0.30% and 0.47% for GTGP participants and non-participants, respectively. This increased probability was equivalent to the effects of 500 and 783 yuan/ha increase in the payment. So the effect of an average level of crop

Table 2 Summary statistics of land features of cropland plots of all surveyed households (n = 969)

Variables	Description	Mean	SD
Wildlife raid rate	Proportion of cropland raided by wild animals (e.g., 0.1 = 10 percentage points)	0.10	0.21
Area	In ha	0.08	0.09
Walking distance	Walking distance from each plot to the corresponding household (in minutes)	9.68	9.37
Elevation	In 100 m	6.44	0.99
Slope	In degree	9.63	4.15
Aspect	0 = south-facing; 180 = north-facing	65.34	41.96

Table 3 Random-effects estimation of policy attributes, plot features, and household characteristics on PES enrollment

Independent variables	Coefficients[a] (SE)	Marginal effects
Payment (in 1000 yuan)	0.421*** (0.008)	0.006
Duration	0.151*** (0.006)	0.002
Wildlife raid rate	3.074*** (0.154)	0.047
Wildlife raid rate * GTGP participation	− 1.105** (0.407)	− 0.017
Area	1.481*** (0.450)	0.022
Walking distance	0.086*** (0.003)	0.001
Elevation	0.127*** (0.033)	0.002
Slope	0.090*** (0.008)	0.001
Aspect	0.001 (0.001)	0.00002
GTGP participation	0.714*** (0.099)	0.021
Household size	− 0.244*** (0.024)	− 0.004
Farming income	− 0.026*** (0.006)	− 0.0004
Off-farm income	0.014*** (0.001)	0.0002
Cropland	− 1.025*** (0.185)	− 0.016
Age	0.060*** (0.004)	0.001
Education	0.065*** (0.014)	0.001
Constant	− 10.998*** (0.354)	
σ_μ[b]	3.387*** (0.034)	
ρ[b]	0.920*** (0.001)	
χ^2[c]	20.363***	
Observations	2907	
Number of plots	969	

[a]Significance: ** $p \leq 0.01$; *** $p \leq 0.001$

[b]The random-effects probit parameters for σ_μ and ρ were statistically significant, suggesting that the random-effects model is appropriate

[c]The test statistic for a χ^2 test of the random-effects model versus the pooled model is 19456 with one degree of freedom, which is statistically significant (p value < 0.001)

raiding (10%, see Table 2) was equivalent to the effect of about 21% and 33% of the initial GTGP payment on the enrollment for GTGP participants and non-participants, respectively. The walking distance from each cropland plot to the corresponding household, land plot area, elevation, and slope of cropland plots had significant positive effects on the program enrollment (Table 3). An additional minute of walking distance, 1 ha in land plot area, 100 m in elevation, and one degree in slope increased the probability of enrollment by 0.1, 2.2, 0.2, and 0.1%, respectively.

GTGP participants were 2.1% more likely to enroll their cropland plots than non-participants (Table 3). Household size had a significant negative effect on the enrollment. An additional household member reduced the probability of enrollment by 0.4%. We detected different effects from different types of household income on the program enrollment. Farming income had a significant negative effect on the enrollment, while off-farm income had a significant positive effect on the enrollment. An additional 1000 yuan in farming income reduced the probability of enrollment by 0.04%, and an additional 1000 yuan in off-farm income increased the probability of enrollment by 0.02%. The amount of cropland under cultivation had a significant negative effect on the program enrollment. An additional ha of cropland reduced the probability of enrollment by 1.6%. Age and education of household heads had significant positive effects on the program enrollment. An additional year in age and in education, each increased the probability of enrollment by 0.1%.

