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Rural transition in the loess hilly and gully region: From the perspective of "flowing" cropland

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A R T I C L E I N F O

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A B S T R A C T

The loess hilly and gully region of China supports a fragile ecosystem that has been subject to serious water loss and soil erosion in recent decades. In response, ongoing soil and water conservation and ecological restoration efforts have been conducted. A review of the region's development history indicates that the utilization mode of cropland in rural areas played an important role in the course of soil and water conservation and socioeconomic development. As a representative area, this study evaluated the status of the Yangjuangou catchment of Liqu Town, Baota District, Shaanxi Province. The dynamic processes, driving factors, variation characteristics, and intrinsic mechanisms of changes in cropland use since the 1980s were analyzed using remote sensing and participatory interview survey data. The results showed that changes in cropland use in Yangjuangou catchment occurred in four stages, including slope cropland utilization stage (1985–1998), the Grain for Green Project stage (1999–2007), agricultural structure adjustment stage (2008–2012), and cropland abandonment stage (2013–2017). These changes in cropland use were driven by policy, economic, socio-cultural, and environmental factors and showed certain characteristics. Specifically, cropland exhibited a "core-margin" funnel-shaped pattern in vertical space, with its changes tending to "flow" toward the core; its utilization intensity generally increased, and the area of intensive utilization and intensive elements gradually shifted. In recent years, spatial patterns gradually developed a sustainable "ecology-production" spatial pattern and abandoned cropland exhibited "contagion" spatial patterns. Finally, based on the behavior mechanisms of farmers and government, we found that the driving force for changes in cropland has changed over time. Initially, food demand on farmers and the goal of ecological safety promoted by the government were dominant. But more recently, the drivers have changed to development demand on farmers and the equal government objectives of promoting ecological safety, rural development, and food security. This study provides a microcosmic perspective on understanding the process and rules of changes in cropland use in the loess hilly and gully region. It also helps to understand the rural transition, providing a reference for developing rural development strategies and policies in this region.

1. Introduction

The loess hilly and gully region, located at the junction of the northern and northwestern regions of China within a climatic transition zone from semi-humid to semi-arid and arid climate, is characterized by a thick and loose loess layer and concentrated rainfall in summer. It has also been subject to the most serious soil erosion in China and possibly even globally (McVicar et al., 2007; Fu et al., 2011; Liu et al., 2015; Cao et al., 2018a). The main causes of this erosion are the long-term imposed effects of unsustainable land reclamation behavior on the fragile ecosystem, forming a vicious cycle wherein higher land reclamation leads to lower land productivity, and because of the lower land productivity, more land reclamation occurs (Liu et al., 2006). Serious soil erosion in the region results in crossing gullies, broken terrain, and low crop production, restricting regional economic development and household life quality. Concurrently, soil erosion also results in a hanging river at the lower reaches of the Yellow River, which has been referred to as the "scourge" of China. Thus, ecological construction and sustainable development in this region are vital to the safety of life and property in the Huang-Huai-Hai Plain (Shi and Shao, 2000; Wunder, 2001).

In this context, efforts to conserve soil and water in the loess hilly and

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gully region have continued in China. Five project phases have been implemented with different strategies and measures, including slope improvement, the joint governance of gullies and slopes, comprehensive management of small watersheds, the Grain for Green Project, and the Gully Land Consolidation Project (Peng, 2013; Cao et al., 2018a). Particularly, since the Grain for Green Project has been implemented, slope cropland has been gradually declined in use and vegetation coverage has increased considerably. Furthermore, water loss and soil erosion have clearly declined and the annual sediment discharge of the Yellow River has reduced to the level of the traditional agriculture period (Chen et al., 2015). Therefore, the Grain for Green Project is regarded as the largest and most effective ecological construction project in China (Lü et al., 2012; Wang et al., 2015). However, large areas of the vegetation restoration of cropland results in local deficits of food supplies (Chen et al., 2015; Wang et al., 2015; Liu and Li, 2017). In 2010, to increase the amount of cultivated and urban construction land, the Gully Land Consolidation Project took the lead in Yan'an City, Shaanxi Province in the loess hilly and gully region. This effort provided a reference for balancing ecological safety, food security, and urbanization after the Grain for Green Project (Liu et al., 2015; Li et al., 2016b).

While ecological restoration efforts were ongoing in the loess hilly and gully region, the Chinese government also promoted the Reform & Opening-up Policy, joined the World Trade Organization (WTO), and participated in the international division of labor, leading to rapid industrialization and urbanization. These policies profoundly changed vast rural areas and resulted in substantial changes in agricultural structure, employment structure, and agricultural techniques (Liu et al., 2013). The economic significance of agriculture has gradually declined, while migration from rural areas to urban have increased and agricultural mechanization has improved; these changes continuously reshape the social and economic structure in rural areas (Woods, 2009; Long and Liu, 2016). Rural production, living, and ecological spaces also have been restructured (Chen and Zhang, 2008; Long and Tu, 2016). In rural production areas, cropland conversion, grain crops conversion, and extensive cropland utilization co-exist alongside cropland abandonment (Long et al., 2016; Shi et al., 2018). Rural living spaces are characterized by vacant and damaged dwellings found throughout the countryside and scattered rural dwellings (Liu et al., 2010, 2014). Finally, pollution emissions are poorly controlled with little management, resulting in polluted rural ecological space. In recent years, the number of migrant workers in the loess hilly and gully region has increased (Cao et al., 2018b), and ungraded cropland with poor production conditions and low yields have been gradually phased out of production.

