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Assessing divergent consequences of payments for ecosystem services on rural livelihoods: A case-study in China's Loess Hills

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Abstract

Payments for ecosystem services (PES) are often used as a tool for arresting land degradation and desertification. Nevertheless, deeper investigation of farm household systems (FHSs) changes during PES projects is rather limited. It is important to understand how various FHSs evolve with the divergent resource allocation strategies aiming at livelihood security in response to the PES scheme. Taking the Grain for Green Programme (GGP) in China as an example, the intended and unintended consequences of a PES scheme on land management and conservation are analyzed. Using principal component analysis and cluster analysis, FHSs types are identified, whereas composite indices regarding environmental, economic, and food security are created to assess the livelihood security of each type. This is followed by a regression analysis to explore the determinants of the livelihood security, as well as a cost–benefit analysis that investigates the multidimensional costs and benefits of FHSs types. The results show that seven distinct FHSs types evolved under the GGP PES scheme, with significant differences in livelihood security components. The strategy of setting aside the optimal share of land for ecosystem services, such as erosion reduction, and then compensating the economic loss with permanent and market-oriented farming activities (greenhouse horticulture and orchards) can establish a positive link between economic development and environmental protection. Findings indicate that careful consideration of market, institutional, and policy interventions for supporting FHSs reorganization under PES schemes is needed to align the environmental goals with food and economic security goals of farm households, ensuring sustainability of the benefits while limiting the unintended consequences.

KEYWORDS

archetype analysis, cost–benefit analysis, ecosytem services assessment, farm typology, land conservation, livelihood security

1 | INTRODUCTION

The process of dryland degradation, also called desertification, threatens the food security and sustainable livelihoods of around 2 billion people living on approximately 41% of the world's land mass (Dregne, 2002; Middleton, Stringer, Goudie, & Thomas, 2011; Musinguzi et al., 2015). As a consequence of nonsustainable land management, land degradation is increasingly seen as a critical global threat (Song & Liu, 2017) that is exacerbated by steadily increasing throughput demands due to population and economic growth

(Amjath-Babu & Kaechele, 2015). Scholars and policy makers are in search of novel ways to tackle land degradation while meeting the divergent goals of production and conservation in terms of increasing food security, reducing poverty, and sustaining ecosystems. Payments for ecosystem services (PES) is a prominent approach that is touted as a cost-effective means to improve environmental management and livelihoods by rewarding people for their efforts in providing ecosystem services (Abulizi et al., 2016; Kronenberg & Hubacek, 2016). It could help restore degraded lands and facilitate sustainable land management with adequate policy support (Reed et al., 2015). Nevertheless, PES schemes might also introduce unintended side effects, such as reinforcing poverty traps (Boonstra & de Boer, 2014; Kronenberg & Hubacek, 2016) or accelerating land degradation. Hence, it is necessary to assess the multiple values of land uses under PES schemes in pursuit of sustainability. The current study endeavours to understand the intended and unintended implications of PES for the security of rural livelihoods in drylands within the context of a land conservation programme in China.

Although both northern and southern China face severe land degradation (Wang, Lu, Fang, & Shen, 2007; Wang, Yang, & Zhang, 2016), desertification is widespread and severe in northern China (Dai, 2010). In the Loess Plateau of northern China, irrational use of sloping land by local farmers caused widespread land degradation (Zhao, Wu, Gao, & Persaud, 2015). In 1999, the Chinese government initiated the Grain for Green Programme (GGP), also known as the sloping land conversion programme, at the national level in order to both restore natural ecosystems and mitigate negative off-site effects (e.g., drought, flood, dust storm, and sedimentation of reservoirs at off-site locations) of land uses (Gong et al., 2006; Yang et al., 2013). The goal was to convert 14.63 million ha of farmland on slopes of 15°–25° or greater and revegetate 17.33 million ha of sparsely vegetated land by 2010 (Bennett, 2008; Yin & Yin, 2010). Unlike traditional technical approaches to desertification, the programme operates through reward schemes designed to facilitate a sustainable transition in rural livelihoods (Bennett, 2008; Grosjean & Kontoleon, 2009). Grain, planting stock, and cash transfers are provided to farmers as incentives for turning cultivated land back into forest and grassland. Farmers have the option of converting sloping cropland into ‘ecological forest,’ defined as ecological services providing species such as *Robiniapseudoacacia* and *Cunninghamialanceolata*; ‘economic forest,’ that is, orchards of cash crops such as apples, chestnuts, and oranges; or grassland (Kolinjivadi & Sunderland, 2012). As participation in this programme is not completely voluntary (Yin, 2009) in all regions, in this article, we refer to the GGP as a PES-like programme with the spatial segregation of food production and compensated land conservation.

Under the GGP PES programme, cropping, grazing, and timber logging in restored forest as well as on grasslands are prohibited and violators are penalized, usually with a fine; guidelines on rules and criteria for the conversion of croplands are specified in local conditions (Dai, 2010; Lu, van Ittersumb, & Rabbinge, 2004). In return, farmers participating in the programme receive rewards through a two-tier compensation scheme: a grain subsidy of 2,250 $kg{\cdot}ha^{-1}yr^{-1}$ for cropland converted to forests in the Yangtze River Basin and 1,500 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$ in the Yellow River Basin. The duration of compensation would be 8 years if ecologically benign trees (species mainly providing ecological functions and services) are planted; 5 years if commercial trees (species producing timber, fruits, nuts, and other products) are established; and 2 years if grassland is rehabilitated (Yin & Zhao, 2012). It was expected that farmers will be able to adapt into alternate farming systems (e.g., glasshouse horticulture) on the remaining farmland or choose alternate employment possibilities within the duration of the compensation scheme. In addition to the grain compensation, participating households receive a cash subsidy of 300 $RMB^{\cdot ha-1yr-1}$ (1 US$ = 8.2 RMB). In 2004, the grain compensation was replaced with cash compensation by setting the grain price at a constant rate of 1.40 RMB/kg (Yin & Yin, 2010). The switchover was intended to reduce costs of transporting grain to participating households all over the Country (Song et al., 2014) and to address concerns about national food security given the simultaneous decline in farmland (due to urban encroachment and property development) and increase in food demand (State Forestry Administration (SFA), 2009). The revised cash compensation to farmers was then 3,450 and 2,400 $RMB{\cdot}ha^{-1}{\cdot}yr^{-1}$ for Yangtze and Yellow River Basins, respectively. Considering the fact that the initial target for land retirement and farm land conversion was not achieved within the planned duration of the PES programme, with many participating farmers still facing poverty and difficulty in finding alternative employment, the China State Council decided in 2007 to extend the programme until 2020, but at half of the initial compensation rate (China State Council, 2007).

The GGP PES programme is widely recognized as being effective in terms of land conversion, with up to 146,000 km^2 of cropland being returned to forest or grasslands at the national level between 1999 and 2010 (Yin & Yin, 2010). It was gradually implemented in 25 regions and cities involving 3.20 million households and 124 million farmers (Wang, Shen, & Zhang, 2014). Given its large scope and profound impacts, the present study attempts to explore two hypotheses with regard to the impact of the PES scheme on livelihood security. One hypothesis is that divergent farm household systems (FHSs) emerged in China's Loess Hills, with each having a unique scale, intensity and strategy in securing livelihoods in response to the GGP PES intervention. ‘Scale’ relates to resource use (e.g., amounts of land, capital, and labour), whereas ‘intensity’ refers to production per hectare or per animal (Cortez-Arriola et al., 2015; van der Ploeg, 2003). Here, the household livelihood strategy means a plan of alterations and adjustments of FHSs in response to the introduction of the GGP PES scheme (Li, Amjath-Babu, & Zander, 2016). The other hypothesis is that the various FHSs types that evolved out of land conservation efforts, each have a divergent production portfolio and, thus, vary in the level of livelihood security. After initiating the GGP PES programme, the reorganization of household livelihood strategies, given the land set aside for conservation, demanded a reallocation of capital resources, whether human, social, financial, natural, or physical (Cooperative for Assistance and Relief Everywhere, 2002). Collectively, and individually, this could result in differential rates of return to environmental (biophysical) and human (socioeconomic) agents (Turner II et al., 2003). This raises questions about the extent to which these returns can reduce both poverty and combat land degradation (Carter & Olinto, 2003; Ellis, 1998). In addition, there is a need to further understand the role of local conditions in terms of technology, institutions, and markets in coordinating with the PES towards a 'win-win' outcome (Groom, Grosjean, Kontoleon, Swanson, & Zhang, 2010).

Therefore, this study applies multivariate analysis techniques and develops composite indices, with the objectives to (a) generate typology of current FHSs; (b) assess portfolios of production and livelihood security outcomes across various types of FHSs; and (c) explore constraints on and contributors to livelihood security in the context of the GGP programme (PES).

2 | METHODOLOGY

2.1 | Study area

As typical of the Loess Plateau in northern China, Yan'he Township in An'sai County (Figure 1) is experiencing land degradation that is, in turn, linked to poverty and food insecurity among farm households (Lu et al., 2004). It is one of the first areas to begin implementing the GGP PES programme, where rural households are compensated for restoring forest or grass cover on sloping land (slope exceeding 25°), aiming to reduce soil erosion and improve flood protection. In addition to payments for these ecosystem services, intensive farming of the remaining farm land and diversification into nonfarm activities were encouraged in order to enhance rural livelihoods and alleviate poverty. Between 1998 and 2009, 53% of the farmland in An'sai County was converted into forests, whereas agriculture on the remaining land was intensified. An increase in irrigated area (21%), crop rotation (3%), along with the use of fertilizers (2.4%), mulch (4.5%), pesticides (1.7%), diesel fuel (5.7%), and farming machines (51%) are registered in the region (Ansai Statistical Bureau, 1999–2013), despite the land retirement. Manual farm labour decreased by 18%, whereas off-farm labour increased by 174% (Ansai Statistical Bureau, 1999–2013). The obvious impact of the PES scheme on environment, agriculture, and livelihoods makes the Yan'he Township an ideal place for studying the PES-induced FHSs types, their impact on livelihood security, and the conditioning factors.

The survey site, Yan'he Township in An'sai County, is 16 km south of the county seat and 25 km northwest of Yan'an City, with a representative topography of the Loess Hills and a semiarid climate as well as a population density of 73 inhabitants per square kilometre, which is typical for this area (Liu, Xu, & Liu, 2012). It covers 210.7 km^2 (0.1%) of the Loess Hills region, interlaced with hills, ravines, and plains, along with an average gully density of approximately 4.7 km km-2 (Xu, Tang, Zhang, & Yang, 2009). The soils, consisting of 60% to 70% silt, less than 15% clay, and less than 30% sand, have a high $CaCO_3$ content (approximately 9% to 14%) and a pH value above 8.0 (Lu, Van Ittersum, & Rabbinge, 2003). Annual precipitation ranges from 296.6 to 645.0 mm (mean 505.3 mm); annual temperatures vary from −23.6°C to 36.8°C (mean 8.8°C). The rainy season is from July to September, accounting for nearly 74% of the total annual rainfall (Lu et al., 2003; Lu et al., 2004). The average household size is 4.3, with farming being the primary economic activity for 64.4% of the population (Ansai Statistical Bureau, 1999–2013). Rainfed farming is practiced by smallholders (approximately 0.1 ha, which is close to the average area in China; Lichtenberg & Ding, 2009), though rainfall is limited and erratic. The average value of agricultural input is 17,338 RMB/ha, with an irrigated arable area of 15%, which falls below the national average by 7,157 RMB and 23.5%, respectively. The average agricultural productivity of 8,339 RMB per capita is 40% below the national average and mainly comes from cropping (88%) and livestock (7.5%; Ansai Statistical Bureau, 1999–2013; National Bureau of Statistics of China, 2014).

