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Accounting for ecosystem services in compensating for the costs of effective conservation in protected areas

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ABSTRACT

Protected areas are a major approach for conserving ecosystem services globally. Effective conservation in protected areas must integrate human livelihoods into the design and management of conservation. Although ecosystem services can contribute to reducing local people's costs of conservation, exploitation of ecosystem services often results in ecosystem degradation. One important ecosystem service is fuelwood, which is used by > 2.5 billion people worldwide. Conservation policy design needs information on the demand for and values of fuelwood that can be extracted without compromising conservation goals of protected areas. We estimated local people's willingness to pay (WTP) for access to fuelwood in China's Wolong Nature Reserve, which is undergoing a net increase in forest area. Forest recovery in Wolong resulted from both the protection of the reserve and conservation under China's Natural Forest Conservation Program (NFCP). The estimated mean WTP for access to fuelwood accounted for about 21% of the payment under the NFCP. Among household characteristics, the cultural practice of cooking pig fodder, for which there were poor substitutes, played a major role in driving the demand for fuelwood. Although fuelwood collection can be prevented through increased conservation payments, fuelwood collection under forest management that fulfills conservation goals of the reserve can substantially reduce the costs of conservation. In addition, many other ecosystem services are also important to local people's livelihoods, and the combined values of different ecosystem services can substantially lower the costs of effective conservation in Wolong and many other protected areas around the world.

1. Introduction

Protected areas are a major approach for conserving biodiversity and ecosystem services globally (Millennium Ecosystem Assessment, 2005). However, even protected areas are not exempt from human impacts (Curran et al., 2004; Liu et al., 2001). Protected areas often apply restrictions on human access to natural resources, resulting in the loss of fuel, food, and income that local people obtain from ecosystem services in these areas (Adams et al., 2004). Although billions of dollars have been invested by governments and conservation practitioners to create and maintain protected areas around the world, currently, the majority of conservation costs are borne by local people (Balmford and Whitten, 2003; Naughton-Treves et al., 2005; Watson et al., 2014). Due to conflicts between conservation and human livelihoods, command-and-control types of conservation often fail to achieve conservation goals (Adams et al., 2004; Watson et al., 2014). When human livelihoods are not well-integrated into the design and management of protected areas, the effectiveness of protected areas becomes an open question (Leverington et al., 2010; Watson et al., 2014).

Effective conservation through protected areas should address local people's concerns and embrace protected areas as coupled human-natural systems (Liu et al., 2015; Liu et al., 2007; Naughton-Treves et al., 2005). Conservation efforts, such as Integrated Conservation and Development Projects (ICDPs) and Payments for Ecosystem Services (PES), have been implemented to integrate human livelihoods into conservation through promoting socioeconomic development and reducing human pressure (Chen et al., 2010; Naughton-Treves et al., 2005; Wunder, 2007). However, conservation funds are scarce globally and far below the requirements for compensating local people's costs of conservation (Balmford and Whitten, 2003). As a result, many of these conservation efforts have not been effective (Sanchez-Azofeifa et al., 2007).

Protected areas generate a variety of ecosystem services (Daily, 1997; Xu et al., 2017), and local people can utilize these services for both subsistence use and income generation (Bray et al., 2008; Putz et al., 2012). Studies have reported that the opportunity costs of local

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people for forgoing access to ecosystem services in protected areas can account for 18% to 54% of household income (Bush et al., 2013; Shrestha et al., 2007; Shyamsundar and Kramer, 1996). Even without logging, the economic values of Non-Timber Forest Products (NTFPs) such as fuelwood, fruits and medicines can contribute between 14% and 44% of household income (Kalaba et al., 2013; Kar and Jacobson, 2012; Schaafsma et al., 2014). Although these case studies are site specific and may represent areas where the opportunity costs of conservation were relatively high, accommodating some local exploitation of ecosystem services can substantially reduce the costs of conservation. In order to avoid undermining conservation, any exploitation of ecosystem services needs to be done within the conservation goals of protected areas (Rands et al., 2010). Further, conservation policies that ensure sustainable use of ecosystem services may increase transaction costs of conservation. Therefore, management of ecosystem service use without compromising conservation goals of protected areas is still a challenge.

