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When farmers walk away: a mixed-methods investigation of farmland abandonment through land-use change and farmer interviews in the Chengdu-Chongqing economic circle, southwestern China

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Farmland abandonment poses a critical threat to food security, ecological stability, and sustainable rural development, particularly in China's hilly and mountainous regions. This study examines the spatial distribution and socioeconomic determinants of farmland abandonment in the Chengdu-Chongqing Economic Circle (CCEC), located in the upper Yangtze River Basin. Drawing on multi-temporal land use data, we quantify the extent and spatial variation of abandonment over the past decade. Supplementary household survey data were analyzed using a Binary Logistic Regression Model to identify key drivers behind farmers' abandonment decisions. The results reveal pronounced spatial heterogeneity, with dryland abandonment exceeding 20% and paddy field abandonment surpassing 8% in peripheral mountainous zones. Major positive drivers include household labor aging ($\beta = 1.218$; marginal effect: 27.1%), low net farming income (below 7500 RMB/hectare; 21.4%), high dependence on hired labor (18.3%), and land fragmentation ($\beta = 0.217$; 5.3%). In contrast, higher educational attainment, access to agricultural subsidies, greater policy awareness, and larger household size significantly reduce abandonment likelihood. While natural and institutional factors were considered, socioeconomic variables exhibited more statistically robust and consistent influence on farmland abandonment decisions within the study area. These findings provide empirical insights for designing targeted rural revitalization policies that address labor shortages, enhance agricultural returns, and promote sustainable land use in mountainous regions.

KEYWORDS

food security, farmland abandonment, socioeconomic drivers, binary logistic regression model, Chengdu-Chongqing economic circle

1 Introduction

In the context of China's strategic agenda for ensuring national food security, farmland protection has increasingly become a fundamental and long-term policy priority (Wang et al., 2023; Lichtenberg and Ding, 2008; Liang et al., 2015). Farmland, as the cornerstone of agricultural production, directly influences the stability of the food supply system and the sustainable development of agriculture (Lu et al., 2022; Qi et al., 2018). With growing pressures from rapid population growth, accelerated urban expansion, land use changes, and the escalating effects of climate change, the availability, continuity, and productivity of arable land have come under significant stress. This has further elevated the strategic significance of farmland protection as a central component of national development planning. Beyond its essential contribution to food production, farmland also provides a range of critical ecosystem services, including soil fertility conservation, hydrological regulation, carbon sequestration, and biodiversity preservation. Therefore, effective farmland protection is not only vital for agricultural sustainability but also for broader ecological security and climate resilience (He et al., 2020; Wade et al., 2008).

Socioeconomic factors play a pivotal role in sustaining rural livelihoods, particularly in developing countries such as China, where agriculture remains the predominant source of income for a substantial proportion of rural households (Deller et al., 2003). The degradation or reduction of arable land not only weakens the foundation of the agricultural economy but also poses serious threats to rural social stability, exacerbating risks of marginalization, inequality, and persistent poverty. Consequently, the protection of farmland transcends the boundaries of agronomic or environmental policy; it is a fundamental pillar of rural revitalization, social equity, and sustainable territorial governance. On a global scale, farmland protection is also closely aligned with the objectives of the United Nations Sustainable Development Goals (SDGs), particularly those aimed at ensuring food security, halting land degradation, and safeguarding rural livelihoods and community resilience (Ramankutty et al., 2018).

Farmland abandonment is not a phenomenon unique to China. Across Europe, particularly in countries like Spain, Italy, and Greece, large-scale land abandonment has been observed in mountainous and marginal areas due to rural depopulation, industrialization, and Common Agricultural Policy (CAP) reforms (MacDonald et al., 2000; Rey Benayas et al., 2007). In Eastern Europe, post-socialist land reforms triggered significant fragmentation and underutilization of farmland (Van Vliet et al., 2015). Similar patterns have been reported in North America, where marginal lands in the United States and Canada have been abandoned due to urbanization, changes in agricultural subsidies, and declining profitability in traditional farming systems. In parts of Latin America and Sub-Saharan Africa, land abandonment is often driven by rural-urban migration, armed conflict, land tenure insecurity, or unsustainable land management practices. In Japan and South Korea, aging rural populations and youth outmigration have also contributed to widespread land abandonment. These global cases underscore the complexity of abandonment dynamics, typically shaped by a combination of demographic, economic, environmental, and institutional transitions,

highlighting the need for context-specific strategies in land use policy.

Despite the presence of robust institutional frameworks and ongoing policy innovations, farmland abandonment continues to emerge as a pressing challenge across various regions (Liang et al., 2015; Lu et al., 2022). Defined as the cessation or significant reduction of agricultural activities on arable land, this phenomenon has far-reaching implications for national food production, soil and land degradation, and the erosion of rural socio-economic resilience. In China, the issue is particularly pronounced in hilly and mountainous areas, where fragmented terrain, low agricultural profitability, and widespread access to off-farm employment collectively contribute to widespread land abandonment. Recent empirical studies have further revealed the complexity and regional heterogeneity of farmland abandonment dynamics in southern and southwestern China. For instance, studies in mountainous areas of southwestern China have identified steep topography, labor shortages, and an aging rural population as core drivers of abandonment (Yu et al., 2025). These region-specific studies provide complementary perspectives. Similarly, researchers have shown that family structure and gaps in social policy implementation significantly shape abandonment behavior among peasants in scattered villages across southern China (Chen et al., 2025). Farmland abandonment does not stem from a single determinant but rather reflects a complex interplay among economic constraints, environmental limitations, and household-level behavioral decisions (Lu et al., 2022).