2.2 | Conceptual framework on the formation of FHSs types in response to the PES scheme

The FHSs are embedded in human-environment systems that dynamically interact through feedback loops (Figure 2). The GGP PES programme that aims to balance the environmental and human welfares

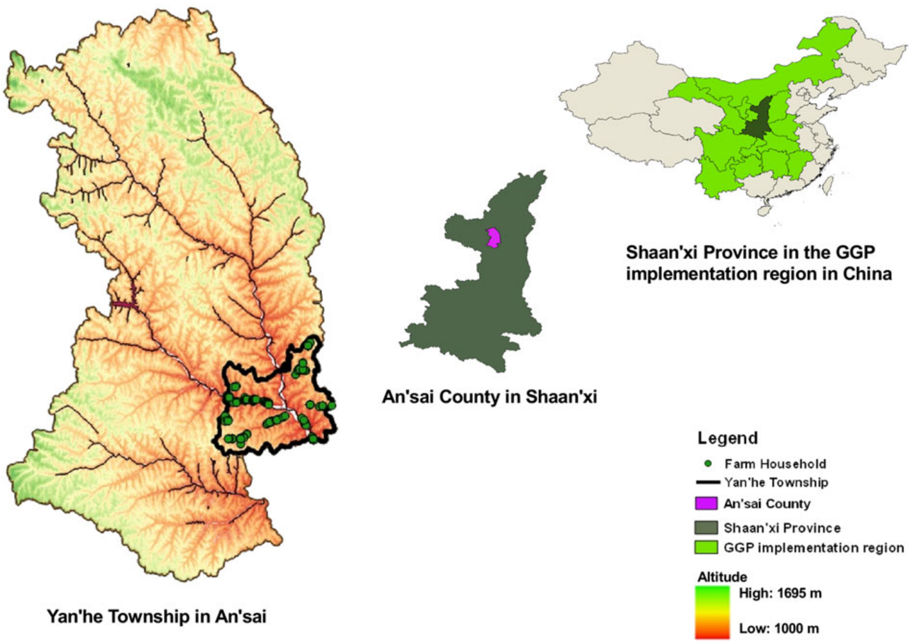

FIGURE 1 Study area of Yan'he Township, in China's Loess Hills region [Colour figure can be viewed at wileyonlinelibrary.com]

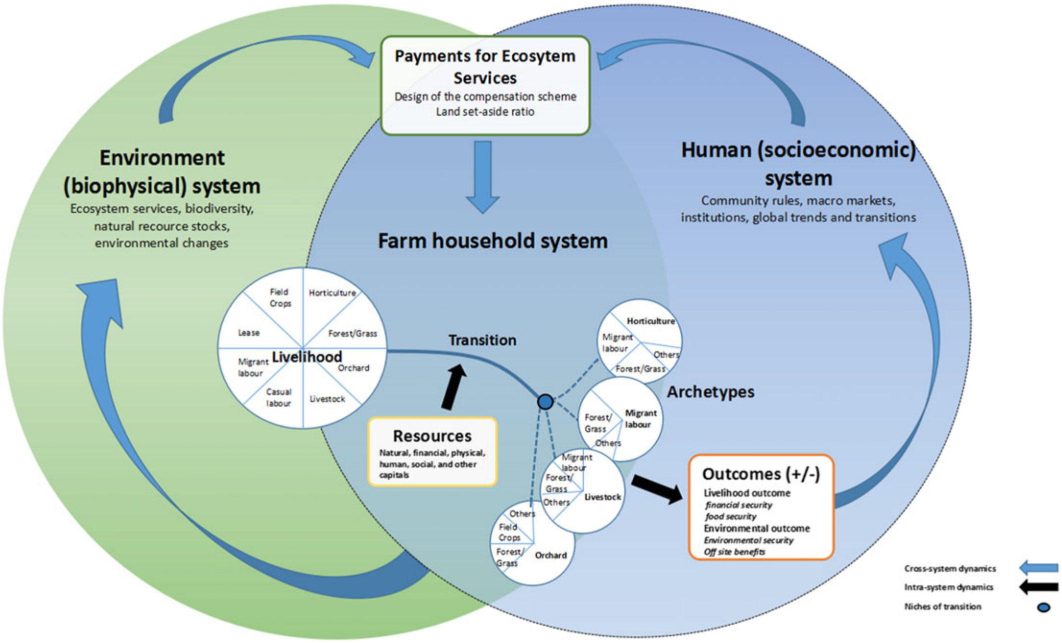

FIGURE 2 Payments for ecosystem services: an instrument to balance the environmental and human welfares of farm household systems [Colour figure can be viewed at wileyonlinelibrary.com]

is seen as a policy shock that altered the transition dynamics of FHSs in the Loess Plateau through its induced change in land use depending on the land set-aside ratio and compensation received (Li, Amjath-Babu, & Zander, 2016). In response to the PES intervention, FHSs attempted to adapt their income generating activities on the remaining farmland (e.g., farming, land lease, and nonfarm diversification) and to build capacities to maintain, if not improve, their standard of living (Ellis, 1998). The transition process to emergent archetypes was conditioned by factors (niches of transition), such as farmland reallocated to forest or grass land, subsidies received to cover for income loss, and farm labour transferred to off-farm jobs. Nevertheless, the alternate livelihood activities chosen by farmers that ultimately defined their FHSs or archetypes are determined by the natural, financial, physical, human, social, and other resources possessed and region-specific market-environment conditions (Alvarez, Paas, Descheemaeker, Tittonell, & Groot, 2014; Li, Amjath-Babu, & Zander, 2016). This scenario led to a wide variety of livelihood strategies, resulting in diverse types of FHSs with different levels of land conservation actions and distinct production portfolios, thus resulting in different levels of financial, food or environmental, and hence livelihood security (Figure 2).

In the literature, the diversity of FHSs is often captured by farm typology (Alvarez et al., 2014; Lopez-Ridaura et al., 2018), whereas the security of household livelihood is assessed by developing composite indices (Booysen, 2002; Lopez-Ridaura et al., 2018). The farm typology approach can help in understanding the farm household diversity and identifying the major FHSs (Haileslassie et al., 2016). The composite indices approach is a useful tool to reveal complex realities, although it is criticized not just for being simplistic but also for lacking transparency and objectivity in selecting indictors and weighting schemes (Conceição & Bandura, 2008; Sumner, 2006). The integration of the farm typology approach and the composite indices approach leads to a type of archetype analysis (Merino, Sietz, Jost, & Berger, 2018) that aids in understanding the dynamics of FHSs in general but fine-grained to account for local particulars (Eisenack, 2012).

2.3 | Sampling and data collection

This study followed a three-stage stratified sampling procedure. The study consists of 16 out of the 28 villages in Yan'he Township (Table 1), covering both V-shaped valley districts and riparian districts. Within each district, villages were chosen according to their different altitudes and market distances. Within each village, households were randomly interviewed, with a confidence interval of 6 at a 95% confidence level. In total, 246 households were randomly selected out of 3,390 households, with household heads personally interviewed in order to collect farm-level data.

The household survey was conducted between February and May 2014 using a semistructured questionnaire to collect demographic information, agronomic practices, agro-ecological and socioeconomic resources, farm and nonfarm activities, financial performance, food availability, environmental conservation levels, and access to local services in 2013. For the sake of data accuracy and coherence, the first author conducted the entire survey with personal interviews. The survey collected detailed information with regard to farming practices, such as open-field cropping (grain and fodder crops cultivated on open fields without greenhouses), horticulture (fruit and vegetables cultivated in greenhouses), orchard growing (cultivation of apple, peach, haw, etc.), and livestock farming (raising swine, sheep, donkey, etc.). Additional farm-level data was generated from analyzing soil maps (Ansai Agro-Tech Extension and Service Station, 2010) by using GIS software as well as recording farms' location by a GPS device.

A comprehensive set of variables (39 in total: see Table A1) was collected. The total active workforce in man-day equivalents and family labour in per-capita equivalents was calculated by applying

TABLE 1 Description of farm household survey sampling

Village	Number (share) of samples	Altitude (mean in metres)	Distance to market (mean in metres)
Highlands of V-shaped valley districts			
Houjiagou	9 (3.7%)	1,111	8,500
Siyaoxian	13 (5.3%)	1,197	12,200
Yanta	7 (2.8%)	1,115	8,300
Yujiahe	14 (5.7%)	1,191	16,600
Zhaiziwan	15 (6.1%)	1,175	13,100
Middle elevations of V-shaped valley districts			
Gaojiamao	25 (10.2%)	1,114	11,700
Yayao	15 (6.1%)	1,137	10,500
Lowlands of V-shaped valley districts			
Zhuanyaogou	11 (4.5%)	1,050	3,100
Fangjiahe	14 (5.7%)	1,068	5,200
Zhifanggou	6 (2.4%)	1,053	9,700
Upstream of riparian districts			
Chafang	20 (8.1%)	1,052	7,200
Yunping	19 (7.7%)	1,039	8,400
Midstream of riparian districts			
Hougoumen	20 (8.1%)	1,031	7,200
Yanjiawan	18 (7.3%)	1,023	4,800
Downstream of riparian districts			
Lijiawan	23 (9.4%)	1,006	1,700
Yangjiagou	17 (6.9%)	1,008	5,700
Total	246	1,079	8,200

conversion factors to male and female household members in different age groups as follows: 1.0 for males aged between 16 and 60 years; 0.75 for females between 16 and 60 years; 0.75 for males above 60 years; 0.5 for females above 60 years. Household members below 16 and above 70 years of age were not considered. The livestock unit was calculated as a reference unit, which facilitates the aggregation of livestock from various species and age as follows: 1.0 for dairy cattle, 0.75 for beef cattle, 0.80 for calves, 0.65 for bulls; 0.8 and 0.5 for donkeys and horses above and below 2 years old, respectively; 0.44 for breeding sows and 0.20 for gilts; 0.10 for sheep and goats; 0.017 for cocks, hens, pullets in lay, and rabbits; and 0.003 for ducks, geese, and other poultry (Nix, 2003). In addition, farm prices for goods and services, which vary across households, were taken into account. Net incomes and net margins were calculated by revenues (i.e., the income from the sale of goods and services) and variable costs such as feeding costs, sanitation costs, costs of machine repair and fuels, cropping costs (e.g., fertilizers, pesticides, seeds, seedlings, plastic mulches, and ploughing), costs of casual labour, transport costs, marketing costs (e.g., brokers), and other costs. Total income represented the sum of all money received by a household, including all forms of earnings (e.g., farming incomes and subsidies, wages, and salaries) received in 2013. The net incomes of orchard and livestock production were converted to annuities by calculating revenues and costs over their whole lifetime. The amount of nitrogen, phosphorus, and potassium was obtained from the percentage of pure elemental N, P, and K by weight in the various chemical and organic fertilizers applied.

