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The hollowing out of rural china at the micro level: A case study of three traditional villages in southern Anhui province

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ABSTRACT

The vacancy of traditional dwellings not only signifies the abandonment of buildings and cultural decline but also reflects population outflow and the weakening of rural industries. This issue poses a significant threat to the survival of traditional villages, impacting local communities, cultural heritage preservation, and the sustainable development of rural areas. To comprehensively analyze the factors contributing to traditional dwelling vacancy, this study examines architectural, demographic, and economic determinants through micro data regression analysis. The key findings are as follows: (1) Over 50 % of traditional dwellings in the three villages of southern Anhui are vacant, primarily due to population outflow and industrial decline resulting from a shortage of young labor. (2) Architectural factors influence vacancy risk: Spatial composition and maintenance status play a significant role, with houses that include additional structures and courtyards being less likely to be abandoned. Moreover, self-repair efforts by resident's help maintain usability and mitigate long-term vacancy, underscoring the necessity for targeted renovation policies. (3) Drivers of population outflow and industrial decline: The transition to off-farm employment is a primary factor contributing to the shortage of young labor. Employment opportunities and household income structure directly influence migration decisions, particularly among young individuals. As rural economies become less dependent on agriculture, an increasing number of people seek urban jobs, further accelerating industrial decline and rural aging. Addressing these challenges necessitates economic diversification and the enhancement of local industries. (4) Mediating role of population outflow: While shortages of young labor do not directly cause housing vacancies, they function as a mediating factor through population outflow. The greater the loss of young workers, the higher the risk of dwelling vacancy, underscoring the interconnectedness of demographic shifts and rural decline. (5) Importance of villager participation: Although traditional dwelling renovation projects exist in the three villages, active villager participation is essential for long-term sustainable development and urban-village integration. Policies should empower residents by providing financial and technical support while fostering community-driven initiatives. Strengthening villagers' sense of ownership promotes cultural heritage preservation, social cohesion, and economic resilience, ensuring that rural sustainability becomes a community-led effort rather than an externally imposed solution.

1. Introduction

The "hollowing out" of villages refers to the prolonged vacancy of a large number of rural houses or their occupation by only a small number of residents, with many of these structures falling into disrepair (Feng et al., 1999; Amodio, T., 2022). In China, the intensification of this phenomenon is closely linked to the urban-rural divide that emerged following the economic reforms of 1978 (Long et al., 2011). First, rapid urbanization and industrialization have driven large-scale rural-to-urban outflow (Long et al., 2010). As the economic system transitioned from a planned to a market economy, farmers increasingly moved to cities in pursuit of better access to production resources and improved living conditions to facilitate wealth accumulation. In 1978, the urban population accounted for only 17.92 % of the total, whereas by 2023, the rural population had declined to just 33.84 % (National Bureau of Statistics of China NBSC, 2024). Second, rural demographics reveal an aging population and declining birth rates. By late 2022, demographic data revealed that 19.8 % of the national population was

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aged 60 and older, with those aged 65 and above reaching 14.9 %. Conversely, the youth demographic (aged 0–15) represented only 18.1 %, a figure that is disproportionately lower in rural regions (Wang, 2023). These demographic shifts have further exacerbated rural depopulation and the decline of the agricultural labor force. Additionally, urban settlement restrictions have contributed to the formation of a large outflow workforce and floating population. In 2022, inter-provincial outflow workers numbered 67.51 million, representing 38.2 % of the total outflow workforce, while intra-provincial migrants reached 109.07 million, or 61.8 %. This large-scale exodus has further intensified the hollowing out of rural villages (National Bureau of Statistics of China, 2024).

Between 1996 and 2022, China's total arable land area decreased by approximately 11,528,000 ha, representing a 9.6 % decline (Food and Agriculture Organization of the United Nations (FAO), 2025), 1996–2022). As the country's economic structure shifted from agriculture-led development to industrialization and urbanization (Chen et al., 2014), balancing arable land protection with urban expansion has become a key policy concern. To safeguard food security, the Chinese government has implemented strict arable land protection targets and established red lines for the preservation of permanent basic farmland (Ministry of Natural Resources, PRC., 2019). However, challenges related to the inheritance and utilization of arable land have become increasingly prominent due to factors such as rural-to-urban outflow, the expansion of non-farm employment opportunities, and an aging rural population (Zou et al., 2018). Concurrently, the composition of farmers' incomes has undergone significant changes. According to national survey data, about 60 % of households underwent livelihood transitions from 2010 to 2018. This period witnessed a widespread shift from exclusive reliance on agriculture toward livelihood diversification and off-farm employment (Cui et al., 2024). While agricultural households are characterized by low asset endowments and farming dependence, non-labor households face even greater economic vulnerability (e.g., pensions and subsidies), relying on transfer income due to a lack of labor. Conversely, wage-earning households (or 'migrant workers') achieve higher income levels through wage labor (Sun et al., 2019).

Rural dwellings are seasonally or permanently vacant due to various factors (Liu et al., 2010). Since the reform and opening-up, and particularly in the early 21st century, traditional earth and wooden houses have been gradually replaced by brick and concrete structures, enhancing safety and improving living conditions (Deng et al., 2018). In village areas prone to geological disasters, the abandonment of original settlements has become increasingly evident (Galadini, F., 2022). Additionally, the trend of rural hollowing has been further exacerbated by the expansion of rural housing. In 1978, the per capita housing space in China's towns and villages was 6.7 and 8.1 square meters, respectively. By 2016, these figures had increased to 36.6 square meters, and 40.8 square meters (National Bureau of Statistics of China, 2017), with the growth in the countryside being particularly pronounced.

As a result, rural "hollowing out" is primarily driven by urban development, with out-migration accelerating the decline of agriculture (Zhou, 2008; Liu et al., 2010). This process leads to vacant housing, economic downturns, the deterioration of buildings, and land waste (Zhang et al., 2025, 2016; Long et al., 2009; Li and Wu, 2017). As the trend intensifies, many villages are rapidly "hollowing out" and even facing disintegration or disappearance (Chen and Liu, 2012).

Traditional villages, also known as ancient villages, are settlements that originated in earlier periods and were relatively well preserved, featuring rich cultural heritage, traditional customs, and natural resources (Ministry of Housing and Urban-Rural Development, 2012; Ministry of Housing and Urban-Rural Development, 2012; Ministry of Housing and Urban-Rural Development, 2014). As of 2025, 8155 villages in China have been included in the list of traditional villages (Xinhua News Agency, 2023). However, the phenomenon of "hollowing out" poses a significant threat to the preservation of its material heritage and the transmission of folk culture (Bi et al., 2025). It also exhibits distinct characteristics and driving mechanisms that differentiate it from ordinary villages (Zhou et al., 2019; Hou and Shi, 2021). Vacant houses accelerate the deterioration of traditional architecture, hinder environmental improvements, and contribute to land and cultural resource waste (Liu and Xu, 2021). The root cause of this phenomenon lies in low agricultural productivity, while urban employment opportunities serve as external catalysts, and ineffective management acts as a direct contributing factor (Wang et al., 2020).

Existing research on the "hollowing out" of Chinese villages has primarily focused on large-scale geographical levels, such as national, provincial, and municipal scales (Liu et al., 2009, 2021; Yang et al., 2019; Zhang et al., 2019; Guo et al., 2022; Xu et al., 2023). Surveys indicate that rural populations in economically developed areas along the eastern seaboard experience higher rates of outflow, making the phenomenon of hollowing out particularly pronounced. In traditional agricultural regions such as the Yellow and Huaihai Plains and the Two Lakes Plains, the accelerated de-Africanization of the population has led to the emergence of "vacant dwellings or dual residences," further exacerbating rural hollowing out (Yang et al., 2012). Notably, the degree of hollowing out is more severe in the southern and western parts of Anhui Province (Xiao and Liu, 2017), where the three villages examined in this study are located.

In recent years, research on the "hollowing out" of traditional villages has been predominantly based on microscopic case studies (Qu et al., 2022; Tian and Ding, 2024). However, given the vast number of traditional villages in China, additional case studies are needed to provide a more comprehensive understanding of this phenomenon. As of 2025, Anhui Province has 470 traditional villages included in the national protection list, ranking seventh in China (Xinhua News, 2023), with 95 % of these villages located in southern Anhui. The hollowing out of traditional villages is driven by a complex interplay of economic, institutional, social, and environmental factors (Fu et al., 2024; Liu et al., 2021; Liu and Xu, 2021). For example, in the case study of Dongcun in Suzhou City (Wang et al., 2020), the authors measured the degree of village hollowing out across three dimensions: land, population, and industry. Subsequently, multiple regression models were constructed based on land hollowing out, population hollowing out, and industrial and economic hollowing out to micro-analyze their formation mechanisms. This targeted approach is worthy of further reference and expansion in future research.

Therefore, this study focuses on traditional villages in the peripheral, non-tourism-developed areas of southern Anhui. This selection addresses the existing bias towards macro-regional analyses or tourism-oriented cases. By integrating factors such as architectural form, population mobility, and industrial decline, the research employs regression and mediation models to conduct a multidimensional quantitative analysis. Beyond expanding the geographical scope, this study incorporates fieldwork insights to highlight villagers' spontaneous adaptive strategies to hollowing, thereby enhancing both explanatory power and practical relevance.

2. Research contexts: objects and data

2.1. Research scope

The research area of this paper is located in Huangshan City, Anhui Province, historically known as Huizhou. Huizhou is characterized by a geographically enclosed, mountainous terrain with limited land resources. It has historically served as a key migration destination during times of war, contributing to the gradual evolution of a distinctive folk culture (Tang, 2014). Nowadays, Anhui Province, as an integral part of the Yangtze River Delta Economic Circle and neighboring major economic hubs such as Shanghai, Hangzhou, and Nanjing, has consistently been a leading source of outflow of population and outflow workers in China (Dong, 2019; Anhui, n.d). Simultaneously, Anhui remains a major tea-producing region with a high seasonal demand for labor during the

annual tea-picking period, resulting in a two-way labor flow within and beyond the province. Against this backdrop, Anhui region generally adopted a "Combining labor and agricultural" model (Zhang and Chen, 2015), in which villagers balance economic gains and labor demands by integrating agricultural production with migrant work.

A total of 310 villages in Huangshan City, Anhui Province, have been included in the national list of traditional villages, preserving a significant number of historically valuable traditional dwellings. Prior to the introduction of national policies, Anhui Province had already enacted preliminary regulations for the protection of traditional villages (Anhui Provincial Department of Culture and Tourism, 2018; Huangshan Municipal People's Government Office, 2010; The State Council of the People's Republic of China., 2024). These were later expanded to include dedicated funding, institutional frameworks, and the adaptive reuse of historic buildings (China News Network, 2013; Huangshan Municipal People's Government Office, 2014; Xinhua News Agency, 2007). Nevertheless, despite this top-down system that extends from individual structures to whole villages and increasingly comprehensive development plans (Fig. 1), fieldwork indicates persistently high vacancy rates in the central areas of the three case-study villages: Taoyuan (59 %), Wentang (73 %), and Lixi (52 %). In all three, recent planning has remained predominantly oriented toward tourism development.