While socioeconomic factors such as labor availability and income levels are widely acknowledged as primary drivers of farmland abandonment, recent studies have increasingly emphasized the role of natural conditions. Variables such as topography, soil fertility, and climate variability can significantly influence the viability of agricultural land (Estel et al., 2015). In many cases, steep terrain, low suitability for mechanized cultivation, inadequate irrigation infrastructure, and exposure to environmental risks including erosion, landslides, and droughts reduce both the economic feasibility and ecological sustainability of farming. Regions with limited agroecological potential are often the first to be abandoned during processes of rural transformation or demographic change. Institutional factors also exert substantial influence on land-use decisions. These include the security of land tenure, the clarity and stability of property rights, the effectiveness of policy implementation, the design of agricultural subsidy schemes, and the structure of rural governance systems. For instance, fragmented land ownership, insecure rental arrangements, and weakly coordinated rural revitalization efforts can create uncertainty that discourages continued cultivation. When institutional support is insufficient or incentives are poorly aligned with farmers' needs, agricultural activity may decline or land may be left uncultivated for extended periods.

A growing body of research has examined farmland protection and abandonment from a range of disciplinary perspectives. Existing studies have investigated the dynamics of farmland quantity and quality (Solomon, 1984; Song and Liu, 2017; Zhang et al., 2019; Shi et al., 2013), evaluated the effectiveness of preservation policies, and explored the roles of institutional actors and farmer participation (Liang et al., 2015; Zhang et al., 2022; You et al., 2021). Evidence suggests that specific elements of policy design, including land-use regulations, taxation frameworks, and ecological compensation

mechanisms, significantly influence farmers' willingness to engage in land conservation (Ferris and Frank, 2021; Duke, 2008; Qian et al., 2021). Comparative policy analyses conducted across Europe have underscored the importance of legal enforceability and institutional integration in achieving farmland protection objectives (Oliveira et al., 2019). Furthermore, recent studies have highlighted the roles of social capital, interpersonal trust, and community norms in enhancing the effectiveness of participatory conservation efforts (Wossen et al., 2015). Nevertheless, some regulatory instruments, although successful in curbing land misuse, may lead to unintended consequences such as diminished incentives for active land management and increased rural out-migration, thereby generating hidden social and ecological costs.

In China, the strategic imperative of farmland protection is accentuated by pronounced structural constraints: the nation sustains a population exceeding 1.4 billion, yet possesses only 12.86 million hectares of farmland, resulting in a *per capita* availability of merely 0.09 ha (Ministry of Natural Resources of the People's Republic of China; <https://x.m.mnr.gov.cn/sj/>). Data from the Third National Land Survey highlight the acute imbalance between limited land resources and escalating food demand. In response, the Chinese government has instituted the most rigorous farmland protection framework to date, encompassing legal prohibitions on non-agricultural land conversion, the delineation of permanent basic farmland, and the deployment of comprehensive land-use monitoring systems (Yang et al., 2020). These policy measures not only seek to safeguard the quantitative baseline of farmland but also aim to enhance its ecological integrity and sustainable productivity through the integration of ecological restoration and institutional governance mechanisms.

The Chengdu–Chongqing Economic Circle (CCEC) serves as a representative case in southwestern China due to its dual role as a critical grain-producing region and its location within ecologically fragile mountainous terrain. The region is undergoing rapid rural–urban transformation, marked by significant rural depopulation, land fragmentation, and uneven agricultural development, all of which contribute to increasing farmland abandonment. In addition, complex topography, limited infrastructure, and environmental stressors such as soil erosion, low fertility, and climate variability further constrain agricultural viability (Dai et al., 2018; Zhang et al., 2021). As a national development priority, the CCEC holds policy relevance for land-use governance in transitional economies across China and the Global South. Based on LUCC (Land Use/Cover Change) data, this study analyzed the spatial distribution and extent of farmland abandonment in the CCEC over the past decade. A Binary Logistic Regression Model, based on household interview data, was employed to identify the key natural, socioeconomic, and institutional factors influencing farmers' land-use decisions. The findings aim to provide a scientific basis for formulating more targeted and effective farmland protection strategies in mountainous and rapidly urbanizing regions.

2 Materials and methods

2.1 Study area

The CCEC is located in the upper reaches of the Yangtze River, within the Sichuan Basin. As the most advanced and

dynamic urbanization hub in western China, it holds substantial potential for future growth (Zeng et al., 2022). Rooted in the principles of green development, the region has seen continuous improvements in ecological quality, supported by a solid foundation for ecological co-construction and environmental protection. The CCEC encompasses the central urban area of Chongqing and extends across 27 districts and counties (Figure 1), covering a total area of approximately 185,000 km². As of the end of 2019, the CCEC had a permanent resident population of approximately 98.75 million and a gross regional product of 7.8 trillion RMB, with a *per capita* GDP of about 79,000 RMB, reflecting its significant economic stature. Strategically positioned as an ecological barrier zone in the upper Yangtze River basin, the CCEC plays a pivotal role in soil and water conservation, water resource management, and biodiversity protection.

