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Effects of China's payment for ecosystem services programs on cropland abandonment: A case study in Tiantangzhai Township, Anhui, China

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ABSTRACT

Cropland abandonment has emerged as a common phenomenon in land use transitions. Both cropland abandonment and Payment for Ecosystem Services (PES) programs can facilitate the provision of ecosystem services. However, the relationship between cropland abandonment and PES programs remains poorly understood. China has recently undergone considerable cropland abandonment in mountainous areas. Meanwhile, China adopted a series of forest conservation and restoration policies under the scheme of PES starting in the late 1990s. In this study, we track the temporal trend of cropland abandonment under China's two PES programs, Conversion of Cropland to Forest Program (CCFP) and Ecological Welfare Forest Program (EWFP), in Tiantangzhai Township, Anhui Province. We use a random-coefficients logistic regression model to examine the roles that these two PES programs, together with other factors, played in cropland abandonment. Results indicate that: 1) the overall cropland abandonment rates for the CCFP-participating households were lower than those for the non-participants in the years immediately after the implementation of the CCFP, but there was an acceleration of cropland abandonment by the CCFP participants afterwards, leading to the convergence of cropland abandonment rates between the two types of households. 2) Although CCFP payment did not have a long-term effect on cropland abandonment, a larger amount of EWFP payment significantly increased the likelihood of cropland abandonment. 3) Land parcel biophysical characteristics that facilitated cropland abandonment include proximity to EWFP and CCFP forests, poor accessibility and unfavorable topographic positions, and 4) among household socioeconomic conditions, poor farm labor availability and high proportion of local off-farm income in total gross income increased the likelihood of cropland abandonment, while owning domestic animals decreased the likelihood of abandoning cropland. EWFP cash compensation (socioeconomic factors) and distances from cropland parcels to both EWFP and CCFP forest lands (geographic factors) had direct and indirect impacts on cropland abandonment, potentially facilitating the provision of ecosystem services through forest restoration and regrowth on the abandoned land. These findings are highly valuable for policy-makers designing similar PES programs with higher cost-effectiveness and better selection of croplands as targets for reforestation.

1. Introduction

Land-cover and land-use change (LCLUC) has profound impacts on vital ecosystem goods and services across the world (DeFries et al., 2004; Kareiva et al., 2007). Land cover has been transformed tremendously by human beings through land use practices (Foley et al., 2005). Two dominant forms of the transformation are agricultural expansion and deforestation (Geist and Lambin, 2002; Lambin et al., 2003). Recently, land use transitions occurred as new patterns of LCLUC associated with economic development (Lambin and Meyfroidt, 2010). Due to rapid urbanization and economic growth, farmers in rural areas migrate to cities to seek better off-farm economic opportunities. The loss of labor impels rural households to abandon their marginal croplands (Rudel et al., 2005). As a result, cropland abandonment has emerged as a prominent manifestation of land use transitions with socioeconomic development.

Cropland abandonment occurs when continued farming of land ceases to bring sufficient benefits over costs (MacDonald et al., 2000). It is a ubiquitous phenomenon worldwide. Studies in Europe have found widespread land abandonment at marginal areas due to rural exodus and agricultural intensification (Mather, 2001). Meanwhile, post-Soviet Russian experienced substantial agricultural land abandonment, resulting from socioeconomic and institutional changes after the collapse of the Soviet Union (Prishchepov et al., 2013). Developing countries have also undergone cropland abandonment. In Vietnam, for instance, farmers in the mountainous regions abandoned their low-yielding

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farmlands in the uplands while intensified agriculture in the lowlands (Meyfroidt and Lambin, 2008).

Cropland abandonment creates a reverse transformation from human-dominated fields to land surfaces with less human interference. This process has multiple ecological impacts on the environment. The abandoned land, followed by natural succession to grass or secondary forest (Rudel, 2009), offers the potential of increasing carbon storage (Kuemmerle et al., 2011; Silver et al., 2000), reducing runoff and soil erosion (Jiao et al., 2007; Liu et al., 2012), and restoring forest ecosystems (Bowen et al., 2007; Chazdon, 2008). Cropland abandonment also has far-reaching socioeconomic consequences, such as food provision and rural labor allocation. Studies have observed a remarkable amount of abandoned croplands across the world, further adding threats to food security, particularly when cultivated land become scarcer resource under the rapid population growth (Lambin and Meyfroidt, 2011; Ramankutty et al., 2002). Land abandonment also influences households' livelihood strategies. In the Nepalese Himalaya, for example, the abandonment of agricultural fields caused food shortage in villages, forcing households to migrate out to seek non-farm jobs (Khanal and Watanabe, 2006). Given the consequences of cropland abandonment on both environmental conservation and social development, understanding the determinants of cropland abandonment is important in advancing the knowledge of land use transitions.

The abandonment of cropland manifests land-use decision by rural households at the local scale. Unfavorable environmental conditions can impose extra costs of farming, leading to land abandonment in remote areas. Studies have found high risks of cropland abandonment in marginal areas, where topographic features are characterized by rough terrain, high elevation and poor accessibility (Dong et al., 2011; Müller et al., 2009; Sikor et al., 2009). Not only do biophysical features of the cropland affect the likelihood of cropland abandonment, socioeconomic characteristics of rural households can also influence the decision of abandoning croplands (Benayas et al., 2007). For example, a household owning a small area of cropland with a large household size is less likely to abandon the cropland due to the need of food provision. However, the involvement of non-agricultural activities, such as off-farm work, can reduce farm labor availability, leading to cropland abandonment. Personal attributes, such as age, gender and education, of the household head may also be important factors for cropland abandonment, although their effects vary (Müller and Munroe, 2008). For instance, a household head with higher education is more likely to get an off-farm job, which facilitates cropland abandonment, but such a household may also apply technology (e.g., use of machines) to expand croplands and/or intensify agriculture. Cropland abandonment can also be induced by environmental policies that encourage land use transitions (Rudel et al., 2005; Sierra and Russman, 2006; Chen et al., 2014). Recently, Payment for Ecosystem Services (PES) has emerged as an innovative approach in environmental policies to enhance ecosystem services (Wunder et al., 2008; Chen et al., 2017). Yet, the effects of the PES programs on cropland abandonment are not well understood.