2.4 | Statistical analysis

The analysis here aims at defining FHSs types and assessing livelihood security. To do so, first, a principal component analysis (PCA) was performed in order to explore the data structure and select key variables for the cluster analysis; second, a cluster analysis was applied to identify archetypical patterns (or typologies) of FHSs; and third, composite indices were developed to map the identified FHSs of environmental, economic, and food security outcomes. This kind of archetype analysis (Merino et al., 2018) provides a cross comparison of FHSs and a ranking of FHSs types based on livelihood security outcomes, while also facilitating the exploration of how local constraints and enabling conditions shape the livelihood security of identified FHSs.

2.4.1 | Multivariate approaches for identifying FHSs

PCA and K-means cluster analysis (KCA) were performed on the detailed dataset (39 variables) for identifying FHSs (Ibes, 2015; Kuivanen et al., 2016). A data set of 242 valid samples created after checking for missing values, potential errors, and outliers was used for PCA after Kaiser–Meyer–Olkin and Barlett's sphericity tests. The PCA investigated the relationships between these variables and reduced them into a smaller number of independent components, which the KCA then used to create homogeneous groups in the data set. Prior to KCA, Ward's method of cluster analysis was performed on the dataset to identify the number of clusters, which was used as a starting value in the KCA. Ward's method minimizes the variance within clusters and identifies clusters of a relatively equal size (Bidogeza, Berentsen, Graaff, & Oude Lansink, 2009; Kobrich, Rehman, & Khan, 2003). In addition, a one-way analysis of variance test was conducted to depict the difference in variance among clusters.

2.4.2 | Composite indices of environmental, economic, and food security

'Livelihood security' is defined as adequate and sustainable access to income and resources to meet basic needs and is understood in both monetary and nonmonetary terms (Dzanku, 2015; Gautam & Andersen, 2016; Grosse, Harttgen, & Klasen, 2008), given the material circumstances as well as social and environmental contexts (Naraya, Patel, Schafft, Rademacher, & Koch-Schulte, 2000). It determines the level of vulnerability of a household to income, food, health, and nutritional shocks (Chambers, 1989). By applying the composite indices approach, the present study assesses the livelihood security of FHSs in relation to environmental, economic, and food security (Table 2).

(a) Environmental security: The 'area of natural vegetation' was chosen to represent a given household's environmental assets, including forest and grass vegetation. The 'present cost of water used per cultivated hectare' is subtractive, implying the relative amount of water drawn from hydrological systems. 'The quantity of manure applied per cultivated hectare' shows the degree of nutrient recycling and soil nutrient replenishment, as well as crop–livestock interaction (Haileslassie et al., 2016). In addition, the study uses an 'index of crop diversity,' as calculated by Equation (1), to represent each farm's conservation of genetic resources. Here,

TABLE 2 Description of the composite indicators used to analyze environmental, economic, and food security

Security pillars	Indicator	Description	Mean	Std. deviation
Environmental security	Natural vegetation	Area under forest and grass vegetation, in ha	0.915	0.565
	Crop diversity	Crop diversity index, 0 means no diversity (i.e., household grows no crops or only one crop) and 1 represents infinite diversity.	0.438	0.288
	Water use	Expenditure of irrigation paid per cultivated hectare, in RMB/ha (subtractive)	−573.751	927.308
	Application of organic fertilizer	Quantity of dry manure applied per cultivated hectare, in kg ha-1	22,404.730	28,162.590
Economic security	Cash sufficiency	Months per year the household had sufficient cash to meet expenses	10.388	3.242
	Liquidity	Current ratio, higher than 1 means no problem with short-term debt payments	3.512	2.444
	Solvency	Equity-to-asset ratio, higher ratios mean less risk	2.315	2.481
	Income from nonfarm work	Ratio of nonfarm income to total household income, in %	12,502.7	12,048.9
	Income diversity	Income diversity indices: 1–5, 1 means a single income activity	1.944	0.739
	Animal stock	Present value of household's livestock animals, in RMB	3,683.1	12,186.2
Food security	Food purchase	Ratio of food expenditure to total household expenditure, in %	0.178	0.098
	Nutrition	Ratio of household protein consumption to recommended values, in %	1.304	0.363
	Land abandonment	Area of farmland abandoned by the household, ranges from 0 to 1.13, in ha (subtractive)	−0.066	0.167

$$\mathrm{CDI} = 1 - \sum_{j=1}^{n} \left(\frac{a_j}{A}\right)^2, \quad (1)$$

where a_j is the area of the jth crop and A is the total area planted for all crops for a specific household. The index is 0 for a household that shows no crop diversity and 1 represents maximum diversity (Shahidullah, Talukder, Kabir, Kahn, & Elahi, 2006).

(b) Economic security: the 'number of months per year that a given farm household had sufficient cash' for expenses was obtained by performing a cash flow estimate of all cash receipts and cash expenditures that occurred during the survey year (Edwards, 2004). In addition, liquidity and solvency aspects of the farm households with regard to debts were measured by the 'current-account ratio as well as the equity-to-asset ratio' (Plastina, 2015). These were chosen to examine credit access as well as cycles of debt and poverty (Naraya et al., 2000, p. 129). In addition, 'the share of nonfarm income relative to total household income, the present value of animal stock,' and an 'income diversity index' (IDI) are selected to reflect risk management capacity (i.e., income skewing and diversification) and risk-coping capacity (i.e., self-insurance) in the context of land set aside (Dercon, 2009). The nonfarm share indicates alternative sources of livelihood to reorganize farming activities after a possible disturbance (Eakin & Appendini, 2008), whereas the IDI acts as a proxy for the diversity of income sources. The present value of animal stock is considered as self-insurance, meaning that households could protect themselves by selling livestock in event of hardship. The IDI is calculated as

$$IDI = \left[\sum_{k=1}^{n} IP_k^2\right]^{-1}, \quad (2)$$

where IP_k is the proportion of income activity k to total income and n is the number of income activities for a specific household in 2013. The index ranges from a minimum of 1 for a household that derives all its income from a single activity to a maximum of 5 for a household that receives its income across six activities (open-field crops, horticulture, livestock, orchard, casual employment, and contractual employment).

(c) Food security (Gautam & Andersen, 2016; Naraya et al., 2000, p. 29): the 'ratio of food expenditure to total household expenditure' was chosen to depict a household's food consumption and purchasing power. 'Protein intake' indicates nutritional security, which is calculated by comparing all kinds of food consumed with the recommended consumption of protein set at 58 g per person per day (Food and Agriculture Organization of the United Nations, 1972, 2011). The 'area of abandoned farmland' was defined subtractive here to predict the risk to food production.

Using the weighting schemes (Tables A2–A5) created by the PCA (Ibes, 2015; Mutabazi, Amjath-Babu, & Sieber, 2015), the associated indicators are integrated and composite security indices calculated to examine the three aspects of security: environmental, economic, and food.

$$HS_i = \sum_{m}^{n} w\left(V_{im}^{n'}\right), \quad (3)$$

where HS_i is the composite score of security index of the ith household, w is the weight attributed each indicator, and $V_{im}^{n'}$ is the ith household's standardized value ($\frac{V_{im}^{n}-\text{Median}}{\text{Max}-\text{Min}}$) for the *m*th indicator of the *n*th aspect of security.

Next, the composite score of *HS* is transformed into values ranging from 0 to 100 using Equation (4):

$$HS_i^s = \left(\frac{HS_i - HS_{\min}}{HS_{\max} - HS_{\min}}\right) \times 100, \qquad i = 1, 2, 3, \ldots I, \tag{4}$$

where HS_i^s is the standardized value of security index of the *i*th household, with $HS_{\max}$ and $HS_{\min}$ representing the maximum and minimum values of security of the dataset. A value of 0 indicates the lowest level of security, whereas 100 depicts the highest level.

2.4.3 | Determinants of environmental, economic, and food security

Despite having calculated the security indices, it is still interesting to explore their determinants. The hypothesis stated before posits that environmental, economic, and food security is determined by households' major characteristics, access to financial and institutional services, and their strategies to reorganize livelihoods under PES. Therefore, a regression analysis was conducted to determine the linkage of the composite indices of the three security aspects to the selected independent variables representing livelihood strategies, farm characteristics, access to financial and institutional services, and the GGP scheme. The independent variables of livelihood strategies and farm characteristics (Table A6) were derived from the original variables (Table A1) by using the PCA, which identified patterns in the data set and helped to avoid multicollinearity in the regression analysis. Livelihood strategies is defined by the strategy of setting aside land for ecosystem services and then compensating the economic loss by various alternative income-generating activities, such as nonfarm employment, livestock rearing, orchard and horticulture farming, and so on; farm characteristics are defined by the household demographic information, such as 'education and experience level, household size,' and land characteristics such as 'soil pH'; financial and institutional services is defined by 'farmers' access to credit, skill training, and veterinary and agronomic services'; the GGP scheme is defined by the 'ratio of set-aside land to cultivated farmland.' The multiple regression model is

$$HS_s^{'} = \beta_0 + \beta_1(X_s) + \varepsilon, \tag{5}$$

where $HS_s^{'}$ is the estimated value of the three security aspects, ε is the error term, β_0 is the constant coefficient, and β_1 is the coefficient of X_s, which comprises the independent variables as stated above.

2.4.4 | Stakeholder focused cost–benefit analysis

For a comprehensive understanding of the impacts of interventions like the GGP PES scheme, it is necessary to investigate the costs and benefits ascribed to different stakeholders. Cost–benefit analysis (CBA) is a systematic process that calculates and compares the costs and benefits of a decision or intervention accruing to different stakeholder groups: the private sector, the public sector, households, and the environment (Chambwera et al., 2012). The CBA can indicate whether it is advisable to pursue the decision or intervention. In the context of the GGP PES programme in the Loess Hills, farmers are interested in maximizing economic profits, whereas scholars and policy makers are in search of a balanced livelihood security given the environment, economy, and food dimensions. Therefore, the monetary estimates in this study define benefits as 'increases in net margin' (i.e., a farm household's total sales revenue minus variable costs, divided by total sales revenue) and costs as 'reductions in net margin' ascribed to farm households. For government and other public agencies, the benefits are defined as 'increases in the estimated level of livelihood security' (i.e., environmental, economic, and food security) and costs are 'reductions in the level of livelihood security.' The presented CBA is expected to assist stakeholders in making informed decisions about the GGP and similar PES schemes that seek to support sustainable rural development.