2.2 Data sources and processing

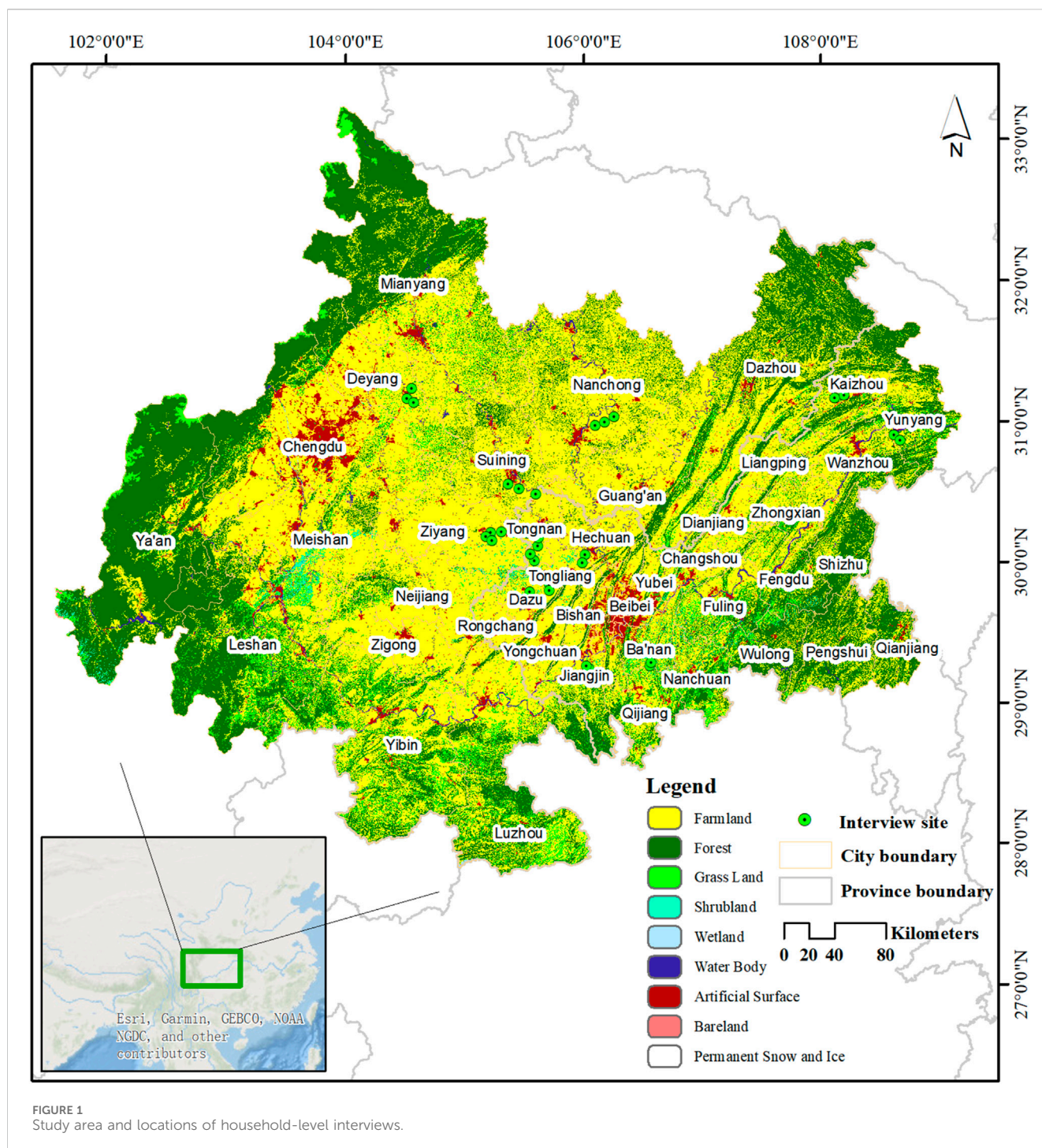
2.2.1 Extraction of farmland abandonment patches

Land use data were sourced from two authoritative national databases: the Second National Land Survey Database of China (2009) and the Third National Land Survey Database of China (2019), both administered by the Ministry of Natural Resources of the People's Republic of China (<https://x.m.mnr.gov.cn/sj/>) (Zhao et al., 2021; Han et al., 2023). These datasets provide comprehensive, high-resolution spatial information on land use patterns, enabling a robust temporal comparison of farmland dynamics over the past decade. Using ArcGIS 10.8 (ESRI Inc., Redlands, CA, USA), an overlay analysis was conducted between the 2009 farmland (paddy and dryland) patches and the 2019 land use patches within the study area. Dynamic land parcels converted from farmland to forestland or grassland during 2009–2019 were identified. Based on this, abandoned farmland patches were extracted and delineated to support subsequent calculation of farmland abandonment rates.

In this study, farmland abandonment is defined as the conversion of paddy fields and dryland to forestland, grassland, or wasteland, as identified through land use change analysis. This definition reflects the cessation of agricultural activities and represents a long-term or permanent withdrawal from cultivation. While some land conversions may result from planned ecological restoration initiatives or policy-driven incentives, such as afforestation programs (e.g., the “Grain for Green” project), these transitions nonetheless indicate a substantive functional exit from agricultural use. Including conversion to wasteland acknowledges the broader spectrum of farmland abandonment phenomena, encompassing both natural regeneration and land degradation processes that contribute to the decline of active cultivation.

2.2.2 Calculation of farmland abandonment rate

The extent of farmland abandonment within the study area is quantitatively assessed using the farmland abandonment rate, which serves as a key indicator to reflect the intensity and spatial variation of land-use change over time. The abandonment rate is



calculated based on the proportion of farmland that has ceased agricultural activity during the study period, as shown in Equation 1:

$$A_i = \frac{\sum a_i}{\sum s_i} \quad (1)$$

Where A_i represents the abandonment rate of farmland patches within the area, a_i is the abandoned area of the i th patch, and s_i is the area of the i th patch before abandonment.