As shown in the figure (Fig. 2), the three villages in southern Anhui, which are the focus of this study, are located in the northwest of Qimen County, Huangshan City, within the mountainous and hilly region along the Anhui-Gan (Jiangxi) border. This area is geographically remote and distant from local district and county government centers. In Anhui Province, many villages designated as traditional villages or World Heritage Sites (Hongcun and Xidi), have been developed into tourist attractions and are under centralized protection and development. However, the three villages examined in this study remain on the periphery of current planning initiatives. For example, the "World Heritage Area project" aims to leverage the recognition of famous villages to promote the development of certain traditional villages in Qimen County (Anhui Provincial Department of Housing and Urban-Rural Development, 2021). However, whether tourism is the sole viable solution for the survival of all traditional villages in Huangshan City remains an open question worthy of further exploration.

As shown in the figure (Fig. 3), the central village areas of the three villages are located near the river water source, with historical relics concentrated in these regions. Their architectural and cultural heritage, ecological resources, tea plantations, and cultivated land collectively form the foundation for tourism and agricultural development, potentially making them the core areas for future tourism and cultural preservation. Therefore, this study focuses on the central village areas of these three villages to examine the phenomenon of village hollowing and its influencing factors. Additionally, the issue is exacerbated by broader demographic trends, including population aging and the outmigration of young laborers. Thus, this study seeks to identify the underlying causes of residential vacancy in traditional villages in Anhui and provide a reference for other villages in southern Anhui to develop coping strategies.

In 2014, Taoyuan Village merged several administrative villages into a single entity due to a significant decline in the population of neighboring villages, resulting in the downgrading of its original administrative status to a "group". However, in this study, the name "Taoyuan Village" is retained based on its inclusion in the official list of traditional Chinese villages. Wentang Village, which lacks a designated new village zone plan, features a mixed landscape of old and new houses, with both areas merging to form the central village zone. In contrast, Lixi Village has planned a new village area less than 1 km from the central village to alleviate housing shortages in the old settlement.

2.2. Data sources

(1) On-Site Village Survey

According to the village development plan provided by the village committee, basic data on demographics and industrial structure were obtained. In conjunction with field interviews, the occupancy status and construction age of each traditional dwelling were determined. During fieldwork, drones were employed to collect detailed data on the expansion of traditional dwellings and the layout of courtyards, as well as to capture aerial photographs of structures that were difficult to access. Additionally, a rangefinder was used to precisely measure the internal structure of selected traditional houses as part of an individual case study.

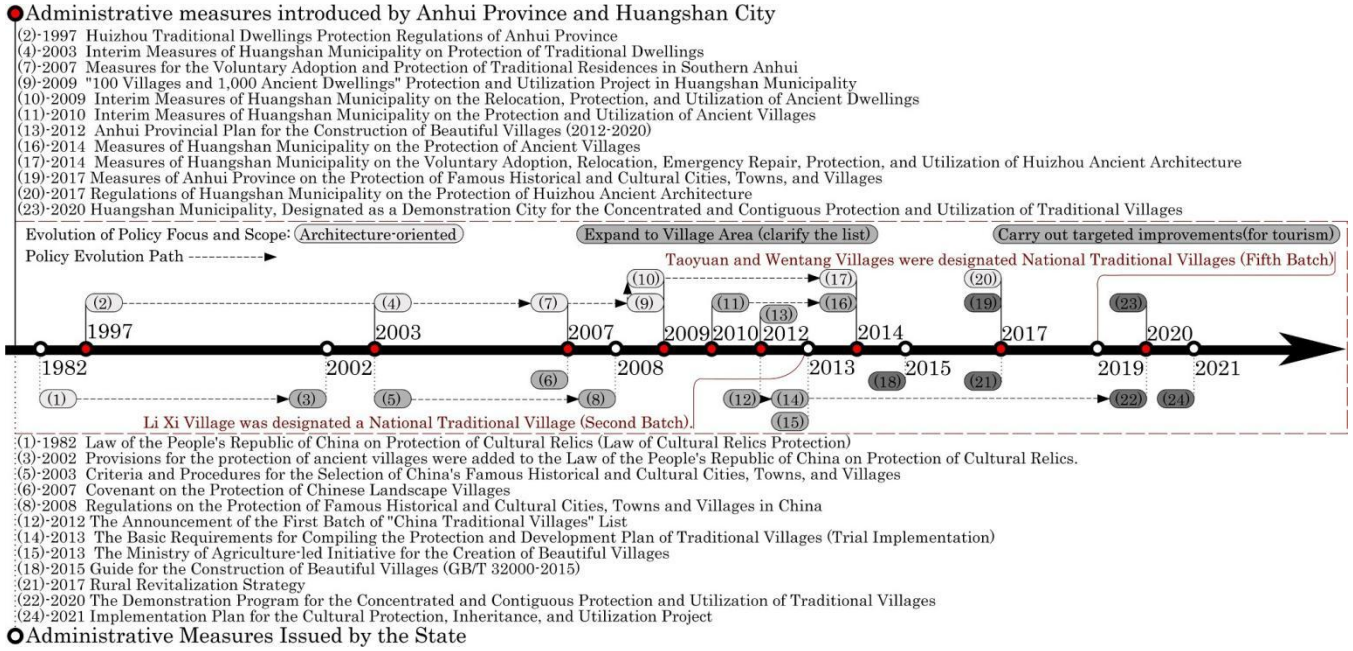


Fig. 1. Policy Measures Implemented at the National Level and at the Local Levels of Anhui Province and Huangshan City.

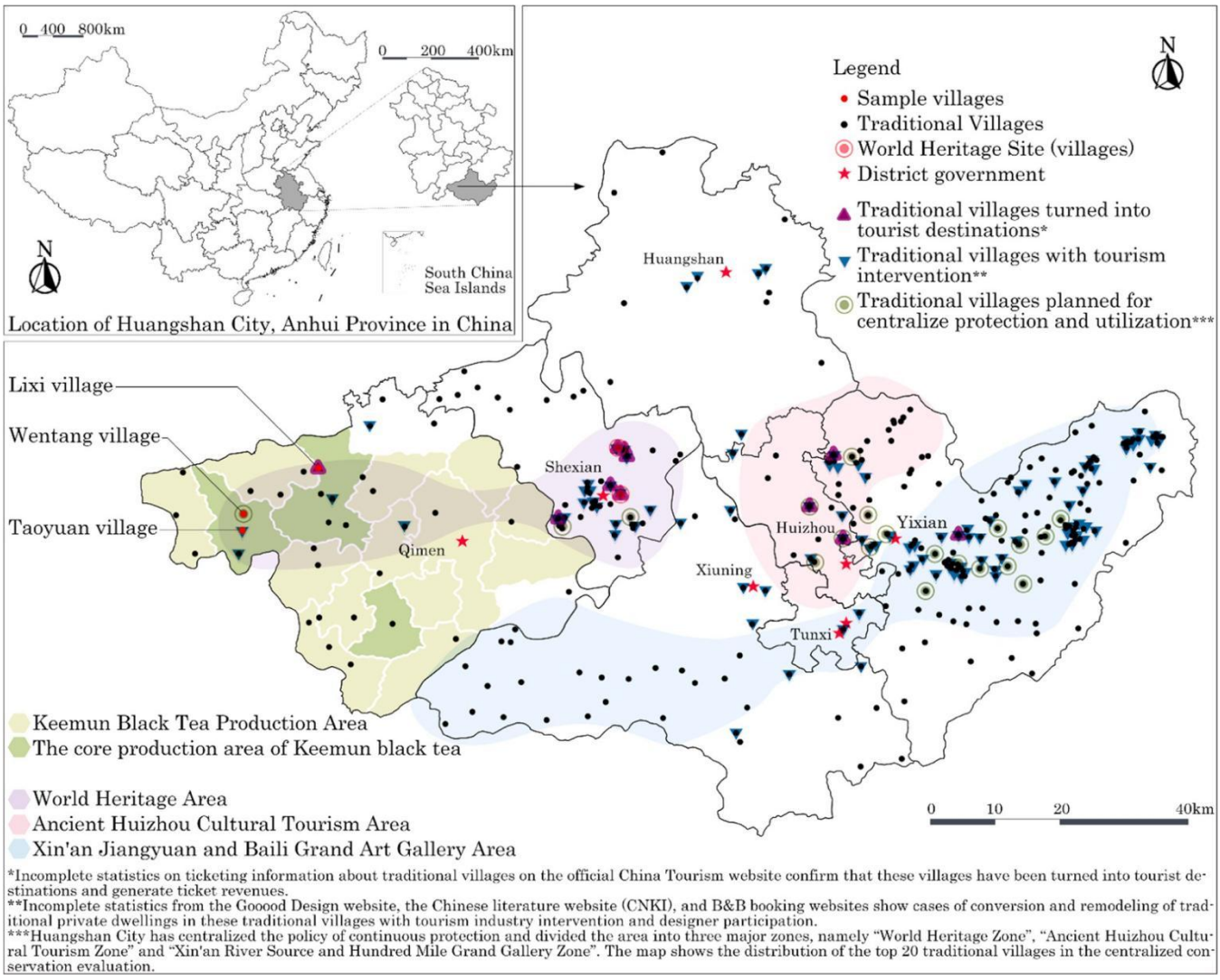


Fig. 2. Location of the three villages in southern Anhui Province.

(2) Population Outflow Survey

This study utilizes population registration data provided by the village committee and population mapping surveys conducted during the COVID-19 pandemic to obtain information on population dynamics and outflow trends. To further clarify villagers' settlement intentions and the reasons for outflow, interviews were conducted with village residents and village chiefs to supplement and validate the data.

3. Research methodology

3.1. Vacant traditional dwellings

(1) Vacancy Rate Calculation

Survey results indicate that the first floor of the main house in traditional village dwellings remains the primary living space for villagers, whereas the second floor is largely vacant or used for storage. The narrow streets and alleys characteristic of Huizhou's traditional villages, originally designed for settlement security and defense in ancient times, have now become inconvenient factors in modern life. Additionally, due to the need to preserve traditional architectural styles and the restrictions on residential land expansion, renovating or enlarging existing houses is challenging. Consequently, the vacancy rate is quantitatively calculated based on the number of main houses in residential dwellings.

(2) Types of Spatial Composition of Traditional Dwellings

Originally established during the Song Dynasty and reaching their peak prosperity in the Ming and Qing Dynasties, these three villages have preserved numerous historical relics, including ancestral halls, Huizhou-style dwellings, ancient temples, and pagodas (Traditional Chinese Village Digital Museum, n.d; Traditional Chinese Village Digital Museum, n.d; Traditional Chinese Village Digital Museum, n.d). The architectural style of Huizhou dwellings is distinct, shaped by geographical and climatic factors. Characteristic features include narrow doors and high windows, light wells, and steeply sloping tile roofs, which serve both defensive and functional purposes (Shan, 2010; Wang, 2013). The traditional Huizhou houses examined in this study are rooted in an agrarian lifestyle and are generally modest in scale, typically consisting of a main house accompanied by attached sheds, cottages, or courtyards.

