Effects of Payment for Ecosystem Services and Tourism on Conservation and Development: Trade-Off or Synergistic?

YUJUN WANG,[a,b] HONGBO YANG,[b] VANESSA HULL,[c] JINDONG ZHANG,[a] XIAODONG CHEN,[b] XIANG LI,[d] ZEJUN ZHANG,[a] CHENG LI,[a] FANG WANG,[e] ZHIQIANG ZHAO,[f] YING TANG,[f] AND JIANGUO LIU[f]

[a] *Key Laboratory of Southwest China Wildlife Resources Conservation (Ministry of Education), China West Normal University, Nanchong, Sichuan Province, China*
[b] *Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China*
[c] *Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida*
[d] *Faculty of Law, Politics and Economics, Chiba University, Chiba, Japan*
[e] *College of Life Science, Fudan University, Shanghai, China*
[f] *Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan*

(Manuscript received 7 September 2023, in final form 20 December 2023, accepted 22 January 2024)

ABSTRACT: The effects of various strategies aimed at simultaneously promoting environmental conservation and human development are closely related to sustainable development regionally and globally. However, although the effects of many such strategies have been evaluated by ecologists and sociologists separately, their ability to simultaneously meet these two anticipated goals (i.e., environmental conservation and human development) at the fine spatial scale remains unclear. To answer this fundamental but crucial question, incorporating household and forest change data, we concurrently estimated the ecological and socioeconomic effects of two world-renowned Payment for Ecosystem Services (PES) programs (i.e., the Nature Forest Conservation Program, the Grain to Green Program) and nature-based tourism in 30 protected areas across 8 provinces in China. Here we showed a trade-off between the ecological and economic effects of two PES programs, while synergistic effects exist in the ecological and economic benefits of tourism. Attributes of household and protected areas significantly influenced economic and environmental benefits as well. Our research provides new insights into the complex effects of PES programs and tourism, and crucial information to support their adequate and sustainable implementation in China and the rest of the world.

SIGNIFICANCE STATEMENT: This work answers a fundamental but crucial question, that is, whether the policies commonly advocated to incorporate environmental conservation and human development can yield positive effects both for conservation and economic development. Our evaluation is also timely to inform some shortness (i.e., negligible economic effects, or the lack of expected positive economic benefits) and provides new insights (e.g., the implication of households and protected-areas attributes in conservation and economic outcomes) of Payment for Ecosystem Services (PES) programs and the complex effects of instruments in the context of multiple policies, particularly given the upcoming 2030 deadline for achieving the Sustainable Development goals (SDGs). We expected that implications in this study can provide important lessons for these two instruments, other PES programs, and other conservation and development instruments to support their adequate and sustainable implementation in China and beyond and to contribute to the achievement of relevant SDGs in the remaining years.

KEYWORDS: Social science; Ecology; Asia; Decision-making; Land use; Policy

1. Introduction

The United Nations pursues 17 Sustainable Development goals (SDGs; Colglazier 2015), which collectively advocate for action to eliminate poverty and inequality; safeguard the planet; and ensure universal well-being, justice, and prosperity. These 17 SDGs mainly focus on two dimensions—human development (e.g., SDG1-11) and environmental conservation (e.g., SDG13-15). However, these two dimensions have been historically concomitant and conflicting, even in many protected areas (PAs). A PA is defined by the International Union for Conservation of Nature (IUCN) as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values," which are the cornerstones of conservation (Dudley 2008). Over the past few decades, the rapid development of the whole of human society has occurred at the cost of environmental degradation. For instance, anthropogenic climate change has put global life, including human beings, at great risk (Pecl et al. 2017). Brazil converted many

Supplemental information related to this paper is available at the Journals Online website: https://doi.org/10.1175/EI-D-23-0014.s1.

Corresponding author: Jindong Zhang, zhangjd224@cwnu.edu.cn

Earth Interactions is published jointly by the American Meteorological Society, the American Geophysical Union, and the Association of American Geographers.

DOI: 10.1175/EI-D-23-0014.1 e230014

forests into pasture and farmland to meet the needs of economic development from 1990 to 2005 (Lapola et al. 2013). China's biodiversity and ecosystem services are also deteriorating quickly as a result of rapid economic growth since the initiation of the "reform and opening up" policy in the 1970s (Ouyang et al. 2016).