2.3 Farmer-level abandonment analysis

2.3.1 Questionnaire design and variable construction

In order to identify the major determinants of farmland abandonment among farmers, a structured household questionnaire survey was conducted in the CCEC from March 2024 to April 2025. Although the timing of the household survey (March 2024 to April 2025) slightly lags behind the land use change period (2009–2019), the retrospective nature of farmer-reported

abandonment behavior provides reasonably accurate data, particularly for long-term abandonment (e.g., over 10 years). Therefore, despite the temporal mismatch, the survey perspective remains representative and valid for analyzing farmland abandonment dynamics within the study area.

The questionnaire design was grounded in established theoretical frameworks, including the Sustainable Livelihoods Framework (Scoones, 1998) and the Theory of Planned Behavior (Ajzen, 1991), to comprehensively capture socioeconomic, institutional, and behavioral determinants of farmland abandonment. Variables were selected based on literature review and field pretests to ensure relevance and validity in reflecting key factors influencing farmer decision-making.

The questionnaire comprises five major dimensions (Supplementary Appendix A):

1. Farmer and household characteristics, including the gender, age, and education level of the household head, household size, and the age structure of the primary labor force (e.g., proportion of elderly or minors);
2. Farmland characteristics, such as total cultivated area, number of land parcels, average plot size, terrain slope, soil quality, irrigation condition, and distance from plots to the household residence;
3. Livelihood strategies, capturing the share of off-farm income, migration history, employment status of laborers, labor input, and per hectare cost of hired labor;
4. Policy awareness and institutional factors, including the respondent's awareness of land-related subsidy policies, participation in government agricultural programs or land transfer schemes, and trust in local governance;
5. Farmland use behavior and attitudes, including perceived profitability of grain farming, willingness to continue cultivation, perceived risks, and expectations regarding future land use policy and rural development.

Questionnaires were distributed through face-to-face interviews conducted by trained enumerators to ensure consistency and data quality. Sampling employed a stratified random approach covering multiple representative districts across the CCEC, aiming to capture spatial and socioeconomic heterogeneity within the study area. Data collection followed standardized protocols, including pre-survey training, pilot testing, and field supervision. Completed questionnaires were reviewed for completeness and accuracy before data entry and cleaning.

The dependent variable is a binary indicator of farmland abandonment, coded as one if the household reported abandoning any farmland during the past 10 years, and 0 otherwise. The explanatory variables include continuous, categorical, and ordinal types, capturing household demographics, land and labor endowments, livelihood configurations, policy exposure, and behavioral intentions (Supplementary Appendix B).

2.3.2 Identification of influencing factors

To quantitatively assess the factors influencing farmers' decisions to abandon farmland, a Binary Logistic

Regression Model was employed (Harrell, 2015), as shown in Equation 2:

$$\Pr(Y_i = 1) = \frac{e^{X_i\beta}}{1 + e^{X_i\beta}} \quad (2)$$

where Y_i is the binary outcome variable indicating whether household i abandoned farmland; X_i is a vector of explanatory variables capturing demographic, economic, and policy factors; β is a vector of parameters to be estimated; $\Pr(Y_i = 1)$ denotes the probability that the household abandoned farmland.

The model was estimated using Maximum Likelihood Estimation (MLE). Robust standard errors were employed to account for potential heteroskedasticity. Marginal effects were further computed to interpret the impact of each explanatory variable on the probability of farmland abandonment (Harrell et al., 2015; Tranmer and Elliot, 2008).

3 Results

3.1 Spatial distribution characteristics of farmland abandonment rates

The farmland abandonment rates in the CCEC exhibited significant regional variation, characterized by a spatial pattern of low abandonment rates in central urban areas and high rates in surrounding hilly regions (Figures 2, 3). The main urban districts of Chongqing and core districts of Chengdu showed no abandonment. In contrast, peripheral mountainous areas such as Qianjiang, Kaizhou, Zhongxian, Pengshui, and Yunyang demonstrated significantly higher abandonment rates, with dryland abandonment generally exceeding 20% and paddy field abandonment rates above 8%. This pattern reflects structural challenges including severe rural labor outmigration and declining agricultural profitability. Among different farmland types, dryland abandonment rates are notably higher than those of paddy fields, with the highest dryland abandonment rate reaching 27.4%, while the maximum paddy field abandonment rate is 10.3%.

3.2 Statistics of questionnaire data

A total of 345 valid questionnaires were collected from households in the CCEC. The average net profit from grain farming was reported to be approximately 19,495 RMB per hectare, while total production cost—including inputs and labor—averaged around 11,994 RMB per hectare. However, over 62% of respondents perceived grain production as having low profitability, and more than half indicated a high dependence on external hired labor. Furthermore, 46% of respondents reported that their household's primary labor force was composed of elderly individuals or minors, reflecting severe rural labor shortages.