China is the largest developing country by population in the world. Historically, China was constantly under the pressure of producing enough food to feed its large population. A nationwide movement was initiated by the central government in the 1950s to reclaim wasteland to become cropland (Ye et al., 2009). Since the adoption of the reform and opening-up policies in the late 1970s, China's economy has witnessed a double-digit growth for three decades. Such rapid economic growth offered unprecedented opportunities for rural residents to work in cities with much higher pay than farming. The migrating population in China reached more than two hundred million, the majority of whom were migrants from rural to urban areas (Liang, 2016). The rising mobility of the rural population was inevitably followed by a land-use trend of cropland abandonment in marginal areas, as observed in many other countries (Busch, 2006; Grau and Aide, 2008; López et al., 2006).

In the late 1990s, the Chinese government initiated a series of forest conservation and restoration policies after a half-century of unsustainable forest exploitation (Song and Zhang, 2009; Zhang et al., 2000). Most of the new forest programs were implemented using the PES approach. In many cases, PES programs are implemented through land-use management such as preserving existing forests and establishing forests on non-forest lands (Engel et al., 2008; Chen et al., 2009a; Pattanayak et al., 2010). One of the conservation policies is the Ecological Welfare Forests Program (EWFP), which was implemented with logging bans that aimed to protect natural forests to stave off ecosystem degradation (Dai et al., 2009). Commercial logging is prohibited for EWFP forests, but local households with natural forests receive compensation from the government for giving up timber harvesting privilege. Thus, the EWFP is essentially a PES program.

Among all the PES programs, China's Conversion of Cropland to Forest Program (CCFP) has received the greatest attention due to its large-scale impacts on forest rehabilitation (Liu et al., 2008). The CCFP was initially experimented in three provinces in 1999, and then was officially adopted in 2001 as a national policy (Zhang and Song, 2006; Chen et al., 2009b). The program has become the world's largest PES program that primarily aimed to convert croplands on steep slopes or in ecologically sensitive areas to forests or grasslands. Participating households enroll their qualified croplands into the program, and receive compensation from the central government based on the land area enrolled. Because the major goal of the CCFP is soil and water conservation, most enrolled croplands are located on steep slopes. Therefore, the CCFP is also known as the Sloping Land Conversion Program in the literature (Xu et al., 2010; Yin et al., 2014). The compensation to participating households from the CCFP was grain in the first year, and was switched to cash in the following years. This also earned the program another nickname, the Grain to Green Program (Liu et al., 2008). Since the implementation of the CCFP, official statistics from the State Forestry Administration have revealed a substantial increase in forest cover. By 2013, over 9.2 million hectares of croplands in total have been enrolled into the CCFP (SFA, 2014). As the first round (16-year period) will end soon, China State Council approved the initiation of the second round of the CCFP. Policy-makers have planned to convert additional 600,000 ha of croplands to forests (SFA, 2015).

Accompanied with the implementation of China's PES programs is the prevailing abandonment of croplands in mountainous areas (Dong et al., 2011; Zhang et al., 2014). Given the potential of providing ecosystem services by the abandoned land, cropland abandonment could expand the benefits of PES. The emergence of cropland abandonment under the PES programs raises the following question: Do the PES programs play a role in cropland abandonment by rural households? There is a paucity of study examining the relationship between rural households' land-use decision on cropland abandonment and the participation in the PES programs. Cropland abandonment could be a "spillover" or unintended effect of the PES programs. Understanding the underlying factors that influence households' decision on cropland abandonment can help policy-makers design similar PES programs more cost-effectively in the future. The present study uses a case study in Tiantangzhai Township, Anhui, China, to explore the social-ecological determinants of cropland abandonment that may be influenced by the CCFP and the EWFP.

2. Methods

2.1. Study area

Tiantangzhai Township is located in the eastern part of the Dabieshan Mountain Ranges in western Anhui Province, China (Fig. 1). The region falls in the northern edge of subtropical climate zone, covering an area of 189 km^2 with elevations varying from 363 to 1729 m above sea level. The mean annual temperature is 16.4 °C and the mean annual precipitation is 1350 mm (Song et al., 2014). Tiantangzhai is remote from the major developed area within a county that is recognized as a "county in poverty" by the central government. The

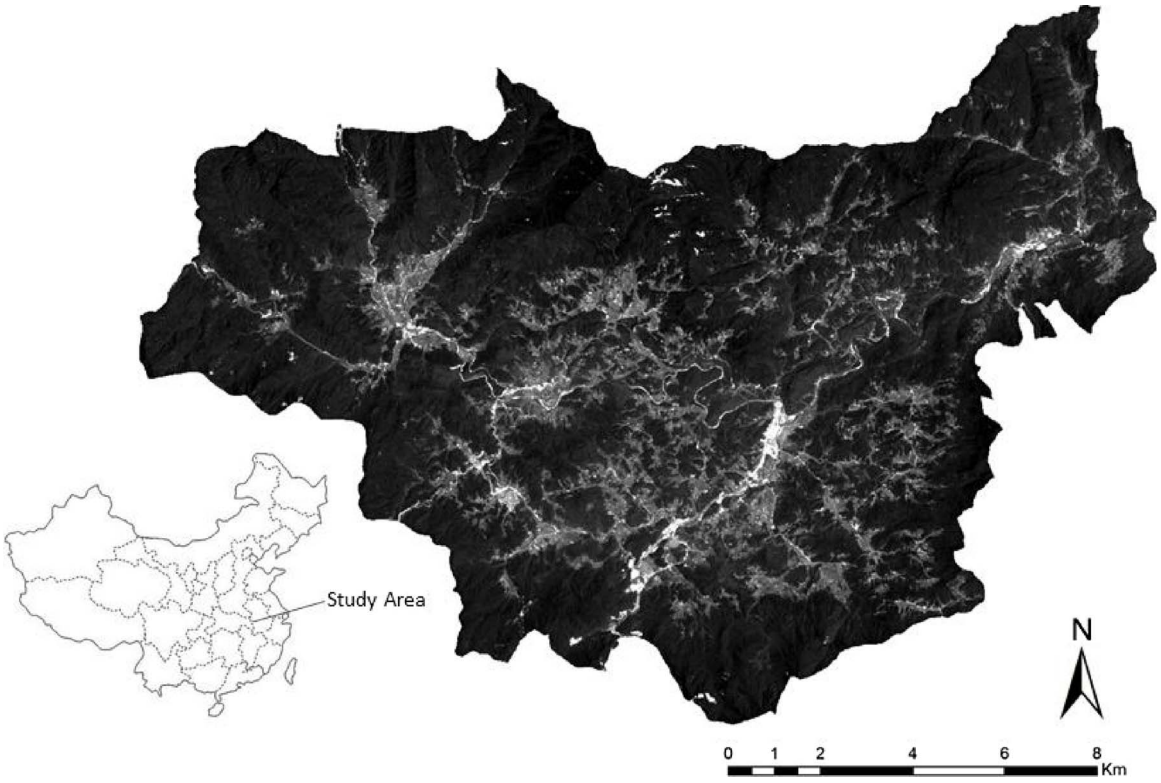

Fig. 1. Study area: 2013 Landsat OLI image (panchromatic band) of Tiantangzhai Township in Anhui, China.