Before the SDGs were proposed, various policies and strategies arose worldwide to pursue a win-win between environmental conservation and human development. Payment for ecosystem services (PES) programs have proliferated globally to promote environmental conservation while fostering livelihood transitions and alleviating poverty (Liu et al. 2008; Li et al. 2011). Among them, the Natural Forest Conservation Program (NFCP) and the Grain to Green Program (GTGP) are among the biggest PES programs in China and the world in terms of spatial scale and potential influence (Liu et al. 2008). The NFCP conserves natural forests by instituting logging bans and monitoring activities to prevent illegal logging paired with incentives to forest enterprises or farmers; the GTGP converts cropland on steep slopes to forest or grassland by providing farmers with goods (e.g., grain) or financial subsidies (Liu et al. 2008). The ecological and economic effects of these two PES policies have been widely evaluated. Some studies have found that these programs have produced many positive ecological benefits, such as forest recovery (Viña et al. 2016), wildlife habitat restoration (Tuanmu et al. 2016), and ecosystem services improvement (Ouyang et al. 2016), as well as positive socioeconomic outcomes, such as increased income (Liang et al. 2012) and well-being (Brownson et al. 2020). However, others demonstrated that they have no or even negative ecological (Li et al. 2013) and socioeconomic influences (Yang et al. 2013; Yang et al. 2018). These contradictory findings gave rise to confusion about the benefits of these two programs. Furthermore, despite many studies, it remains uncertain whether they can yield positive effects both for environmental conservation and human development. Yang et al. assessed the environmental and socioeconomic effects of the NFCP in Wolong Nature Reserve, indicating positive ecological outcome along with positive (e.g., provide payment, increase tourism) and negative (e.g., economic losses due to crop raiding by wildlife) effects on local households (Yang et al. 2013). However, the socioeconomic effects were evaluated using households' perceptions regarding NFCP and were not confirmed with actual family income. To address these gaps, more comprehensive, quantitative, and empirical studies that simultaneously evaluate the variation in ecological and socioeconomic effects are still needed.

Nature-based tourism is also commonly advocated to simultaneously promote conservation and human development, and it is often implemented in PAs. Many countries with rich biodiversity are struggling with poor economies. They have vigorously promoted nature-based tourism as a tool in their PAs to reconcile the conflict between conservation and development (He et al. 2008). Although great potential benefits are anticipated, tourism in PAs is commonly found to cause ecological degradation, such as vegetation clearing/damage (Farrell and Marion 2001; Jahani et al. 2020) and threatening wildlife (Farrell and Marion 2001; Rastogi et al. 2015) with little or negative benefit to the local community (He et al. 2008; Liu et al. 2012; Rastogi et al. 2015), an outcome that perpetuates a negative perception of the value of nature-based tourism. However, these studies are often evaluated by ecologists or social scientists separately. The concurrent ecological and socioeconomic effects of tourism at multiple scales are largely unknown. Despite many studies, the ability of those instruments to simultaneously meet two anticipated goals (i.e., environmental conservation and human development) at the fine spatial scale remains vague. Moreover, in many places, PES programs and tourism occur at the same time and produce the local ecological and socioeconomic outcomes we observed, but few studies have addressed their simultaneous effects (trade-offs or synergies) on conservation and human development. To answer this fundamental question, we concurrently estimate the effects of the two most common instruments (i.e., PES-NFCP and GTGP; nature-based tourism) on conservation and economic outcome of 30 PAs across 8 provinces in China (Fig. 1; Table S1 in the online supplemental material). With household survey data from 3315 households, we evaluated the impacts of NFCP, GTGP, and tourism on household income to assess their socioeconomic effects. Meanwhile, we evaluated their ecological effects by quantifying the impacts of these instruments on forest loss from 2009 to 2017 and forest gain from 2000 to 2012. We also investigated the households' and PAs' attributes influencing conservation and economic outcome and explored their implications, such as livelihood activities, human capital, reputation, and management level.

2. Materials and methods

a. Household data and assessment

In 2015/16, we conducted a household survey on the residents of 30 protected areas across 8 provinces in China (Fig. 1, along with Table S1 in the online supplemental material). These PAs were selected because they are important areas for biodiversity conservation and current and historical distribution of giant pandas (*Ailuropoda melanoleuca*; Hu et al. 1985), an iconic species of global conservation concern. The household questionnaire consists of the following parts: the household's demographic features; the household's capital, such as natural (e.g., farmland) and human capital (e.g., laborers); the participation in PES, such as amount of subsidy; the household's livelihood activities, such as their production activities (e.g., agriculture, livestock, tourism, labor migration, and local off-farm business); and the household's income, consumption, and expenditure. Since households are the basic units of people's activities (Wallace 2002), we collected data at the household level. We chose household heads and their spouses as interviewees because they are the main decision-makers in family activities, and they are familiar with family situations. A total of 3545 questionnaires were completed. Among the 3545 questionnaires, 3315 provided valid responses, 230 questionnaires were partially invalid because of incomplete answers and were excluded from our analysis.

Then we employed a linear regression model to analyze the effects of PES, tourism, and other control variables on the