3.3 Influencing factors of farmland abandonment

3.3.1 Positive influencing factors

The binary logistic regression results (Table 1) indicate several factors that significantly increase the likelihood of farmland

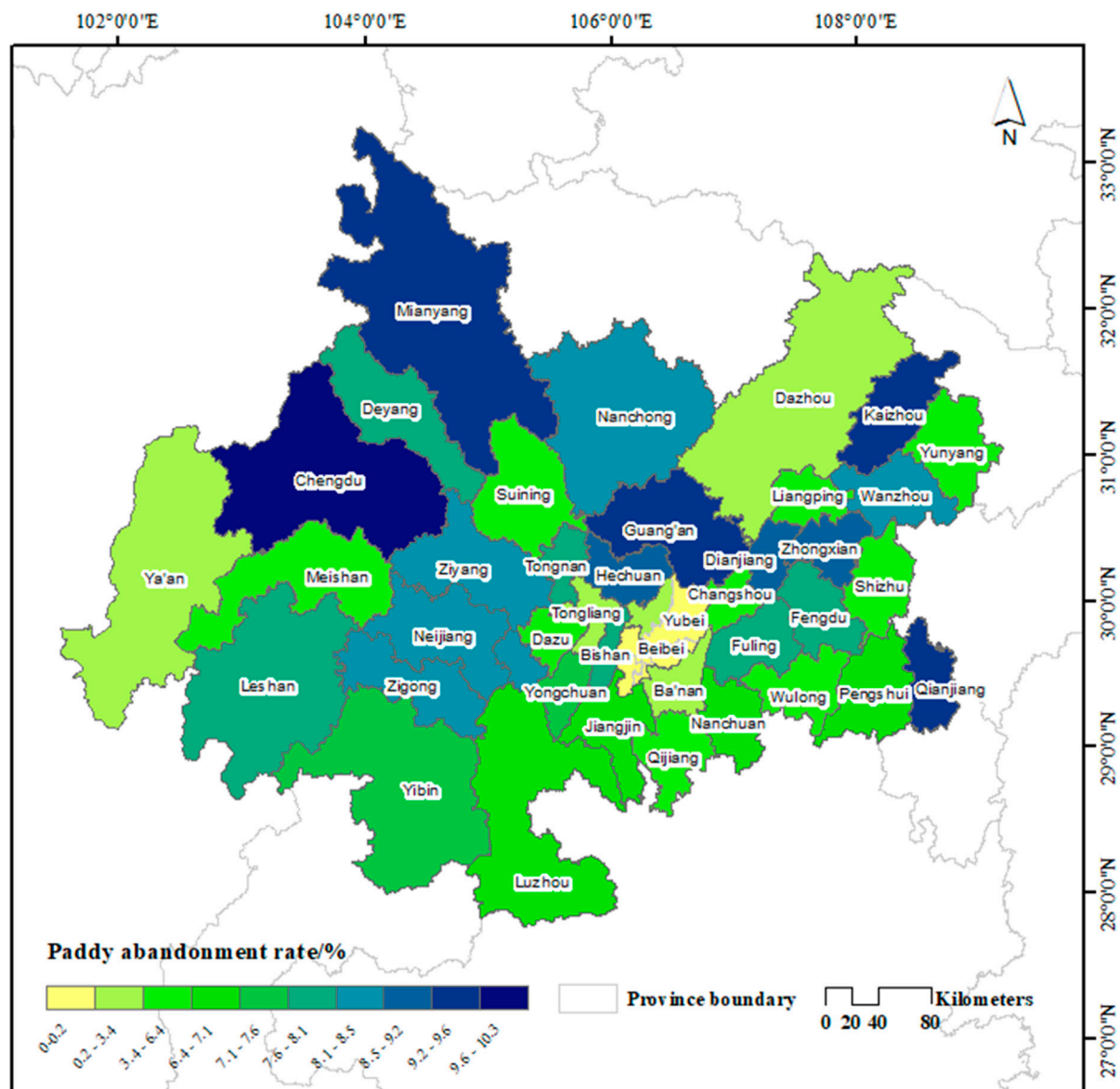


FIGURE 2
Spatial distribution characteristics of paddy abandonment in the CCEC.

abandonment. Notably, the age structure of household labor (labor_age) exhibits a strong positive effect, with a coefficient of 1.218 ($p < 0.01$) and a marginal effect of 0.271. This suggests that households with an older primary labor force are 27.1% more likely to abandon farmland. Similarly, lower net income from farming activities (net_income) is associated with increased abandonment risk, showing a coefficient of 0.967 ($p < 0.01$) and a marginal effect of 0.214. Additionally, higher labor hiring costs (hire_cost) significantly contribute to abandonment decisions, with a coefficient of 0.754 ($p < 0.05$) and a marginal effect of 0.183. Land fragmentation (land_fragmentation) also positively influences abandonment, albeit with a smaller effect size ($\beta = 0.217$, $p < 0.05$), indicating that scattered plots may increase the difficulty and cost of cultivation, thus encouraging abandonment.

3.3.2 Negative influencing factors

Conversely, several variables demonstrate a mitigating effect on farmland abandonment. Education level (education_level) shows a significant negative association ($\beta = -0.546$, $p < 0.05$), with a marginal effect of -0.128 , suggesting that higher educational attainment reduces the probability of abandonment by 12.8%. Access to agricultural subsidies (agri_subsidy_access) also negatively affects abandonment likelihood ($\beta = -0.693$, $p < 0.01$), indicating that financial support plays an important role in encouraging continued cultivation. Policy awareness (policy_awareness) and family size (family_size) exhibit negative coefficients (-0.320 and -0.134 , respectively), though their statistical significance is weaker ($p < 0.10$), implying potential but less robust influence. Furthermore, land transfer (land_transfer) exhibits a positive but statistically insignificant effect ($\beta = 0.412$, $p =$