climate condition makes the area favorable for vegetation growth and thus natural forests dominate the landscape. The township forms part of Tianma National Nature Reserve with well-developed tourism. The Nature Reserve was designated to protect the largest patch of natural evergreen and deciduous mixed broadleaf forests in the Dabieshan Mountain Ranges in eastern China (Han et al., 2011). Under regulations of the Nature Reserve, natural forests are protected by the EWFP, which was established under the classification-based forest management in the middle 1990s (Dai et al., 2009). Adopting the PES approach in the late 1990s, the Chinese government compensates households with EWFP forests at a rate of 131.25 Yuan/ha/year (this rate is subject to change and the number provided here is for 2013) to buy the ecosystem services these forests provide. In return, rural households forfeit their commercial logging privilege of these forests, although subsistence use of wood (e.g., fuelwood) is allowed. Nearly all rural households in Tiantangzhai have some natural forests and hence are participating in the EWFP. Despite the low compensation rate of the EWFP, households living in remote areas or high up in the mountain often have large areas of natural forests (i.e. EWFP forests) and thus receive sizable EWFP subsidies. For instance, some rural households receive more than 4000 yuan of EWFP subsidy (corresponding to over 30 ha of natural forests) per year according to the official records by the local forestry station. Thus, the amount of EWFP subsidy varies widely among rural households in the township.

The CCFP has been implemented in Tiantangzhai Township since 2002. According to the official records, 753 out of a total of 4369 households in the township are participating in the program. Participating households may create one of two types of forests on their cropland parcels: ecological (e.g., sweetgum, maple) or economic (e.g., walnut, pecan) forests. The main ecological tree species for CCFP forests in Tiantangzhai are sweetgum and poplar, while economic trees are very limited. For ecological forests, the first round of the CCFP was implemented for a 16-year period, which is comprised of two 8-year contract periods. The CCFP compensation rate was 3450 Yuan/ha/year during the initial contract period. After the first 8-year contract ended, the central government renewed it for another 8 years, but at a lower compensation rate of 1875 Yuan/ha/year. The enrollment of land parcels into the CCFP was organized by the local government, since the land to be enrolled in the program should meet certain criteria (e.g., on steep slopes or in ecologically sensitive areas). During the process of land targeting, the local government first carried out fieldwork to identify the qualified land parcels using topographic maps and/or satellite images, and then visited the corresponding rural households to "persuade" them to enroll these lands. As a result, the participation of the CCFP was not entirely voluntary and the selection of land parcels should not be biased by household factors. For example, some households were not able to enroll their land parcels into the CCFP because their land parcels were located in the "wrong" places. Except for reforested land in the CCFP and natural forest land in the EWFP, other forest land without enrolling in either of the two programs is, if any, very limited. Thus, all forests in Tiantangzhai can be categorized as either CCFP forests or EWFP forests.

Like most rural areas in China, cropland parcels in Tiantangzhai were collectively controlled by communities (called resident groups) with a small proportion allocated to individual households for management before the rural reform (Li et al., 1998). Land parcels, particularly those for subsistence grain production, were not allowed to be abandoned according to state regulations. Since the implementation of the Household Responsibility System (HRS) in the early 1980s, all collective land parcels were allocated to individual households (Mullan et al., 2011). Each household was responsible to manage some fertile and some not so productive croplands. Although the ultimate land owner is the state, farmers enjoy a high degree of usufruct rights under the current land tenure system. For example, village leaders rarely adjust the holdings of land parcels managed by the households, and farmers have rights to lease or rent their land parcels, choose which crop to grow, and even fallow or abandon land parcels. Two primary types of agricultural land have been found in this mountainous region: paddy land and dryland. Paddy land is mainly used for rice, and dryland for dryland crops such as corn, sweet potato and wheat.

In Tiantangzhai, rural farmers also engage in other livelihoods, such as local off-farm work, local non-farm business and migration. A previous pilot study found that rural households in Tiantangzhai relied more on off-farm income and remittances from migration than on income from agricultural activities (Song et al., 2014). For example, some farmers who previously lived high up in the mountain moved down to other places within the township for better economic opportunities. These "local-migrants" tended to find off-farm jobs or to establish small businesses in the local areas not so far from their original households. Hence, they were still able to offer farm labor when needed. Other household members, known as "out-migrants", migrated out of the county, mostly to urban areas far from their original households, and thus rarely returned to help with the farm work.

2.2. Household survey and fieldwork

We conducted surveys with 250 households in the summer of 2013. Before the household survey, we obtained a list of all rural households in the township from the local forestry station. The list contains information of household heads, whether participating in the CCFP, the amount of CCFP forest land, and the amount of EWFP forest land. We then divided the household population into two strata: CCFP-participating households and non-participants, and randomly selected 125 households from each of the strata. If a selected household was unable to be interviewed due to some reasons (e.g., all household members migrated out and no adequate respondent was available), the nearest neighbor of that household was selected as a substitute. This sampling approach aimed to generate comparable sample sizes for both CCFP participants and non-participants with little systematic differences. During the survey, we chose the household head as the interviewee. If the household head was not available (e.g., migrated out to cities), we interviewed the person who was in charge of the day-to-day business on the household, and must be at least 18 years old. If no such a qualified person existed, we would replace the sampled household with its immediate neighbor. One of the households did not manage any land parcels and thus was dropped from the sample in this study. Eventually, the survey ended up with 138 CCFP-participating households and 111 non-participants. We collected household demographic information, socioeconomic data, and the participation in the two PES programs (i.e. EWFP and CCFP). Descriptive statistics of household characteristics among CCFP participants and non-participants are provided in Table 1. Statistical tests did not find significant difference for any of these characteristics between the two types of households.