One of the important ecosystem services is fuelwood, which is a primary energy source for > 2.5 billion people worldwide (Global Energy Assessment, 2012). A meta-analysis of 51 case studies from 17 countries found that the value of fuelwood accounts for an average of about 7% of household income (Vedeld et al., 2007). However, fuelwood collection has been considered one of the major drivers of forest degradation globally and deforestation in some areas (Geist and Lambin, 2002; McNally et al., 2011), including in protected areas (Naughton-Treves et al., 2005). Therefore, many protected areas have enforced restrictions on local people's fuelwood collection, which often resulted in increased conflicts between human livelihoods and conservation (He et al., 2009; Weladji and Tchamba, 2003). However, fuelwood is also harvested in many places where forest regrowth exceeds the demand for fuelwood (Arnold et al., 2006; Bailis et al., 2015). Studies have found that allowing access to fuelwood can positively affect local people's attitudes toward conservation (Allendorf et al., 2006; Bajracharya et al., 2006).

Because fuelwood provides a valuable ecosystem service, conservation policy design can benefit from information on the demand for and value of fuelwood that local people utilize in and around protected areas. Although there is a substantial literature on the economic valuation of ecosystem services, including fuelwood, most studies within protected areas have estimated either the costs for keeping protected areas intact, or the values of exploiting NTFPs at levels that often lead to ecosystem degradation (Kusters et al., 2006; Peres et al., 2003). Little is known about the value of exploiting ecosystem services in protected areas without compromising conservation goals. Further, most NTFP valuation studies have relied on self-reported monetary values, or physical quantities and applied a price based on a market value or the price of substitutes of the NTFPs (Mamo et al., 2007; McElwee, 2008; Uberhuaga et al., 2012). However, in many areas market access or substitutes for fuelwood in local markets are lacking or non-existent, making valuation difficult. In addition to economic market values, fuelwood may also contain non-market values such as social and cultural values, so that even where they exist, market prices for substitutes often cannot capture the full value of the ecosystem services to local people.

The contingent valuation method (CVM) is a non-market valuation approach that can capture the full range of values of ecosystem services to the individual households, though it would not capture externalities a household's actions may have on other households. CVM has been widely used in the economic valuation of ecosystem services (Carson, 2000), including evaluation of the opportunity costs for forgoing access to resources in protected areas (Bush et al., 2013; Shyamsundar and Kramer, 1996). These studies estimate people's willingness to pay (WTP) for forest conservation (Amirnejad et al., 2006; Mill et al., 2007; Pouta, 2005), air regulation (Banzhaf et al., 2006), ecosystem management (Gurluk, 2006), conservation in protected areas (Adams et al., 2008; Hadker et al., 1997), and the implementation of conservation programs (Moreno-Sanchez et al., 2012; Ortega-Pacheco et al., 2009; Sattout et al., 2007; Shultz and Soliz, 2007). To our knowledge, CVM has not been applied to the valuation of fuelwood. In most CVM studies for the valuation of ecosystem services, a dichotomous choice method (also known as discrete choice method) is preferred over open-ended responses mainly because of its incentive compatibility and the reduction of protest bids. Dichotomous choice method was also endorsed by the National Oceanic and Atmospheric Administration (NOAA) Panel on Contingent Valuation (Haab and McConnell, 2002).

Studies on the WTP for forest ecosystem services have found mixed relationships between income and WTP. Some studies have found significant positive correlations between income and WTP (Adams et al., 2008; Amirnejad et al., 2006; Ortega-Pacheco et al., 2009; Vincent et al., 2014), but other studies did not find such a correlation (Pouta, 2005; Shultz and Soliz, 2007). Younger people and people with higher education tended to have higher WTP for ecosystem services (Amirnejad et al., 2006; Banzhaf et al., 2006; Hadker et al., 1997). Findings on the relationship between household size and WTP are mixed (Gurluk, 2006; Kramer and Mercer, 1997). Studies have also found significantly higher WTP for ecosystem services among people who perceived more frequent use of the ecosystem services (Kramer and Mercer, 1997; Sattout et al., 2007). In addition, the geographic location of people was also a significant determinant of WTP for ecosystem services (Banzhaf et al., 2006; Moreno-Sanchez et al., 2012).