As shown in the figure (Fig. 4), the traditional dwellings examined in this study can be categorized as follows: I. Main house; II-1. Main house + addition building; II-2. Main house + addition building + courtyard; II-3. Main house + courtyard; III. Combination：multiple rooms. Survey data indicate that the

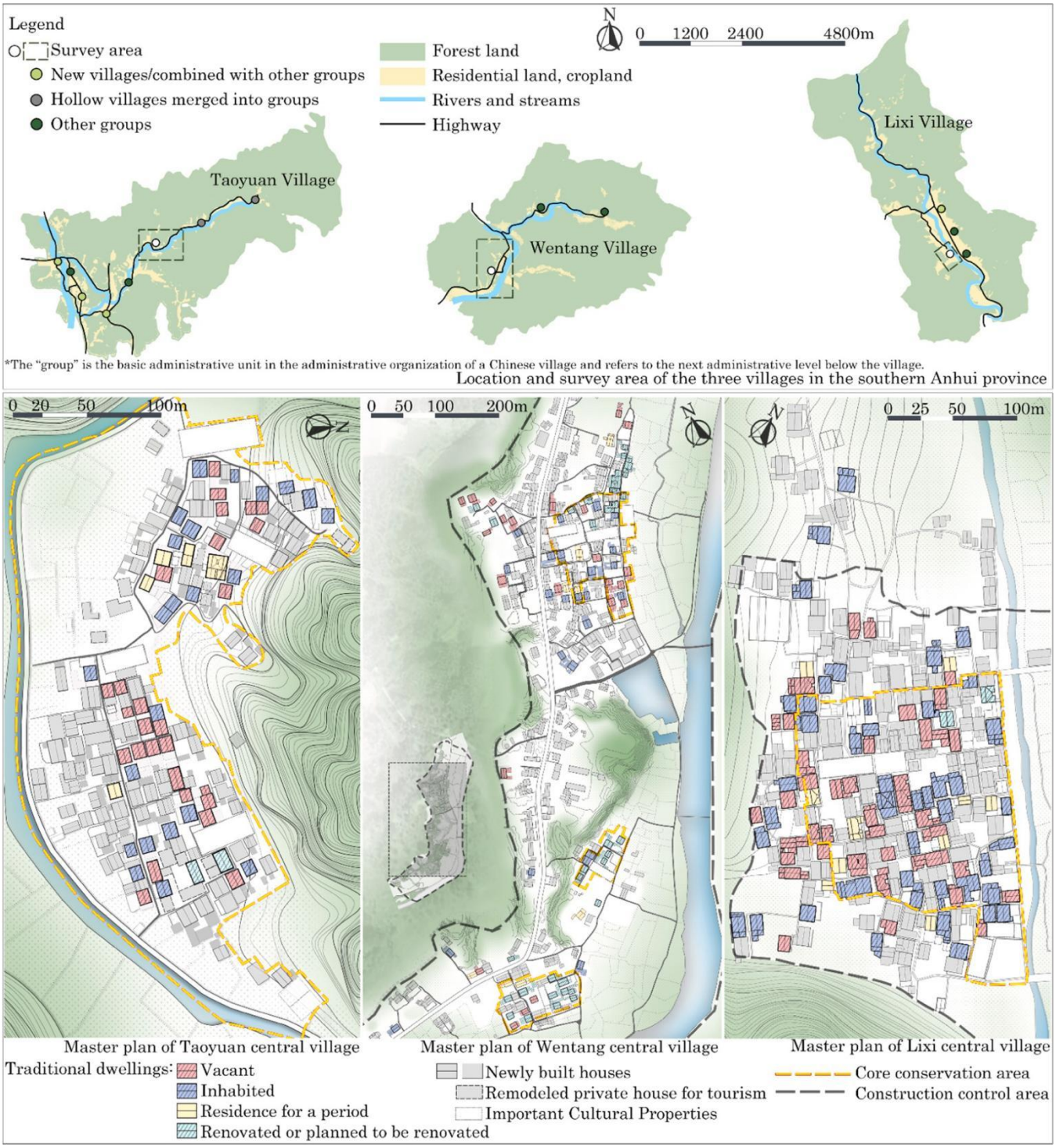


Fig. 3. Profile of the three villages in southern Anhui Province.

vacancy rate for type "II-2." is 15.8 % in Taoyuan Village, 19.1 % in Wentang Village, and 8.8 % in Lixi Village, which is slightly lower compared to other types. In terms of spatial layout, these types of dwellings may be relatively livable.

(3) Deterioration and Vacancy Risk

As shown in the figure (Fig. 5), the older a traditional dwelling is, the higher its vacancy risk becomes. This is particularly evident in dwellings over 100 years old, where deterioration accelerates due to a lack of maintenance and the challenges associated with repairs. Therefore, regular maintenance is essential for the long-term preservation of traditional dwellings.

(4) Conservation Measures and Current Status of Traditional Dwelling Repairs

The protection of traditional Huizhou villages and dwellings is governed by the Law of the People's Republic of China on the Protection of Cultural Relics, which was enacted in 1982 and has since been reinforced through local policies. Survey results indicate that the state of repair and preservation of traditional dwellings in the three villages in southern Anhui can be

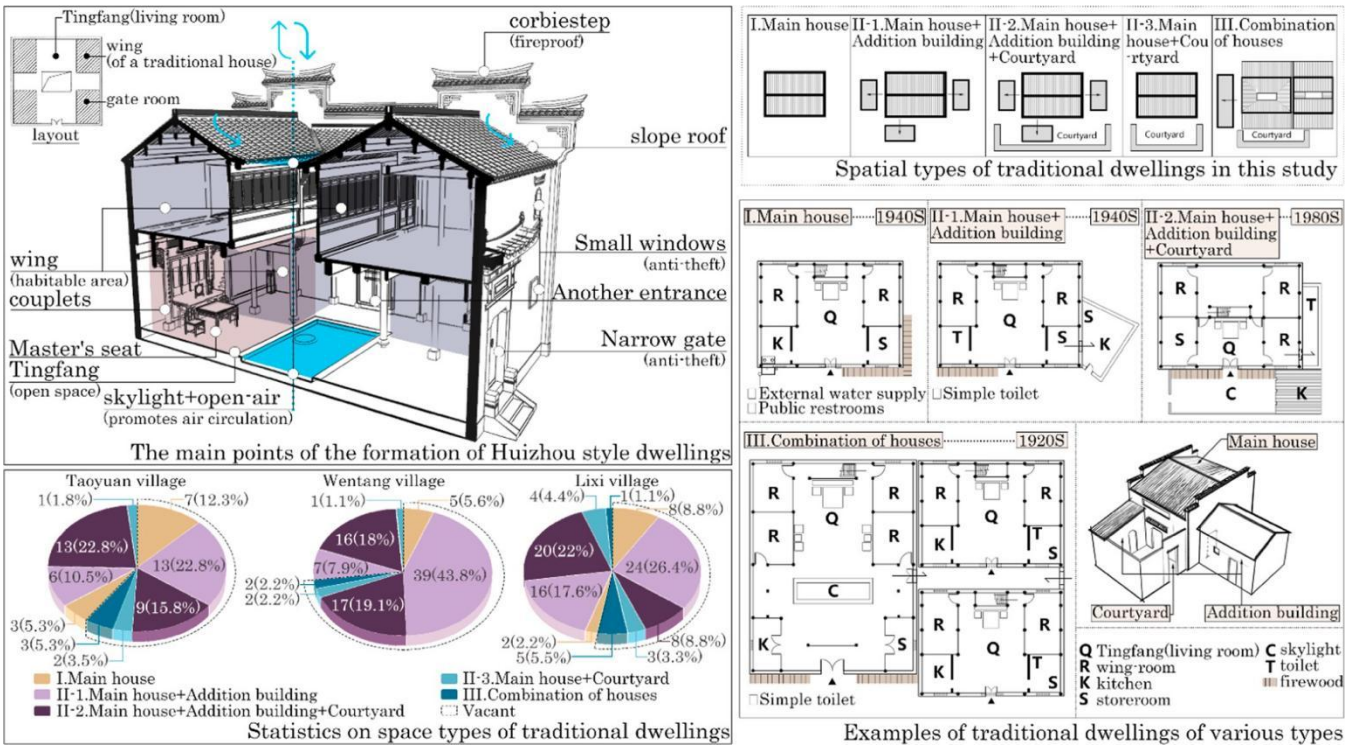


Fig. 4. Types of spatial composition of traditional dwellings and quantitative statistics.

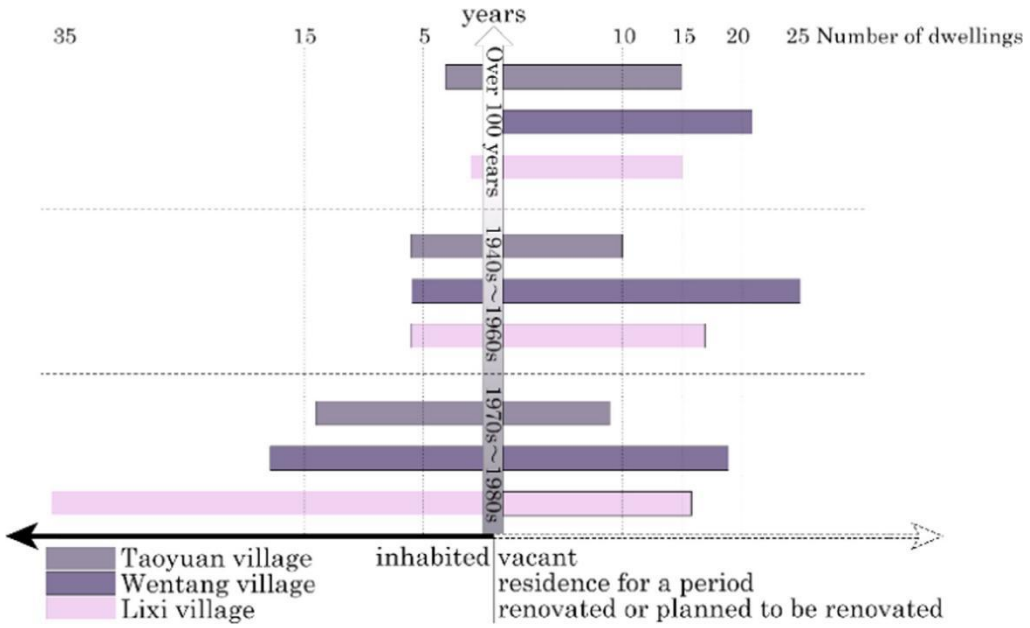


Fig. 5. Statistics on age and number of vacant dwellings.

categorized as follows (Fig. 6):

a. Not repaired for many years (over the past 20 years): not renovated or updated with living facilities for a long time and aging seriously.

b. Repaired with government funding: the government provides financial assistance for dwelling repair.

c. Repaired by villagers on their own initiative: the owners raise their own funds.

d. Functionally remodeled by villagers: dwellings are adapted for tourism, such as local specialties stores, farmhouses, or internally remodeled to improve the living conditions.

e. Remodeled with commercial investment: dwellings are renovated through government or joint enterprise funding for tourism and commercial operations.