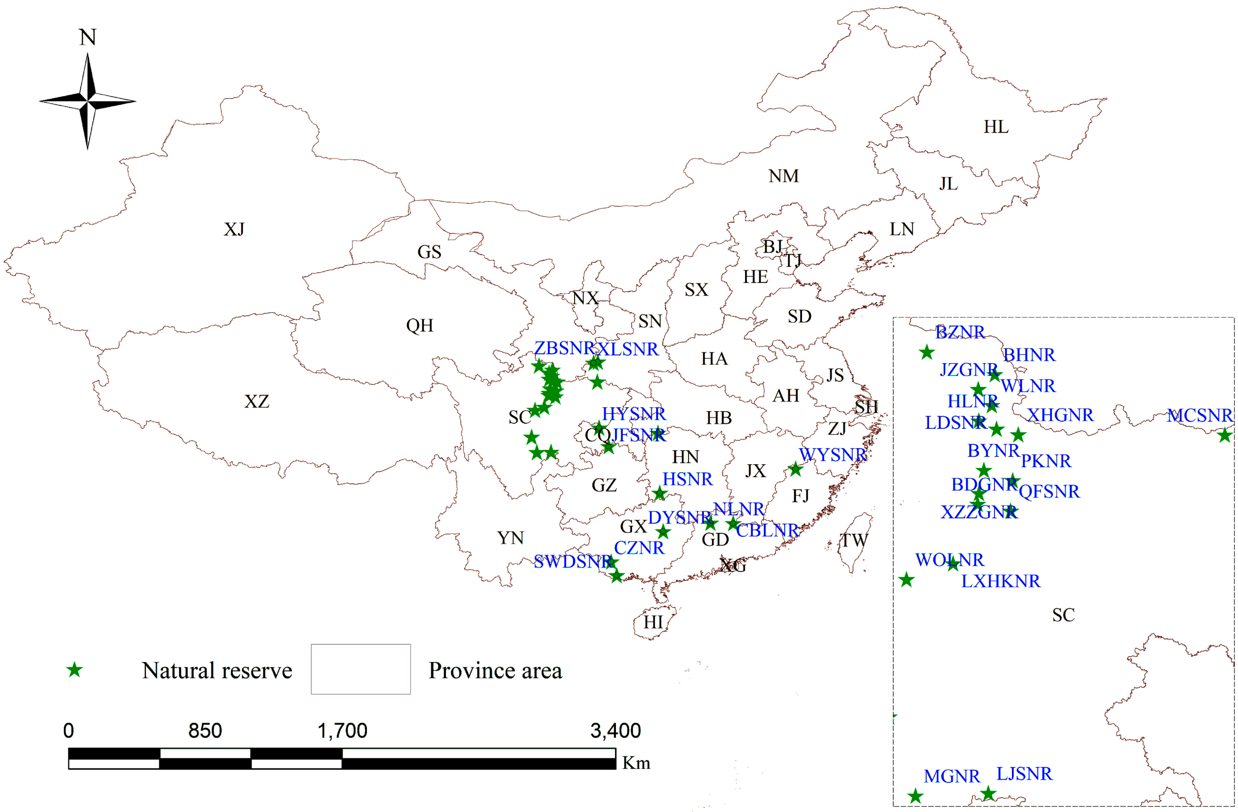

FIG. 1. Geographical distribution of the 30 studied PAs in China. The inset shows the distribution of PAs located in Sichuan. Blue letters are the abbreviations of nature reserves. For the full names, see Table S1 in the online supplemental material. Brown letters are abbreviations for provinces (AH, Anhui; BJ, Beijing; CQ, Chongqing; FJ, Fujian; GD, Guangdong; GS, Gansu; GX, Guangxi; GZ, Guizhou; HA, Henan; HB, Hubei; HE, Hebei; HI, Hainan; HL, Heilongjiang; HN, Hunan; JL, Jilin; JS, Jiangsu; JX, Jiangxi; LN, Liaoning; NM, Inner Mongolia; NX, Ningxia; QH, Qinghai; SC, Sichuan; SD, Shandong; SH, Shanghai; SN, Shaanxi; SX, Shanxi; TJ, Tianjin; XJ, Xinjiang; XZ, Tibet; YN, Yunnan; ZJ, Zhejiang).

economic development of PAs. Our dependent variable was a continuous variable representing the income (a log transformation was performed) of sampled households for each PA. Our independent variables of interest were the two PES programs (i.e., NFCP and GTGP) and tourism development. Additionally, we also included other attributes of the household (e.g., livelihood activities, human capital) and PA (e.g., reputation, management level: whether the PA is national level or not) that may affect the economic development of PAs as control variables. Here, according to the frequency of the names of PAs appearing online, for example, the numbers of published papers from the China National Knowledge Infrastructure (CNKI) and Google Scholar, we ranked the PAs and regarded the top 20% ($n = 6$) as famous PAs with high reputation. It should be noted that our objective was to investigate the complex effects of policies in the context of different factors (i.e., multiple policies, household and PA attributes), rather than quantify the impact of each policy individually. Therefore, we choose the regression method instead of more rigorous tools (e.g., matching) for statistical analysis. Descriptive statistics [i.e., mean and standard deviation (SD)] for these attributes/variables in the model of household income are provided in Table S2 in the online supplemental material.

b. *Forest data and assessment*

Through binary logistic regression, we estimated the ecological effectiveness of each policy by quantifying its effect on forest loss during the period of 2009–17 and forest gain during the period of 2000–12. We evaluated the effects on forest loss from 2009 to 2017 only because some of the PAs (e.g., Wolong Nature Reserve, Longxi-Hongkou Nature Reserve) were greatly affected by the Wenchuan earthquake, which caused extensive destruction of forests and vegetation in the reserve in 2008 (Zhang et al. 2008). To minimize the potential confounding effects of the Wenchuan earthquake on the analysis, and to evaluate the effect of these instruments and other factors on forest loss, we selected forest loss data from 2009 to 2017 for further analysis. Furthermore, due to the limitation of available data, we used forest gain data from 2000 to 2012.