3 | RESULTS AND DISCUSSION

Here, we demonstrate a farm-level FHSs analytical methodology using an archetype analysis that brings out FHSs types, a regression analysis on conditioning factors, and a CBA for understanding gains and losses to stakeholders. It provides comprehensive insight into how the PES scheme contributes to the formation of FHSs as well as the varied gains or losses in economic, environmental, and food security based on FHSs type as well as reveals the role of conditioning factors in deciding the final outcome, that is, livelihood security.

3.1 | Household characteristics and livelihood strategies

Eleven components generated by the PCA explain 73% of the variance (Table A6). In the PCA framework, the correlation between a component and its corresponding variables is called a loading, which reveals the shared information (Mutabazi et al., 2015). Thus, the principal components represent the major characteristics of farm households and their livelihood strategies to combine and transform resources. The first component (C1), which explains 15.7% of the variance (Table A7), is correlated with soil organic matter, orchard size, intercropping, altitude, labour input in orchard work, mulch and bags, chemical fertilizers, pesticides, distance to market, and experience in orchard cultivation. Therefore, C1 represents a strategy of 'intensive orchard farming in highland areas.' The second component (C2), explaining 11% of variance, is correlated with the availability of farming labour and the inputs of horticulture labour, irrigation, organic fertilizers, chemical fertilizers, and pesticides, as well as the household head's experience in horticulture. C2 represents a 'horticulture farming' strategy. Next, open-field size, area per plot, and labour input in open-field work are correlated with the third component (C3), which explains 8.6% of the variance and can be regarded as the 'open-field cropping' strategy. The fourth component (C4), explaining 7.7% of variance, is correlated with horticulture size, rented farmland, continuous cropping, and rent. Thus, C4 implies the strategy of 'horticulture on rented land.' The fifth component (C5), which explains 6% of the variance, is correlated with labour input in livestock rearing, the number of animals, and animal feed. Hence, C5 can be defined as the strategy of 'livestock rearing using purchased feed.' The sixth component, C6, explains 5.4% of the variance and is correlated with land area and GGP land, which implies the strategy of 'land set-aside (PES).'

The remaining five components each explain around 4% of the variance with eigenvalues greater than 1 (Table A7). Major defining characteristics of farm households in China's Loess Hills included the education level of the head of household (C7), household size (C8), soil pH (C9), and experience of the head of household in working with livestock (C10). The 11th component (C11) is negatively correlated with casual employment and positively with contractual employment. Therefore, C11 can be considered as the 'nonfarm work' strategy, in which contractual employment and casual employment are alternatives to each other. The PCA results not only bring to light farm households' major characteristics but also their typical livelihood strategies under PES, facilitating the subsequent cluster analysis for identifying FHSs types and an overall livelihood security assessment.

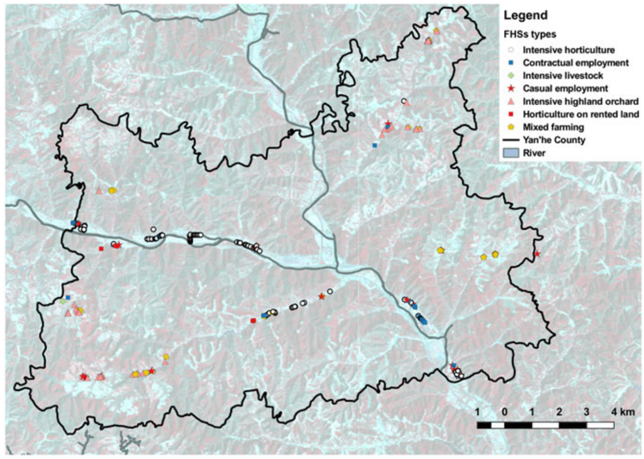

FIGURE 3 Distribution of seven types of farm household systems (FHSs) across the valley and riparian districts [Colour figure can be viewed at wileyonlinelibrary.com]

3.2 | FHSs in China's Loess Hills under PES

3.2.1 | Types of FHSs

Subsequently, a cluster analysis using Ward's method is performed on the PCA components. The agglomeration schedule and dendrogram indicate that seven clusters could be generated by the KCA (Table A6). These clusters form a typology system that includes seven FHSs types across the valley and riparian districts (Table 3 and Figure 3) of China's Loess Hills. These FHSs types are named according to the major livelihood strategy of the FHSs type along with different degrees of land set-aside activity. The FHSs Type 1 named *intensive horticulture* referred to predominantly set-aside land (73% of total area: see Table A8) with intensive horticulture characterized by high inputs in farming labour, irrigation, fertilizers, and pesticides on the rest of the land. Type 2, *contractual employment*, indicated the involvement of contractual nonfarm work with 67% of the land set aside and around 60% of the remaining farmland rented out. FHSs Type 3, *intensive livestock*, represented animal rearing by purchased feed; these households had the largest family workforce and land area, where 54% of land was allocated to GGP and the remaining land was mixed with orchards (18%) and open fields (18%). Type 4, *casual employment*, was characterized by the pervasiveness of nonfarm work without fixed contracts in the off season; similar to the contractual employment system, these households often had relatively young heads (under 45 years old) and small farm size, with 65% of the land set aside and about 20% of their remaining farmland leased out. In terms of FHSs Type 5, *intensive highland orchard*, heads of household were generally poorly educated and lived far from markets, with 58% of their land set aside. Type 6, *horticulture on rented land*, showed a combination of land set aside (53%) with horticulture on the rest of the area and on rented land with highly educated heads of household, large family sizes, and high application of intercropping and continuous cropping practices. The last type was 7, *mixed farming*, which is a combination of land set aside (52%) with open-field cropping (33%), orchard cultivation (13%), and horticulture farming (2%).

A closer look at the typology system reveals the heterogeneity of FHSs in China's Loess Hills. Research (Tsunekawa, Liu, Yamanaka, & Du, 2014) indicates that GGP implementation resulted in large increases in greenhouse horticulture and fruit production; our research confirms this trend, with over 60% of the farm households in the study area (Table 3) mainly earning their livelihoods from horticulture and orchard cultivation in terms of intensive horticulture (38%), intensive highland orchard (20%), and horticulture on rented land (2%). About 25% of the farm households mainly engaged in nonfarm work, that is, contractual employment and casual employment. The rest took up mixed farming (13%) and intensive livestock farming (1%). The paucity of horticulture on rented land and intensive livestock farming can be explained by the prohibition of grazing under the PES programme, that is, the GGP (Lu et al., 2004; Yao, Guo, & Huo, 2010; Yin & Yin, 2010), and the low incidence of land rental transactions in rural China (Kung, 2002; You, 2012). Variability of FHSs also exists in the proportions of farm households in each type across the

TABLE 3 farm household systems (FHSs) types and their distribution across districts

FHSs type	Code	Number (share) of samples	Districts	
			V-shaped valley	Floodplain (riparian)
Intensive horticulture	1	92 (38%)	19 (15.2%)	73 (62.4%)
Contractual employment	2	41 (16.9%)	9 (7.2%)	32 (27.4%)
Intensive livestock	3	3 (1.2%)	3 (2.4%)	—
Casual employment	4	20 (8.3%)	8 (6.4%)	12 (10.3%)
Intensive highland orchard	5	49 (20.2%)	49 (39.2%)	—
Horticulture on rented land	6	5 (2.1%)	5 (4%)	—
Mixed farming	7	32 (13.2%)	32 (25.6%)	—

TABLE 4 Characteristics of productive performance across farm household systems (FHSs) types

Variable	FHSs types							All (N = 242)	
	Intensive horticulture (N = 92)	Contractual employment (N = 41)	Intensive livestock (N = 3)	Casual employment (N = 20)	Intensive highland orchard (N = 49)	Horticulture on rented land (N = 5)	Mixed farming (N = 32)	Mean	Std. deviation
Net margin ($farm^{-1}$ yr^{-1})	0.56	0.69	0.03	0.49	0.12	0.66	0.10	0.42***	0.65
Total income (RMB $hour^{-1}$)	35.7	32.5	10.6	50.7	21.8	59.8	25.1	32.4***	27.5
Net income of open-field cropping (RMB $farm^{-1}$ yr^{-1})	2,064.9	1,628.1	5,316.7	3,602.3	3,343.4	2,336	5,918.7	2,932.4***	5,208.2
Net income of horticulture (RMB $farm^{-1}$ yr^{-1})	24,190.5	2,215.5	0	4,442.7	711.9	59,346.6	13,420.1	13,083.8***	21,260.8
Net income of orchard (RMB $farm^{-1}$ yr^{-1})	187.9	439.5	1,196.0	542.8	2,545.7	261.4	578.7	802.9***	1,398.2
Net income of livestock (RMB $farm^{-1}$ yr^{-1})	937.5	156.4	18,945.2	1,261.9	2,690.7	7,482.4	3,044.6	1,824.1***	6,538.4
Net income of contractual employment (RMB $farm^{-1}$ yr^{-1})	16,475.2	62,818.3	23,666.7	11,068.5	13,059.2	22,800.0	14,471.9	23,143.1***	29,017.7
Net income of casual employment (RMB $farm^{-1}$ yr^{-1})	5,589.8	5,678.0	4,000.0	40,568.0	7,492.9	6,180.0	9,664.4	9,412.1***	17,706.9
Farming costs (RMB $farm^{-1}$ yr^{-1})	10,514.2	744.3	67,883.3	2,611.8	5,627.3	21,856.8	7,491.3	7,762.2***	12,518.6
Costs of nonfarm work (RMB $farm^{-1}$ yr^{-1})	2,066.5	5,696.3	0	35,488.5	1,630.6	8,000.0	3,398.1	5,628.4***	33,494.0
Remaining farmland abandoned (ha)	0.087	0.083	0	0.073	0.027	0.147	0.033	0.066***	0.167
N per sown area (kg ha^{-1})	816.3	281.2	293.6	325.1	374.9	308.4	453.0	530.7***	446.9
P per sown area (kg ha^{-1})	612.0	125.8	155.6	105.7	212.8	220.6	223.9	341.9***	391.1
K per sown area (kg ha^{-1})	510.3	59.0	117.9	86.8	88.2	139.6	93.2	245.7***	409.7

*0.1 level of significance, **0.05 level of significance, ***0.01 level of significance in differences across FHSs types.

landscape districts. In the riparian districts, the majority (62%) took on an 'intensive horticulture' profile, with all others becoming involved in nonfarm work. In contrast, the FHSs in the V-shaped valley districts seem to be more diverse, with 'intensive highland orchard' and 'mixed farming with set-aside land' being the major FHSs types.