(5) Ownership of Traditional Dwellings

In China, rural homestead land is collectively owned by village communities, while households hold only use rights, and transfers are tightly regulated. In traditional villages, cultural heritage protection further restricts transactions, alterations and demolition of dwellings. Under this regime, intergenerational

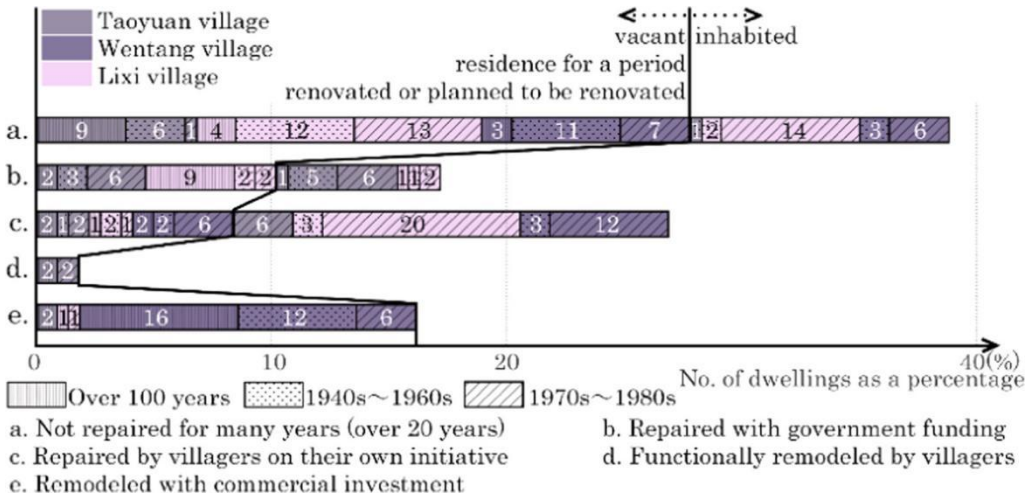


Fig. 6. State of conservation measures statistics of traditional dwellings.

inheritance and ambiguities in collective property rights often result in fragmented, multi-household ownership and related disputes, making it difficult to reach agreement on repair, adaptation or reuse. Out-migration and prolonged absenteeism further hinder routine maintenance and contribute to long-term vacancy. Survey data show that vacant houses associated with fragmented ownership and urban migration account for 31.58 % in Taoyuan, 31.46 % in Wentang and 30.77 % in Lixi. Interviews also indicate that government subsidies for dwellings included in tourism projects encourage some villagers to retain ancestral houses as speculative assets, while intra-family disagreements over their disposal and capitalization keep many of these properties idle.

3.2. Population outflow

(1) Outflow Patterns of Villagers

To quantify villagers' outflow tendencies, this study categorizes outflow patterns into three types based on the distance between their traditional residence (old house) and the new house:

Short-distance outflow: Intra-village relocation, commonly observed when residents move from an old settlement to a new one.

Medium-distance outflow: Relocation to nearby villages with better transportation access, education, and healthcare resources, typically in proximity to towns or county centers.

Long-distance outflow: Relocation to cities or other provinces, primarily driven by employment and educational opportunities. Younger generations, particularly nuclear families, tend to prefer settling in urban areas.

(2) Temporary Population Movements

China's land system maintains a distinction between urban and rural areas, with urban land owned by the state and rural land collectively owned by villages. When rural residents outflow, their land and residential sites often remain vacant due to strict transfer restrictions. The issue of vacancies is particularly pronounced in traditional dwellings, which are subject to cultural heritage protection regulations, preventing arbitrary remodeling or demolition.

Under this land system, rural population movements are predominantly temporary, primarily driven by employment or education. For example, with the acceleration of urbanization in recent years, the "school consolidation and merger" reform has led to the closure of rural schools and the centralization of educational resources in towns and cities. As a result, rural dependence on urban education has increased, further contributing to population loss.

In addition to these common trends, Anhui, as a major tea-producing region in China, has a tea industry primarily based on smallholder farming, relying on hand-picking and traditional processing methods. In the three villages examined in this study, villagers tend to outflow seasonally, returning to their hometowns in the spring for tea picking and engaging in farming during the summer. Income from tea plantations remains one of the main sources of income for these villagers.

(3) Permanent Out-Migration

Have permanently relocated to cities, often driven by higher education opportunities, settlement eligibility, or employment prospects. This trend accelerates rural aging and depopulation, directly contributing to the abandonment of traditional dwellings and the weakening of rural communities.

(4) "Migratory Bird" Households

This refers to families in which the primary workforce is employed in urban areas, while other household members remain in rural villages, relying on a combination of urban incomes and agricultural activities for their livelihoods. Additionally, some villagers choose to maintain an urban-rural commuting lifestyle due to regulatory protections on traditional dwellings, which prevent their direct demolition or reconstruction, combined with the high cost of urban homeownership. A survey of three villages in southern Anhui indicates that 25.33 % of households in Taoyuan Village, 50 % in Wentang Village, and 34.65 % in Lixi Village fall into this category.

3.3. Industry decline

(1) Aging of the Farming Population

Survey results indicate that the resident population in these villages is primarily composed of elderly couples or elderly people living alone, as their children have outflowed to new villages, county towns, or cities for employment, education, or other factors. These "empty nesters" remain engaged in agricultural activities or balance both retirement and farming, playing a role in rural society. As a result, there is a shortage of young laborers, which restricts both the inheritance of agricultural practices and the overall economic development of these villages. According to the survey, more than half of the resident population in the three villages is made up of households with a predominantly elderly population. This demographic shift suggests that as this generation passes away, the vacancy rate of traditional dwellings will

increase, and the proportion of active agricultural operators will further decline.

(2) The Impact of Tourism on Traditional Villages and Villagers' Participation

With the introduction of tourism, the industrial structure of villages has gradually diversified. Some households no longer rely solely on traditional agriculture but have shifted to retail, farming, lodging, and tourism-related services, leveraging local resources to cater to visitors.

However, in the three villages surveyed, villagers' participation in tourism remains low. According to field surveys and statistical data, the tourism participation rate for both villagers residing in traditional dwellings and those in newly built homes did not exceed 2 %, indicating a persistently low level of involvement. This suggests that the direct impact of tourism on villagers' livelihoods is still relatively limited.

3.4. Indicators of influencing factors

Based on the inductive analysis above, the primary factors influencing the vacancy of traditional dwellings can be categorized into three quantifiable dimensions (Table 1): architectural characteristics, household economic conditions, and demographic factors. Consequently, regression modeling is employed as a quantitative analysis method to examine its effects on dwelling vacancy, outflow population, and industrial decline.

The number of students serves as a key indicator of young people's outflow and settlement tendencies, potentially reflecting the scarcity of educational resources. Additionally, this study incorporates per capita cultivated land area as an illustrative variable. In villages still reliant on agriculture, a larger cultivated land area suggests greater sustainability of agricultural livelihoods, which may influence both the residential stability of traditional dwellings and outflow patterns.

The total number of traditional houses in the three villages surveyed in this study is 237, while the total number of households residing in them, or living in multigenerational arrangements, reaches 283. This broader and more detailed data set supports the analysis of intergenerational shelter use and outflow trends.

a. Binary logistic regression model

A binary logistic regression model is a statistical model designed for dichotomous classification tasks, primarily used to predict the probability of a target variable belonging to one of two categories. In this study, housing vacancy is set as the explanatory variable, while building-level factors serve as explanatory variables to quantitatively assess their effects on the probability of a house being vacant. The binomial logistic regression formula is as follows:

$$P = \frac{\exp(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k)}{1 + \exp(\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k)}$$

In the binary logistic regression model, P represents the probability that the target variable equals 1 (vacant), ranging from 0 to 1. The explanatory variables x_1, x_2,...,x_k denote factors believed to contribute to housing vacancy, such as construction age and spatial composition. The partial regression coefficients β_1, β_2,...,β_k quantify the extent to which each explanatory variable influences the probability of a house being vacant, enabling a quantitative evaluation of their contributions. The total number of explanatory variables included in the model is denoted by k.

b. Multiple Linear Regression Model

In this study, household economic factors (e.g., Type of off-farm employment, Arable land per capita) and population composition variables (e.g., Generational composition, number of the elderly, number of students) are set as explanatory variables. The labor outflow rate and age distribution of laborers serve as target variables.

Table 1
Three types of relevant variables affecting the vacancy of traditional dwellings.

Category	Variable	Description Measurement	
Explanatory variable			
Traditional dwellings Architectural situation	Building year	Building year of dwelling (years)	Scale
	Types of Spatial Composition	(I.) =1, (II-1.) =2, (II-2.) =3, (II-3.) =4, (III.) =5	Nominal
	Ownership	Single family hold in=1, Multi-family holding=2	Nominal
	Maintenance status	(a.) =1, (b.) =2, (c.) =3, (d.) =4, (e.) =5	Nominal
	New residence location	Main village/ None= 1, Urban area/ both= 2, Rural areas (other villages) = 3	Nominal
Family economic aspects	Type of off farm employment	Abandonment of farm/urban employment = 1, Farming + off farm= 2, Farming-based= 3	Nominal
	Income composition	①、②、③、④、⑤: ①+ ②= 1, ①+ ②+ ③= 2, ①+ ④= 3, ①+ ⑤= 4, ①+ ④+ ⑤= 5, ③+ ④= 6, ④= 7	Nominal
	Arable land per capita	Arable land area (mu, 1 mu≈667 m²)	Scale
Family population structure	Generational composition	Household registration: ; Elderly only= 4, Elderly+ 2nd generation= 3, Elderly+ 2nd generation+ 3rd generation= 2, 2nd generation+ 3rd generation/single= 1	Nominal
	Number of students	Sum of juvenile students younger than 18 and undergraduates	Scale
	Number of the elderly	Count of the people older than 60	Scale
Target variable			
Residential state of traditional dwelling		Vacant (residence for a period, renovated) = 1, Inhabited= 0	Nominal
Percentage of outflow population and long-term outflow population		Number of outflow population and long-term outflow population/number of persons registered in household registers = %	Scale
Age of the youngest agricultural laborer		Age18~44 = 1, 45–60 = 2, over 60 = 3, abandoned farming= 4	Scale

Note:
I. Main house, II-1. Main house + addition building, II-2. Main house + addition building + courtyard, II-3. Main house + courtyard, III. Combination: multiple rooms.
a. Not repaired for many years (over the past 20 years), b. Repaired with government funding, c. Repaired by villagers on their own initiative, d. Functionally remodeled by villagers, e. Remodeled with commercial investment
①: Agriculture (black tea, rice, etc.) ②: Business in the village (retail, carpentry, etc.) ③: Tourism-oriented (farmhouse, family restaurant, etc.) ④: Working outside the home (including families who moved to towns) ⑤: None (pension, unemployment, etc.)