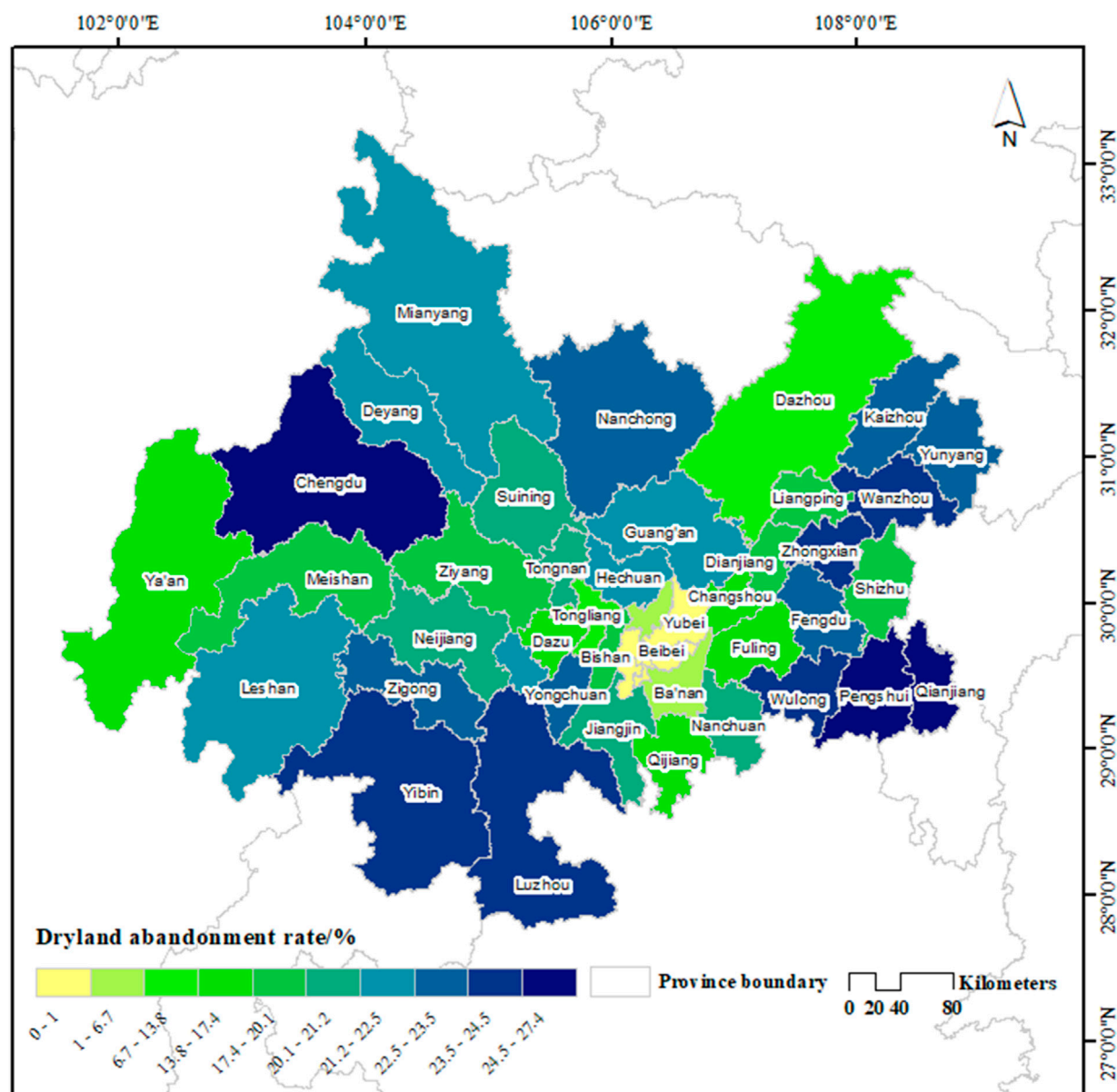


FIGURE 3
Spatial distribution characteristics of dryland abandonment in the CCEC.

0.101), indicating that land market mechanisms may not yet play a decisive role in influencing abandonment decisions in the study area.

4 Discussion

4.1 Spatial and socioeconomic patterns of farmland abandonment in the CCEC

The spatial distribution of farmland abandonment within the CCEC displays pronounced regional heterogeneity, primarily influenced by differing urbanization and socioeconomic dynamics. In the core urban areas, farmland abandonment represents an advanced stage of land-use transformation,

characterized by the widespread conversion of agricultural lands into urban infrastructure, commercial developments, and residential zones (Li et al., 2014; Seto et al., 2012; Gao et al., 2023). This near-total loss of farmland in urban centers aligns with intense urban consolidation processes observed in rapidly expanding metropolitan regions globally. Such spatial shifts not only diminish the total farmland available but also push agricultural activities toward suburban and rural peripheries, effectively redefining the rural-urban land-use interface. These patterns highlight the urgent need for integrated land-use planning strategies that balance ongoing urban expansion with the protection and sustainable management of peri-urban agricultural ecosystems (Gao et al., 2023).

In contrast, the peripheral mountainous and hilly areas of the CCEC experience significantly higher rates of farmland

TABLE 1 Summary of farmers' responses on the causes of farmland abandonment.