3.2.2 | Production outcomes of the FHSs types

Levels of production outcomes show significant differences across FHSs types (Table 4). With the exception of intensive livestock FHSs, all types have good profitability with net marginal values (i.e., the net income as a percentage of the revenue for the 2013 production year) exceeding 0.1. The FHSs types associated with horticulture and nonfarm work (contractual and casual employment) achieved high profitability with a value above 0.5. Similarly, contractual employment, horticulture, and casual employment received higher net income than other activities, with an average value being 23,143, 13,083, and 9,412 RMB per farm per year, respectively. With the exception of intensive livestock FHSs, the total income per working hour of all FHSs types was generally higher than the hourly minimum wages in the study area (11.9–14.8 RMB in Shaanxi Province). We can also see that horticulture on rented land and casual employment had the highest labour productivity, whereas intensive livestock farming had the lowest. The low profitability and productivity of intensive livestock FHSs were probably due to the high costs of feed purchases, given the grazing constraints imposed by the GGP. The average farming costs of intensive livestock FHSs were 67,883 RMB per farm in 2013, which was significantly higher than the others. Although horticulture and nonfarm work were profitable and productive, local farmers may have had difficulties in overcoming entry barriers (McGowan, 2014), including the need for human and/or financial capital for acquiring skills and making production investments (Reardon, Taylor, Stamoulis, Lamjouw, & Balisacan, 2000; Woldenhanna & Oskam, 2001). It is also worth noting that intensive horticulture FHSs had massive inputs of N, P, and K (about 816, 612, and 510 kg ha^{-1}). The excessive N fertilizer applications (>1,000 kg ha^{-1}) with less than 10% of fertilizer N being recovered (similar to the intensive greenhouse vegetable planting systems in China; Chen, Wang, & Wang, 2004; Zhu, Li, Christie, & Li, 2005) would have led to significant onsite and off-site environmental degradation (Liu & Diamond, 2005), thus impacting ecosystem services (Ju et al., 2009; Liu & Diamond, 2005). Hu, Song, Lu, Poschenrieder, and Schmidhalter (2012) also report fertility and salinity problems in greenhouse soils in the North China Plain. Nevertheless, since the GGP was initiated, the control of agricultural nonpoint source pollution is not considered as important as ecological restoration in China (Peng, Cheng, Xu, Yin, & Xu, 2007).

It is obvious that various types of FHSs each require different resources and generate different levels of production outcomes. This scenario calls for further assessment considering environmental, economic, and food security dimensions, as presented in the next section.

3.3 | Multidimensional security assessment across FHSs types

3.3.1 | Environmental, economic, and food security

Farm households were assigned to one of three classes based on the level of their security indices using the normal distribution of a global score (Figure 4). Globally, the majority of farm households (69.8%) were in the 'moderately secure' zone, whereas the rest were distributed equally (around 15%) in the 'less secure' or 'highly secure' classes. For environmental and food security, most FHSs (above 90%) were in the

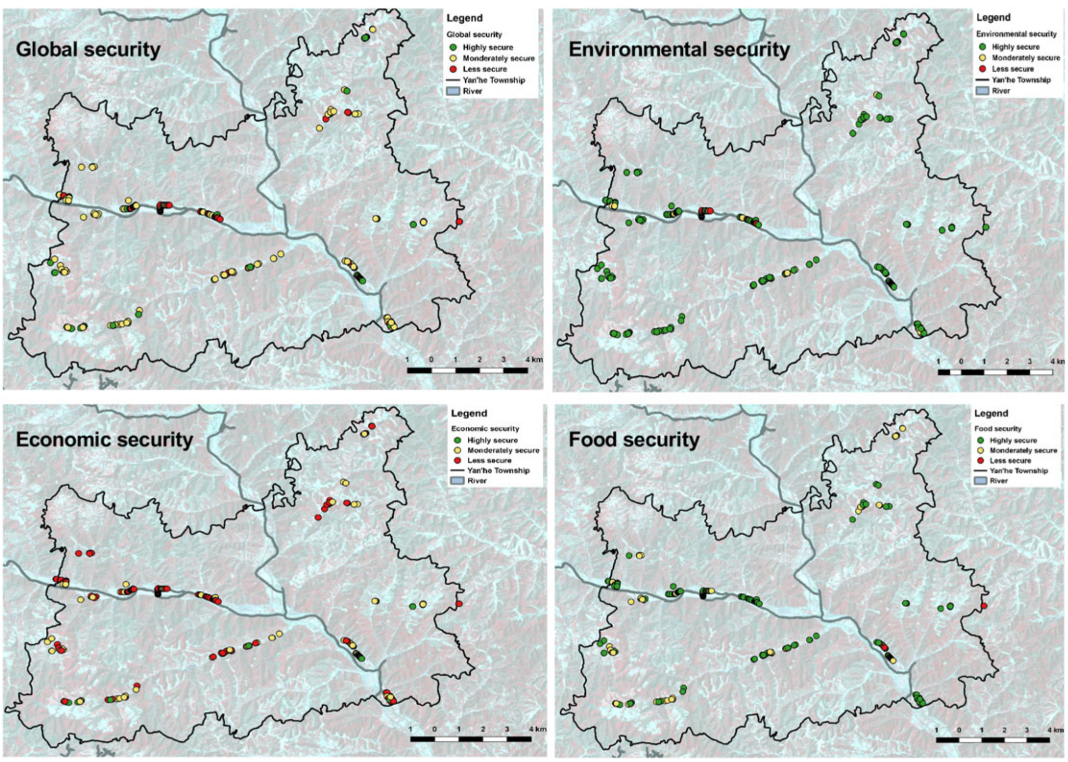

FIGURE 4 Relative security of farm households based on normal distribution percentile [Colour figure can be viewed at wileyonlinelibrary.com]

moderately secure and highly secure classes. Previous studies reported improved food security (Wang et al., 2014) as well as increased proportions of forest and grassland (Cao, Chen, Xu, & Liu, 2007; Liu & Wu, 2010) following the implementation of the GGP. These outcomes are in contrast with the economic security aspect, where most FHSs fell under the 'less secure' (50.4%) or 'moderately secure' (43%) categories. This indicates a need to change the economic incentive structure in the regions where the PES system is active.

There are significant differences in the magnitude of security indices across the seven FHSs types (Table 5). The global (across all types) security index shows that mixed-farming FHSs had the highest score for overall security (55.5), whereas intensive horticulture FHSs had the lowest score (37.1). In terms of security aspects, mixed-farming FHSs had the highest levels of environmental and economic security (88.4 and 43.4); intensive horticulture FHSs had the lowest level of environmental security (59.8) and a low rate of economic security (29.6). As shown in Table 4, mixed-farming FHSs has the lowest labour productivity and profitability, but intensive horticulture FHSs has high rates of these indicators. The lack of correlation among economic security, productivity, and profitability indicates the existence of local constraints in attaining livelihood security. In addition, variation of the three security aspects is apparent. The mean figure for economic security (32.2) was the lowest, whereas indices for environmental security (72.6) and food security (64.6) were twice as high. This is consistent with the findings of previous studies. Liang, Li, Feldman, and Daily (2012) find that the GGP neither targeted asset-poor households nor adjusted economic structures in a way that increased household incomes, though the programme does indeed promote food security and environmental conservation (Liu & Wu, 2010). Zhi and Li (2004) even find that 17% of households had lower incomes after participating in the programme. The GGP relaxed households' liquidity constraints by a fixed government payment that was higher than the net profits gained from cultivating sloping cropland at the beginning of the programme's introduction (Liu & Wu, 2010; Uchida, Rozelle, & Xu, 2009). However, this effect was partly offset by the increasing opportunity costs over time, particularly in terms of food prices, which have increased significantly since the introduction of the programme (Song et al., 2014).

As evident from our survey, villages' land conservation efforts were carefully monitored, and households' activities (e.g., grazing) were strongly restricted. Nevertheless, economic development and environmental protection are not necessarily mutually exclusive (Haileslassie et al., 2016; Institute for Financial Management and Research, 2011). As shown in Table 6, the relation between environmental security and economic security is positive and significant ($p < 0.01$) for all. Although the level of economic security was relatively low, there exists a positive correlation between economic development and environmental protection under this PES programme. This implies that land conservation efforts mixed with more permanent and market-oriented farming activities (greenhouse horticulture and orchards) can establish a symbiotic interaction between the economy and the environment. In addition, there also exists a positive correlation between economic security and food security for all FHSs. Thus, these provide policy makers a feasible mode for a 'win-win' PES intervention that targets rural poverty and environmental degradation in China's Loess Hills.

3.3.2 | Determinants of environmental–economic–food security

Results of regression analysis (Table 7) demonstrate the determinants of environmental, economic, and food security for all FHSs types, providing the implications of local constraints on, and contributors to, the

TABLE 5 Variability of composite security indices across FHSs types

Security	FHSs types							All (*N* = 242)	
	Intensive horticulture (*N* = 92)	Contractual employment (*N* = 41)	Intensive livestock (*N* = 3)	Casual employment (*N* = 20)	Intensive highland orchard (*N* = 49)	Horticulture on rented land (*N* = 5)	Mixed farming (*N* = 32)	Mean	Std. deviation
Global	37.12	44.87	51.47	44.61	48.46	49.73	55.51	44.22***	14.88
Environmental security	59.76	71.24	86.35	74.47	85.19	81.68	88.40	72.64***	16.70
Economic security	29.57	29.56	37.59	28.06	32.91	35.79	43.35	32.17**	16.31
Food security	65.27	65.41	70.33	67.08	61.41	64.90	64.03	64.55*	14.84

Note. Less secure < 30, moderately secure 30 - 60, highly secure > 60.

*0.1 level of significance, **0.05 level of significance, ***0.01 level of significance in differences.

TABLE 6 Correlation between composite security indices across farm household systems (FHSs) types

FHSs types	Environmental vs. economic security	Environmental vs. food security	Food vs. economic security
Intensive horticulture (*N* = 92)	0.233**	−0.126	0.182
Contractual employment (*N* = 41)	−0.054	0.000	0.198
Intensive livestock (*N* = 3)	0.687	0.979	0.822
Casual employment (*N* = 20)	−0.041	−0.311	0.353
Intensive highland orchard (*N* = 49)	0.342**	0.137	0.195
Horticulture on rented land (*N* = 5)	0.632	−0.068	−0.348
Mixed farming (*N* = 32)	−0.091	−0.187	0.328
All (*N* = 242)	0.328***	−0.095	0.189***

*0.1 level of significance, **0.05 level of significance, ***0.01 level of significance.