Forest gain and loss information for ecological assessment was derived from a 30-m-resolution global forest change database (Hansen et al. 2013), and the data of forest loss have been updated to 2017 online. We obtained binary forest maps of forest gain during 2000–12 and forest loss during 2009–17 of the 30 PAs under evaluation from the global forest change database, respectively. From the binary forest maps of forest loss, we selected representative random point samples of loss and nonloss and then extracted corresponding attributes to points. The data were then used to build logistic models to assess the impact of instruments and PA attributes on forest loss. The binary data of forest gain were obtained through the same method. Note that we defined forest and nonforest based on tree cover. We first obtained the global tree-cover data of 2000 from the forest change database mentioned above and extracted values to forest points, and then selected these points with tree-cover value above the threshold of 10% for further analysis. According to the Food and Agriculture Organization (FAO) of the United Nations' definition of a forest, we chose 10 as a threshold, and the pixels with tree-cover values greater than 10 were considered as forest (Forest Resources Assessment 2015).

To ensure that a representative sample of pixels is included in the effect estimation, we determined the required sample sizes for forest gain, loss, and nonchanged (nongain and nonloss) using the following equation (Krejcie and Morgan 1970):

$$\text{sample size} = \frac{N \times X^2 \times P(1-P)}{e^2 \times (N-1) + X^2 \times P(1-P)},$$

where N is the total number of forest pixels in the forest gain, nongain, loss, and nonloss categories; X^2 is the chi square for the specified confidence level (95% here) at 1 degree of freedom; e is the margin of error (2.5% was used here), measuring the desired level of accuracy; and p is the proportion of forest pixels that may experience gain or loss, which was set to 0.5 to provide the maximum sample size that may be required to achieve the desired level of accuracy as suggested by Krejcie and Morgan (1970).

These two representative samples of forest loss and gain formed the dependent variables in our analysis of the ecological effectiveness of policies. Since forest loss and gain are binary variables, we used binary logistic regression models and estimated the odds ratio (OR) for each variable to represent the effect size. The independent variables of interest included NFCP, GTGP, nature-based tourism and PA attributes (e.g., area, established time, management level and reputation). We also added other factors that may affect forest loss during the period of 2009–17 and forest gain during the period of 2000–12 as control variables including elevation, aspect, slope, and characteristics such as distance to major city (Weiss et al. 2018) and distance to household. Considering the large geographical area of the 30 PAs, we hypothesized that climatic differences (e.g., temperature, precipitation) in different geographical locations may also affect the gain of forest. Thus, we added the average monthly temperature, average monthly maximum temperature, average monthly minimum temperature, average monthly precipitation, and average monthly solar radiation of previous 30 years [during 1970–2000; data from Fick and Hijmans (2017)] as control variables in the logistic regression model of forest gain. However, the initial analysis results indicated a strong correlation among these climate variables and elevation, as well as precipitation and temperature (Table S3 in the online supplemental material). In comparison with elevation, the effect of climate on vegetation growth is more direct, and the explanatory power of temperature for tree growth surpasses that of precipitation (Li et al. 2020). Therefore, we ultimately choose average temperature as the control factor of climate to be included in the final model. In addition, although we limited our forest loss data analysis to after 2008 to avoid the confounding impacts from the Wenchuan earthquake, secondary disasters occurring in the subsequent years may also cause forest loss, and the postearthquake protection policies may also affect forest gain. Therefore, we added earthquake as a control variable in the model of forest loss and forest gain. Statistics for the binary data of forest loss and gain are in Tables S4 and S5, respectively, in the online supplemental material, and a summary of the data used and available sources are in Table s6 in the online supplemental material.

3. Results

a. *Results of the linear regression model on household income*

Table 1 shows the effects of two PES programs, tourism, and other variables on household income. Participation in the GTGP and NFCP did not increase household income as expected, while tourism development ($P < 0.001$) had a significant positive impact on household income (Table 1). When compared with those who do not participate in the tourism industry, the household income of those who participate in tourism is 61.7% higher. In addition, the reputation of PAs ($P < 0.001$), all livelihood activities ($P < 0.001$), the number of dependents ($P < 0.01$), number of laborers ($P < 0.05$), house area ($P < 0.001$), and farmland ($P < 0.05$) exhibited significant positive correlations with household income. Specifically, the income of households in famous PAs is 26.8% higher than that of the household in less-famous PAs. Households that are involved in labor migration earn 49.4% more than those that are not. Households that keep livestock have a 20.5% higher income than those that do not. Households that farm earn 37.3% more than households that do not farm. Each additional person in the number of dependents and labor force in the household increases household income by 2.9% and 2%, respectively. For every 1-mu increase in household farmland area, household income increases by 0.1%. A 1-m^2 increase in house area increases household income by 0.1%. The variance inflation factors (VIF) calculated were all less than 5, suggesting acceptable multicollinearity of all of the explanatory variables.

b. *Results of the binary logistic regression model on forest loss*

Table 2 provides information on the effects of two PES programs, tourism, and other variables on forest loss. The NFCP ($P < 0.001$) policy exhibited a significant negative correlation with forest loss from 2009 to 2017. Relative to PAs without the implementation of the NFCP, the probability of forest loss in PAs where NFCP was implemented decreased by 80.2%. On the contrary, the implementation of the GTGP policy

TABLE 1. Results of the linear regression model (adjusted $R^2 = 0.378$) on predictors of household income in PAs. One, two, and three asterisks represent significance at the 5%, 1%, and 0.1% levels, respectively, and SE is standard error and is in the parentheses.