In addition, we collected detailed information on each of the cropland parcels of the surveyed households, including land parcel type (paddy land or dryland), area, and walking distance to the corresponding house (measured in minutes). If a land parcel had been abandoned, we would ask a following-up question on the year of the abandonment. The nature of land abandonment needs to be differentiated from that of fallow during the interview. A household may temporarily leave a piece of land in fallow to mitigate soil degradation for future cultivation, but a household that decides to abandon a land parcel has no plan to farm on that parcel in the foreseeable future. This notion was clarified to the respondents in the survey since the abandoned land parcels were of interest. Moreover, if a household rented out their land parcels to its neighboring households, these parcels would not be considered as being abandoned because the household received rents. We also asked the abandonment reason for each abandoned parcel, and categorized the respondents' answers into six major reasons: R1, lack of labor due to migration or aging; R2, crop raiding by wild animals; R3, too far away from the house; R4, not worthwhile for cropping due to high opportunity costs of forgoing employment alternatives; R5, lack of reliable water supply for crop growth, and R6, frequent natural disasters such as flooding, drought, insects, and disease. Finally, we set the study time period to 2003–2013 in the analysis, because land parcel abandonment after the implementation of the CCFP (in 2002) was the primary interest.

After interviewing a household, we visited all the land parcels of that household to collect their geographic coordinates with a Global Positioning System (GPS) unit. We obtained the geographic coordinates of the approximate center of each land parcel because we could not afford the amount of time and associated labor costs to delineate the boundaries of all the parcels in the field. With the coordinates recorded, we overlaid the parcel points with the Digital Elevation Model (DEM) of the study area, and derived biophysical characteristics of each land parcel, such as elevation, slope and aspect. We also calculated the Euclidean distances of each parcel to the nearest edges of both natural forests (i.e. EWFP forests) and CCFP forests classified based on satellite images (Zhang et al., 2018). The natural forests were classified using the Random Forest algorithm based on a 2002 Landsat ETM+ image, which was before the implementation of the CCFP (see details in Zhang et al., 2018). The CCFP forest stands were identified based on the topographic maps provided by Tiantangzhai Forestry Station. With the help of the staff members from the forestry station, we delineated the boundary of each CCFP forest patch from a World View 2 satellite image acquired on July 13, 2013.

2.3. Statistical analyses

The temporal trend of cropland abandonment was captured by estimating cumulative probabilities of survived land parcels (i.e., land parcels that had not been abandoned) for each year since 2002. We depicted the probability curves (Goel et al., 2010) for CCFP-participating households and non-participants, and tested the equity of the two curves with the log-rank statistic to track the difference of abandonment rates between the two groups. For the abandoned land

Table 1
Descriptive statistics of household characteristics for CCFP participants and non-participants.

Variable	CCFP = 1		CCFP = 0		Difference in means[a]
	Mean	Std. Dev.	Mean	Std. Dev.	
Mean walking distance to cropland parcels (minute)	10.19	6.91	11.20	9.69	−1.00
Household elevation (100 m)	6.53	0.98	6.30	0.94	0.22
Age of household head	53.00	9.17	51.84	10.15	1.16
Gender of household head (1 = female, 0 = male)	0.06	0.23	0.04	0.19	0.02
Education of household head (year)	7.07	2.66	6.80	2.78	0.27
Number of non-migrants aged 18–60	1.90	1.04	1.66	1.13	0.24
Total area of croplands (ha)	0.38	0.17	0.39	0.19	−0.01
Whether experienced crop raiding by wildlife (0/1)	0.43	0.50	0.40	0.49	0.03
Whether owned domestic animals (0/1)	0.72	0.45	0.74	0.44	−0.02
Proportion of local off-farm income in total gross income	0.30	0.41	0.28	0.40	0.03
Fuelwood use per year (1000 kg)	8.49	5.47	9.32	6.39	−0.83

[a] Statistical tests (t-tests) find no significant difference in means (at the 5% level) for any of the variables between the two types of households.

Table 2
Statistical summary of parcel areas (ha) for abandoned cropland parcels and parcels in use.

CCFP participation	Abandoned parcels (Obs. = 229)			Parcels in use (Obs. = 973)		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Yes	124	0.099	0.086	523	0.088	0.097
No	105	0.091	0.066	450	0.080	0.070
Total	229	0.095	0.077	973	0.084	0.085

parcels, we tallied the percentage of each abandonment reason for the two types of households during 1) the entire time period (2003–2013) and three sub-periods: 2) 2003–2007, 3) 2008–2011, and 4) 2012–2013. We separated the study period into the three sub-periods for two reasons. First, they corresponded to different stages of the implementation of the CCFP. Second, the separation was based on the *posteriori* knowledge of the temporal trajectory of cropland abandonment. For example, it is worthwhile to reveal the abandonment reasons in the last two years (2012–2013), when there was an increasing trend of cropland abandonment by CCFP participants.

Random-coefficients multilevel models are developed for analyzing hierarchically structured data. The multilevel statistical models are useful to study land use change, where data are often nested across various levels (Pan and Bilsborrow, 2005; Zhang et al., 2014). For example, land-use decisions are influenced by biophysical conditions at the parcel level and socioeconomic factors at the household level, and farming activities among different land parcels within the same households are more similar than between households. Thus, a random-coefficients logistic regression model (Guo and Zhao, 2000) was used to examine both fixed effects of parcel and household characteristics and random effects among households on cropland abandonment. The dependent variable of the model is whether the land parcel had been abandoned (=1) or was still under cultivation (=0) by the time of the survey in 2013. The independent variables include biophysical characteristics of the land parcels and socioeconomic characteristics of the households.

At the parcel level, we included two variables relating to geographic aspects of the PES programs in the model, which are the distances of the parcel to the nearest EWFP forest edge (*Distance to EWFP*) and CCFP forest edge (*Distance to CCFP*). Land parcels that are closer to EWFP and CCFP forests may naturally have less favorable conditions that influence cropland abandonment even without the PES programs. In order to isolate the effects of these two variables, we included topographic features at the parcel location, including elevation (*Parcel elevation*), aspect (*Parcel aspect*) and Topographic Wetness Index (*TWI*), to control their confounding effects. TWI is a proxy of soil moisture based on the slope and the upslope area flowing through a certain point (Sørensen et al., 2006). The larger the TWI value is, the higher the soil moisture might be. Other parcel-level variables included in the model are land parcel area (*Parcel area*), land parcel type, i.e. paddy land or dryland (*Parcel type*), and the distance from the parcel to the corresponding house measured in minutes needed walking (*Walking distance*).