TABLE 7 Determinants of composite security indices in relation to farm household systems types

Influencing factor	Variable	Mean	Environmental security			Economic security			Food security		
			Coef.	SE	t	Coef.	SE	t	Coef.	SE	t
Livelihood strategies	Intensive highland orchard (C1)	0	9.374	0.814	11.520***	5.524	1.094	5.047***	−0.539	1.096	−0.492
	Intensive horticulture (C2)	0	−3.445	0.742	−4.643***	0.042	0.998	0.043	−1.296	0.999	−1.296
	Open-field cropping (C3)	0	3.712	0.761	4.880***	2.569	1.023	2.511**	−0.169	1.024	−0.165
	Horticulture on rented land (C4)	0	4.552	0.823	5.533***	0.523	1.106	0.472	−2.237	1.108	−2.019**
	Livestock rearing (C5)	0	0.491	0.84	0.585	1.401	1.13	1.24	2.813	1.132	2.486**
	Land set aside, PES, (C6)	0	2.819	0.829	3.399***	−0.046	1.116	−0.042	2.472	1.117	2.213**
	Nonfarm work (C11)	0	1.471	0.689	2.133**	−1.935	0.927	−2.086**	−2.062	0.929	−2.221**
Farm characteristics	Education level of household head (C7)	0	−1.213	0.806	−1.505	−2.654	1.084	−2.448**	0.717	1.085	0.66
	Household size (C8)	0	−0.805	0.724	−1.111	3.997	0.974	4.104***	−0.235	0.975	−0.241
	Soil pH (C9)	0	−2.071	0.682	−3.035***	3.06	0.918	3.335***	1.411	0.919	1.536
	Experience in livestock farming (C10)	0	0.958	0.744	1.287	0.462	1.001	0.462	2.308	1.002	2.302**
Financial and institutional services	Access to credit or not, 1/0	0.248	0.239	0.72	0.333	2.051	0.968	2.118**	1.682	0.969	1.735*
	Access to training or not, 1/0	0.438	0.309	0.845	0.366	2.488	1.137	2.188**	−1.099	1.139	−0.965
	Access to veterinary services or not, 1/0	0.041	−0.875	1.039	−0.843	2.882	1.397	2.062**	−0.725	1.399	−0.518
	Access to agronomic services or not, 1/0	0.310	−0.865	0.763	−1.134	0.999	1.026	0.973	−0.547	1.028	−0.532
GGP scheme	Ratio of GGP land to cultivated farmland	3.396	−7.277	1.877	−3.876***	7.189	2.525	2.847***	5.916	2.528	2.340**
	Squared GGP ratio	35.701	3.048	1.637	1.862	−4.941	2.202	−2.244**	−3.268	2.205	−1.482
	Constant		72.64	0.675	107.677***	32.167	0.907	35.452***	64.554	0.909	71.053***

Note. Observations = 242. Environmental security model; F = 22.709, prob > F = 0.0001, R^2 = 0.633; Economic security model; F = 5.752, prob > F = 0.0001, R^2 = 0.304; Food security model; F = 2.446, prob > F = 0.002, R^2 = 0.157.

*0.1 level of significance. **0.05 level of significance. ***0.01 level of significance.

'win-win' scenario in the Loess Hills. A number of independent variables concerning households' access to financial and institutional services, their major characteristics and livelihood strategies, and the PES scheme show significant influences.

Livelihood strategies of FHSs

All livelihood strategies (Table 7), except intensive horticulture, have a positive effect on households' environmental security under the GGP PES programme. This negative impact of intensive horticulture can be explained by the high levels of fertilizer use in terms of N, P, and K (Table 4) and the increased use of irrigation water. For economic security, land set aside in combination with highland orchards as well as with open-field cropping had significant and positive effects (p < 0.01). This is due to the higher profitability and productivity as well as the low production costs of the associated FHSs types (Table 4). For food security, a mix of set-aside land and livestock rearing as well as the strategy of setting aside a large share of land had positive effects (p < 0.01). In contrast, the strategy of adopting nonfarm work or horticulture on rented land impaired food security (p < 0.05). This is probably because of the zero level of 'remaining farmland abandoned' (Table 4) in the type of intensive livestock as well as the high average in contractual employment, casual employment, and horticulture on rented land. Farmers are prone to take more profitable enterprises (high opportunity costs of cereal production) such as intensive horticulture and nonfarm employment, and the latter is often related to land abandonment, which impacts food production (Baldock, Beaufoy, Brouwer, & Godeschalk, 1996; Gellrich, Baur, & Zimmermann, 2007; Strijker, 2005).

Regarding the strategy of nonfarm employment after land set-asides, there is evidence that self-employment and wage income-earning activities are a driving force for improving household income and reducing poverty in rural China (de Brauw, 2002; Liang et al, 2012). In terms of the study samples, the average age of the head of household is about 48, but the average education level was less than 6 years of schooling and nonfarm experience was only 8 years (Table A8). Around 59% of nonfarm workers had never had any skilled training, whereas up to 82% of them had neither employment contracts nor unemployment insurance. In addition, the high costs of nonfarm work (Table 4) combined with restrictions on credit access (Gale & Park, 2002; Lingohr-Wolf, 2011) and on land rental transactions (Kung, 2002; You, 2012) seemed to increase households' financial risk and shrink their expenditures for food and other consumption bundles (Li, Amjath-Babu, Zander, Liu, & Mueller, 2016).

Farm characteristics and financial and institutional services

When looking at farm characteristics and access to financial and institutional services, most variables had significant effects on economic security (Table 7). Households with higher education levels have often had high opportunity costs associated with agricultural labour (Gellrich et al., 2007; Strijker, 2005), and hence, many take nonfarm employment. Given the local constraints mentioned above, significant reduction in labour availability undermines economic security. This could potentially be offset by labour pooling, developing intensive agriculture, and increased access to credit, skill training, and veterinary services. More labour availability could increase households' income sources and opportunities, and hence, labour pooling could be one possible option. Intensive agriculture may effectively increase food production and farm income but brings with it potential risks of environmental pollution in terms of deteriorated water quality and degraded soil (McGuire, Morton, & Cast, 2013; Peng et al., 2007). For example, overfertilization causing high NO_3^- accumulation probably results in water quality deterioration (see Hu et al., 2012). Farmers' access to credit markets, skill training, and veterinary services can relax local technological and market constraints. For environmental security, alkali soils (pH > 8.5) limited agricultural production and contaminated the environment due to their low infiltration capacity and poor drainage, and they need technical interventions to address this issue. For food security, experience in livestock rearing and credit access facilitated the development of intensive livestock farming and improved food production by reducing farmland abandonment. Improving access to water-saving technologies, adopting management practices that retain soil, nutrients, and moisture, practicing controlled stocking levels and rotational grazing can help farmers to better attain economic security without compromising environmental security (Orchard, Stringer, & Manyatsi, 2017).

For China's Loess Hills and similar dryland areas, a well-designed PES needs associated policy interventions to help farmers break local technological, institutional, and market constraints in pursuing a FHSs reorganization that can balance food, environment, and economic benefits. More training programme and adequate technological assistance are required in order to support participating farmers who are engaging in intensive agriculture. Clear guidelines (or cross compliance requirements) on the use of synthetic fertilizers and strict restrictions on appropriate fertilization rates are necessary to reverse the continual overuse of N fertilizer that has occurred since the 1990s (Ju et al., 2009). Soil rehabilitation practices are also required to resolve salinity and alkali soil problems.

Scheme of the GGP PES programme

In case of the PES scheme, the ratio of set-aside land to cultivated farmland after land set-aside (the GGP ratio shown in Table 7) had significant influences on all three security aspects. Economic security and food security showed an inverted U-shaped relationship to the GGP ratio, but environmental security had a U-shaped relationship. The threshold levels of the ratio for each security aspect were found via the derivative of equations of the estimated relations shown in Table 7. The significant threshold of economic security indicates that the estimated value of economic security would be at its maximum if the ratio remained at 0.63. Although the thresholds of environmental security (1.04) and food security (0.79) were insignificant, it also implies that a ratio below 1 was required. However, the actual average of GGP ratio was above 3, with the average area of set-aside land and cultivated farmland being around 0.90 and 0.40 ha per household, respectively. This emphasizes the need to adjust the share of land set aside in this PES scheme to enhance livelihood security. This may reduce the output from the remaining area required for sustaining the livelihood of farmers and hence may reduce the intensity of farming.

Given the importance of land conservation, it is also important to increase households' cultivated farmland by reducing land abandonment and fragmentation. In every household in the study area, up to 6% of the remaining farmland was abandoned and around 7% was rented out on average. The major reason reported by interviewed farmers was that this land was 'too far from settlement' or 'badly shaped.' The average size of abandoned land was 0.09 ha per plot, which was significantly smaller than the cultivated land (0.24 ha per plot). Fragmentation of landholding leads to a gradual reduction in farm size (Niroula & Thapa, 2005) and difficulties in using machinery and appropriate technologies (Rembold, 2003). Therefore, policy interventions targeting land consolidation and stimulating land rental transactions are necessary for efficient land use and better livelihood security in addition to optimization of area under land set aside, especially in this PES scheme.

3.4 | Costs and benefits of different FHSs types

Under the implementation of the GGP PES scheme, seven FHSs types evolved with significantly different characteristics of productive performance (Table 4) and levels of composite security indices (Table 5). The FHSs types generate different costs and benefits among stakeholders, such as farmers, scholars, and policy makers. By performing a stakeholder-based CBA, the gains and losses from adopting a specific type of FHSs are assessed and compared with the mean value of all samples in this section. It is expected to reveal the trade-offs in stakeholder interests given the FHSs types.

As shown in Table 8, the adoption of intensive livestock farming, intensive highland orchard, or mixed farming generated losses in net margin. In contrast, the adoption of intensive horticulture, contractual and casual employment, or horticulture on rented land created gains in net margin (benefits). These can be explained by the fact that the total income per working hour differs greatly across FHSs types (Table 4). In particular, the adoption of FHSs type of contractual employment had the largest increases in net margin due to its higher income per hour and lowest production (farming and nonfarm) costs. In terms of livelihood security, the adoption of intensive livestock farming or contractual employment reduced the composite index of environmental security, but mixed farming provided the largest increase in environmental security (15.76). The composite index of economic security decreases with the adoption of intensive horticulture or contractual and casual employment, whereas it increases with the adoption of intensive livestock farming, intensive highland orchard, horticulture

TABLE 8 Costs and benefits from adopting different types of farm household systems (FHSs) types

Costs/Benefits	FHSs types						
	Intensive horticulture (*N* = 92)	Contractual employment (*N* = 41)	Intensive livestock (*N* = 3)	Casual employment (*N* = 20)	Intensive highland orchard (*N* = 49)	Horticulture on rented land (*N* = 5)	Mixed farming (*N* = 32)
Net margin	0.14	0.27	−0.39	0.07	−0.30	0.24	−0.32
Environmental security	−12.88	−1.40	13.71	1.83	12.55	9.04	15.76
Economic security	−2.60	−2.61	5.42	−4.11	0.74	3.62	11.18
Food security	0.72	0.86	5.78	2.53	−3.14	0.35	−0.52

on rented land, or mixed farming. All types generated increases in the composite index of food security except the adoption of intensive highland orchard (−3.14) and mixed farming (−0.52). The adoption of intensive livestock farming (5.78) or casual employment (2.53) realized the greatest food security benefits. It shows that the adoption of intensive livestock farming or horticulture on rented land has the most balanced environmental, economic, and food security benefits.