The goal of the present study is to estimate local people's WTP for fuelwood services under forest management that fulfills conservation goals. A household survey was conducted to elicit WTP for access to fuelwood. Statistical analyses of stakeholders' responses also allowed us to identify household characteristics and respondents' features that drive demand for fuelwood collection. We chose China's Wolong Nature Reserve as our demonstration site for this study because we can draw on our two-decade research experience in the reserve (e.g., An et al., 2006; Chen et al., 2012b; Chen et al., 2010; Linderman et al., 2006; Liu et al., 1999; Liu et al., 2012; Tuanmu et al., 2011; Yang et al., 2015). Many results and methods developed in the reserve have been applied to studies at regional, national, and global levels (e.g., An et al., 2014; Bawa et al., 2010; Bradbury et al., 2014; Liu et al., 2003; Liu and Raven, 2010; Liu et al., 2016b; Vina et al., 2010; Xu et al., 2006; Yu and Liu, 2007).

2. Material and methods

2.1. Background and study site

Wolong Nature Reserve is located in Sichuan Province of China (Fig. 1). It was designated as a national nature reserve in 1963 with a size of about 200 km^2, and was expanded to about 2000 km^2 in 1975. This reserve is within one of the top 25 global biodiversity hotspots (Myers et al., 2000), and supports > 6000 plant and animal species. In addition, the reserve also contains about 4500 human residents (Liu et al., 2007). Most local residents are farmers and are involved in a variety of activities such as fuelwood collection, cultivating maize and vegetables, grazing, and support for tourism (Chen et al., 2009a, 2009b). Although the reserve banned commercial logging, the establishment of the reserve alone did not effectively prevent illegal timber harvesting (though subsequent policies described below did). Previous studies in this reserve have demonstrated that these human activities resulted in past deforestation (Liu et al., 2001; Viña et al., 2007).

Even though it takes substantial effort to collect fuelwood (men did most of fuelwood collection) in the extremely rugged terrain, local residents have traditionally used fuelwood as their main energy source for heating and for cooking human food and pig fodder. Fuelwood was not sold in the local market. The only main alternative energy source to fuelwood is electricity. Although local residents preferred electricity to fuelwood because electricity is more convenient and cleaner without indoor air pollution (Chen et al., 2012a), electricity was mainly used for lighting and electronic appliances because electricity was more