DISCUSSION

In evaluating the effect of crop raiding on the participation in PES, we found that PES can create unanticipated feedback in CHANS, and that feedback can simultaneously benefit the ecosystem and harm the social system. Specifically, increases in natural land cover supported by PES allowed wildlife populations to rebound in areas adjacent to agricultural plots. The consequent jump in crop raiding

harmed local people by reducing the value of the remaining agricultural plots, but made land conservation through PES more affordable for program administrators. Our results suggest that crop raiding has compromised local people's livelihoods, and a substantial portion of economic benefit from the GTGP and the EWFP was offset by the feedback effect of crop raiding from these PES programs. We found the effect of wildlife crop raiding on the enrollment was less for GTGP participants than that for non-participants, which may reflect the fact that cropland plots of a household tend to be dispersed across the landscape, and GTGP participants have already enrolled much of their cropland plots that were vulnerable to crop raiding into the GTGP. Long-term expansion of a PES program such as these could ultimately eliminate agricultural lifestyles of local people, unless programs were modified to prevent the feedback mechanism created by wildlife-related crop raiding. Prioritizing PES contracts that create relatively large contiguous areas of protected and agricultural area may dampen the positive feedback seen when the PES contracts create fragmented and mixed distribution of natural and agricultural land cover that is extremely vulnerable to crop raiding.

Numerous studies on PES programs suggest landholders prefer shorter contracts because they provide flexibility needed to change land use in response to swings in commodity prices (Rodriguez et al. 2012), more autonomy (Sorice et al. 2013), and landholders tend to dislike any requirements for permanent protection (Comerford 2014). The negative relationship between program duration and PES participation was flipped in our study. The tendency of respondents to prefer longer contracts may reflect the fact that land plots that are enrolled in our proposed PES have high costs of reconversion back to agriculture due to reforestation in the land plots. Therefore, longer program duration can be more convenient for rural households to arrange their labor allocations, develop alternative income-generation activities, and plan for the livelihoods in the future. In addition, longer-term PES programs also guarantee a greater amount of total payment. However, the positive relationship between program duration and PES participation may flip to a negative relationship if longer contracts (e.g., $>$ 10 years) were considered because such programs may prevent landholders from capitalizing on swings in market prices (Chen et al. 2009a). Indeed some research suggests 10-year contracts reflect a tipping point for PES programs on forested land in the Southeastern United States (Rodriguez et al. 2012).

We also found household socioeconomic characteristics can significantly affect PES participation. Farming income had a significant negative effect on the program enrollment, and off-farm incomes had a significant positive effect on enrollment. The inherent tension between off-farm employment and farming suggests respondents who wanted to allocate labor off farm saw PES programs as a way to reduce labor demands on the farm. This may also explain why older, more educated, and households with a smaller size were more interested in PES. Because farming is labor intensive, enrolling cropland plots in a PES program is a convenient way to release labor demand (Nagubadi et al. 1996; Zbinden and Lee 2005), and heads of household with higher education levels have more capacity for alternative income-generation activities in off-farm settings. Higher dependence of crop production among households with more cropland may explain why they were less likely to enroll in PES. The tendency for past participants to be more interested in future PES programs may reflect both familiarity with PES promoting interest and the tendency for landholders with stronger sense of stewardship to enroll in all such plans (Rodriguez et al. 2012; Comerford 2014, Ramsdell et al. In press).

Geographic attributes of a land plot that decreased opportunity costs for enrollment in PES (i.e., high elevation, high slope, high distance from the household) were positively related with the program enrollment, which was consistent with findings in the literature (Zbinden and Lee 2005; Chen et al. 2009b). Cropland plots that were located in greater elevation and slopes and were farther away from the corresponding household tend to be marginal land and require greater efforts for farming. The area of land plot had a significant positive effect on the program enrollment, presumably because enrollment of larger land plots generates more payment from PES.

In addition to wildlife crop raiding, PES may shape many other human–environment interactions. For instance, labor forces released from agriculture due to PES may be attracted to off-farm employment in urban settings (Uchida et al. 2009), which may produce feedback effect on the rural environment by reducing human pressure on the natural resources. These human–environment interactions should be incorporated into the design and evaluation of PES. Future research should also attempt to identify the potential non-linear relationship between program duration and PES participation, and how this relationship may be different among households with different characteristics and land plots with different features.

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