Parameter	Description	Coef (SE)	P	VIF
Constant		3.725 (0.343)	0.000***	—
Major variables				
NFCP	Whether the household participates in NFCP (1. yes; 0. no)	0.013 (0.021)	0.520	1.048
GTGP	Whether the household participates in GTGP (1. yes; 0. no)	−0.005 (0.023)	0.837	1.364
Tourism	Whether the household participates in the tourism industry (1. yes; 0. no)	0.617 (0.036)	0.000***	1.124
Control variables				
Human capital				
Dependents	No. of seniors (>65 years old), students and children (<6 years old) in the household	0.029 (0.009)	0.001**	1.017
Laborers	No. of laborers in household	0.020 (0.007)	0.004**	1.045
Financial capital				
Log(GDP2000)	Log-transformed provincial per capita GDP in 2000 (in yuan)	−0.140 (0.092)	0.128	1.324
Physical capital				
Farmland	Total farmland acreage of household (in mu)	0.001 (0.000)	0.034*	1.009
House area	Total floor area of house (m^2)	0.001 (0.000)	0.000***	1.170
Intangible capital				
Reputation	Whether the PA is famous (1. yes; 0. no)	0.268 (0.032)	0.000***	1.406
Management level	Whether the PA is national level (1. yes; 0. no)	0.009 (0.024)	0.691	1.339
Livelihood activities				
Labor migration	Whether there is temporary out-migration to work in cities (1. yes; 0. no)	0.494 (0.023)	0.000***	1.055
Livestock	Whether yak and other livestock are kept (1. yes; 0. no)	0.205 (0.030)	0.000***	1.009
Agriculture	Whether farming is conducted (1. yes; 0. no)	0.373 (0.021)	0.000***	1.068
Local nonfarm	Whether there is local off-farm labor (1. yes; 0. no)	0.356 (0.020)	0.000***	1.056

($P < 0.001$) had a significant positive impact on forest loss. In PAs with the implementation of the GTGP, the probability of forest loss increased by 93.4%. In addition, we also found that elevation ($P < 0.001$), aspect ($P < 0.001$), travel time to major city ($P < 0.001$), and distance to household ($P < 0.01$) were negatively correlated with forest loss. For every 100-m increase in elevation, the probability of forest loss decreased by 7.8%. With each 1° increase in aspect, the probability of forest loss decreased by 0.2%. For every 0.1-h increase in travel time to major cities, the probability of forest loss decreased by 1.3%. Additionally, with every 1-m increase in distance from houses to forests, the probability of loss decreased by 74.1%. While establishment time ($P < 0.001$), management level ($P < 0.01$), PA reputation ($P < 0.001$), and the Wenchuan earthquake and associated secondary disasters ($P < 0.001$) had a significant positive effect on forest loss during 2009–17. Relative to a PA established earlier, the probability of forest loss increases by 6.1% for a PA established 1 yr later. The probability of forest loss in national-level PAs is approximately 3 times higher than that in local-level PAs. Relative to less-famous PAs, the probability of forest loss in famous PAs increased by 86.2%. PAs located in earthquake-prone regions had a sixfold higher probability of forest loss than those outside earthquake-prone regions. The VIF calculated were all less than 5, suggesting acceptable multicollinearity of all the explanatory variables.

c. *Results of the binary logistic regression model on forest gain*

Table 3 provides information regarding the influence of two PES programs, tourism, and other variables on forest gain. The implementation of the NFCP ($P < 0.001$), the GTGP ($P < 0.01$) and tourism development ($P < 0.01$) all had a significant positive impact on forest gain from 2000 to 2012. The probability of forest gain in PAs implementing the NFCP and the GTGP is approximately 3 times and 2 times as high, respectively, as in PAs without these programs. Similarly, forest in PAs with tourism development are twice as likely to experience a gain as those in PAs without tourism development. Meanwhile, distance to household ($P < 0.001$), average temperature ($P < 0.001$) and the Wenchuan earthquake ($P < 0.001$) were significantly positively correlated with forest gain. For every 1-m increase in the distance from forests to houses, the probability of forest gain increases threefold. With each 1° increase in average temperature, the probability of forest gain increases by 31.7%. Forests located in earthquake-prone regions have 2 times the probability of gain when compared with those outside earthquake-prone regions. Conversely, aspect ($P < 0.001$), slope ($P < 0.001$), management level ($P < 0.05$), and tree cover in 2000 ($P < 0.001$) had a significant negative impact on forest gain. For each 1° increase in aspect and slope, the probability of forest gain decreases by 0.2% and 2.2%, respectively. The probability of forest gain in national-level PAs is 32.4% lower than that in local-level PAs. Additionally, for every 1% increase in baseline tree cover, the probability of forest gain decreases by 4.9%. The VIF calculated were all less than 5, suggesting acceptable multicollinearity of all the explanatory variables.

4. Discussion

Worldwide, there is a major drive to harmonize environmental conservation with human development through design and

TABLE 2. Results of the binary logistic regression model on predictors of forest loss in PAs from 2009 to 2017. One, two, and three asterisks represent significance at the 5%, 1%, and 0.1% levels, respectively.