At the household level, the two variables measuring socioeconomic aspects of the PES programs are total amounts of EWFP cash compensation (*EWFP payment*) and CCFP cash compensation (*CCFP payment*) received by the household in the past 12 months. Other household-level variables include personal attributes (viz. *Age*, *Gender*, and *Education*) of the household head, elevation at the household location (*Household elevation*), number of non-migrants (aged 18–60) who were able to provide farm labor (*Farm labor*), total area of croplands managed by the household (*Cropland area*), whether experienced crop raiding by wildlife (*Crop raiding*), whether owned domestic animals (*Animal*), proportion of local off-farm income in total gross income (*Off-farm income share*), and total amount of fuelwood consumed per year (*Fuelwood use*). Instead of a single lumped total income as an independent variable, we used detailed factors that contribute to the overall livelihood (e.g., total amount of cropland, domestic animals owned, local off-farm income share, and fuelwood use). These variables provide more nuanced understanding on land-use decision by rural households.

The independent variables at the parcel and household levels are listed in Tables 3 and 4, respectively. The random-coefficients logistic regression model was estimated with a random intercept and fixed slopes, as shown in Eq. (1).

$$\log\left(\frac{\Pr(Y_{ij}=1)}{1-\Pr(Y_{ij}=1)}\right)=\beta_0+\sum_{p=1}^{P}\beta_p X_{ijp}+\sum_{q=1}^{Q}\gamma_q Z_{jq}+\mu_j+\varepsilon_{ij} \quad (1)$$

where $\Pr(Y_{ij}=1)$ is the probability of the abandonment of the i^{th} parcel by the j^{th} household; X_{ijp} is the p^{th} predictor describing parcel features and Z_{jq} is the q^{th} predictor of the j^{th} household's characteristic that influence the abandonment of land parcels. The intercept is captured by the coefficient β_0, and the fixed effects are captured by the coefficients β_p and γ_q corresponding to X_{ijp} and Z_{jq}, respectively. In addition, ε_{ij} and μ_j capture the random effects at the parcel level and the household level, respectively.

3. Results

3.1. Temporal dynamics of cropland abandonment

Among a total of 1202 land parcels of the surveyed households, 229 parcels had been abandoned by 2013 (Table 2). Abandoned parcels had a larger mean area than parcels in use for both CCFP participants and non-participants. Parcels of CCFP participants had a larger mean area than those of non-participants. At the time of the household survey, the abandonment rate of land parcels for CCFP participants almost equaled that for non-participants.

The survival rates of individual land parcels showed declining trends for both CCFP participants and non-participants during 2003–2013 (Fig. 2). Once a parcel of cropland was abandoned, it is hard to be put back in use. Therefore, the survival rates monotonically decreased as more cropland parcels were abandoned. The overall survival rates of land parcels for CCFP participants were generally higher than those for non-participants before 2013. However, the two trend lines converged by 2013, leading to insignificant difference between the two groups of households. This converging trend suggests an acceleration of cropland abandonment by CCFP participants near the time of the household survey.

3.2. Reasons of cropland abandonment

We begin with the interpretation of the reasons of cropland

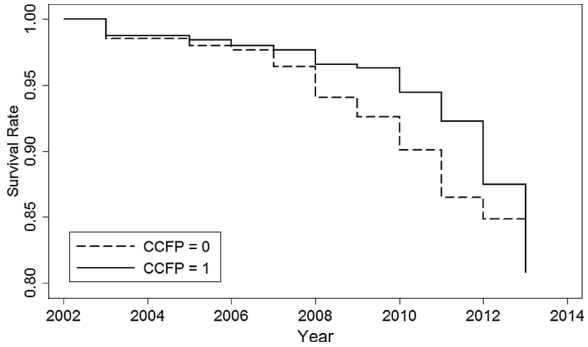

Fig. 2. Temporal trajectories of survival rates based on individual cropland parcels for CCFP-participating households and non-participants during 2003–2013.
Notes: The log-rank test of the equality shows no significant difference (Chi2 = 0.03, Pr > Chi2 = 0.873) between the two survival functions by 2013, but the difference is statistically significant (with p-values below 0.01) during 2009–2011.

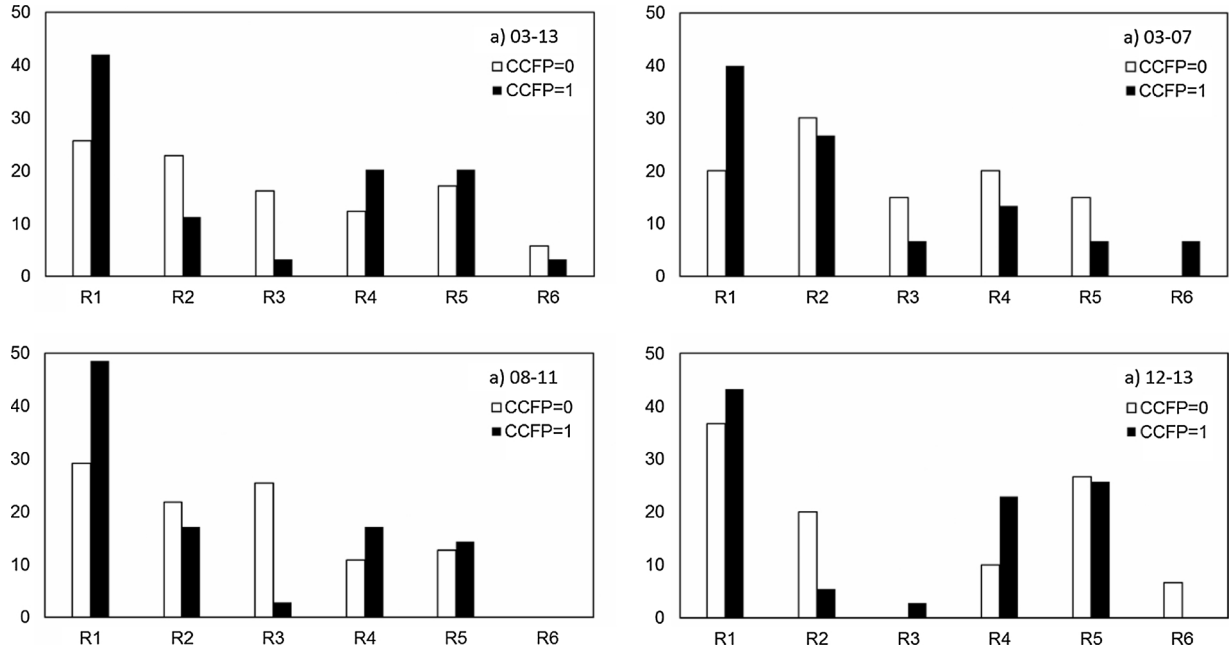

Fig. 3. Reasons of cropland abandonment for CCFP-participating households and non-participants during a) the entire time period (2003–2013), b) 2003–2007, c) 2008–2011, and d) 2012–2013.