By evaluating the historical development of the loess plateau, it is clear that cropland use in rural areas plays an important role in the course of soil and water conservation and socioeconomic development. Cropland use in this region has shifted from land reclamation, terrace construction and conversion to forests and grassland, to dam construction and ultimately cropland abandonment. Throughout these changes, reasonable cropland use promoted economic safety and sustainable development in this region. Moreover, land use by human activities always occurred within the framework of natural, economic, and social systems (Li, 2002). Focusing on cropland to investigate the transition process and mechanisms driving the nature-society-economy system in this region will help us better understand the course and characteristics of development, and reveal how human activity adapts to and modifies nature in the rural area of this region. Analyzing cropland changes can also help us understand the influence of industrialization and urbanization on rural development.

Scholars have used Landsat data to interpret land use and analyze the process of land use change in the loess plateau. Due to the Grain for Green Project, cropland area significantly declined and forest and grassland areas rapidly increased (Lü et al., 2012). The statistical analysis combined with DEM data has shown that the reduction in cropland occurred mostly in the regions with relatively high elevations and slopes during 1986–2010. Specifically, relevant land use change generally occurred between 800 and 1600 m, where cropland and unused land decreased and forest land increased; the area of cropland also primarily decreased in areas where the slope was greater than 15° and forest and construction land increased at all gradients (Zhang et al., 2012; Li et al., 2016a).

Gully density in the loess plateau peaks in the area of Suide-Mizhi of northern Shaanxi Province and gradually declines from north to south. The value of gully density ranges from 1.7 to 6.4 km/km^2 (Tian et al., 2013). The resolution of Landsat and DEM data used in recent studies is typically approximately 30 m × 30 m, which is insufficient to reveal changes in cropland use because there are numerous gullies in the loess hilly and gully region. Moreover, in previous studies, land use change was typically evaluated in five-year increments, and the continuity of research was relatively weak. Although the density of gullies in the loess hilly and gully region is high, the changes in cropland use in small catchments are similar to some extent. Therefore, a comprehensive assessment combining high-resolution remote sensing and farmer interview survey data can be used to develop a general framework for the course and characteristics governing changes in cropland use in a small catchment. The assessment will also establish a foundation for understanding changes in cropland use, increasing the sustainable use of cropland, and revealing the course of rural transition in the loess hilly and gully region.

In this study, we analyzed remote sensing images and participatory interview survey materials from the Yangjuangou catchment of Liqu Town in Baota District, Shaanxi Province to reveal trends in cropland use in the catchment since the 1980s. Based on our analysis, we then summarized the characteristic changes in cropland use and revealed the socioeconomic driving mechanism of these changes, finally presenting rural transition in the loess hilly and gully region. In particular, this study provides a clear understanding of the vertical variation in cropland use in this region.

2. Methodology

2.1. Research area

The Yangjuangou catchment is located in Liqu Town in northwestern Yan'an City, Shaanxi Province. It is a typical loess hilly and gully region of 3.11 km^2 (Fig. 1), which runs from north to south. It divides into two branches at the end of the catchment, with the western one bigger than the eastern. The two sides of the catchment are characterized by gentle slopes and have an elevation between 982 and 1250 m. Land use is dominated by woodland (264.34 hm^2 or 84.91%), followed by 32.47 hm^2 of cropland (10.43%) (Table 1). The area is characterized by a semi-arid continental monsoon climate, with annual sunshine of 2563 h. The relative humidity is 56%, and there are 195 frost-free days. The multi-year average rainfall is approximately 550 mm; rain and heat occur within the same seasons, and precipitation is concentrated in July–September (Liu et al., 2017). The Yangjuangou catchment includes the entire Yangjuangou Village of Liqu Town and part of Nianzhuang Village. The registered population was 186 in 2017, with 40 permanent residents. The Yangjuangou catchment is representative of the small catchments widely distributed in the loess hilly and gully region.

2.2. Data and methods

This study used cropland use data in the Yangjuangou catchment since the 1980s, major cropland use events, and cropland use behavior of farmers. The authors conducted a land survey in the catchment October 25–31, 2017.

High-resolution remote sensing images (Google remote sensing images) and historical aerial photos (aerial photos in the 1980s) were combined with participatory interview surveys to identify changes and current characteristics of cropland. We consulted 2–3 villagers who were relatively familiar with the cropland use and its changes in the village

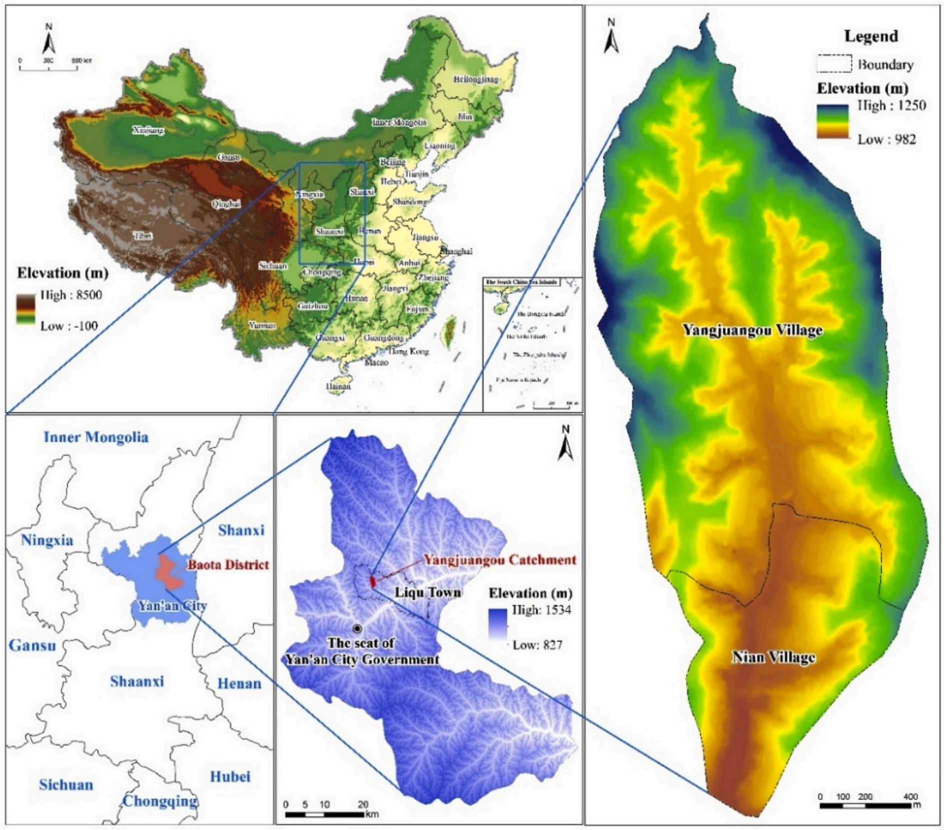

Fig. 1. Location of the Yangjuangou catchment in Yan'an City, Shaanxi Province, China.