From the farmer's perspective, contractual employment, horticulture on rented land, and intensive horticulture are the most profitable types of FHSs to adopt for their livelihoods; the intensive livestock farming FHSs is the worst choice. Nevertheless, the adoption of livestock integrated farming seems to improve environmental, economic, and food security; thus, its wider adoption is advisable. This implies that different stakeholders (e.g., farmers, scholars and policy makers) who make decisions on, and undertake actions in, the FHSs reorganization under the PES scheme may search for different costs and benefits. Similarly, the adoption of intensive horticulture as well as contractual and casual employment was profitable for farmers, but at a cost of economic and environmental security from the perspective of scholars and policy makers. The resultant costs in economic security are attributed to the associated financial burden by high farming costs in case of intensive horticulture (Table 4), which is conditioned by entry barriers like the needed skill set. In case of contractual and casual employment, the labour market and immigration restrictions (e.g., household registration system) can act as impediments. Controlled grazing instead of a blanket ban on grazing may offer greater benefits in tapping the advantages of intensive livestock-based farming households. These findings indicate the need to involve multiple stakeholders in a participatory assessment of the costs and benefits of PES programme (Hermanns et al., 2017).

4 | CONCLUSIONS

We find that there are seven types of FHSs across the valley and riparian areas of China's Loess Hills under the GGP PES scheme. Each type is unique in terms of livelihood assets and household characteristics, thus also unique in livelihood strategies as well as in levels of production outcomes regarding profitability, productivity, income structure, and production costs. Therefore, this particular PES scheme brought different levels of economic benefits and different consequences for livelihood security across these FHSs with varying land conservation outcomes. The majority of farm households earned livelihoods under the PES scheme by adopting intensive farming (i.e., horticulture and orchard cultivation) and nonfarm employment to utilize the excess labour created by the land-saving action, achieving moderate levels in the composite livelihood security index. The adoption of intensive horticulture cultivation or nonfarm employment helped in generating additional monetary benefits but came at the cost of high initial investments as well as excessive water and fertilizer use, which undermines local ecosystems and economic security. The analysis shows that a PES scheme aiming at integrated land conservation efforts with more permanent and market-oriented farming activities (greenhouse horticulture, orchards, and livestock) can offset such negative repercussions, thus establishing a positive link between economic development and environmental protection. An optimized share of land set aside to farm land can offer better livelihood security outcomes and restricted grazing on conserved lands can offer better economic outcomes for livestock-based FHSs. It also suggests that association of market, institutions, and policy support is required in reorganizing FHSs for realizing sustainable livelihoods and achieving the 'win-win' objectives of rural poverty reduction and environmental conservation. It is expected that future PES systems will consider the fact that careful reorganization of FHSs is a necessary condition for aligning the environmental goals with food and economic security goals of farm households, hence ensuring sustainability of the benefits while limiting the unintended consequences.

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APPENDIX

TABLE A1 Principal component analysis component loadings of agro-ecological and socioeconomic variables

		Component										
Variable	Description	1	2	3	4	5	6	7	8	9	10	11
Soil pH	Soil pH at a depth of 0–20 cm (obtained from the soil map)	−0.20	−0.04	−0.07	0.02	−0.15	0.18	−0.07	−0.09	**−0.75**	−0.22	0.21
Soil organic matter	Soil organic carbon at a depth of 0–20 cm, k/kg (obtained from the soil map)	**0.52**	−0.18	−0.13	0.09	0.07	−0.08	0.39	0.06	0.35	−0.04	0.04
Land area	Total area owned by the household, ha	0.35	0.07	0.31	0.10	0.15	**0.82**	−0.04	−0.03	−0.01	0.07	−0.02
Open-field size	Total area of open field with crops, ha	0.21	−0.11	**0.88**	0.08	0.16	0.08	0.08	−0.07	0.11	0.07	−0.04
Horticulture size	Total area of horticulture with greenhouse, ha	−0.18	0.42	−0.13	**0.79**	−0.04	0.00	−0.02	0.08	−0.02	0.05	−0.01
Orchard size	Total area of orchard, ha	**0.81**	−0.06	0.25	−0.11	0.06	0.14	−0.09	−0.08	0.17	0.06	−0.01
Farmland rented	Total area of land rented, ha	0.07	0.14	0.38	**0.71**	0.02	0.02	−0.14	−0.01	−0.04	−0.12	0.02
Farmland rented out	Total area of land rented out, ha	−0.27	−0.18	−0.28	−0.08	−0.18	0.34	−0.28	−0.09	0.40	0.00	0.25
Area per plot	Area of farmland per plot, ha	0.48	−0.04	**0.72**	0.02	0.02	0.18	0.06	−0.12	0.01	0.03	0.06
GGP land	Total area of land compensated for by the GGP, ha	0.13	0.05	0.06	0.03	0.10	**0.90**	0.05	0.02	−0.14	0.00	−0.04
Intercropping	Total area intercropped, ha	**0.56**	−0.04	0.20	0.07	0.20	−0.03	−0.14	0.00	0.38	0.03	0.03
Continuous cropping	Total area with continuous cropping, ha	−0.15	0.24	0.05	**0.70**	−0.06	0.06	0.13	−0.07	0.05	0.17	0.00
Altitude	Altitude of the household, m	**0.70**	−0.17	0.35	−0.03	0.24	0.14	0.27	−0.13	0.00	0.02	−0.09
Household size	Members living and eating in the household, per capita	−0.15	0.01	−0.06	0.00	−0.01	−0.04	0.00	**0.86**	0.01	0.05	0.06
Farming labour	Total active workforce of the household in farming, man-day	0.27	**0.80**	0.08	0.08	0.21	0.05	0.14	−0.13	−0.02	0.09	−0.01
Casual employment	Total active workforce in casual employment, man-day	−0.04	−0.35	−0.11	−0.07	−0.13	0.05	−0.12	0.21	0.16	0.00	**−0.70**
Contractual employment	Total active workforce in contractual employment, man-day	−0.14	−0.31	−0.17	−0.02	−0.09	0.01	−0.14	0.31	0.03	−0.03	**0.74**
Horticultural labour	Total active workforce (family and hired) in horticulture, man-day	−0.38	**0.80**	−0.23	0.18	−0.10	−0.02	−0.05	−0.03	0.02	−0.05	0.04
Orchard labour	Total active workforce (family and hired) in orchard, man-day	**0.88**	0.02	0.08	−0.16	0.03	0.07	0.03	−0.10	−0.04	0.00	−0.01
Livestock labour	Total active workforce (family and hired) in livestock, man-day	0.11	−0.06	0.29	0.02	**0.71**	0.13	0.21	−0.02	0.05	0.30	−0.01
Open-field labour	Total active workforce (family and hired) in open-field cropping, man-day	0.13	−0.14	**0.88**	0.01	0.18	0.07	0.07	0.00	0.01	0.05	−0.03
GGP labour	Total active workforce of the household in GGP land, man-day	−0.16	0.01	0.41	0.19	0.13	0.19	0.38	−0.23	−0.18	0.31	0.00
Number of animals	Total number of livestock, LU	0.02	0.00	0.20	−0.03	**0.80**	0.09	0.08	0.09	−0.04	0.17	0.04
Rent	Annual outlays for rented land, RMB	0.00	0.13	−0.01	**0.88**	0.02	0.02	−0.12	−0.05	−0.04	−0.04	0.01
Irrigation	Annual outlays for irrigation water, electricity and equipment, RMB	−0.20	**0.66**	−0.14	0.38	−0.06	0.07	−0.19	0.07	0.02	0.00	0.03
Mulch and bag	Annual outlays for plastic sheeting or organic residues covered on field and bag wrapping fruits, RMB	**0.82**	0.18	−0.04	−0.03	−0.05	0.01	−0.09	0.04	0.03	0.13	−0.04
Tillage and ploughing	Annual outlays for ploughing, tillage, and machine harvesting, RMB	0.39	0.27	0.02	0.20	0.17	−0.08	0.11	−0.24	−0.06	−0.30	0.05
Nonfarm cost	Annual outlays for nonfarm work, RMB	0.01	−0.28	−0.22	0.09	−0.03	0.02	−0.28	0.13	−0.35	0.18	−0.18
Animal feed	Annual outlays for animal feed, RMB	0.05	−0.01	−0.02	−0.04	**0.83**	0.02	−0.06	−0.12	0.14	−0.15	−0.01
Organic fertilizer	Annual outlays for manure and other organic fertilizers, RMB	0.08	**0.69**	−0.22	0.35	0.09	0.02	−0.11	0.16	−0.03	0.06	0.11
Chemical fertilizer	Annual outlays for chemical fertilizers, RMB	**0.51**	**0.59**	0.25	0.08	−0.15	0.13	−0.12	−0.01	−0.07	0.10	0.01
Pesticides	Annual outlays for pesticides, RMB	**0.51**	**0.63**	−0.06	0.22	−0.12	0.02	−0.03	0.03	0.03	0.05	−0.10

(Continues)

TABLE A1 (Continued)

Variable	Description	Component										
		1	2	3	4	5	6	7	8	9	10	11
Distance to market	Distance from household location to the closest market, km	**0.67**	−0.12	0.25	0.07	0.11	0.22	0.32	−0.14	−0.13	−0.09	−0.10
Age	Age of household head, years	0.07	0.16	0.18	−0.02	−0.03	0.40	0.32	−0.40	0.14	0.21	0.26
Education	Number of years of household head at school, years	−0.06	0.08	−0.10	0.14	−0.07	−0.02	**−0.72**	−0.02	−0.03	−0.09	0.02
Experience in horticulture	Number of years of experience in horticulture, years	−0.37	**0.68**	−0.03	0.17	−0.12	−0.03	0.02	−0.16	0.05	−0.08	−0.07
Experience in orchard	Number of years of experience in orchard work, years	**0.85**	−0.07	0.09	−0.14	−0.04	0.08	0.07	−0.02	0.01	0.04	0.00
Experience in nonfarm	Number of years of experience in nonfarm work, years	−0.07	−0.15	−0.12	−0.17	−0.14	0.24	0.22	0.45	0.22	−0.49	−0.07
Experience in livestock	Number of years of experience in livestock work, years	0.18	0.06	0.09	0.01	0.16	0.11	0.20	0.04	0.22	**0.73**	−0.03
% of variance[a]		15.73	10.99	8.63	7.73	6.02	5.36	4.14	4.02	3.62	3.51	3.41

Note. Bold values indicate component loading greater than 0.5. Kaiser–Meyer–Olkin measure of sampling adequacy: 0.708. Bartlett's test of sphericity, Chi-square: 6,833.375 ($p < 0.001$).

[a]Please see Table A7 for the eigenvalues of the 11 principal components.

TABLE A2 Principal component analysis component loadings of variables for environmental security

Indicators	Component	
	1	2
Natural vegetation	−0.193	**0.840**
Crop diversity	0.353	**0.687**
Water use	**0.906**	0.003
Application of organic fertilizer	**−0.916**	−0.066
% of variance	45.57	29.53

Note. Bold values indicate component loading greater than 0.5.

TABLE A3 Principal component analysis component loadings of variables for economic security

Indicators	Component	
	1	2
Cash sufficiency	0.390	**−0.608**
Liquidity	**0.972**	−0.075
Solvency	**0.973**	−0.060
Income from nonfarm work	0.461	**−0.532**
Income diversity	0.060	**0.688**
Animal stock	−0.041	**0.667**
% of variance	37.674	26.318

Note. Bold values indicate component loading greater than 0.5.