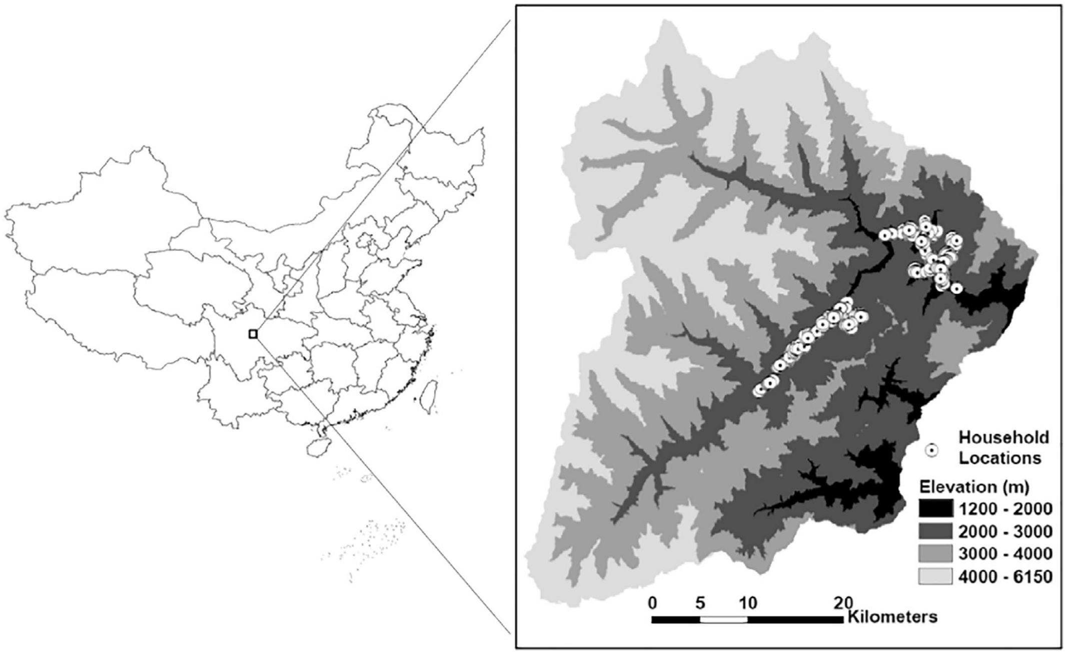

Fig. 1. Locations and elevation levels of Wolong Nature Reserve and local households within the reserve.

expensive than fuelwood, and the voltage and stability of electricity were not reliable (An et al., 2002). The reserve administration implemented a few policies in order to reduce the impacts of fuelwood collection and encourage the use of electricity to replace fuelwood. For instance, a policy that aimed to limit the amount and location of fuelwood collection was difficult to enforce due to limited investments in monitoring fuelwood collection (Wolong Nature Reserve, 2000). Another policy in 2001 funded reconstruction of the electricity network to improve the voltage and stability of electricity for all residents, and subsidize electricity price to enhance affordability (Wolong Nature Reserve, 2005). However, local residents still relied on fuelwood as their main energy source because fuelwood is a traditional use and is free except for the labor required for gathering. Therefore, these conservation policies were not effective without compensating local people's opportunity costs or substantial investments in monitoring human influences.

The Natural Forest Conservation Program (NFCP) is a nation-wide PES program in China to conserve natural forests through logging bans and afforestation, and NFCP is one of the largest PES programs in the world (Liu et al., 2013; Liu et al., 2008). The main reasons for implementing NFCP were severe droughts in 1997 and the major floods in 1998, which were widely considered to be the result of increased soil erosion partially due to excessive deforestation (Liu and Diamond, 2005; Vina et al., 2016; World Bank, 2001). The NFCP was implemented as a pilot program in 1998, and has been a nation-wide program since 2001. Economic incentives are provided to shift forest enterprises and rural communities from timber harvesting to tree plantations and forest management through aerial seeding and artificial planting (Liu et al., 2008; Zuo, 2002). In addition, alternative employment is also provided to traditional forest enterprises. Through the NFCP, the government aimed to reduce timber harvests in natural forests from 32 million m^3 in 1997 to 12 million m^3 in 2003, and afforest 31 million ha by 2010. It was reported that about 61 billion yuan (1 USD = 6.5 yuan as of March 2016) was invested in NFCP through 2005 (Liu et al., 2008). Related stakeholders are provided conservation payments for 10 years, although specific implementation in different regions is different.

NFCP has been implemented in Wolong since 2001. All households in Wolong enrolled in the NFCP for 10 years. Individual households or groups of 2 to 15 households were assigned a natural forest parcel for monitoring to prevent illegal harvesting (Yang et al., 2013). Any timber harvesting, including those for subsistence use, needs approval from the government. As compensation, each household receives an annual payment of about 850 yuan, corresponding to about 4.1% of the average annual household income in 2009. Households are encouraged to spend the NFCP payment on electricity to replace fuelwood. The government assesses the monitoring performance of participating households biannually. If illegal harvesting is found in a forest parcel, corresponding monitoring households lose part or all of their NFCP payment of the year. Households who harvest illegally lose their NFCP contracts. The NFCP contracts have been effectively enforced (Yang et al., 2013) and were renewed in 2011 for another 10 years.

Evidence suggests these changes in forest management altered the dynamics of forest cover within Wolong Nature Reserve. Analyses of satellite imagery showed a rapid forest loss even after the establishment of the reserve (Liu et al., 2001). For instance, from 1994 to 2001, forest cover reduced from 814 km^2 to 710 km^2. The deforestation trend was reversed to forest recovery after 2001, reaching 801 km^2 of forests by 2007 (Liu et al., 2016a; Viña et al., 2011). Among factors that may affect forest cover change, the implementation of NFCP was considered the major reason for the forest transition in Wolong (Tuanmu et al., 2016; Viña et al., 2011). Under NFCP, illegal timber harvesting was effectively banned, and much of fuelwood use was replaced with electricity. As a result, fuelwood consumption reduced about 40% (Chen et al., 2014). In addition, both our field observations and interviews with informants suggested that local people have changed their way of collecting fuelwood from cutting trees to collecting deadwood and branches of trees in order to fulfill the obligations under the NFCP. Although local residents continued to collect fuelwood as one of their main energy sources, forest management under the NFCP has effectively prevented fuelwood collection from compromising conservation goals of the reserve.