Table 1
Structure of land use types in the Yangjuangou catchment in 2017.

First-level land type	Second-level land type	Area	Proportion	First-level land type	Second-level land type	Area	Proportion
Cropland	Dam	8.27	2.66	Industrial and storage land	Mining lease	2.04	0.66
	Terrace	24.20	7.77	Housing land	Rural housing land	1.56	0.50
Garden plot	Orchard	3.13	1.01	Transportation land	Country road	1.01	0.32
Woodland	Forest	224.63	72.16	Water & water conservancy facilities land	Pond	0.34	0.11
	Bush	39.71	12.75	Others	Facility agriculture	0.52	0.17
Grassland	Wild	5.32	1.71		Bare	0.57	0.18

and focused on understanding the type, border, time nodes, and reason for changes in cropland use. The abandoned cropland was surveyed and residents were interviewed to identify when fields were abandoned, ownership information, the family information of the owner, and employment information relative to the abandoned cropland. An interview survey of permanent farmers was conducted to acquire basic demographic information, the types, location & timing changes of employment, and the types, distribution & changes of cropland. Finally, a database of family demographics for the entire village was established, including population, age, types of employment, working time, and income. During the analysis, information was confirmed with village cadres and villagers of the catchment numerous times via telephone to ensure that the acquired data were accurate and reliable.

3. Results

3.1. Changes in cropland use

Village cadres and local villagers helped us understand the changes in cropland use and the dynamic rural development process in the Yangjuangou catchment since the 1980s. We divided the changes in cropland use into four stages based on measures and characteristics of cropland use (Fig. 2).

(1) Slope cropland utilization stage (1985–1998). In this stage, cropland was mainly located on slopes, mountaintops, and hilltops. Although the crop yield of the dam cropland was relatively high compared to the slope cropland, the dam cropland was unstable because it was often subject to floods due to low vegetation coverage and serious soil erosion on mountaintops and slopes. The main mode of soil and water conservation in the loess plateau at this stage was comprehensive management of small watersheds, which emphasized combining engineering, cultivation, and biological measures (Peng, 2013). To respond to the national call for soil and water conservation, tree planting and afforestation of 17.67 hm^2 of slope cropland relatively far from the villages occurred in the catchment in 1987. The cropland per capita in the Yangjuangou catchment was relative high, and planting trees and afforestation was relatively smooth. In 1996, to improve grain yield, the villagers conducted a land consolidation project with government support to change the slope cropland to terrace through volunteer work. A total of 10.67 hm^2 of narrow terrace cropland was constructed.

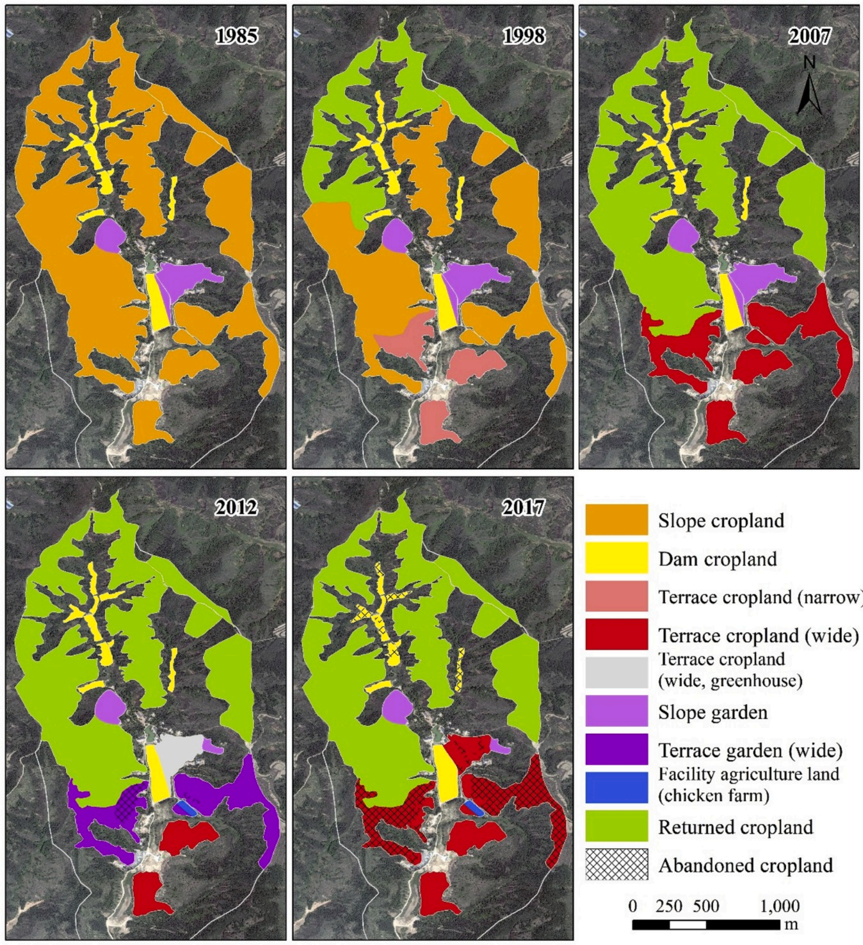

Fig. 2. Patterns of cropland use in the Yangjuangou catchment 1985–2017
Note: Background images are remote sensing images from 2017.