This analysis enables a quantitative evaluation of the contribution of each factor, facilitating a comprehensive understanding of population outflow and industrial decline. The basic formula for multiple linear regression is as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \epsilon$$

In the multiple linear regression model, Y represents the target variable (e.g., labor outflow rate or labor age distribution), while x_1, x_2,...,x_n are the explanatory variables, such as household economic

factors and population composition metrics. The regression coefficients β_1, β_2,...,β_n indicate the magnitude of the effect of each explanatory variable on the target variable. The error term ϵ accounts for the portion of the model that cannot be explained by the selected variables. This framework enables a quantitative assessment of the relationship between economic and demographic factors and their impact on population outflow and industrial decline.

c. Spearman's Correlation Analysis

Spearman's correlation analysis is a nonparametric statistical method used to measure the monotonic relationship between two variables. In this study, Spearman's correlation is applied to assess the relationships between vacancy rate, labor outflow rate, and age distribution of laborers. The Spearman's correlation coefficient (ρ\rhoρ) is calculated using the formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

Where d_i represents the rank difference between paired observations, and nnn is the number of observations. The coefficient ranges from —1–1, where 1 indicates a perfect positive monotonic relationship, —1 indicates a perfect negative monotonic relationship, and 0 suggests no correlation.

4. Results and analysis

To ensure the reproducibility of the results obtained, this study does not employ univariate regression. Instead, all data are subjected to multiple regression analysis to evaluate the strength and magnitude of the influencing factors. This approach allows for a more comprehensive assessment of the relationships between variables, ensuring a robust and reliable analysis.

4.1. Binary logistic regression results of vacant traditional dwellings

The sample consists of 237 traditional dwellings, with the explanatory variables categorized into five groups: "Building Year", "Spatial Composition", "Ownership", "Maintenance Status", and "Location of the New Residence". These factors were further subdivided into 16 specific items. The target variable indicates whether a traditional dwelling is vacant (1) or inhabited (0). A binary logistic regression model was applied to analyze the impact of these explanatory variables on housing vacancy, enabling a quantitative assessment of their influence.

Binary logistic regression analysis employs a stepwise approach, sequentially adding or removing variables to refine the model. In this analysis, 16 explanatory variables were initially included, and unnecessary variables were eliminated to simplify the model. Variables were selected or removed in each step based on their statistical significance, ensuring that the final model remained statistically reliable. Additionally, reducing the number of variables enhances the interpretability of the model, making it easier to analyze the key factors influencing dwelling vacancy.

(1) Selection of the model

The Hosmer-Lemeshow test results, as shown in Table 2, indicate that Step 1 has a p-value of 0.926, suggesting an excellent model fit. In Step 2, the p-value decreases to 0.605, indicating a slightly weaker fit but still within an acceptable range. Regarding overall accuracy, Step 1 achieves 81.4 %, which is marginally higher than the 81.0 % of Step 2. However, when considering Nagelkerke R^2, Step 2 demonstrates an explanatory power of 0.602, while Step 1 has a slightly higher explanatory power of 0.649.

Based on these results, Step 1 was selected as the final model, as its variables were statistically significant, and the Hosmer-Lemeshow test indicated a sufficiently good fit, ensuring a balance between model simplicity and statistical robustness.

Table 2
Stepwise logistic regression model fit and performance.

Model Evaluation	Metric	Step1	Step2
Hosmer-Lemeshow Test	Chi-square	3.134	6.381
	df	8	8
	Sig.(p)	0.926	0.605
Model summary	-2 Log Likelihood	161.181[a]	176.175[a]
	Cox-Snell R^2	0.477	0.443
	Nagelkerke R^2	0.649	0.602
Overall Correct Percentage (%)		81.4 %	81 %

(2) Analysis of results

This Table 3 presents the results of the analysis, highlighting key variables influencing dwelling vacancy. One of the most impactful factors is Spatial Composition, particularly type II-2. (Main house + Addition building + Courtyard), which significantly reduces the likelihood of vacancy. Similarly, type II-3. (Main house + Courtyard) and type III. (Combination of houses) also exhibits a lower probability of vacancy, with p-values of 0.068 and 0.082, respectively. However, since these values exceed the 0.05 significance threshold, their effects are not statistically significant. Another critical factor is "Maintenance Status", specifically c. (Repaired by villagers on their own initiative), which significantly reduces the vacancy rate. Conversely, among the "New Residence Location" variables, "Urban area/both" is associated with an increased probability of dwelling vacancy, suggesting that relocation to urban areas contributes to dwelling abandonment in traditional villages.

With respect to "Building Year", since it is a continuous variable, its cumulative impact can be significant when the range of variation is large. For instance, if a dwelling's age approaches 50 years, the cumulative effect is calculated as $0.956^{50} \approx 0.105$, indicating that the risk of dwelling vacancy may be significantly lower for older dwellings. In contrast, when considering short-term or category-specific effects, "Spatial Composition (II-2.)" has a greater impact on vacancy reduction compared to "Building Year". However, in terms of long-term or cumulative effects, "Building Year" (B=0.045) may exert a broader influence, particularly when there are large chronological differences among buildings.

Table 3
Binary logistic regression results of vacant traditional dwellings (Step1[a]).

Variable	Coefficient *B*	*S.E.*	*Wald*	*p*	*OR*
Building year	-0.045	0.012	14.311**	0.000	0.956
(I.)			18.130	0.001	
(II-1.)	-0.812	0.777	1.092	0.296	0.444
(II-2.)	-2.419	0.799	9.153**	0.002	0.089
(II-3.)	-2.009	1.102	3.321*	0.068	0.134
(III.)	-2.790	1.602	3.033*	0.082	0.061
Multi-family holding	20.228	6276.5	0.000	0.997	6096
(a.)			12.602	0.013	
(b.)	-1.103	0.563	3.843**	0.050	0.332
(c.)	-1.559	0.461	12.406**	0.001	0.202
(d.)	-25.216	16360.9	0.000	0.999	0.000
(e.)	19.852	6042.76	0.000	0.997	4186
Main village/None			4.947	0.084	
Urban area/both	0.928	0.423	4.804**	0.028	2.529
Rural areas (other villages)	0.809	0.762	1.130	0.288	2.247
Constant	89.206	23.311	14.644	0.000	5.518

Note: ** $p < 0.05$. * $p < 0.1$. S.E. represents Standard Error, OR represents Odds Ratio.

(3) Critical factors and policy recommendations

As mentioned above, spatial composition, particularly type II-2. (Main house + Addition building + Courtyard) is a key factor in mitigating housing vacancy. Therefore, it is essential to prioritize support for the design and reconstruction of private traditional dwelling conversions while also developing policies that promote the maintenance and adaptive reuse of older traditional dwellings. Additionally, since population outflow to urban areas may further exacerbate the issue of vacancy, policy interventions should be implemented to encourage rural residency. This could include incentives for rural living, improvements in infrastructure and services, and programs that enhance economic opportunities in traditional villages, ultimately fostering a more sustainable rural settlement pattern. By fostering a more livable and economically viable rural environment, these policies can mitigate population outflow pressures and contribute to the sustainable revitalization of traditional villages.

4.2. Results of multiple linear regression for population outflow

The sample size for this study is 283 households, with the explanatory variables categorized into seven groups and further subdivided into more than 18 specific items. These variables include "New residence location", "Type of off-farm employment", "Income composition", "Arable land per capita", "Generational composition", "number of students", and "number of elderly people".

The income composition category consists of data combinations of multiple items, such as "①+ ④+ ⑤" or "①+ ④". The target variables for this analysis are the proportion of outflow population and long-term outflow population, which were examined using multiple linear regression to assess the influence of various socioeconomic and demographic factors on outflow patterns.

Multiple linear regression analyses use a stepwise approach, where variables are added or removed sequentially to select the most appropriate variables for the model. In this type of analysis, the explanatory power of the model can be enhanced by selecting among the explanatory variables whose effects on the target variable are statistically significant. In addition, removing irrelevant variables or variables of low relevance prevents overfitting and improves generalizability. A feature of the stepwise method is that even if a large number of variables are included, only the variables with the greatest impact are selected, so that simple and easy-to-solve models can be constructed. The model's coefficient of determination (R^2) or adjusted coefficient of determination is used as an indicator to continuously test whether the added variables improve the explanatory power of the model.

(1) Selection of the model

In Steps 1–6(Table 4), the Sig. F change is 0.000, and the R^2 value increases significantly, confirming that these steps are statistically reliable. However, in Steps 7 and 8, although the Sig. F change remains significant, the F change is minimal, indicating that the added variables have a limited effect on the model. These results validate that the model up to Step 6 is both statistically robust and exhibits a sufficient increase in R^2. Therefore, Step 6 was selected to construct a reliable model incorporating the key explanatory variables. According to the fitting results, the R^2 value is 0.752, meaning that 75.2 % of the variance in the target variables is explained by the selected explanatory variables. This result demonstrates that the model possesses high explanatory power and effectively captures the primary factors influencing outflow population and dwelling vacancy trends.

Table 4
Stepwise multiple linear regression model summary and ANOVA test (Population outflow).

Model	Model Summary			ANOVA[a]	
	R^2	F Change	Sig. F Change	F	Sig.(p)
1	0.399	186.792	0.000	186.792	0.000
2	0.573	113.653	0.000	187.665	0.000
3	0.658	69.709	0.000	179.047	0.000
4	0.701	39.911	0.000	162.991	0.000
5	0.726	25.322	0.000	146.865	0.000
6	0.752	28.359	0.000	139.202	0.000
7	0.759	7.906	0.005	123.431	0.000
8	0.763	4.735	0.030	110.061	0.000

(2) Analysis of results

This Table 5 presents the results of multiple linear regression analyses, evaluating the impact of each explanatory variable on the proportion of outflow population and long-term outflow population (the target variable). Among the variables, "④.Working outside the home (including families who moved to towns)" has the greatest influence on the outflow rate. The combined variables "①+ ④" and "①+ ④+ ⑤" also exhibit significant effects, ranking as the next most influential factors. Conversely, variables such as "New residence location (Main village/None)", "Generational composition (Elderly only)", and "Type of off-farm employment (Farming-based)" contribute to a lower outflow rate, though their individual impact remains relatively small. These findings highlight the dominant role of employment opportunities outside the home in driving outflow, while traditional rural occupations and generational composition play a more moderate role in population retention.

As discussed above, local employment-generating projects should be promoted to reduce dependence on urban areas for job opportunities. This can be achieved by developing local industries and strengthening the tourism sector, creating more sustainable employment within rural communities. Additionally, since the "①+ ④" income composition has the second-largest impact after the population exodus rate, balancing agricultural work with external employment remains a challenge. To enhance agricultural profitability, policies should focus on promoting the production and consumption of local agricultural products while stimulating intra-regional economic activity. For the "①+ ④+ ⑤" income group, family structure plays a significant role in outflow decisions. Therefore, supporting two- or three-generation households is crucial. Specific measures should include childcare and eldercare subsidies to ease the burden on multigenerational families and encourage cohabitation. Furthermore, developing composite settlements and improving local public services—such as education, healthcare, and welfare—can help align work and living spaces, fostering a more sustainable rural community. These initiatives can enhance rural quality of life and promote long-term population retention.