2.2. Household survey

A household survey was implemented from June to August of 2010 in Wolong Nature Reserve. Our interviewees were household heads or their spouses because they are usually the decision makers of household

Table 1
Summary statistics of proposed cost, respondents' choice, and household characteristics.

Variables	Description	Mean	Standard deviation
Choice	1 = reduced payment allowing fuelwood collection; 0 = current payment without fuelwood collection	0.502	0.501
Proposed cost	In yuan	175.238	116.865
Laborers	Number of working-age people (18–60 years of age) in the household	3.086	1.549
Income	In 1000 yuan	20.743	19.315
Cropland area	Cropland of the household (ha)	0.293	0.215
Fuelwood heating	1 = use fuelwood for heating; 0 = otherwise	0.507	0.501
Fuelwood food	1 = use fuelwood for cooking food; 0 = otherwise	0.229	0.420
Fuelwood fodder	1 = use fuelwood for cooking pig fodder; 0 = otherwise	0.750	0.434
Forest distance	Distance to the nearest forest parcel (in 100 m)	1.229	0.909
Elevation	Elevation of the household (in 100 m asl.)	18.565	2.236
Age	In years	49.714	11.972
Gender	1 = female; 0 = male	0.379	0.486
Education	In years	4.511	3.316

affairs. We used stratified random sampling (An et al., 2003), and selected 157 households from the government's household registration list for the reserve. The number of households that were selected from each of six villages was proportional to its size. Valid interviews were completed with 140 households for an 89% response rate. The elicited information includes household fuelwood use, demographic information and socioeconomic data. We also measured the locations and elevations of sampled households, and calculated the distance from each household to the nearest forest parcel. Our surveyed households had an average of 3.09 laborers (defined as people 18 to 60 years of age, Table 1). The average household income in 2009 was 20.74 thousand yuan. In addition, these households had an average of 0.29 ha of cropland. About 51%, 23% and 75% of the households used fuelwood for heating, cooking human food and cooking pig fodder in 2009, respectively (Table 1). The mean elevation of the locations of these households was 1857 m, and the mean distance between the households and their nearest forest parcel was 123 m. Most of our respondents were male, and the average age was 50. The education levels were low (mean = 4.51 years).

Our respondents were also asked three dichotomous choice questions to estimate willingness-to-pay for fuelwood collection. At the time of survey, the NFCP contracts were about to mature. We told respondents that the government was considering continuing the NFCP, but the specific implementation and the payment had not been decided yet. We stated that there were two possible scenarios: (i) the NFCP would be renewed, they could still collect fuelwood, but the annual payment from the NFCP would be reduced by "*cost*" (where *cost* varied across questions), or (ii) the NFCP payment would remain the same but they cannot collect fuelwood anymore and the government will strictly monitor fuelwood collection. Our respondents were familiar with the government assessment and monitoring of fuelwood collection because that has already been implemented under the NFCP. We asked their preference between a reduced payment allowing fuelwood collection (referred to as choosing fuelwood hereafter) and the current payment without fuelwood collection. We used monetary measures in Chinese currency (i.e. yuan) as the payment vehicle because the NFCP provides direct monetary payments. Based on a pretest of the survey with 30 households, the values of the proposed cost for these dichotomous choice questions were randomly drawn from 50, 150, and 400 yuan. After about a quarter of our surveys, the design was evaluated and updated following Rollins (1997); specifically, the high level of the proposed cost was changed from 400 to 300 yuan in order to allow more variation in responses. About half of our respondents chose the reduced payment allowing fuelwood collection. The mean proposed cost for the reduced payment was 175 yuan (Table 1).