TABLE A4 Principal component analysis component loadings of variables for food security

Indicators	Component	
	1	2
Food purchase	**0.734**	−0.218
Nutritional	**0.769**	0.190
Land abandonment	−0.010	**0.964**
% of variance	37.674	33.763

Note. Bold values indicate component loading greater than 0.5.

TABLE A5 Principal component analysis component loadings of variables for global security

Security pillars	Indicator	Component 1	2	3	4	5
Environmental security	Natural vegetation	−0.115	−0.044	0.351	0.570	−0.320
	Crop diversity	−0.081	0.219	0.810	0.098	0.037
	Water use	0.012	0.892	0.027	−0.039	0.085
	Application of organic fertilizer	−0.013	−0.909	−0.082	0.063	0.005
Economic security	Cash sufficiency	0.487	−0.119	−0.260	−0.067	−0.443
	Liquidity	0.950	0.046	0.028	0.001	−0.020
	Solvency	0.941	0.119	0.039	−0.013	−0.020
	Income from nonfarm	0.465	0.377	−0.562	0.004	−0.033
	Income diversity	0.002	0.000	0.783	0.027	0.150
	Animal stock	−0.242	0.275	0.191	0.526	0.207
Food security	Food purchase	0.630	−0.167	−0.301	−0.070	0.138
	Nutritional	0.140	−0.230	−0.143	0.767	0.080
	Land abandonment	0.053	0.027	0.099	0.028	0.845
% of variance		21.079	15.400	14.936	9.350	8.564

Note. Bold values indicate component loading greater than 0.5. Kaiser–Meyer–Olkin measure of sampling adequacy: 0.647. Bartlett's test of sphericity, Chi-square: 1,395.278 ($p < 0.001$).

TABLE A6 Results of cluster analysis

PCA components	Intensive horticulture (N = 92)	Contractual employment (N = 41)	Intensive livestock (N = 3)	Casual employment (N = 20)	Intensive highland orchard (N = 49)	Horticulture on rented land (N = 5)	Mixed farming (N = 32)
Intensive highland orchard (C1)	**−0.513**	−0.416	0.264	−0.178	**1.504**	0.286	−0.254
Intensive horticulture (C2)	**0.874**	**−1.078**	−0.121	**−1.155**	−0.098	0.280	−0.292
Open-field cropping (C3)	−0.348	−0.402	**−0.630**	−0.494	−0.017	−0.010	**1.911**
Horticulture on rented land (C4)	−0.088	−0.142	−0.436	−0.015	−0.266	**5.621**	0.015
Livestock rearing (C5)	−0.119	−0.224	**7.299**	−0.221	−0.130	0.168	0.255
Land set aside, PES, (C6)	−0.030	−0.237	0.302	−0.313	0.153	0.322	0.273
Education level of household head (C7)	0.022	−0.383	−0.236	**−0.706**	**0.522**	**−0.508**	0.172
Household size (C8)	0.023	0.243	**−0.519**	0.342	−0.300	0.491	−0.160
Soil pH (C9)	−0.015	0.174	**1.055**	−0.086	−0.134	−0.092	−0.006
Experience in livestock farming (C10)	−0.098	−0.131	**−1.179**	0.096	−0.095	−0.170	**0.674**
Nonfarm work (C11)	−0.063	**1.126**	0.037	**−1.922**	0.035	0.102	−0.133

Note. Bold values indicate a mean component value greater than 0.5.

TABLE A7 Total variance explained

	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.217	21.068	21.068	8.217	21.068	21.068	6.136	15.733	15.733
2	5.647	14.480	35.548	5.647	14.480	35.548	4.287	10.993	26.727
3	3.210	8.230	43.778	3.210	8.230	43.778	3.365	8.627	35.354
4	1.982	5.081	48.859	1.982	5.081	48.859	3.016	7.732	43.086
5	1.830	4.693	53.552	1.830	4.693	53.552	2.346	6.016	49.102
6	1.665	4.270	57.822	1.665	4.270	57.822	2.091	5.361	54.463
7	1.377	3.531	61.354	1.377	3.531	61.354	1.616	4.144	58.608
8	1.263	3.239	64.593	1.263	3.239	64.593	1.566	4.016	62.624
9	1.171	3.003	67.596	1.171	3.003	67.596	1.410	3.615	66.239
10	1.118	2.867	70.463	1.118	2.867	70.463	1.368	3.507	69.746
11	1.049	2.691	73.154	1.049	2.691	73.154	1.329	3.408	73.154

(Continues)

TABLE A7 (Continued)

Component	Initial eigenvalues Total	% of Variance	Cumulative %	Extraction sums of squared loadings Total	% of Variance	Cumulative %	Rotation sums of squared loadings Total	% of Variance	Cumulative %
12	0.931	2.387	75.541						
13	0.894	2.292	77.834						
14	0.814	2.088	79.921						
15	0.764	1.960	81.881						
16	0.676	1.734	83.615						
17	0.638	1.636	85.251						
18	0.594	1.524	86.775						
19	0.539	1.382	88.156						
20	0.467	1.196	89.353						
21	0.455	1.165	90.518						
22	0.430	1.103	91.621						
23	0.397	1.019	92.639						
24	0.363	0.931	93.571						
25	0.325	0.834	94.405						
26	0.299	0.767	95.172						
27	0.252	0.647	95.818						
28	0.236	0.606	96.424						
29	0.225	0.577	97.001						
30	0.211	0.542	97.543						
31	0.199	0.510	98.054						
32	0.177	0.454	98.508						
33	0.135	0.347	98.855						
34	0.121	0.309	99.164						
35	0.115	0.295	99.459						
36	0.092	0.237	99.696						
37	0.075	0.193	99.889						
38	0.033	0.086	99.974						
39	0.010	0.026	100.000						

TABLE A8 Characteristics of farm household systems (FHSs) types (equality of group mean)

Variable	FHSs types: Intensive horticulture (*N* = 92)	Contractual employment (*N* = 41)	Intensive livestock (*N* = 3)	Casual employment (*N* = 20)	Intensive highland orchard (*N* = 49)	Horticulture on rented land (*N* = 5)	Mixed farming (*N* = 32)	All (*N* = 242): Mean	Std. deviation
Soil pH	8.18	8.18	8.14	8.17	8.17	8.18	8.17	8.17**	0.02
Soil organic matter	8.92	8.99	9.20	8.98	9.23	8.96	8.98	9.01***	0.27
Land area	1.22	0.96	2.22	0.99	1.87	2.19	2.01	1.43***	0.76
Open-field size	0.04	0.05	0.38	0.07	0.24	0.27	0.67	0.18***	0.26
Horticulture size	0.17	0.03	0.00	0.03	0.01	0.86	0.04	0.10***	0.15
Orchard size	0.01	0.06	0.40	0.07	0.55	0.07	0.28	0.17***	0.31
Farmland rented	0.04	0.01	0.00	0.03	0.04	0.65	0.13	0.06***	0.15
Farmland rented out	0.07	0.19	0.00	0.08	0.01	0.00	0.01	0.07***	0.13
Area per plot	0.14	0.15	0.29	0.12	0.39	0.25	0.51	0.24***	0.19
GGP land	0.89	0.64	1.19	0.64	1.08	1.15	1.09	0.90***	0.55
Intercropping	0.02	0.05	0.71	0.04	0.40	0.47	0.26	0.15***	0.41
Continuous cropping	0.11	0.02	0.00	0.01	0.01	0.74	0.13	0.08***	0.20
Altitude	1,036.54	1,041.35	1,195.67	1,061.35	1,159.33	1,062.60	1,121.72	1,078.04***	63.81
Household size	3.74	3.98	3.33	3.90	2.94	3.80	3.25	3.56***	1.20
Farming labour	226.86	36.22	285.00	49.25	203.92	222.00	174.69	168.96***	100.33

(Continues)

TABLE A8 (Continued)

Variable	FHSs types: Intensive horticulture (N = 92)	Contractual employment (N = 41)	Intensive livestock (N = 3)	Casual employment (N = 20)	Intensive highland orchard (N = 49)	Horticulture on rented land (N = 5)	Mixed farming (N = 32)	All (N = 242): Mean	Std. deviation
Casual employment	30.31	24.15	15.00	282.75	37.88	13.20	43.27	52.83***	91.94
Contractual employment	140.43	491.65	163.33	77.50	107.76	148.00	79.22	180.46***	224.49
Horticulture labour	223.64	21.59	0.00	14.25	6.73	180.40	24.84	98.23***	119.22
Orchard labour	1.10	4.76	93.33	23.00	154.73	10.00	34.69	40.40***	74.33
Livestock labour	2.72	3.17	156.67	2.00	22.24	16.00	55.94	15.91***	35.84
Open-field labour	5.27	6.83	35.00	10.00	22.59	22.00	61.03	17.52***	23.67
GGP labour	3.96	0.88	6.67	0.00	5.45	10.00	16.47	5.22***	9.13
Number of animals	0.13	0.10	12.95	0.04	0.69	1.04	2.31	0.70***	2.44
Rent	286.02	20.73	0.00	64.50	51.02	5,183.60	168.13	257.24***	858.10
Irrigation	296.95	22.07	0.00	23.00	5.71	727.20	47.19	140.95***	260.40
Mulch and bag	154.07	24.24	33.33	254.40	1,528.80	560.40	132.88	422.82***	907.38
Tillage and plow	218.74	66.83	533.33	89.75	401.84	504.00	155.00	220.78***	280.04
Nonfarm cost	1,986.74	5,971.95	0.00	18,385.50	814.29	8,000.00	229.38	3,647.02***	14,075.68
Animal feed	21.74	29.27	40,000.00	0.00	352.86	0.00	572.19	656.20***	4,782.84
Organic fertilizer	1,687.45	330.24	833.33	129.00	874.45	4,230.00	414.22	1,037.68***	1,175.47
Chemical fertilizer	1,466.60	160.98	516.67	491.70	2,357.29	2,529.60	1,620.69	1,375.74***	1,422.65
Pesticides	599.89	48.49	233.33	213.50	718.37	1,148.00	243.09	458.13***	457.92
Distance to market	6.12	5.55	12.10	7.17	12.64	7.94	10.23	8.08***	4.02
Age	47.85	44.44	50.00	38.85	51.96	48.00	53.34	48.12***	9.32
Education	6.47	6.59	3.00	7.05	4.10	7.80	5.19	5.87***	3.39
Experience in horticulture	8.83	0.12	0.00	0.00	0.29	8.80	2.19	3.90***	5.83
Experience in orchard	0.21	1.66	4.33	2.60	13.35	0.80	4.19	3.90***	6.87
Experience in nonfarm work	8.60	11.02	5.33	9.10	8.92	3.80	5.25	8.53**	7.50
Experience in livestock	2.41	0.63	6.67	1.30	4.49	3.20	7.72	3.21***	6.15

*0.1 level of significance, **0.05 level of significance, ***0.01 level of significance in differences across FHSs types.