4.3. Multiple linear regression results for industrial decline

The sample size for this study consisted of 283 households, with explanatory variables set according to the "Factors Affecting the Outflow of Population." These variables were classified into seven categories and further subdivided into at least 18 specific items. Since some data combined multiple factors (e.g., "①+④+⑤" or "①+②+③").

The stepwise method was still used for this analysis. This eliminates variables that are too highly correlated (multicollinearity) and ensures stability of the regression coefficients. In addition, by eliminating unnecessary variables, it was possible to construct a suitable and easily interpretable model.

(1) Selection of the model

In Step 7(Table 6), the Sig. F Change = 0.000 indicates that the model is statistically significant and can be considered reliable. While Step 8 achieves a slightly higher $R^2$0.750, the Sig. F Change = 0.030, making it less significant than Step 7. Additionally, Step 8 shows a decline in the significance of the newly added

Table 5
Results of multiple linear regression for population outflow (Model 6).

Variable	Unstandardised coefficients		Standardised coefficients β	*t*-statistics	Sig.(p)	VIF
	B	*S.E.*				
Constant	0.402	0.053		7.645	0.000	
Type of off-farm employment (Farming-based)	-0.106	0.033	-0.129	-3.195*	0.002	
④	0.589	0.057	0.682	10.306*	0.000	1.813
Generational composition (Elderly only)	-0.111	0.051	-0.110	-2.177*	0.030	4.869
New residence location (Main village/None)	-0.176	0.028	-0.232	-6.270*	0.000	2.849
①+ ④	0.420	0.056	0.417	7.433*	0.000	1.518
①+ ④+ ⑤	0.268	0.050	0.337	5.325*	0.000	3.498

Note: * p < 0.05. S.E. represents Standard Error, VIF is the Variance Inflation Factor (multicollinearity test).
④: Working outside the home (including families who moved to towns)
+ ④: Agriculture (black tea, rice, etc.) + Working outside the home (including families who moved to towns)
①+ ④+ ⑤: Agriculture (black tea, rice, etc.) + Working outside the home (including families who moved to towns) + None (pension, unemployment, etc.)

(3) Critical factors and policy recommendations

Table 6
Stepwise multiple linear regression model summary and ANOVA test (Industrial Decline).

Model	Model Summary			ANOVA[a]	
	R^2	F Change	Sig. F Change	F	Sig.(p)
1	0.435	216.103	0.000	216.103	0.000
2	0.581	97.321	0.000	193.750	0.000
3	0.647	52.802	0.000	170.664	0.000
4	0.647	0.104	0.748	256.765	0.000
5	0.680	28.794	0.000	197.767	0.000
6	0.706	24.176	0.000	166.690	0.000
7	0.744	41.214	0.000	160.885	0.000
8	0.750	7.037	0.008	138.166	0.000
9	0.758	8.756	0.003	123.006	0.000
10	0.762	4.307	0.039	109.463	0.000

variables, suggesting that their contribution to the model is limited. Furthermore, Steps 9 and 10 exhibit the highest explanatory power with R^2= 0.758 —0.762. However, the increased complexity of the model at these stages reduces interpretability and raises concerns about overfitting.

Based on these findings, Step 7 was selected to construct a reliable model that includes the most relevant explanatory variables. With an R^2= 0.744, the model explains 74.4 % of the variance in the target variable, demonstrating high explanatory power while maintaining simplicity and interpretability.

(2) Analysis of results

This Table 7 presents the results of multiple linear regression analysis examining factors influencing the age of the youngest agricultural laborer. The variable with the greatest impact on labor force rejuvenation and agricultural sustainability is "Type of off-farm employment (Farming + Off-farm)", followed by "(Farming-based)", indicating that maintaining a balance between farming and external employment supports a younger agricultural workforce.

Additionally, "New residence location (Main village/None)" contributes to some extent to the rejuvenation of the farming population, suggesting that those who remain in or do not relocate from the village tend to engage in agricultural work at a younger age. Similarly, in the case of "New residence location (Urban area/both)", there is a slight contribution to retaining young people in agriculture. However, its influence is weaker than that of "(Main village/None)", indicating that rural-based settlement is more strongly associated with maintaining a younger agricultural labor force. Notably, "①+ ⑤" is the only positive influence, indicating its association with the aging of the agricultural population.

(3) Critical factors and policy recommendations

The results suggest the need for policies centered on "Type of off-farm employment" and "New residence location" to sustain a young workforce in agricultural areas.

Encouraging local employment through financial incentives, such as start-up bonuses, can help retain young workers. Additionally, improving infrastructure, including high-speed internet and remote work environments, can enable more young people, including urban migrants, to work locally without having to relocate to cities. Strengthening local industries and tourism development can also create diverse employment opportunities within rural areas.

Supporting village-based living is equally important, as residential choices directly influence youth outflow and agricultural abandonment. Policies should include subsidies for housing construction, purchase, and renovation to encourage young people to stay in rural areas.

Furthermore, education and training programs should be developed to facilitate intergenerational knowledge transfer, ensuring that elderly farmers can pass on their expertise to younger generations. Establishing agricultural schools and vocational training centers can increase young people's interest in farming and provide them with modern agricultural skills. By promoting these initiatives, rural areas can enhance youth engagement in agriculture, improve the sustainability of local economies, and foster long-term community development.

Table 7
Results of multiple linear regression for industrial decline (Model 7).

Variable	Unstandardised coefficients		Standardised coefficients β	*t*-statistics	Sig.(p)	VIF
	B	*S.E.*				
Constant	4.919	0.159		31.008	0.000	
Type of off-farm employment (Farming+off-farm)	-2.325	0.109	-0.961	-21.280*	0.000	2.205
Type of off-farm employment (Farming-based)	-2.041	0.149	-0.799	-13.685*	0.000	3.682
①+ ⑤	0.904	0.127	0.295	7.132*	0.000	1.856
New residence location (Main village/None)	-1.033	0.125	-0.437	-8.256*	0.000	3.029
New residence location (Urban area/both)	-0.947	0.148	-0.401	-6.420*	0.000	4.223

Note: * p < 0.05. S.E. represents Standard Error, VIF is the Variance Inflation Factor (multicollinearity test).
+ ⑤: Agriculture (black tea, rice, etc.) + None (pension, unemployment, etc.)

4.4. Results of correlation analysis and mediation effects analysis

The above analysis confirms that the sample consists of 237 traditional private houses and 283 households, and that the corresponding target variables (dwelling vacancy, population outflow percentage, and the age of the youngest agricultural laborer) are strongly correlated with their respective explanatory variables.

However, the analysis does not establish a direct relationship between the three target variables themselves. While each target variable is independently associated with its respective explanatory variables, the interdependence among housing vacancies, population outflow, and laborer aging require further examination. Additional mediation or structural equation modeling could help determine whether these variables influence one another directly or through intermediate factors.

When conducting the analysis, it is essential to standardize the sample size to ensure data consistency and precision. Since the number of vacant houses was 237 and the number of households was 283, 46 additional samples were recorded as "1" for vacant houses to align the dataset, thereby standardizing the sample size.

To examine the relationships between dwelling vacancy, population outflow rate, and industrial decline, correlation analysis was performed. This analysis confirmed significant associations among these factors, indicating their interconnected nature. Furthermore, to verify the mediation effects, covariance structure analysis was conducted, allowing for a deeper understanding of the indirect relationships between population outflow, dwelling vacancy, and industrial decline in traditional villages.

(1) Correlation analysis results

Spearman's correlation coefficient is a nonparametric statistical method used to measure the monotonic relationship between two variables, making it suitable for analyzing nonlinear associations and ranked (sequential) data.

In this study, Spearman's correlation analysis was conducted using SPSS to assess the relationships between vacancy rate, population outflow rate, and the age of the youngest agricultural laborer. This analysis helps determine the strength and direction of associations between these key variables, providing insights into how dwelling vacancy, population mobility, and workforce aging are interconnected in traditional villages.

As shown in Table 8, the results indicate a particularly strong relationship between the proportion of outflow population and vacant dwelling, with a correlation coefficient of 0.603, confirming a strong positive correlation. This suggests that as the number of outflowed households increases, traditional dwellings are more likely to become vacant. Since this correlation is statistically significant at the 0.01 level, it confirms a solid statistical relationship.

Additionally, the correlation coefficient between the proportion of outflow population and the age of the youngest agricultural laborer is 0.385, indicating a moderate positive correlation. This suggests that in households with a high proportion of outflow, the age of agricultural laborers tends to be higher. In other words, as more villagers leave the village for employment, those who remain behind in the agricultural laborer tend to be older, contributing to the aging of the rural labor force. This relationship is also statistically significant at the 0.01 level.

Furthermore, the correlation coefficient between vacant dwellings and the age of the youngest agricultural laborer is 0.208, representing a weak positive correlation. Despite the weaker relationship, this finding suggests that traditional dwellings are more likely to become vacant in households where laborers are aging. Since this correlation is also significant at the 0.01 level, it supports the conclusion that both rural aging and population outflow play a role in increasing dwelling vacancy.

Based on the above findings, a binary logistic regression analysis was conducted to further examine the relationship between population outflow, the age of the youngest agricultural laborer, and dwelling vacancy. In this model, the proportion of population outflow and the age of the youngest agricultural laborer were set as explanatory variables, while vacancy status (1 = vacant, 0 = inhabited) was the target variable.

The results (Table 9) strongly indicate that the proportion of population outflow is the most significant factor influencing the dwelling vacancy. Specifically, a higher proportion of outflow households significantly increases the likelihood of a dwelling becoming vacant. This finding reinforces the idea that rural depopulation directly contributes to the rise in vacant traditional dwellings. Conversely, the age of the youngest agricultural laborer was found to be statistically insignificant, suggesting that its impact on vacancy status is limited. This implies that while rural aging may play a role in long-term demographic shifts, the immediate driver of dwelling vacancy is population outflow. The likelihood ratio chi-square test with $p < 0.05$ confirms that at least one of the explanatory variables significantly impacts the dwelling vacancy rate, indicating the model has predictive validity.

(2) Mediation effect analysis results

Because the age of the youngest agricultural worker exhibits only a weak positive correlation with housing vacancy and no significant effect in the binary logistic regression, we further investigate potential mechanisms using structural equation modeling (SEM) with mediation analysis. Mediation analysis examines whether the effect of an explanatory variable on an outcome is transmitted through an intermediate variable. Using SEM, it quantifies both direct and indirect effects,

Table 8
Spearman's rank correlation coefficients among vacancy rate, proportion of outflow, and age of the youngest agricultural laborer.