2.3. Econometric model

Utility theory is used to characterize household choices between NFCP programs and derive WTP for access to fuelwood. Household well-being is represented by a utility function, and households are assumed to make choices to maximize their utility. Household utility is a function of their consumption of marketed goods and services, as well as their production of goods and services for consumption (e.g., crops for own consumption). Household utility may also be affected by their sociodemographic variables (e.g., education), their tastes, and other non-marketed goods and services (e.g., cultural practices). Households face a budget constraint such that purchases of market goods and services are constrained by their income, and income may come from wages and profits from agricultural production. Agricultural production, and hence profits and own consumption, is a function of available labor, hectares of cropland, and livestock. Fuelwood is also produced by the household by using labor and is affected by access to forests. Fuelwood uses that enhance utility include fuelwood for heating, household cooking and cooking pig fodder, but electricity can substitute for some of these. Household WTP for access to fuelwood, WTP_i, is such that their level of household utility with their original income and with no fuelwood collection is equal to their level of household utility with their income reduced by WTP_i but with fuelwood collection. The resulting WTP function is then expected to be a function of factors such as income, cropland area, labor availability, whether or not fuelwood is used in different activities, distance to forests, and demographic factors.

Household responses to the survey questions about their preference over NFCP programs were used to estimate WTP. Respondents' choice takes the value of one if respondents chose the reduced payment allowing fuelwood collection (i.e. choosing fuelwood), and zero if respondents chose the current payment without fuelwood collection. We assume a respondent chose fuelwood if his/her true WTP_i for access to fuelwood was greater than the cost. We modeled WTP_i as a linear function of household characteristics, βX_i, plus a normally distributed random term with correlation across a household's choices. Empirically, responses to dichotomous choice questions were modeled with a random-effects probit model as:

$$Prob(vote_{ij} = 1) = \Phi((\beta X_i - cost_{ij})/\sigma), \tag{1}$$

where $Prob(vote_{ij} = 1)$ is the probability that the ith household chose fuelwood given the jth proposed cost, $\Phi(\cdot)$ is the cumulative normal distribution function, X_i represents the respondent's features and the characteristics of the ith household that are presented in Table 1, β is a parameter vector associated with X_i, $cost_{ij}$ represents the jth proposed cost faced by the ith household that were presented to respondents in the proposed dichotomous choice questions, and σ is the common standard deviation of the underlying errors. In this specification, the value of σ can be estimated based on the coefficient on the proposed cost, α, as σ equals to $-1/\alpha$ (Haab and McConnell, 2002). The mean WTP can be estimated as

$$\text{mean WTP} = \overline{X}\beta/(-\alpha), \tag{2}$$

where $\overline{X}$ is the mean value of X.

The coefficients in a probit model do not directly indicate the marginal effects of explanatory variables (i.e., the change in dependent variable with respect to a change in an independent variable). The marginal effects of continuous variables are estimated as (Greene, 2003):

$$\frac{\partial Prob(vote = 1)}{\partial Z} = \phi(Z\beta)\beta, \tag{3}$$

where Z represents all explanatory variables, $\phi(\cdot)$ is the standard normal density function, and the derivative is calculated at the mean of Z. The marginal effect for a dummy variable, d, is estimated as:

$$Prob(vote = 1 \mid \overline{Z}(d), d = 1) - Prob(vote = 1 \mid \overline{Z}(d), d = 0), \tag{4}$$

where $\overline{Z}(d)$ represents the means of all other explanatory variables.

3. Results

The estimated mean WTP for access to fuelwood by local people in Wolong Nature Reserve was 179 yuan that was calculated based on Eq. (2). This mean value amounts to about 21% of the payment under the current implementation of the NFCP. Because the implementation of the NFCP substantially reduced fuelwood collection, and forests have been recovering under the current level of fuelwood uses, our results show that the fuelwood that can be used without sacrificing conservation goals of the reserve has value to the local people. Further, any conservation approaches that aim to exclude fuelwood uses completely while maintaining the well-being of local people would cost over 20% more in Wolong.