(2) The Grain for Green Project stage (1999–2007). In 1999, Shaanxi Province took the lead as a pilot site to implement the Grain for Green Project. The project was characterized as a mechanism for relieving farmers and returning cropland. The Yangjuangou catchment actively implemented this policy, converting 4.66 hm^2 of slope cropland in 1999 and 28.93 hm^2 in 2002. Concurrently, the government actively promoted cropland construction for growing grain rations and implemented a changing slope to terrace land consolidation project by providing villagers with discounted interest loans, which broadened the previous narrow terrace cropland and converted additional slope cropland. The total area affected was 22.54 hm^2. The construction of wide terrace cropland benefited from machinery promoted as part of the regulation project.

(3) Agricultural structure adjustment stage (2008–2012). In 2008, the government supported the catchment in planting 13.86 hm^2 of fruit trees and constructing 2 hm^2 of arches to develop the vegetable planting industry after land consolidation on a previous orchard, relatively close to the settlement. In 2010, through comprehensive use of government subsidies and self-raised funds, the villagers constructed a chicken farm on terrace cropland and developed the breeding industry (covering an area of 0.33 hm^2), more distant from the settlement. Generally, with the support and guidance of government policies, villagers actively adjusted their agricultural structure and increased forestry and livestock breeding to increase their income. However, the planting and management of fruit trees did not receive adequate attention, achieving rare economic returns. Additionally, farmers gradually shifted from fruit trees to cropland. At this stage, a small number of farmers migrated out to obtain jobs and began to abandon their cropland. The abandoned cropland was mostly terrace cropland relatively far from the village and a small portion of terrace cropland with high productivity. The abandoned area totaled 1.02 hm^2, 4.21% of the terrace cropland and 3.14% of the total cropland.

(4) Cropland abandonment stage (2013–2017). In July of 2013, Yan'an suffered heavy rainfall, which exceeded the 100-year event. Some arches in the catchment were drenched by rainwater, and some farmers transformed the arches to cropland. In 2014, the government supported a comprehensive improvement of the largest group of dam cropland and upgraded their spillway canals and irrigation systems. At this stage, the number of migrant workers increased, and permanent residents were less than a quarter of the registered population in 2017. Nearly half (43.36%) of the cropland had been abandoned. The abandoned area of terrace cropland and dam cropland was 11.37 hm^2, 32.77% of total terrace cropland, and 2.71 hm^2, 46.98% of total dam cropland, respectively.

Throughout these cropland use changes, the ability of cropland to conserve soil and water generally increased continuously. Based on their ability to conserve soil and water, the 11 land types were ranked as follows: returned cropland, abandoned cropland, dam cropland, wild grassland, facility agricultural land (chicken farm), terrace garden (wide), terrace cropland (wide, greenhouse), terrace cropland (wide), terrace cropland (narrow), slope garden, and slope cropland. The transition matrix of cropland use indicated that in the first three stages since 1985, the capacity for soil and water conservation continuously increased, and, in the fourth stage, the capacity slightly declined (Fig. 3). In addition, between 1985 and 2017, the registered population of the Yangjuangou catchment increased, the number of migrant workers rapidly increased, and the number of permanent residents and grain yields steadily declined (Fig. 4).

3.2. Factors influencing changes in cropland use

In different stages, the factors affected changes in cropland use in Yangjuangou catchment varied. These generally included policy, economic, socio-cultural, and natural factors.

(1) **Policy factors.** Soil and water conservation and land administration policies affected changes in cropland use throughout the catchment. Severe water loss and soil erosion in the loess hilly and gully region has always garnered the country's attention, and policy factors played an important role in changes in cropland use. In the four stages above, significant changes in cropland use resulted from planting trees and afforestation, the Grain for Green Project, the changing slope to terrace land consolidation, agricultural structure adjustment, and gully land consolidation, which were driven by top-down policies. In addition, land sharing under the land contractual operation system resulted in cropland fragmentation, which subsequently affected productivity improvements by farmers and cropland abandonment (Jin and Deininger, 2009; Zhang and Yang, 2012). The land survey data reflected this fragmentation of the abandoned cropland in the Yangjuangou catchment. The average area of abandoned plots in the dam cropland was 0.99 mu (1 hm^2 = 15 mu), while the average area of normally cultivating plots was 1.24 mu; the average area of abandoned plots in the terrace cropland was 1.68 mu, while the average area of normally cultivating plots was 3.24 mu.

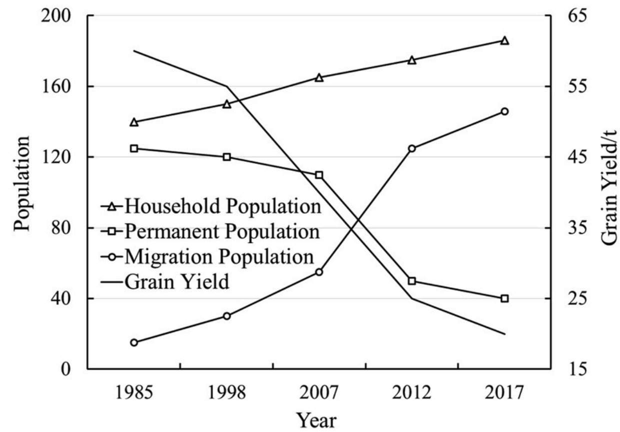

Fig. 4. Changes in population and grain yields in the Yangjuangou catchment. Note: Data are based on the responses from village cadres and villagers, and were verified via phone conversations with all respondents.