Spearman Rho		Vacancy rate	Percentage of outflow population and long-term outflow population	Age of the youngest agricultural laborer
Vacancy rate	Correlation Coefficient	1	0.603**	0.208**
	Significance (Two-tailed)	.	0.000	0.000
	Sample Size	283	283	283
Percentage of outflow population and long-term outflow population	Correlation Coefficient	0.603**	1	0.385**
	Significance (Two-tailed)	0.000	.	0.000
	Sample Size	283	283	283
Age of the youngest agricultural laborer	Correlation Coefficient	0.208**	0.385**	1
	Significance (Two-tailed)	0.000	0.000	.
	Sample Size	283	283	283

Table 9
Binary logistic regression results of vacant traditional dwellings.

Variable	Coefficient *B*	*S.E.*	*Wald*	*p*	*OR*
Percentage of outflow population and long-term outflow population	3.991	0.479	69.313**	0.000	54.10
Age of the youngest agricultural laborer	0.153	0.148	1.068	0.301	1.165
Constant	-1.713	0.428	16.056	0.000	0.180
Chi-squared Test 109.174 ($p<0.05$)					
Hosmer-Lemeshow Test 22.486 ($p<0.05$)					

Note: ** $p < 0.05$. S.E. represents Standard Error, OR represents Odds Ratio.

providing a more nuanced representation of the relationships among population out-migration, the age of the youngest agricultural laborer, and the occupancy status of traditional dwellings.

The results (Table 10) of the mediation analysis examine the relationship between the descriptive variable X (age of the youngest agricultural laborer), the mediating variable M (percentage of outflow population and long-term outflow population), and the outcome variable Y (dwelling vacancy).

According to the table, the overall model is statistically valid, with an R^2= 0.0908 and an F-value = 28.0588. The p-value = 0.000 (less than the 5 % significance level) confirms that the model is statistically significant. The "X + M → Y" model demonstrates explanatory power for the target variable (dwelling vacancy), suggesting that "the proportions of outflow population and long-term outflow population" partially mediates the relationship between "the youngest agricultural laborer's age" and "dwelling vacancy". Additionally, the Nagelkerke R2 value indicates moderate explanatory power, further supported by a p-value = 0.000, which confirms the robustness of the mediation effect and the statistical validity of the overall model.

The above results indicate that the younger the youngest agricultural laborers, the higher the percentage of outflowing population, which in turn significantly increases housing vacancy rates. Addressing the loss of young laborers through targeted policies—such as local employment promotion, improved infrastructure, and housing incentives—is therefore a key strategy for mitigating the housing vacancy problem. By encouraging younger generations to remain in rural communities, it is possible to stabilize the agricultural workforce and reduce the long-term risks of depopulation and structural decline.

5. Discussion

As shown in the figure (Fig. 7), the analysis results indicate that traditional dwelling vacancy is not solely architectural level issue but is also influenced by the social and economic structure of the village, particularly population exodus and labor shortages. To effectively address the vacancy problem, a comprehensive approach is required, taking into account both structural and socioeconomic influences. By integrating population, economic, and architectural solutions, these measures will not only reduce traditional dwelling vacancies but also support the long-term sustainability and revitalization of rural communities.

5.1. Residential vacancy

(1) Key factors inhibiting traditional dwelling vacancies

Among the key factors that reduce vacancy, spatial composition (II-2. main house + addition building + courtyard) and maintenance status (c. Repaired by villagers on their own initiative) are the most significant. Dwellings with additional buildings and courtyards are more likely to remain inhabited, suggesting that a more functional and adaptable spatial composition supports continued occupancy. Similarly, dwellings that have been repaired by their owners show a lower vacancy risk, emphasizing the importance of ongoing preservation and upkeep. Conversely, the "New residence location (Urban area/both)" is associated with a higher vacancy rate in traditional dwellings, reinforcing the idea that rural-to-urban migration directly contributes to housing abandonment. Additionally, the age of the dwelling significantly increases the risk of vacancy, indicating that older structures are more prone to being abandoned, likely due to deterioration, lack of modern amenities, and higher maintenance costs.

(2) Promoting the reuse of traditional dwellings

Based on the results of the analysis, policies should focus on renovating traditional dwellings to enhance their usability, livability, and sustainability. Efforts should be directed toward optimizing space utilization, improving the residential environment, and promoting the repair and adaptive reuse of deteriorated structures.

First, policy support should extend to fostering economic growth, cultural preservation, and tourism development, ensuring that villages remain vibrant and attractive for both residents and visitors. Additionally, village revitalization should not rely solely on the local government but instead adopt a collaborative approach involving businesses, NGOs, and social elites. By leveraging public-private partnerships, a bottom-up development model can be promoted, allowing for community-led decision-making and sustainable development initiatives. Architects can play a crucial role in this process by providing technical expertise, ensuring that renovations align with cultural heritage, and balancing the needs of villagers with architectural requirements. Their involvement can help harmonize modernization with tradition, ensuring that rural revitalization efforts lead to long-term sustainability rather than short-term interventions.

Secondly, to alleviate the problem of vacant traditional dwellings and foster urban-rural economic integration, policies should encourage mobility-based lifestyles that connect cities with rural areas. One effective approach is to develop a shared-housing model, attracting young people, remote workers, and tourists for short-term stays. This not only creates a new type of community but also generates economic income, helping to offset the costs of residential maintenance while revitalizing underutilized dwellings.

Finally, village revitalization does not need to rely solely on tourism-led development. Public reuse of traditional dwellings offers a sustainable pathway to reconcile heritage conservation with improved quality of life. Transforming vacant houses into community facilities such as activity centers, libraries or cultural spaces can address deficits in rural social infrastructure, enhance social cohesion and improve the living environment. Such interventions help rebuild endogenous community vitality and strengthen the long-term residential attractiveness of rural areas beyond short-term tourism demand.

(3) Individual cases

In Taoyuan Village, traditional dwelling No. 56 (Fig. 8) was

Table 10
Mediation Analysis Results: Direct, Indirect, and Bootstrap Effects.

Path	*Effect*	Unstandardized		*t*	*p*	Confidence Interval	Bootstrap		
		Coefficient *B*	*S.E.*			(LLCI, ULCI)	Effect	BootSE	(BootLLCI,BootULCI)
X → M	Direct Effect	0.0993	0.0187	5.2971	0.000	[0.0624, 0.1362]	0.0993	0.0159	[0.0674, 0.1329]
M → Y	Direct Effect	3.9909	0.4794	8.3254	0.000	[3.0513, 4.9304]	3.9909	0.4245	[3.2959, 4.9749]
X → Y	Direct Effect	0.1527	0.1478	1.0336	0.301	[-0.1369, 0.4424]	0.1527	0.1417	[-0.1347, 0.4462]
X →M→ Y	Indirect Effect	0.3962	0.0784	-	-	[0.2687, 0.5768]	0.3962	0.0784	[0.2687, 0.5768]
Model	Model Summary			Model		Model Summary			
	R^2	F	*p*			McFadden R^2	-2LL	*p*	Nagelkerke R^2
X → M	0.0908	28.0588	0.000	X → M → Y		0.3084	244.78	0.000	0.4485

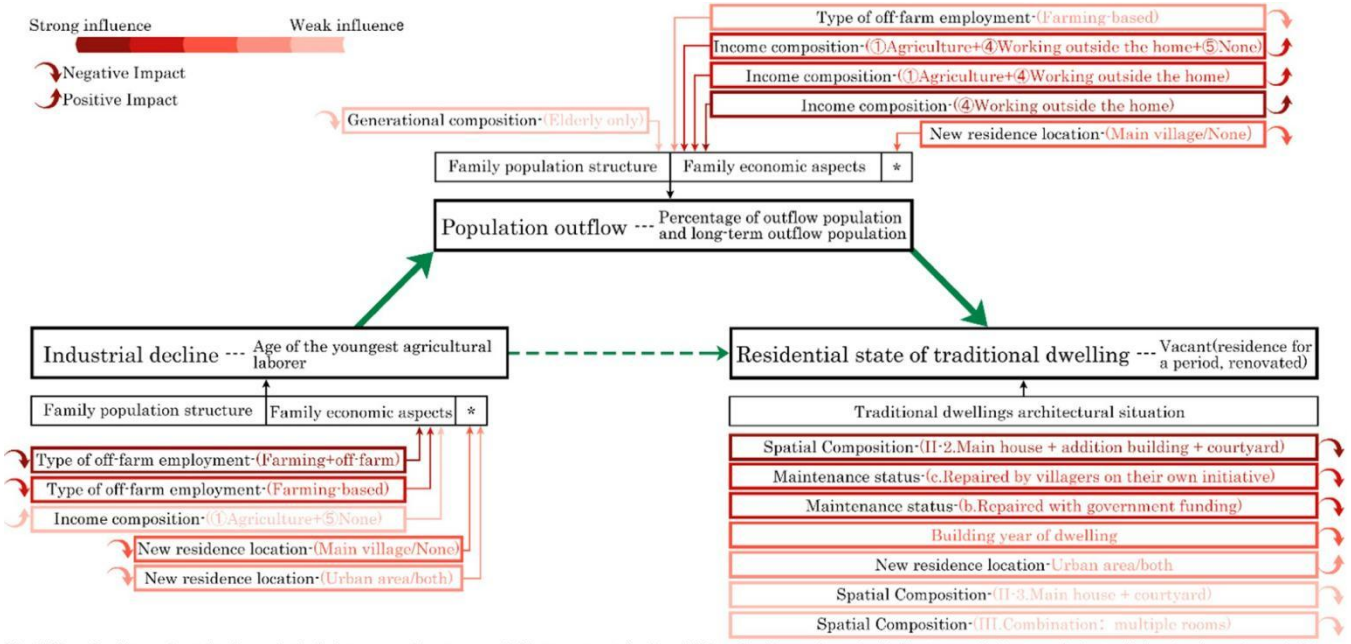


Fig. 7. Factors affecting vacancy, population outflow, and industrial decline in dwellings and their interrelationships.