The estimated effects of model variables such as cost as well as household and respondent characteristics are presented in Table 2. The respondents' choice was positively correlated with the number of laborers, the amount of cropland, the dummy variable representing the use of fuelwood for cooking pig fodder, and the elevation of households, but was negatively correlated with the proposed cost and respondents' age. The proposed cost had significant negative effects on the choice for fuelwood (Table 2), as expected. An additional 100 yuan reduction in the NFCP payment reduced the probability of choosing fuelwood by 0.4 (i.e. it reduced the chance by 40 percentage points). The number of laborers had significant positive effects on respondents' choice, likely because greater labor supply reduces the costs of fuelwood collection. An additional laborer increased the probability of choosing fuelwood by about 0.26 (Table 2). Respondents who owned more cropland were more likely to choose fuelwood. Having an additional 0.1 ha of cropland increased the probability of choosing fuelwood by 0.28. Among different uses of fuelwood, heating and cooking human food did not have significant effects on the choice, while cooking pig fodder significantly increased the probability of choosing fuelwood by about 0.75. Compared to heating and cooking human food, it is much more difficult and expensive to cook pig fodder with electricity because of its large quantity. Further, cooking pig fodder is considered a tradition for many local people.

Table 2
Estimated effects of proposed cost and household characteristics on respondents' choice (observations = 420; number of households = 140).

Independent variables	Coefficients[a] (standard error)	Marginal effects
Proposed cost	− 0.011*** (0.002)	− 0.004***
Laborers	0.642* (0.340)	0.256*
Income	− 0.015 (0.022)	− 0.006
Cropland area	7.071*** (2.425)	2.819***
Fuelwood heating	0.502 (1.607)	0.198
Fuelwood food	− 0.963 (1.461)	− 0.362
Fuelwood fodder	2.771** (1.349)	0.748**
Forest distance	− 0.290 (0.600)	− 0.116
Elevation	0.772** (0.344)	0.308**
Age	− 0.130*** (0.048)	− 0.052***
Gender	0.356 (1.097)	0.141
Education	− 0.233 (0.170)	− 0.093
Constant	− 10.541* (5.950)	
σ_u[b]	4.985*** (0.951)	
ρ[b]	0.961*** (0.014)	
χ^2[c]	158.79***	

[a] Significance: *$p \leq 0.1$; **$p \leq 0.05$; ***$p \leq 0.01$.

[b] Significant parameters for σ_u and ρ suggest 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 158.79 with one degree of freedom, which is statistically significant (p-value < 0.01).

The elevation of household locations also had significant positive effects on respondents' choice (Table 2). An additional 100 m in elevation increased the probability of choosing fuelwood by about 0.31. Due to substantial differences in elevation within the reserve (e.g., the maximum difference in elevation among our surveyed households was > 700 m), households at lower elevations tended to have warmer winters, and therefore use less fuel for heating. Lower elevation households are also closer to markets and more developed urban areas outside the reserve. The negative coefficient on age indicates that younger respondents were more likely to choose fuelwood than older respondents (Table 2). Because fuelwood collection is a labor-intensive activity, being an older respondent might indicate less physical capability for fuelwood collection in high mountains with complex topography (McElwee, 2008), although this could be offset if older respondents have lower opportunity costs. Higher probability of choosing fuelwood among younger respondents may also reflect that the culture of using fuelwood was not fading away among younger generations. In our case, each additional year in age reduced the probability of choosing fuelwood by about 0.05. However, household income, distance to the nearest forest parcel, gender and education level of respondents did not significantly affect the probability of choosing fuelwood.

4. Discussion

Effective conservation policy design needs to address both biological conservation and human livelihoods (Naughton-Treves et al., 2005; Watson et al., 2014), and account for the costs of conservation (Ando et al., 1998). In addition to conservation investments, ecosystem services that protected areas provide can be used to compensate local people for the costs of conservation, contribute to poverty alleviation and prevent these services from disappearing. In fact, most of the world's protected areas are designed to be open to some level of human use (Hull et al., 2011; Naughton-Treves et al., 2005). However, community exploitation of natural resources often results in ecosystem degradation in protected areas (Curran et al., 2004; Kusters et al., 2006). In estimating the value of fuelwood that can be exploited without compromising conservation goals, we found the mean WTP for access to fuelwood by local people in Wolong Nature Reserve was 179 yuan, which was about 21% of the payment under the NFCP. Although increased conservation payments can prevent fuelwood collection and keep Wolong intact, allowing fuelwood collection under forest management that fulfills conservation goals of the reserve can substantially reduce the costs of conservation.