Notes: Y-axis represents percentage of each reason of cropland abandonment provided by the respondents. X-axis represents category of the responses: R1, lack of labor due to migration or aging; R2, crop raiding by wildlife; R3, too far away from the house; R4, not worthwhile for cropping due to high opportunity costs of forgoing employment alternatives; R5, lack of reliable water supply for crop growth; R6, frequent natural disasters such as flooding, drought, insects, and disease.

abandonment during the entire time period (2003–2013) and then interpret results for each sub-period. The general patterns of abandonment reasons provided by the respondents were similar for CCFP-participating households and non-participants during 2003–2013, but important differences for some reason categories existed between these two groups of households (Fig. 3a). For cropland parcels abandoned by CCFP participants, lack of labor due to migration or aging (R1) was the most important reason of cropland abandonment, far exceeding all the other reasons; high opportunity costs of forgoing employment alternatives (R4) and lack of reliable water supply (R5) were the second most important reasons; crop raiding by wildlife (R2), long distance to the house (R3) and frequent natural disasters (R6) made the least contribution to cropland abandonment. For CCFP participants, land parcels that were more susceptible to crop raiding, natural disasters, or farther away from the house, might have been enrolled into the CCFP, making these factors less likely to be the reasons of cropland abandonment. For non-participants, the reasons of cropland abandonment were more diverse. Although lack of labor (R1) was also the most important reason, crop raiding (R2), long distance to the house (R3), high opportunity costs (R4) and lack of reliable water supply (R5) all made substantial contribution to cropland abandonment.

We then move on to the reasons of cropland abandonment during each of the three sub-periods, focusing on the reasons with relatively higher percentages. The temporal trends of the abandonment reasons showed different patterns for the two groups of households (Fig. 3b, c, and d). During 2003–2007, lack of labor was the most important reason of cropland abandonment for CCFP participants, followed by the second most important reason, crop raiding, while the other four reasons made minor contribution. For non-participants, crop raiding was the most important factor contributing to cropland abandonment; lack of labor, long distance to the house, high opportunity costs and lack of water all made less but important contribution.

During 2008–2011, lack of labor, crop raiding and long distance became the top reasons of cropland abandonment for non-participants, while high opportunity costs and lack of reliable water supply remained non-insignificant secondary reasons. For CCFP participants, lack of labor continued to be the dominant contributor to cropland abandonment, nearly twice as important as that for non-participants. The greatest difference between the two groups of households is the contribution of long distance to the house, which is nearly as important as lack of labor for non-participants, but trivial for CCFP participants.

During the last sub-period (2012–2013), lack of labor, high opportunity costs and lack of reliable water supply made the dominant contribution to cropland abandonment for CCFP participants, but the other three reasons had little effects. Again, the reasons of cropland abandonment for non-participants remained diverse. Among all the reasons, lack of labor, crop raiding and lack of water were the dominant factors, while high opportunity costs and frequent natural disasters continued to make substantial contribution.

3.3. Statistical modeling of cropland abandonment

At the parcel level, there was a significant difference in biophysical characteristics between abandoned cropland parcels and parcels in use (Table 3). Overall, abandoned parcels had significantly higher elevations, lower TWI values, and longer walking distances to the corresponding houses than parcels in use. In addition, dryland accounted for a significantly lower proportion of abandoned parcels than paddy land. However, the mean area and aspect of abandoned parcels did not significantly differ from those of parcels in use. The nearest distances of abandoned parcels to EWFP and CCFP forests were both shorter than those of parcels in use, although the difference in distance to CCFP forests was not statistically significant.

Statistics of household-level variables are summarized in Table 4. The household heads had a mean age of 52 and education of 7 years in 2013. Most of the household heads were male. The mean elevation of the household locations was 643 m. The mean number of non-migrants (i.e., people who aged 18–60 and lived at home and thus were able to provide farm labor) was 1.8, while the mean area of total croplands was 0.38 ha. About 41 percent of the households experienced crop raiding by wildlife, and 73 percent of the households owned domestic animals. The mean proportion of local off-farm income in total gross income was

Table 3
Statistics of parcel-level variables for abandoned parcels and parcels in use (Obs. = 1202).

Variable	Description	Abandoned parcels		Parcels in use		Difference in means[a]
		Mean	Std. Dev.	Mean	Std. Dev.	
Parcel area	Area of land parcel (ha)	0.10	0.08	0.08	0.09	0.02
Parcel type	0 = paddy land, 1 = dryland	0.32	0.47	0.48	0.50	−0.16***
Walking distance	Walking distance to house (minute)	14.03	12.57	9.81	10.02	4.22***
Parcel elevation	Elevation at parcel location (100 m)	6.57	0.87	6.44	0.98	0.13*
TWI	Topographic Wetness Index	9.01	3.13	10.07	4.12	−1.06***
Parcel aspect	0 = south-facing, 180 = north-facing	79.74	53.85	74.69	52.46	5.05
Distance to EWFP	Euclidean distance to nearest EWFP forest edge (100 m)	0.62	0.56	0.82	0.76	−0.20***
Distance to CCFP	Euclidean distance to nearest CCFP forest edge (100 m)	3.17	2.78	3.50	3.24	−0.33

[a] T-test was used to test the difference in means of the variables.
* $p < 0.05$.
*** $p < 0.001$.

35%. The mean amount of household fuelwood use per year was 8860 kg. The households received a mean of 350 yuan and 170 yuan of cash compensation from the EWFP and the CCFP, respectively, in the past 12 months.

Results from the random-coefficients logistic regression model revealed significant fixed effects of some parcel features and household characteristics on cropland abandonment (Table 5). Parcel area did not have a significant effect on cropland abandonment, while different types of land parcels experienced different abandonment rates. Dryland was 75% less likely to be abandoned than paddy land. Cropland parcels that were located in adverse topographic positions were more likely to be abandoned. For example, for each additional minute of walking distance the likelihood of cropland abandonment increased by 4.5%, while an additional unit of TWI decreased the likelihood of abandonment by 7.7%. However, parcel elevation and aspect did not have significant effects on cropland abandonment. In relation to the PES programs, the distances of land parcels to the nearest EWFP and CCFP forests had significant effects on cropland abandonment. Every additional 100 m distance away from EWFP and CCFP forests decreased the risk of abandonment by 46% and 8.4%, respectively. In other words, parcels that were closer to PES forests were more likely to be abandoned by rural households after controlling the topographic effects.