(2) **Economic factors.** As the national market economy improved, the effect of economic factors on cropland use in the catchment became clearer. To improve grain yields, the villagers in the catchment spontaneously organized to implement the changing slope to terrace land consolidation in 1996 and they actively participated in agricultural structure adjustment to improve land outputs in 2008. Based on responses from village cadres and villagers, we were able to determine how investments and yields for different cropland types and planting crops were related. Increases in production benefit correlated with transformations in cropland type from slope cropland to dam cropland, as well as the transformation of planted crops from grains and tubers to vegetables (Table 2).

In recent years, the advance of regional industrialization has created a large number of non-agricultural jobs, and labor income

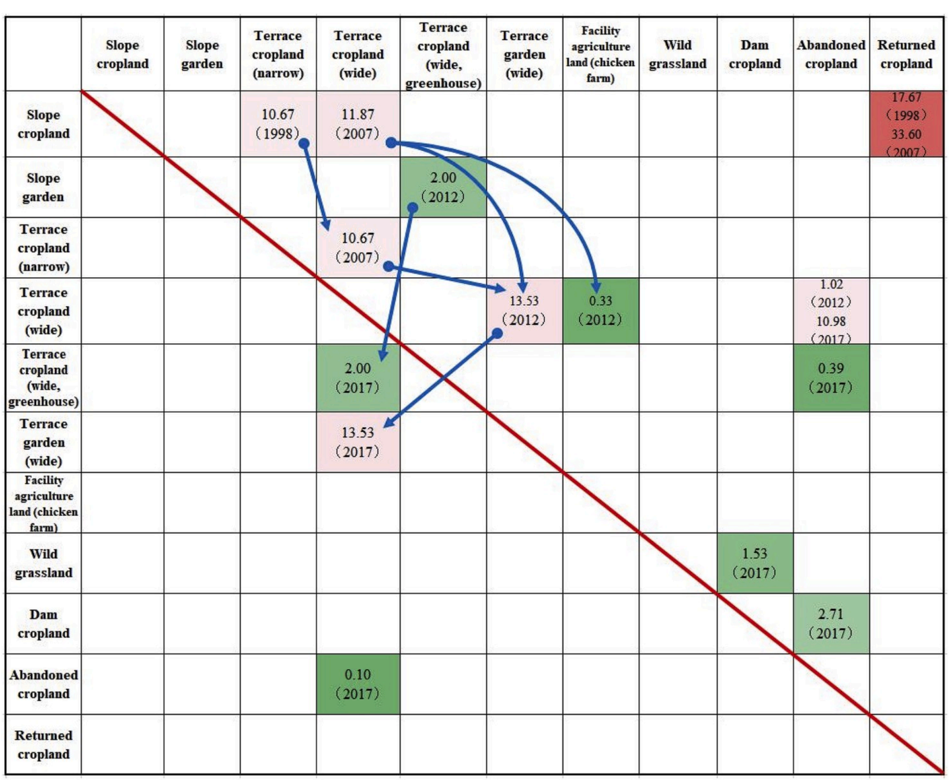

Fig. 3. Transposed matrix of cropland use changes in the Yangjuangou catchment 1985–2017
Note: Cropland use types are ranked according to their capacity for soil and water conservation. Slope cropland had the least capacity to support soil and water conservation, while forest (returned cropland) had the greatest capacity. The upper right corner of the red line represents increases in soil and water conservation capacity and vice versa. The blue line represents multiple changes in the same plot. When the arrow of the blue line points right, it indicates that the soil and water conservation capacities slightly increase and vice versa. The color within the square grid represents the area of land use change. "Red" square grids indicate a relatively large area, and "green" square grids indicate a relatively small area (unit: hm^2). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Input-output of cropland production in the Yangjuangou catchment.

Unit: 1 mu = 1/15 hm^2			Slope cropland			Dam/Terrace cropland			
			Millet	Soybean	Glutinous millet	Maize	Potato	Millet	Greenhouse vegetable
Input	Seed	Weight/kg	1	3	1	2	50	1.5	–
		Cost/RMB	–	–	–	50	–	–	200
	Fertilizer	Weight/kg	25	25	25	60	60	60	–
		Cost/RMB	30	30	30	80	80	80	800
	Insecticide/RMB		–	–	–	–	–	–	350
	Labor/day		4	4	4	6	8	12	180
	Machinery services/RMB		–	–	–	70	70	70	–
Output	Yield/kg		100	50	100	500	1200	400	Tomato: 3000 String bean: 350 Pepper: 300
	Gross income/RMB		150	150	150	850	1000	1100	7500

Note: Data were organized according to interviews with village cadres and villagers.

associated with agricultural production has continuously declined compared to non-agricultural employment. The opportunity cost of engaging in agricultural production increased, bringing about a significant change in the livelihood strategy of farmers from the past dependence on traditional agriculture to non-agricultural employment. Driven by economic factors, an increasing number of young and middle-aged labors have sought employment away from the village. At present, only 40 people permanently live in the village. The survey interview data indicate that migrant workers were young, primarily aged 26–35, while the permanent resident population was older, primarily aged 46–55. Specifically, of the rural migrant population, the proportion of male migrant workers aged below 35 was slightly higher than that of females in the same age range, while the proportions of male and female migrant workers above 36 were not significantly different. The number of migrant workers aged below 55 greatly exceeded that of permanent residents, and the number of migrant workers older than 56 was comparable to or slightly less than that of permanent residents (Fig. 5).

Along with the shift in population, cropland use had transformed from labor-intensive vegetable arches to laborsaving maize planting, and the amount of abandoned cropland had increased. According to our interview surveys, the annual net income of migrant workers was approximately RMB 30,000 yuan, which was significantly higher than that of the permanent population (approximately RMB 18,000 yuan). The yield from cropland did not generally offset this gap (Table 2). Therefore, migrant worker family members tended to plant laborsaving crops, transferred cropland to others to plant, or even abandoned their cropland to make money as migrant workers without having to support their own crop production.