Parameter	Description	Odds ratio	P	VIF
Constant		0.000	0.000***	—
	Major variables			
NFCP	Whether the PA implements NFCP (1. yes; 0. no)	0.198	0.000***	2.180
GTGP	Whether the PA implements GTGP (1. yes; 0. no)	1.934	0.000***	1.460
Tourism	Whether the PA develops tourism (1. yes; 0. no)	0.776	0.165	1.270
	Control variables			
Elevation	Elevation of the forest points (100 m)	0.922	0.000***	2.420
Aspect	Aspect of the forest points (°)	0.998	0.000***	1.010
Slope	Slope of the forest points (°)	0.995	0.115	1.210
Travel time	Distance to major city (in 0.1 h)	0.987	0.000***	1.840
Distance to household	Distance to household (m)	0.259	0.004**	1.080
Area	Area of PA (ha)	1.000	0.284	3.050
Establishment time	Year that PA was established	1.066	0.000***	2.820
Management level	Whether the PA is national level (1. yes; 0. no)	2.998	0.000***	2.730
Reputation	Whether the PA is famous (1. yes; 0. no)	1.862	0.000***	2.120
Earthquake	Whether the PA was affected by the Wenchuan earthquake (1. yes; 0. no)	6.223	0.000***	3.380
Log likelihood chi^2	753.41***			
Pseudo R^2	0.180			

implementation of various policies and/or strategies (Li et al. 2011). The effectiveness of relevant interventions in China, a country supporting among the greatest biological diversity and highest human population on Earth, will have global consequences by way of the country's size and impact on global sustainable development. Here, our research provides new insights into the effectiveness of these policies and strategies. Our results showed the implementation of NFCP was instrumental in restoring and protecting forest. This may be attributed to the fact that our PAs are primarily located in Sichuan, Gansu, and Guangxi, which were significant sites for timber harvesting operations before the year 2000. Thus, these recently logged areas appear to have experienced an intense response to NFCP via forest restoration. The NFCP's accompanying forest monitoring activities to prevent illegal logging may have also contributed to a reduction in forest loss. Meanwhile, the promotion of the GTGP on forest gain can be attributed to the extensive reforestation following the conversion of farmland.

However, contrary to previous research (e.g., Li et al. 2013), we found a significant positive correlation between GTGP implementation and forest loss in PAs. This surprising finding may be explained by the following two reasons. First, although we limited our data analysis to after 2008 to avoid the confounding factors of the Wenchuan earthquake, secondary disasters such as landslides, occasionally occurred in the years since, especially in highly damaged areas (e.g., Longxi Hongkou Nature Reserve

TABLE 3. Results of the binary logistic regression model on predictors of forest gain in PAs from 2000 to 2012. One, two, and three asterisks represent significance at the 5%, 1%, and 0.1% levels, respectively.

Parameter	Description	Odds ratio	$P > \lvert z \rvert$	VIF
Constant		0.000	0.216	—
	Major variables			
NFCP	Whether the PA implements NFCP (1. yes; 0. no)	2.728	0.000***	1.380
GTGP	Whether the PA implements GTGP (1. yes; 0. no)	1.758	0.001**	2.270
Tourism	Whether the PA develops tourism (1. yes; 0. no)	1.993	0.001**	1.200
	Control variables			
Aspect	Aspect of the forest points (°)	0.998	0.000***	1.020
Slope	Slope of the forest points (°)	0.978	0.000***	1.130
Travel time	Distance to major city (in 0.1 h)	1.033	0.136	1.550
Distance to household	Distance to household (m)	4.761	0.000***	1.100
Area	Area of PA (ha)	1.000	0.238	2.730
Establishment time	Year that PA was established	1.011	0.257	2.410
Management level	Whether the PA is national level (1. yes; 0. no)	0.676	0.033**	2.470
Reputation	Whether the PA is famous (1. yes; 0. no)	0.906	0.545	2.120
Tree cover	Tree cover in 2000 (%)	0.951	0.000***	1.080
Average temperature	Average monthly temperature during 1970–2000	1.317	0.000***	3.470
Earthquake	Whether the PA was affected by the Wenchuan earthquake (1. yes; 0. no)	2.061	0.000***	2.750
Log likelihood chi^2	1381.92***			
Pseudo R^2	0.357			

and Qianfoshan Nature Reserve) (Zhang et al. 2008; Zhu et al. 2012). Because GTGP lands are found in steeper areas (≥15° in northwest, ≥25° elsewhere) (Uchida et al. 2005), they are more affected by secondary disasters that could cause forest loss than more gentle slopes on non-GTGP lands. The significant positive impact of earthquake damage ($P < 0.001$) on forest loss, and the significant negative impact of slope ($P < 0.001$) on forest gain corroborate this theory. Second, the GTGP reduced the amount of cropland available for agricultural production by households, which may have spurred farmers to convert other forest land to cropland or other types of agricultural production to make up for income (Wang et al. 2009). In our interviews, we found that some farmers reclaimed their farmland elsewhere or converted the forest and grassland back to cropland or other activities (e.g., tea gardens) to improve household income. These secondary land-use conversions caused forest loss, especially in those areas where tea cultivation is an important economic resource (e.g., Nanling Nature Reserve and Chebaling Nature Reserve, Guangdong Province) (Figs. 2a–f).