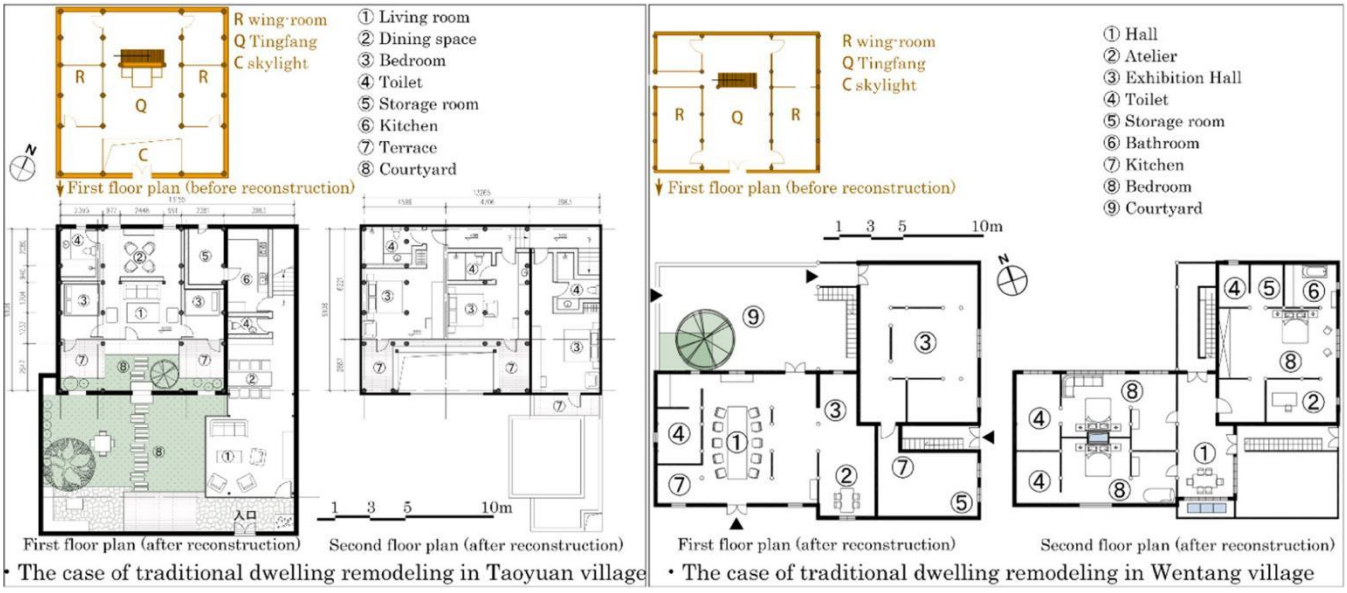


Fig. 8. Individual cases of Taoyuan and Wentang villages.

successfully converted into a B&B hotel, with construction planned by an architect. While preserving the original structure, the space was optimized to better meet modern hospitality standards. Key modifications included expanding the living room and dining area, repositioning the staircase, converting compartments into a bathroom and storage space, and adding three new bedrooms along with a terrace on the second floor. These renovations addressed common issues in traditional dwellings, such as the lack of separate bathrooms, dampness, and poor lighting, making the space more suitable for contemporary accommodation needs.

In Wentang Village, one dwelling has been repurposed into artist studios as part of its "art village" development strategy. This initiative attracts tourists, artists, and scholars for sketching, artistic creation, and cultural exchanges. This traditional dwelling was renovated into an art studio designed to meet the specific needs of creative professionals. The redesigned space can now accommodate 3–5 people, offering areas for artistic work, exhibitions, and seminars. Importantly, the renovation retained distinct Huizhou-style architecture while optimizing the spatial layout, demonstrating how adaptive reuse can preserve cultural heritage while enhancing functionality.

While these individual cases highlight the potential for the adaptive reuse of traditional dwellings, villager participation remains insufficient. Many renovation projects are driven by external stakeholders, such as architects, businesses, or tourism developers, rather than grassroots community engagement. Without active involvement from

local residents, the long-term sustainability and social integration of these initiatives may be limited. Introducing professional design expertise to ensure that renovations enhance residential functionality and safety while complying with legal and regulatory standards may offer a more viable pathway than tourism-led development. By prioritizing and improving the living conditions of indigenous residents, this approach can strengthen their willingness to remain long term, reduce villages' exposure to tourism-related economic volatility, and foster more resilient and sustainable forms of functional and emotional self-sufficiency.

5.2. Population outflow

(1) Influencing factors of population outflow

The results of multiple linear regression analysis indicate that "④ Working outside the home (including families who moved to towns)" has the greatest impact on the proportion of population outflow. This suggests that employment opportunities in urban areas are a primary driver of rural depopulation, as individuals leave villages in search of better job prospects. Additionally, "New residence location (Main village/None)" and "Generational composition (Elderly only)" also significantly influence outflow rates. These factors suggest that villages dominated by elderly residents experience higher rates of population outflow, reinforcing rural aging trends.

Conversely, "Type of off-farm employment (Farming-based)" appears to curb outflow. This suggests that strengthening local agricultural industries and improving rural employment opportunities could play a role in reducing population outflow and stabilizing rural communities.

(2) Increase rural employment opportunities and promote industrial diversification

Based on the analysis, promoting local industries and diversifying the rural economy are essential strategies to reduce population outflow and sustain rural communities. A key approach is to enhance rural employment opportunities, ensuring that residents, especially young laborers, have viable economic alternatives within their villages.

First, integrating agriculture with the tourism industry by leveraging local agricultural resources to develop "agrotourism" for rural revitalization. For example, in the three villages analyzed in this study, traditional skills such as black tea planting, picking, production, classification, and tea tasting can be utilized to develop in-depth experiential tourism. This not only strengthens cultural identity and increases the brand value of the region as a tea-producing area but also stimulates local economic growth. By combining agriculture and tourism, this approach enhances the added value of agricultural products, diversifies employment opportunities, and attracts young people to return to rural areas to pursue careers in agriculture and tourism-related industries. This integration not only supports local economies but also preserves cultural heritage.

Second, in addition to agrotourism, the development of cultural and ecological tourism by offering immersive cultural and natural experiences. For urban tourists, experiencing rural life, traditional dwellings, and local customs provides a unique and enriching travel experience. This not only enhances the tourism appeal of rural areas but also contributes to the long-term sustainability of tourism resources.

Finally, by integrating eco-friendly tourism practices, such as sustainable farming, nature conservation, and green tourism accommodations, rural communities can balance economic development with environmental preservation, ensuring that local landscapes and cultural traditions remain intact for future generations.

(3) Individual cases

As shown in Fig. 9, Case A represents a self-initiated remodeling of a traditional dwelling by villagers, while Case B is a dwelling purchased by villagers with plans for renovation. Although overall villager participation in tourism remains low across the three villages studied, these cases highlight individual efforts toward self-driven tourism development, reflecting a latent interest among villagers in utilizing traditional dwellings for economic opportunities. This suggests that local development is shaped not only by top-down government initiatives but also by bottom-up co-production involving residents and local entrepreneurs. Encouraging residents and diverse "entrepreneurs," including social enterprises, community-based actors and small vendors, to participate in the co-production of public services is crucial (Adewunmi et al., 2023). For example, villagers or returning entrepreneurs can contribute to infrastructure maintenance, traditional building conservation and spatial governance through operating homestays, community services and related ventures.

5.3. Industrial decline

(1) Factors contributing to an insufficient young labor base

The results of multiple linear regression analysis indicate that the "Type of off-farm employment (Farming + off-farm)" has the greatest influence on the youthfulness of the labor force and agricultural sustainability. Additionally, "the①(Agriculture) + ⑤(None)" and "New residence location (Main village/None)" are also significant factors affecting the rate of farmland abandonment and the aging of the rural labor force. The presence of older generations remaining in agriculture without a sufficient influx of young workers contributes to gradual industrial decline, as fewer young people choose to engage in full-time farming. Moreover, new residence location affects labor retention, as those relocating away from the village are less likely to continue farming, accelerating the demographic shift toward an aging workforce.

(2) Construction of a multigenerational cohabitation environment

For elderly residents, care facilities can be introduced to provide assisted living services, while rural medical stations and telemedicine systems can improve healthcare accessibility. Expanding telehealth infrastructure ensures that senior villagers receive consistent medical care.

At the same time, entrepreneurship incentives and telecommuting support can attract young people to return to their hometowns and encourage new residents to settle in rural areas. By integrating urban and rural resources, these initiatives foster a harmonious living environment where different generations can coexist and interact, strengthening community ties and revitalizing rural areas.

(3) Individual cases

As shown in Fig. 9, this example illustrates the remodeling of a traditional residential house that is connected to a modern newly

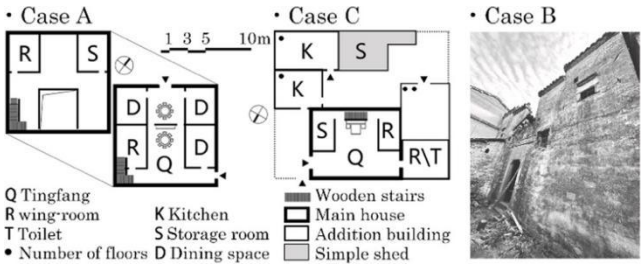


Fig. 9. Individual cases of Taoyuan and Lixi villages.

built house. This approach allows residents to enjoy modern amenities in their new home, while still utilizing the traditional house as a secondary residence. By doing so, the historical and cultural value of the traditional dwelling is preserved, while also meeting modern living needs. Interview results reveal that a traditional dwelling, as common family properties, hold a deep sense of emotional identity and belonging for residents. Despite adopting modern lifestyles, many families choose to preserve their ancestral homes and maintain three-generational cohabitation.

However, such cases remain rare in the three villages. In most households, older residents continue to live in traditional dwellings, while younger generations move to newly built settlements or nearby town centers. This suggests that although multigenerational cohabitation can support cultural transmission, it still requires additional support, including financial incentives, improved infrastructure and targeted policy measures, to sustain intergenerational living and the functional use of traditional dwellings. More fundamentally, and often overlooked, is the rural "rural sense of place," that is, residents' emotional attachment, identity and affection toward their home community (Chigbu., 2013). Given the limited impact of purely material poverty alleviation and infrastructure investment, fostering this sense of belonging is becoming a crucial element in promoting sustainable rural revitalization.

6. Conclusions

This study surveyed the vacancies of traditional dwellings in the study area and analyzed the current state of population outflow and industrial decline, along with their influencing factors. The findings indicate that housing vacancy rate serves as a key indicator of population decline, significantly impacted by factors such as spatial composition, maintenance status, building age, and structural deterioration.

Statistical analyses further reveal strong correlations between housing vacancy rates, population outflow percentages, and the age of the young labor force, indicating that the loss of young workers is a primary driver of increasing housing vacancy. This suggests that vacant dwellings are not merely an architectural issue but a structural challenge affecting the entire traditional village system. Therefore, addressing dwelling vacancy and village renewal requires a comprehensive and multi-faceted strategy.

The study highlights the complex challenges faced by some traditional dwellings in Huangshan City, Anhui Province. The findings emphasize that solutions must be multi-pronged, integrating agricultural revitalization, local industrial development, and improvements to the rural living environment. Strengthening agricultural management, supporting local enterprises, and enhancing infrastructure remain central to revitalizing the local economy and preserving traditional culture, ensuring the long-term sustainability of these historic villages. At the same time, strengthening bottom-up support to enhance villagers' confidence in settlement should not be overlooked. Providing stable income-generating opportunities and supporting local entrepreneurship can increase villagers' attachment to rural development and encourage them to remain in their communities. By reinforcing a sense of belonging and economic security, policies can promote the sustainable use of traditional dwellings, fostering the long-term revitalization of rural communities.

As a major agricultural country, China's agriculture is not only a fundamental industry that ensures food security and livelihoods but is also expected to integrate with the tertiary sector in the future. This integration aims to promote the development of agritourism, experiential agriculture, and other models that enhance the added value of agriculture. Therefore, future research should further refine the survey of the agricultural industry by clarifying the specific scale and income of arable land and tea plantations, providing a more targeted reference for strategic planning in agricultural diversification.

CRediT authorship contribution statement

Yasufumi Uekita: Writing – review & editing, Formal analysis, Conceptualization. **WANG YU:** Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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