(3) **Socio-cultural factors.** The socio-cultural factors affecting changes in cropland use generally related to decisions made by villagers. First, in 2008, fruit trees planted in large areas did not receive adequate care from the villagers, so the fruit trees never produced economic benefits. At present, the fruit trees have either been abandoned or removed to plant other crops. In the adjacent catchments, where fruit trees were planted in the same period, income from fruit trees has become the primary source of household income for villagers. Second, the group psychology of the villagers in the study area may have been a factor in the lack of sustained investment in the construction of arches after the strong precipitation in 2013, and the arches were gradually transformed into cropland or abandoned. However, according to the interview surveys, most farmers believed they would get rich using arches. Third, the villagers selected the type of employment according to their own age and capability, which affected the type and intensity of cropland use. Finally, the deep feelings to cropland (i.e. land complex) expressed by migrant workers illustrated why farmers would rather abandon their cropland than transfer it (Cao et al., 2008), which to some extent resulted in additional abandoned areas.

(4) **Natural factors.** Topographic features and soil characteristics of the catchment drive the inherent features of slope cropland, such as low yield, severe soil erosion, and high ecological damage. Because of these slope cropland features over large areas, the government promoted many projects such as tree plantings and afforestation, the Grain for Green Project, and changing slope to terrace land consolidation, which changed cropland use. Natural features of the slope cropland, such as distance to the settlement, gradient, elevation, and soil quality were also important factors affecting the type and timing of changes in slope cropland use, including abandonment. These, the influence of natural factors also showed spatial relationships, such as contiguous returned cropland and concentrated abandoned cropland.

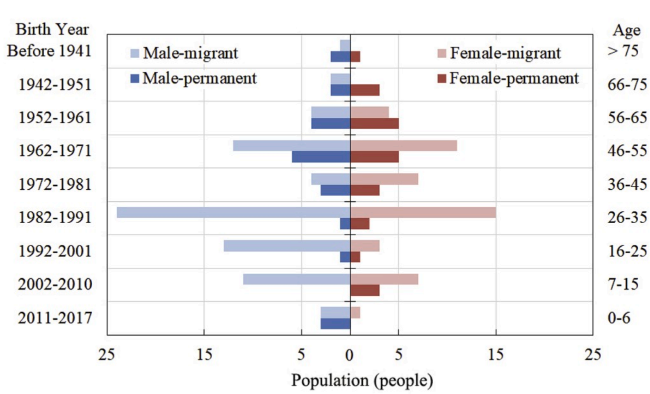

Fig. 5. Age structure of population in the Yangjuangou catchment in 2017.

3.3. Characteristics of changes in cropland use

(1) **Spatial variability.** With the gully and dam cropland observed at the core of the catchment, cropland distribution exhibited a “core-margin" funnel-shaped spatial pattern with terrace cropland and slope cropland located at the margins. Cropland continuously increased toward the funnel-shaped bottom of the catchment with time. In the 1980s, the area of slope cropland was relative large was primarily distributed on the mountaintops, hilltops, and slopes. In the 2000s, most slope cropland was gradually shifted out of agricultural production, and only a small percentage was converted to terrace cropland, leading to the first downward spatial agglomeration of the cropland. In the 2010s, the gully land consolidation to relieve local deficits in food supplies, after the Grain for Green Project and adapt to urbanization and farmers' changes in livelihood, resulted in the expansion of dam cropland and improvements in farm infrastructure. This resulted in the second downward spatial agglomeration of the cropland. Rural housing also gradually concentrated with the

cropland from relative high elevations to the bottom of the catchment.

(2) **Cropland use intensity.** In the 1980s, the cropland area was relatively large, with slope cropland accounting for most. Due to poor soil fertility, frequent natural disasters, and low economic status, farmers invested limited labor and manure in this slope cropland, characterized as requiring extensive cultivation with little harvest. As the core of cropland and agricultural production shifted to the bottom of the catchment, the area of cropland changed from large to small, and investments in labor and fertilizer increased in the terrace and dam croplands (Table 2). Facility agriculture, such as greenhouses and the chicken farm, also appeared. The location of agricultural production moved down in elevation and became more concentrated, while the labor intensity and capital intensity associated with farming increased. In recent years, with the progress of industrialization and urbanization, the urban-rural relationship has gradually strengthened. Due to limited development within villages, farmers shifted their livelihood strategy from maximizing cropland yield to maximizing labor efficiency. The labor intensity for cropland use thus declined, while capital inputs continued to increase.

(3) **Cropland use sustainability.** In the 1980s, cropland was primarily slope cropland, with severe water loss and soil erosion. Crop yields were low, while dam cropland with relatively high productivity often exhibited reduced yields due to damage, and the risk associated with agricultural production was relatively large. As the core of cropland and agricultural production shifted to the bottom of the catchment, the entire catchment gradually shifted toward a sustainable pattern of ecology-production spaces with dam cropland and terrace cropland surrounded by returned cropland. At the end of the study period, the returned cropland was located on the mountaintops, hilltops, and slopes, which provided an improved gully environment for dam cropland and terrace cropland, and ensured the safety and stability of agricultural production.

(4) **Expansion of abandoned cropland.** The collective abandonment of contiguous cropland often began with the abandonment of a single small plot. The small plot of abandoned cropland could become a habitat for a wide variety of animals and plants, and further affected the crop yields of the surrounding cropland plot, causing new rounds of abandonment until the entire region was collectively abandoned. This phenomenon was especially obvious in the terrace cropland, where the abandoned small plot connected the upper and lower slopes of the plot, enlarging the influence of wild animals and plants in the terrace cropland.