In addition to their main goal of conserving ecosystems, both the NFCP and the GTGP also aim to alleviate poverty. Our result suggests that participation in the NFCP and GTGP had no significant impact on household income of residents in PAs. This finding may be due to the following reasons. First, policies produce a wide range of positive or negative effects under different contexts, and they may cancel each other when pooled in a single analysis. Second, as time has passed, prices and the associated cost of living have risen rapidly, and the effects of the fixed payments of these two policies that were originally set back around the year 2000 on household income may have now become negligible. These two theories can be corroborated by the results of our separate modeling of their effects on household income of each PA (Table S7 in the online supplemental material), which shows that the NFCP and GTGP had various effects on household income in different PAs and had no significant impact on residents' income in 89.7% of the sampled PAs. Moreover, the discrepancies in the past results indicate that previous larger-scale studies (e.g., those conducted at the county level) may conceal the impact of policies on marginalized residents (e.g., residents in and around PAs).

Because of the negative ecological impacts of tourism documented in previous studies (e.g., Farrell and Marion 2001; Rastogi et al. 2015), the effectiveness of nature-based tourism to simultaneously promote biodiversity conservation and community development has been questioned. Nevertheless, our research of 30 PAs shows that tourism development had a significant positive correlation with both household income and forest gain. On the one hand, nature-based tourism in PAs usually starts with the development of infrastructure (e.g., public infrastructure and roads from government investments), which provides more temporary jobs to local people (He et al. 2008), while tourism can encourage tourists' consumption to improve local peoples' income. In addition, these income-earning opportunities indirectly reduce the labor force available to participate in activities that contribute to deforestation (e.g., farmland expansion, fuel-wood harvesting; Liu et al. 2016) and promote the shift from firewood to more efficient and convenient energy (e.g., gas and electricity). Therefore, nature-based tourism may harmonize environmental conservation with human development as long as it is properly planned and developed.

Furthermore, we also found that many other attributes of households and PAs considerably affected both local residents' household income and forest conservation. For instance, livelihood activities positively affected household incomes more than policies and historical economic levels. A higher level of management and reputation of the PA both significantly increased forest loss, despite the fact that these PAs often attract more attention and investments from the government and other organizations. Therefore, household and PA attributes play a prominent role in conservation and socioeconomic outcomes. More specific and targeted implementation plans that account for household and regional characteristics are urgently needed to adequately and sustainably implement these instruments. Our research highlights the importance of household and protected areas' attributes in conservation and socioeconomic outcomes, and this implication can also provide important lessons for other ecosystem service payment programs in China and beyond.

Our research can contribute to future policy design, implementation, and effectiveness improvement in the following ways. First, urgent consideration should be given to the impact of natural disasters on converted forestland and post-disaster recovery in the future implementation of the GTGP, and to the supervision and management of converted forest/grassland and entire forest found in PAs to prevent secondary farmland reclamation. Second, the focus of PES design should be on expanding socioeconomic benefits. Given the spatial heterogeneity of effects of PES, we recommend the implementation of refined and differentiated PES schemes to maximize their socioeconomic effectiveness. Third, the tourism industry should be actively encouraged to develop in a way that achieves a mutually beneficial outcome for conservation and human development. Fourth, we suggest integrating tourism development with PES to enhance the sustainability of these policies. The development of the tourism industry symbolizes the monetization of the value of regional natural landscapes, which usually are considered cultural services. Therefore, beneficiaries of ecosystem services (i.e., those benefiting from tourism development) can contribute payments for the ecosystem services they receive, serving as one of the sources of PES funding to enhance the sustainability of PES. Meanwhile, positive ecological outcomes from PES can in turn stimulate tourism development.

It is important to acknowledge the limitations of this study, which may contribute to the improvement of future work. First, taking the SDGs as an example, human development encompasses various aspects such as poverty reduction, good health, affordable clean energy, and gender equality. However, this study only assessed the effects of policies on household income. While household income has been found to be correlated with many other aspects of human development, such as health and energy transition (Borozan 2018), it is necessary for future research to directly evaluate the relationship between policies and other goals. Second, this study only evaluates the effects of policies on forest loss and gain,