Variable	Coefficient (β)	Std. error	Z-value	P-value	Marginal effect	95% Confidence interval (β)	Odds ratio (OR)
labor_age	1.218	0.322	3.783	<0.001	0.271	0.587–1.849	3.38
net_income	0.967	0.286	3.381	0.001	0.214	0.406–1.528	2.63
hire_cost	0.754	0.298	2.53	0.011	0.183	0.170–1.338	2.13
land_transfer	0.412	0.251	1.641	0.101	0.101	–0.080–0.904	1.51
policy_awareness	–0.32	0.189	–1.693	0.091	–0.075	–0.691–0.051	0.73
education_level	–0.546	0.228	–2.395	0.017	–0.128	–0.993–0.099	0.58
family_size	–0.134	0.078	–1.718	0.086	–0.032	–0.287–0.019	0.87
land_fragmentation	0.217	0.094	2.298	0.022	0.061	0.033–0.401	1.24
agri_subsidy_access	–0.693	0.264	–2.625	0.009	–0.171	–1.210–0.176	0.5

abandonment, with some localities exceeding 20%, especially in dryland farming zones. This pattern is predominantly driven by persistent socioeconomic challenges, including the outmigration of rural labor and diminishing agricultural profitability (Zhang et al., 2019; Wang et al., 2022). These findings resonate with New Economics of Labor Migration (NELM), which posits that rural households make migration decisions not merely based on individual income maximization, but as a household strategy to diversify risk and access urban-based income streams. Accordingly, the loss of labor for farming is a byproduct of rational household strategies under conditions of rural economic stagnation and agricultural uncertainty. Given that dryland farming is more labor-intensive and less mechanized than paddy rice cultivation, it is disproportionately affected by these demographic changes (Simelton et al., 2009; Zheng et al., 2024).

4.2 Biophysical and economic drivers of differential abandonment in dryland and paddy fields

The markedly higher abandonment rates observed in dryland compared to paddy fields can be attributed to a complex interplay of biophysical and socioeconomic factors. Drylands are predominantly situated on steeper slopes and marginal soils characterized by low fertility and heightened vulnerability to soil erosion, drought stress, and land degradation, which collectively constrain the long-term viability of agricultural production (Estel et al., 2015). Economically, dryland farming generally yields lower returns due to limited irrigation infrastructure and greater exposure to environmental risks, leading to elevated production costs and reduced profitability that diminish farmers' incentives to maintain cultivation (Yan et al., 2016). In contrast, paddy fields are typically located on more level terrain with fertile soils and well-established irrigation systems, cultivating staple crops such as rice that offer relatively stable yields and market demand. However, paddy cultivation is labor-intensive, requiring continuous and skilled management activities including transplanting, water regulation, and weed control. Consequently, in regions experiencing significant rural labor shortages and aging demographics, the labor demands of paddy farming exacerbate

abandonment risks. This divergence in abandonment patterns between dryland and paddy fields underscores the synergistic effects of labor availability constraints, economic viability, and environmental suitability in shaping land-use decisions.

Beyond socioeconomic factors, natural environmental conditions critically influence farmland abandonment patterns. The hilly and mountainous fringes of the CCEC are characterized by steep slopes, fragmented terrain, and poor soil fertility, which severely constrain the sustainability of agricultural production. These areas are highly vulnerable to ecological risks such as soil erosion, drought, and land degradation, which compound the difficulties of cultivation and frequently render continued farming economically or physically unfeasible. Moreover, the challenging terrain limits the feasibility of mechanization and the development of efficient irrigation infrastructure, thereby increasing labor demands and production costs. Consequently, the interplay of natural constraints and socioeconomic pressures fosters a spatially heterogeneous abandonment pattern, where marginal lands are especially susceptible to functional withdrawal from agricultural use. From the perspective of land change science, these land-use transitions illustrate how structural drivers such as demographic shifts, market accessibility, and biophysical limitations interact to generate emergent patterns of abandonment (Turner et al., 2007). These dynamics further reinforce the spatial differentiation between core agricultural regions and marginal landscapes.

4.3 Economic pressures and policy challenges in marginal agricultural regions

Economic factors exacerbate farmland abandonment in these marginal regions. Declining returns from traditional agriculture, coupled with volatile market prices, rising input costs, and intense competition, diminish incentives for sustained cultivation (Wang et al., 2023). Marginal lands often incur higher production costs and yield lower outputs, reducing their attractiveness for continued farming. Consequently, such lands are frequently left fallow or repurposed for alternative uses, including forestry, pasture, or non-agricultural development. These findings highlight the inadequacy of uniform farmland management policies and

advocate for region-specific strategies aimed at enhancing rural labor retention, piloting mechanization tailored to terraced drylands, and facilitating livelihood diversification to sustain agricultural land use and rural vitality. Such pilot projects could align with the Plan for Accelerating the Construction of an Agricultural Powerhouse (2024–2035), which emphasizes adaptive technologies and regionally differentiated strategies for mechanization in difficult terrain. Furthermore, environmental protection considerations must be integrated into policy design to reconcile agricultural production with ecological conservation, especially in environmentally sensitive mountainous areas (Gao et al., 2023). Future research should prioritize longitudinal monitoring of abandonment trends and evaluate the potential of emerging technological interventions, such as digital agriculture, in mitigating abandonment risks.

4.4 The predominant role of socioeconomic and institutional factors

Our findings emphasize the predominant influence of socioeconomic factors in driving farmland abandonment amid rapid rural transformation (Song and Liu, 2017). The limited explanatory power of natural environmental variables likely stems from the relative agro-ecological uniformity within the study area, which reduces their capacity to explain spatial heterogeneity in abandonment patterns (Plieninger et al., 2016). Likewise, institutional factors such as land tenure security and the rigor of policy enforcement may indeed affect farmland use decisions, yet these influences were challenging to capture quantitatively due to insufficient data resolution and variability (Van Vliet et al., 2015). Notably, land transfer exhibited a positive but statistically insignificant correlation with farmland abandonment, implying inefficiencies within local land rental markets. These inefficiencies may promote land speculation or informal idling instead of encouraging active cultivation, underscoring the importance of further investigations into institutional and market dynamics that shape land use behaviors (Chen et al., 2023). Addressing these issues is crucial for formulating effective policies to mitigate farmland abandonment and promote sustainable land management.