4. Discussion

4.1. Patterns of cropland use

During studying on long-term changes in land use, British geographer Mather (1992) summarized the law of forest transitions, namely, the forest area of a country exhibited a U-type curve as time progresses. The law of forest transitions also indicated, from an indirect perspective, that cropland area exhibited a first increasing and then decreasing trend. Rudel (2005) summarized two paths to forest transitions: economic development path and forest scarcity path. Concurrent with rapid industrialization and urbanization in China, the forest transitions gradually shifted from the forest scarcity path, driven by policies, to the economic development path, driven by socioeconomic development (Li and Li, 2017). These two paths affected the Yangjuangou catchment during 1985–2017. The area of cropland in the catchment decreased correspondingly, and the main driving force for this reduction was the change from policy to economic factors. For example, the area of returned and abandoned cropland has shown a positive correlation with elevation based on multi-phase land use data (Shao et al., 2014; Li et al., 2016a).

Based on the analysis of the changes in cropland use during forest transitions, this study found that the vertical spatial pattern of cropland use exhibited a core-margin funnel-shaped distribution in the Yangjuangou catchment. The funnel-shaped pattern centered on the gully and dam cropland at low elevation, with terrace cropland and slope cropland at the margins and high elevation. The changes in cropland use appear to continuously gather toward the funnel-shaped bottom of the catchment as time passes, like streams. The loess hilly and gully region has many gullies and hummocks, and the small catchment is the basic unit. Based on the general characteristics of the catchment and community, we propose that this rule has some universality in similar regions.

4.2. Mechanisms for rural development

In-depth studies on changes in cropland use provide a basis for understanding the process of rural development in the loess hilly and gully region. According to the theory of man-land relationship for regional systems (Wu, 1991), humans depend on the land, while also having the initiative to change the land. The active role of humans is driven by their demands. According to the economic analysis framework, three groups with distinct behaviors represent humans: individuals, enterprises, and government (Xi, 2001). Changes in cropland use occur because of actions adopted by different groups to satisfy their respective needs. Cropland use was dominated by the collective decision of the primary actor based on regional natural resources features, social and economic conditions affecting resource utilization, substitution to meet the demand within and outside the region, and their resource utilization ability (Fig. 6).

The changes in cropland use in the Yangjuangou catchment primarily involved two groups: farmers and government. In the first two stages, the farmers required subsistence (i.e. obtaining enough food) and the government required ecological safety. To gain adequate food, farmers in the catchment expanded slope croplands and seldom constructed terrace croplands to increase crop yields, resulting in serious water loss and soil erosion. Therefore, the government provided farmers grain freely and promoted the construction of terrace cropland and dam cropland, resulting in the conversion of slope cropland. In the last two stages, the farmers' requirements gradually shifted to development while the government shifted to giving equal weight to ecological safety, rural development, and food security. The government's financial support for agricultural structure adjustment, i.e., fruit trees planting, greenhouse constructing, and chicken farm, received widespread positive responses from farmers. Finally, farmers becoming migrant workforces due to economic forces, resulted in changes in planted crops, from labor-intensive vegetables to labor-saving maize and large expanses of abandoned cropland (Fig. 7).

The approaches of rural development generally included exogenous, endogenous, and mixed exogenous/endogenous development (Terluin, 2003). From the perspective of systems theory, the regional rural development system was composed of a regional rural development core system and regional rural development exterior system; its core was the former system coupled with the rural subject and rural ontological systems (Zhang and Liu, 2008). Zhang and Liu (2008) also derived these three rural development approaches based on analyzing the regional rural development system. On their study of the rural transition in

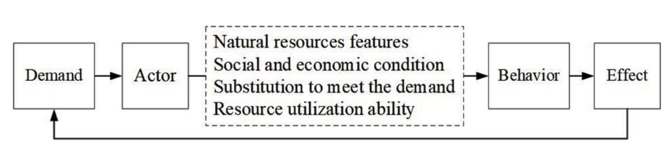

Fig. 6. Schematic diagram of the behavior mechanisms governing cropland use.