For the household characteristics, an additional non-migrant aged 18–60 (an indicator of farm labor availability) significantly decreased the probability of cropland abandonment. Meanwhile, owning domestic animals and earning local off-farm income had significant effects on cropland abandonment. Specifically, households who owned animals were less likely to abandon cropland parcels, but households with a greater proportion of local off-farm income in the total gross income were more likely to abandon their croplands. Personal attributes (age, gender and education) of the household head, household elevation, cropland area, crop raiding and fuelwood use did not significantly influence the likelihood of abandoning land parcels by households. For

Table 5
Fixed effects (odds ratios) and random effects estimation of parcel features and household characteristics on cropland abandonment from the logistic regression model.

Variables	Odds ratio	Standard error	95% Confidence Interval	
Parcel level				
Parcel area	0.224	0.328	0.013	3.952
Parcel type	0.251***	0.061	0.156	0.404
Walking distance	1.045***	0.010	1.025	1.066
Parcel elevation	1.328	0.446	0.688	2.564
TWI	0.923**	0.027	0.872	0.977
Parcel aspect	1.003	0.002	0.999	1.007
Distance to EWFP	0.538**	0.104	0.368	0.785
Distance to CCFP	0.916*	0.040	0.841	0.998
Household level				
Age	0.992	0.013	0.966	1.019
Gender	0.973	0.611	0.284	3.335
Education	0.966	0.048	0.877	1.064
Household elevation	0.776	0.264	0.399	1.511
Farm labor	0.757*	0.105	0.577	0.994
Cropland area	1.353	0.949	0.342	5.353
Crop raiding	1.307	0.331	0.796	2.146
Animal	0.507*	0.150	0.284	0.904
Off-farm income share	2.326*	0.844	1.142	4.738
Fuelwood use	1.018	0.022	0.975	1.063
EWFP payment	2.110*	0.702	1.098	4.052
CCFP payment	0.755	0.431	0.247	2.313
Constant	1.286	1.989	0.062	26.67
Constant variance	1.350	0.410	0.745	2.448
Intra-class correlation	0.291	0.063	0.185	0.427
ROC area	0.724	0.018	0.689	0.758
LR test chi^2 value	31.72***			

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 4
Statistics of household-level variables for the households surveyed in 2013 (Obs. = 249).

Variable	Description	Mean	Std. Dev.
Age	Age of household head	52.48	9.62
Gender	Gender of household head (0 = male, 1 = female)	0.05	0.21
Education	Education of household head (year)	6.95	2.71
Household elevation	Elevation of household (100 m)	6.43	0.97
Farm labor	Number of non-migrants (i.e., people who aged 18–60 and lived at home, being able to provide farm labor)	1.79	1.09
Cropland area	Total area of croplands (ha)	0.38	0.18
Crop raiding	Whether experienced crop raiding by wildlife (0 = no, 1 = yes)	0.41	0.49
Animal	Whether owned domestic animals (0 = no, 1 = yes)	0.73	0.45
Off-farm income share	Proportion of local off-farm income in total gross income	0.35	0.37
Fuelwood use	Total amount of fuelwood consumed per year (1000 kg)	8.86	5.90
EWFP payment	Total amount of cash compensation from EWFP in past 12 months (1000 yuan)	0.35	0.41
CCFP payment	Total amount of cash compensation from CCFP in past 12 months (1000 yuan)	0.17	0.24

PES cash compensation, only EWFP payment was significantly correlated with the likelihood of cropland abandonment. An additional 1000 yuan of EWFP payment increased the probability of cropland abandonment by 111%. However, the amount of CCFP payment did not have an effect on cropland abandonment. The likelihood-ratio test ($Chi^2 = 31.72$, $p < 0.001$) shows that the random-coefficients logistic regression model fits significantly better than an ordinary logistic regression model.

4. Discussion

In this study, we explored the relationship between cropland abandonment and China's two PES programs, i.e. EWFP and CCFP, along with other socioeconomic and biophysical factors. Although CCFP cash compensation did not have a significant effect, an increase in the cash compensation of the EWFP significantly increased the likelihood of cropland abandonment. In our study area, households received much more compensation from the EWFP than that from the CCFP. The mean payment per household from the EWFP was twice as much as that from the CCFP for the households surveyed in 2013 (Table 4). In our sample, the largest EWFP area was about 30 ha, corresponding to over 4000 yuan of cash compensation. Such large amount of EWFP subsidy could significantly ease the financial constraints they would otherwise face. Households that receive large EWFP compensation usually live in remote areas with high elevations. Since the "remoteness" confounds the effect of EWFP and CCFP cash compensation *per se*, we controlled this confounding effect by including household elevation in the model. After isolating the socioeconomic effect of the EWFP, there still existed significant positive correlation between EWFP payment and cropland abandonment. A plausible explanation is that EWFP subsidy made these households affordable to abandon some of the labor-demanding croplands.

Regarding the temporal trajectories of cropland abandonment, there was a significant difference of land parcel survival rates between CCFP-participating households and non-participants during 2009–2011, but the survival trend lines of the two groups had converged by 2013. Statistical results suggested that there were little systematic differences in household characteristics between CCFP participants and non-participants (Table 1). Thus the difference of the two trend lines reflects the effects of CCFP participation, intermingled with other factors, on cropland abandonment. During the entire time period, farm labor availability was the top reason of cropland abandonment (Fig. 3). Meanwhile, at the early (2003–2007) and middle (2008–2011) stages of the CCFP, crop raiding by wildlife was another major reason of cropland abandonment. The increase in forest areas via the CCFP and the EWFP resulted in an increased crop raiding by wildlife, reducing crop yields for the remaining land parcels adjacent to forests. This also explains that the proximity of cropland parcels to EWFP and CCFP forest edges (geographic factors of the PES programs) correlated with a high risk of cropland abandonment (Table 5). The CCFP in China is a well-known PES program, where rural households are incentivized to retire their marginal cropland parcels for forest restoration (Bennett, 2008; Song et al., 2014; Wunder et al., 2008). Land parcels that are located on steep slopes and/or in ecologically-sensitive areas have been targeted by the government for reforestation. Having these poorly-accessible parcels enrolled into the program, CCFP-participating households were less likely to abandon their remaining land parcels in the years immediately after the implementation of the CCFP. At the late stage (2012–2013), however, high opportunity costs of foregoing off-farm employment alternatives and lack of reliable water supply were the primary reasons of cropland abandonment for CCFP participants. This indicates the increase of opportunity costs for farming as a result of overall economic development in China. The convergence of the cropland abandonment rates between CCFP participants and non-participants implies the additionality of forest areas gained from the CCFP, i.e., these forests would not exist without the program.