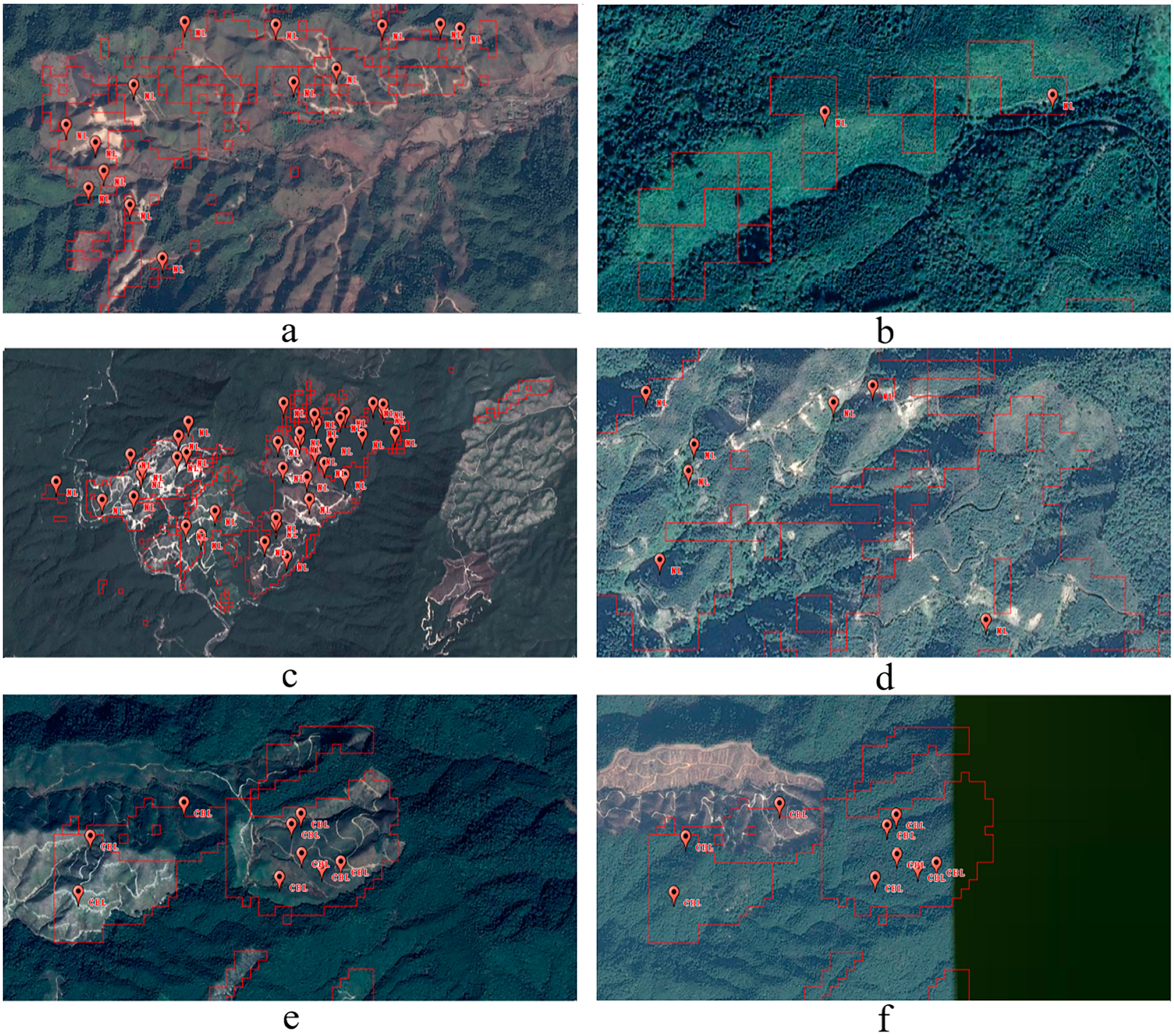

FIG. 2. Images of forest loss from Google Earth. The red rectangles represent areas of forest loss from 2009 to 2017, and the marked points are forest loss points that have been randomly extracted with a radius of 30 m for binary logistic regression analysis; more marked points mean more forest loss. Shown is the forest loss of Nanling Nature Reserve in (a) 2015 and (c) 2012, along with a different area of the same region with (b) loss in 2012 and (d) before loss in 2011 (because of the limitation of earlier historical satellite image data, we can only clearly show part of the same area); Also shown is (e) forest loss in 2016 and (f) before loss in 2014 in the Chebaling Nature Reserve.

without assessing the effect of policies on the ecosystem services supported by forests. Third, the forest cover data used in this study include all types of forests and do not distinguish between natural forests and GTGP forests. Therefore, we can only assess the effects of the two PES programs on forest conservation as a whole and not their respective impacts on natural or planted forests separately.

5. Conclusions

This study assessed the ecological and economic benefits of globally advocated PES and tourism development. The results revealed that the NFCP effectively reduced forest loss and promoted forest gain, while the GTGP significantly fostered forest gain but concurrently increased forest loss. The effects of two PES programs on the income of households in PAs were minimal, even showing no significant effect in most PAs, making it challenging to simultaneously achieve conservation and human development goals. In contrast, tourism development significantly promoted forest gain in 30 PAs while significantly increasing the income of households involved in the tourism industry. Additionally, household characteristics (e.g., human capital, physical capital, and livelihood activities) and PA's attributes (e.g., reputation and management level) were also significantly correlated with household income and forest loss. Our study also emphasized the heterogeneity of economic benefits resulting from the policy implementation as well as the issue of scale effects in the evaluation of PES outcomes.

Acknowledgments. This work was supported by Plateau Scientific Expedition and Research Program (STEP) (2019QZKK0402), the National Natural Science Foundation of China (42071279; 41571517; 31801991; 31572293), the Michigan AgBioResearch, Environmental Science and Policy Program at Michigan State University, the Key Laboratory of Southwest China Wildlife Resources Conservation (China West Normal University), Ministry of Education, China (XNYB19-1), Research innovation team funding project of China West Normal University (CXTD2018-9), and the fund of China West Normal University 17E073, 17E074, 17E077, 20E056). We thank Zhiyun Ouyang of State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences and the support of reserve administrations and staff for our data collection. The authors declare that they have no competing interests.

Data availability statement. Data are available by request from the corresponding author.

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