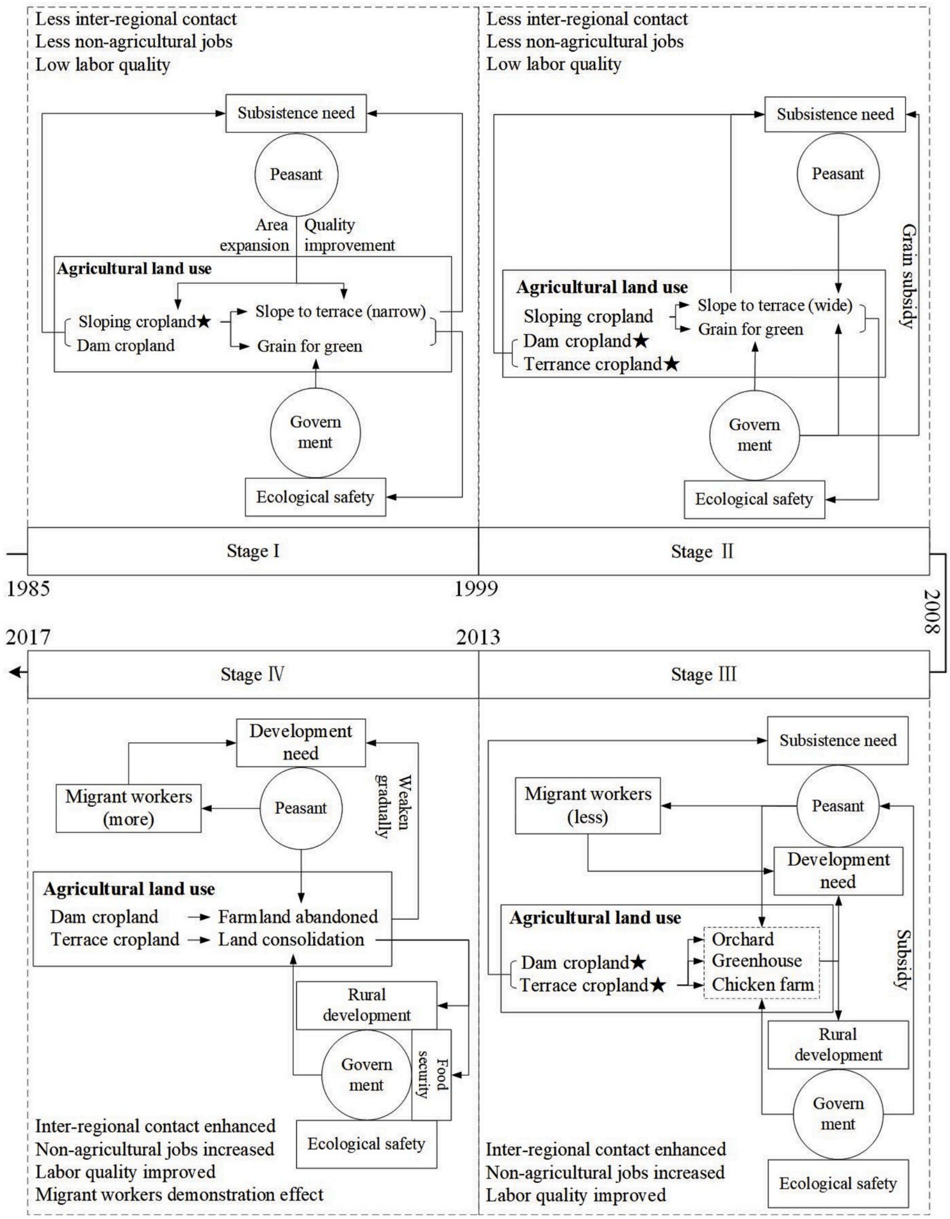

Fig. 7. Schematic diagram of the mechanisms driving changes in cropland use in the Yangjuangou catchment.

flatland agricultural areas, Li et al. (2012) further highlighted the role of humans in rural development within the rural subject system. He suggested that local villagers were the main body of village development and rural elites were the core element. The rural elites played an extremely important role in stimulating internal motivation, integrating external motivation and promoting rural transitional development.

Throughout the rural development process, the Yangjuangou catchment was dominated by exogenous power, with minimal impact from the endogenous driver. Although the catchment facilitated many development opportunities, such as fruit tree planting, greenhouse construction, and breeding industry, it had seen limited benefits because of the minimal leadership from rural elites and limited participation by the community. Because most villages in the loess hilly and gully region have residents with similar knowledge and experience, there were few individuals able to take on the role of rural elites. We should combine the studies on regional developing laws, urban and rural relationship, rural multi-function and short-slab of rural development to comprehensively understand and accurately predict the path of rural development in this region. With this understanding, well-timed policies can intervene to cultivate the endogenous driving force of rural development, thereby providing a reference for rural development in this region.

4.3. *The effectiveness of this study*

Here, we summarized the characteristics of changes in cropland use and revealed the course of rural transition with remote sensing images and participatory interview surveys. The funnel-shaped spatial pattern and increasing intensity of cropland reflected trends in cropland use given the ecological safety demand of government and subsistence and development needs of farmers. The resulting pattern was a combination of sustainable ecology-production spaces and large amounts of abandoned cropland. Moreover, the living strategies of farmers transformed from maximizing cropland yield to maximizing labor efficiency in cropland use while enhancing inter-regional contact. Therefore, the government should heed this trend and take comprehensive measures to meet the growing needs of farmers for a better life, such as gully land consolidation to facilitate agricultural mechanization, rural land system reform to prepare for land transfer, and infrastructure and rural community construction to improve basic public services.

Our research framework was based on three primary methodologies: (1) Using the historical development in the loess plateau from the 1980s–2000s to evaluate the rural transition in this region of China. (2) Classifying cropland and analyzing changes in cropland use with remote sensing images and participatory interview surveys. (3) Revealing the socioeconomic driving mechanism of changes in cropland use and the rural transition. This research framework should provide an important reference for analyzing rural transition in other regions using a microcosmic perspective. However, this research framework requires the time to interpret the remote sensing images and interview farmers, which will consume labor and resources for larger study areas. In addition, this study adopted qualitative methods to analyze factors and driving mechanism of changes in cropland use, and more quantitative methods should be used in future studies.

5. Conclusion

Land use changes in the Yangjuangou catchment of Liqu Town in Baota District of Shaanxi Province were investigated in this study. By interpreting remote sensing images and executing a participatory interview survey, we revealed changes and driving mechanisms of cropland in the catchment since the 1980s. The changes in cropland use in the catchment occurred in four stages, the slope cropland utilization stage (1985–1998), Grain for Green Project stage (1999–2007), agricultural structure adjustment stage (2008–2012), and cropland abandonment stage (2013–2017). Changes in cropland use were affected by policy, economic, socio-cultural, and natural factors.

The changes in cropland use in the catchment had clear characteristics. Cropland changes showed a core-margin funnel-shaped pattern in vertical space, with changes flowing toward the core from the margin with time, like streams. The utilization intensity of cropland generally increased, and the area of intensive utilization and intensive elements gradually shifted. The spatial organization of cropland gradually resulted in a sustainable pattern of "ecology-production" spaces. Finally, abandoned cropland showed patterns similar to contagion in recent years.

Based on the mechanisms driving human behavior, we analyzed changes in cropland use behavior with respect to farmers and government given the natural and socioeconomic conditions in each stage and revealed the intrinsic mechanism for changes in cropland use in the catchment. The food demands of farmers and the goal of ecological safety promoted by the government were the fundamental driving forces for cropland changes in stages I and II. As farmers' food demands were satisfied, the basic driving force shifted to the development demand of farmers and the equal objective of the government to promote ecological safety, rural development, and food security in stages III and IV. In summary, this study provides a microcosmic perspective for understanding the factors governing changes in cropland use in the loess hilly and gully region.

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