In the long term, the CCFP influenced cropland abandonment through labor availability, as more CCFP participants identified labor unavailability as the primary reason of cropland abandonment than non-participants (Fig. 3a). Meanwhile, our statistical model showed significantly positive correlation between off-farm income share and cropland abandonment (Table 5). Previous studies in other areas found positive impacts of the CCFP on labor shift from on-farm to off-farm work, particularly for young household members (Uchida et al., 2009). As the land enrollment gradually relaxed household labor constraints (Groom and Palmer, 2012), CCFP-participating households were able to allocate their surplus farm labor to off-farm work, inducing further abandonment of the remaining croplands. Our findings also suggested that more CCFP participants thought growing crops was not worthwhile at the late stage (2012–2013) of the CCFP (Fig. 3d). Furthermore, participants enjoyed the ownership of CCFP forests, but also had to fulfill the obligation of properly managing the CCFP land. After enrolling their croplands into the CCFP, participating households were responsible for managing the newly-planted trees to become established forest stands during the initial few years because the local government would withhold the subsidy if the CCFP trees did not survive (Bennett et al., 2014). Thus, these households still needed to allocate some labor to manage CCFP trees at the early stage under the supervision of the local government or, in most cases, the local forestry station and village leaders. When the trees grew up and required fewer management actions, the CCFP could serve as a stimulus that encouraged the surplus labor to take some off-farm work and gradually become more involved, and eventually abandon more croplands. As a result, we observed the spike in cropland abandonment by CCFP-participating households toward the time of the household survey in 2013.

The effects of the PES programs on cropland abandonment were examined together with land parcel biophysical characteristics and household socioeconomic factors. Our results showed the importance of topographic conditions (e.g. TWI) and geographic accessibility (e.g. walking distance to the corresponding house) in cropland abandonment, which is in agreement with the findings in other studies (Lakes et al., 2009; Müller et al., 2009, 2013; Sikor et al., 2009). The TWI, which is often included in land cover transition models (Rutherford et al., 2008), contains the information of both available water and slope. An area with a higher TWI value indicates better water availability with a moderate slope, thus a more suitable environmental condition for growing crops, particularly rice (Li and Barker, 2004). Meanwhile, dryland parcels were less likely to be abandoned than paddy land parcels in the study area. This is because that dryland is less sensitive to water shortage due to climate variation, and dryland crops are more resistant to drought. Regarding the parcel area, abandoned parcels had a larger mean area than parcels in use, which seems counter intuitive. However, the difference was not statistically significant. Nor did we find significant correlation between parcel area and cropland abandonment from the model because nearly all land parcels are small (about 0.086 ha per parcel) in this mountainous region.

The abandonment of cropland parcels was also affected by household socioeconomic characteristics, some of which could be indirectly influenced by the PES programs. We found a negative relationship between the number of non-migrants (aged 18–60) and the likelihood of cropland abandonment, signifying the importance of labor availability on household land-use decision (Walker et al., 2002). Additionally, owning domestic animals significantly decreased the risk of cropland abandonment. This is due to the fact that crops, particularly dryland crops, are needed to feed the animals, as is the common case in Asia (Kim and Dale, 2004). Moreover, households with high proportions of local off-farm income in their total gross income were more likely to abandon croplands. In this region, local off-farm income and remittances from migrants made up the lion's share of total household income (Song et al., 2014). Thus, households who received more income from such lucrative activities tended to involve less in farm work on their croplands. It should be noted that households could also rent

out land parcels to their neighbors as an alternative option when they were engaged in off-farm activities. Households who rented out land parcels received rents, which contributed to total household income.

Our study on cropland abandonment offers useful information in evaluating the cost-effectiveness of the CCFP and the EWFP, which is essential for the design of similar PES programs in the future (Engel et al., 2008; Wunder, 2007). In the CCFP, two interrelated aspects of the cost-effectiveness are payment scheme design and land targeting for the enrollment (Chen et al., 2010; Uchida et al., 2005). The Chinese government adopted a two-tier payment scheme for the CCFP: a higher flat payment rate in the Yangtze River Basin than that in the Yellow River Basin (Song et al., 2014). The flat payment rate schemes are less cost-effective than the discriminative payment schemes based on opportunity costs (Chen et al., 2010; Ferraro, 2008). Despite the difficulty of estimating opportunity costs, enrolled parcels tend to have low costs of forgoing cultivation. These land parcels are likely to possess high risks of being abandoned. Targeting such land parcels with less cash compensation can minimize the costs of the implementation of the CCFP and other similar PES programs. The abandoned lands would ultimately turn into natural landscapes such as grasslands or shrubs/forests given sufficient time, potentially providing ecosystem services even without policy interventions, albeit at a slower rate (Silver et al., 2000). Scholars have recently reported the prevalence of cropland abandonment in mountainous areas in China, calling for the need of further consideration for the expansion of the CCFP (Li et al., 2014). The croplands at higher risks of being abandoned can be enrolled in the CCFP with lower costs, leading to faster forest establishment than natural regeneration. Future research may include a time series of data to better capture how the PES programs, intertwined with other factors, have affected cropland abandonment through time. Understanding the process of cropland abandonment can help policy-makers design similar programs in a more cost-effective manner in the future.

5. Conclusions

The present study aims to investigate the relationship between PES programs and cropland abandonment along with other socioeconomic and biophysical factors in a rural area of China, where two PES programs (i.e. EWFP and CCFP) were implemented. The study found that the EWFP and the CCFP, as well as land biophysical features and household socioeconomic characteristics, played complex roles in cropland abandonment in the study area. The survival rates of cropland parcels were higher for CCFP-participating households than those for non-participants in the years immediately after the land enrollment. However, the temporal trends of cropland survival rates for the two types of households had converged by the time of the household survey in 2013, suggesting the additionality of the forested areas gained by the CCFP. Respondents from non-participants provided more diverse reasons of cropland abandonment than those from CCFP participants. Results from the statistical model suggested that CCFP payment did not have a significant effect on cropland abandonment, but a greater amount of EWFP payment can facilitate cropland abandonment. The large amount of EWFP cash compensation received by the households eliminated the necessity to cultivate labor-demanding and low-yielding croplands in marginal areas. Land biophysical factors that induced cropland abandonment include the proximity of cropland parcels to EWFP and CCFP forests, poor accessibility and adverse topographic conditions. Household socioeconomic drivers on cropland abandonment include poor labor availability and high local off-farm income share in total gross income. Meanwhile, owning domestic animals decreased the probability of cropland abandonment. These findings can be highly valuable for policy-makers designing similar PES programs in the future with regard to the cost-effectiveness of payment scheme design and land targeting.

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