4.5 Socioeconomic drivers and policy influences on farmland abandonment

Empirical evidence further indicates that farmland abandonment in the CCEC is fundamentally driven by the dual demographic pressures of rural aging and persistent outmigration of the younger workforce, jointly constraining labor availability. Many farming households increasingly rely on hired labor; however, escalating agricultural wage costs, fueled by urban wage inflation, undermine the economic feasibility of grain cultivation. Although hired labor is commonly used, it mainly consists of relatively young neighbors rather than professional workers, leading to instability and intermittency. Therefore, hired labor does not effectively compensate for the negative effects of labor shortages. This finding corroborates previous studies identifying labor shortages and rising input costs as primary determinants of farmland

abandonment in urbanizing contexts (Hou et al., 2021; Zhou et al., 2020). These findings contribute to a growing body of literature emphasizing the socio-demographic transformation of rural China as a critical factor in shaping land-use outcomes, especially in economically transitioning peri-urban regions. More broadly, our findings echo global debates in land systems science concerning how urbanization and demographic transitions reshape agrarian systems, often rendering traditional farming economically or socially obsolete in transitional regions.

The economic rationale underpinning smallholder decisions is evident in the statistically significant association between low net returns and abandonment behavior. Survey data reveal that a marginal net income from grain production of approximately 7500 RMB per hectare has led numerous farmers to reduce or cease cultivation. Land is often transferred to other users or converted to higher-value uses such as aquaculture or cash crop production. Qualitative interviews corroborate these trends, with multiple respondents reporting land conversion from paddy to dryland or commercial use. This pattern aligns with the broader “non-grainization” phenomenon increasingly documented in peri-urban and developed agricultural regions of China (Ma et al., 2009). The underlying incentive structure is clear: persistently low grain prices combined with insufficient subsidy support encourage smallholders to reallocate land toward more profitable ventures.

Our study demonstrates that higher education levels and access to agricultural subsidies significantly reduce the likelihood of farmland abandonment, underscoring the pivotal role of knowledge and policy support in sustaining farming activities. Higher education enhances farmers’ proficiency in modern agricultural techniques and management, as well as their appreciation of long-term agricultural returns, thereby decreasing abandonment propensity. Nonetheless, it is noteworthy that higher education does not uniformly correlate with continued farming; some highly educated individuals may choose to abandon agriculture in favor of urban employment opportunities, reflecting a complex interplay between education, labor allocation, and farming decisions. Agricultural subsidies, serving as direct economic incentives, effectively alleviate production cost pressures and foster cultivation enthusiasm. Although policy awareness and household size exhibit negative correlations with abandonment, their statistical significance is weaker, possibly reflecting current limitations in policy dissemination and the nuanced influence of household labor structure. Land transfer did not demonstrate a significant effect, but the positive coefficient suggests that land transfer processes may be associated with increased abandonment risk in certain contexts. This underscores the need for further research to understand the conditions under which land market mechanisms influence land use decisions, and to refine policies that support effective and equitable land transfers.

4.6 Integrated policy recommendations for sustainable farmland management

Addressing farmland abandonment in the CCEC requires an integrated, multidimensional policy approach grounded in both empirical evidence and theoretical insight. In particular, we recommend piloting terraced-field mechanization adapted to hilly terrain, supported by subsidies aligned with national modernization goals. Improved subsidy schemes should be differentiated based on land

characteristics and household demographics to optimize resource allocation and incentivize continued cultivation. Additionally, revitalizing the rural workforce through vocational training, entrepreneurship incentives, and infrastructure development must be complemented by educational outreach programs aimed at retaining younger, more educated residents within rural communities. Institutional reforms are also critical, including securing land tenure, enabling flexible land-use rights, and promoting cooperative or larger-scale farming models, especially in areas where traditional smallholder agriculture is becoming unsustainable. By implementing these targeted and context-specific interventions, the CCEC can more effectively curb farmland abandonment, safeguard food security, and enhance long-term rural resilience.

5 Conclusion

Our study examined the spatial patterns and underlying drivers of farmland abandonment in the CCEC. Analysis of land use data from 2009 to 2019 revealed notable spatial heterogeneity in abandonment rates, with peripheral hilly and mountainous regions showing substantially higher levels, especially in dryland areas. Our findings confirm that rural depopulation and low profits remain key obstacles. Based on 345 household surveys and a Binary Logistic Regression Model, we identified several key factors significantly associated with farmland abandonment. Positive influencing factors include aging of the household labor force, low net income from farming, high labor hiring costs, and land fragmentation. These factors increase the likelihood that households will stop farming their land. Conversely, negative factors that mitigate abandonment include higher education levels, access to agricultural subsidies, policy awareness, and larger family size, although some showed weaker statistical significance. Land transfer was found to have a positive but statistically insignificant effect. These results indicate that farmland abandonment in the CCEC is influenced by both economic and demographic pressures, as well as land management conditions. To address this issue, policies should aim to improve farm profitability, reduce labor costs through mechanization or cooperation, strengthen farmers' access to agricultural subsidies and relevant land policies, and enhance policy awareness. Our results support the development of strategies to reduce farmland abandonment and promote sustainable land use, aligning with Sustainable Development Goals 2 (Food Security) and 15 (Life on Land), thereby emphasizing the global relevance of our findings.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by Institute for Ecology and Environmental Resources, Chongqing Academy of Social Sciences. The studies were conducted in accordance with

the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

QW: Writing – review and editing, Writing – original draft, Conceptualization, Funding acquisition, Data curation. PZ: Data curation, Supervision, Writing – review and editing. YD: Supervision, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2025.1650689/full#supplementary-material>

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