In Wolong, the establishment of the reserve alone did not guarantee the sustainable use of forest resources (Liu et al., 2001). Instead, prevention of illegal timber harvesting and reduced fuelwood consumption were primarily correlated with the implementation of the NFCP (Chen et al., 2014; Viña et al., 2011). In addition, electricity as a substitute to fuelwood was available, and local people were able to purchase electricity with the NFCP payment (Chen et al., 2012a). Although much of the fuelwood use has been replaced with electricity, cooking pig fodder with fuelwood is culturally important to local people and was a significant determinant of demand and willingness to pay for fuelwood. It was a tradition to raise pigs and smoke-dry the pork for future use.

Local people found it inconvenient and expensive to use electricity to cook fodder due to a large quantity of pig fodder. Thus, the inability to use fuelwood for the cultural practice of cooking pig fodder would significantly affect local people's well-being if neglected in conservation management.

We also found that respondents who were younger, had more laborers in the household, owned more cropland, and those located at higher elevations were more likely to choose having access to fuelwood, and thus they had higher demand for fuelwood than their counterparts. The effects of household and respondent characteristics on respondents' choice in our study were generally consistent with findings in the literature (Bush et al., 2013; McElwee, 2008; Schaafsma et al., 2014; Uberhuaga et al., 2012). One might expect income would have a significant effect on respondents' choice because fuelwood collection can raise the opportunity cost of time and because electricity, although subsidized, is still an expense. Nevertheless, our findings show that respondents' choice was strongly influenced by the cultural practice of using fuelwood for pig fodder, but was not significantly related to differences in incomes. Compared to previous studies (Amirnejad et al., 2006; Gunatilake, 1998; Mamo et al., 2007), education and the distance to the nearest forest parcel did not significantly correlate with respondents' choice, probably because our respondents generally had a low education level, and all of our sampled households were relatively close to forest parcels (maximum distance = 562 m).

As tens of millions of rural laborers are attracted to off-farm employment in urban regions in China, the number of young laborers and their reliance on cropland in protected areas will likely decrease, which in turn will decrease the demand for fuelwood (Chen et al., 2012a). The trend of rural-to-urban labor migration will continue in China and many other transitional economies in the next few decades (United Nations, 2015), which can substantially reduce the demand for subsistence uses of natural resources in protected areas. Governments and conservation organizations can take advantage of this trend to lower the opportunity costs of local people and enhance the effectiveness of conservation.

The value of fuelwood accounted for only about 1% of the average household income in Wolong, which reflects the fact that there was no legal market for fuelwood, and the fuelwood that we value was for subsistence use without sacrificing conservation goals. In addition, the availability of electricity as an alternative to fuelwood and off-farm employment opportunities in urban regions outside of the reserve reduced local people's demand for fuelwood (Chen et al., 2012a; Cooke et al., 2008). In comparison, although the value of fuelwood as a share of household income is highly variable, in many places it accounts for an average of about 7% of household income (Vedeld et al., 2007), suggesting that fuelwood can contribute even more to reducing the costs of conservation in many other areas where affordable energy substitutes are not readily available. Studies on sustainable use of fuelwood, including the quantity and methods of wood extraction and their impacts on biodiversity and ecosystems, are needed for effective conservation.

In addition to fuelwood, many other ecosystem services, such as wild food, fodder and medicine, are also important to local people's livelihoods (Vedeld et al., 2007). Information on the values of ecosystem services that may be exploited without compromising conservation goals of protected areas can be used for the design of effective conservation through ICDPs and the United Nations program on Reducing Emissions from Deforestation and Forest Degradation (REDD +) (Blom et al., 2010; Chen et al., 2009a, 2009b; Naughton-Treves et al., 2005). It can also be used to guide in the distribution of economic benefits from tourism and other amenity services of protected areas for effective conservation (He et al., 2008). Because conservation funds are still scarce globally, accounting for the combined values of different ecosystem services that can be used without sacrificing conservation goals can substantially lower the costs of effective conservation in protected areas around the world.

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