



## Research article

# Rural human settlement environment, non-agricultural transfer of labour and arable land abandonment in China

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## ABSTRACT

The arable land abandonment caused by the large-scale non-agricultural transfer of labour has attracted substantial attention from all walks of life in China. Promoting improvement in human settlement environment can accelerate the construction of infrastructure, ameliorate grassroots organization and enhance management capacities while simultaneously decelerating agricultural production costs. High level of human settlement environment can also attract the labour force to return, stimulate the vitality of rural elements and endogenous powers. Then, can improving rural human settlement environment alleviate the phenomenon of arable land abandonment caused by non-agricultural labour transfer? In order to answer this question, based on the micro-survey data of 1325 households in 5 provinces of China, this paper uses the Tobit model to empirically test the effects of rural human settlement environment and non-agricultural transfer of labour on arable land abandoned. The results revealed that rural human settlement can alleviate the arable land abandonment caused by non-agricultural transfer of labour to a certain extent. In particular, the improvement of rural human settlement environment that mainly based on the infrastructure construction and organizational management level, has significantly alleviated the arable land abandonment caused by the non-agricultural transfer of labour. Heterogeneity analysis disclosed that, compared with mountainous and hilly areas, the improvement of rural human settlement environment had a more obvious mitigation effect on arable land abandonment in plain areas. Promoting infrastructure construction and strengthening organizational management ability were effective ways to alleviate arable land abandonment in plain areas. Farmer households with high place attachment level were more likely to be attracted by the improvement of rural human settlement environment to return to their hometown, so as to make use of arable land resources. Improving infrastructure, strengthening organizational management level, and promoting cultural and community development were the main measures for farmer households with high place attachment level to reduce arable land abandonment. In addition, there were significant differences in arable land abandonment and its driving factors in different regions. In the central and eastern regions or major grain-producing areas, improving human settlement environment had a significant mitigation effect on arable land abandonment. Therefore, improving the rural human settlement environment according to local conditions, promoting the supportive policy will be inclined to mountainous and hilly areas, enhancing the attractiveness of rural areas, encouraging farmers with high place attachment level to return to their hometowns for employment and entrepreneurship, and accelerating the cultivation of new types of agricultural operators, which will help alleviate the arable land abandonment caused by non-agricultural transfer of labour.

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## 1. Introduction

Rapid advancements have occurred in industrialization and urbanization in China since the reforms and opening-up. China has seen a large increase in employment opportunities and a rapid escalation in non-agricultural wages, causing rural labour to increasingly transfer to urban areas or non-agricultural sectors [1]. Moreover, the continuously increasing agricultural opportunity costs and production factor prices, as well as the restrictions imposed on the fragmentation of arable land have undoubtedly increased agricultural operation costs and resulted in year-on-year declines in comparative incomes, aggravating the withdrawal of labour from agricultural production and making the risk of arable land abandonment particularly prominent [2]. According to official data issued by China, the total number of migrant workers touched 290 million in 2019<sup>①</sup>; and the abandonment rate of arable land in China reached 20 % [3]. Unlike countries with abundant arable land resources, China has a large population base and a serious shortage of per capita land resources, and the contradictions between human beings and land are very severe. The abandonment of arable land would cause imbalances between the supply and demand of agricultural production factors and would affect grain production [4]. It would also change the regional ecological structure, causing soil erosion [5], resource waste [6] and numerous other problems. People from all walks of life are now attending keenly to how the phenomenon of arable land abandonment caused by non-agricultural labour force transfers can be alleviated and how arable land resources can be effectively used in China.

As the important link among agricultural production, rural life and ecological environment, human settlement environment is an organic combination of natural ecology, regional space and human environment in rural regional space [7,8]. Improving such human settlement environment accelerates the construction of infrastructure and community development, elevates the supply and organization of public services at the grassroots level and promotes the high-quality development of agriculture and rural areas [9]. Moreover, it can reduce the arable land abandonment by enhancing the appearance of villages, amplifying the attractiveness of the countryside, encouraging the return of the labour force to the countryside and realizing the optimization and reorganization of factors [8]. Then, would improving rural human settlement environment alleviate the arable land abandonment caused by non-agricultural labour transfer? To answer this question, this study based on the micro-survey data of 1325 households in 5 provinces of China to explore the influence of rural human settlement environment and non-agricultural labour transfer on arable land abandonment. It aimed to test whether improving rural human settlement environment can alleviate the problem of arable land abandonment caused by non-agricultural labour transfer. At the same time, the terrain conditions and place attachment to the village respectively denote objective and subjective factors that affect arable land use decisions taken by farmer households [10–12]. Thus, this paper considered the importance of coping with rising agricultural production cost and attracting the labour force to return for promoting agricultural and rural development. Consequently, two internal mechanisms are formed: agricultural production cost and the place attachment to a village. In objective terms, the study probed the objective disparities in agricultural production costs in different terrains and investigated the differences in agricultural land use decisions made by farmers in the plains as well as in mountainous and hilly areas. In terms of the differences in the subjective place attachment of farmer households', the study effected a comparative analysis of the differences in the decision-making of labour flow of farmer households' whose rural appeal was affected to explore the mitigation effect of rural human settlement environment.

## 2. Literature review

Owing to the concern over arable land resources, the arable land abandonment and its influencing factors have been explored from different perspectives. Thereinto, Non-agricultural transfer of labour is considered as one of the important factors for influencing arable land abandonment. The influence of non-agricultural transfer of labour on arable land abandonment could be divided into macro and micro scales. On the macro scale, after using remote sensing, satellite image and other technologies, the existing literature obtained a relatively consistent conclusion that the nonagricultural transfer caused by the non-agricultural transfer of labour was the main cause of arable land abandonment [4,13,14]. On the micro scale, there was more exploration than consensus: some scholars found that the non-agricultural transfer of rural labour force, and the surplus labour force could not undertake agricultural production, resulting in the arable land abandonment [15,16]. In other studies, non-agricultural transfer could increase farmers' technology adoption capability, which compensated for the loss of agricultural production efficiency caused by labour shortages [17,18] and reduced arable land abandonment. In addition, some literature found that non-agricultural transfer did not necessarily affect farmers' decisions to arable land abandonment [19]. With the deepening of related research, more and more scholars realized that arable land abandonment was the result of multiple factors. In addition to the non-agricultural transfer of labour, the rural human settlement environment has gradually attracted extensive attention from the academic community. Studies on the effects of rural human settlement environment on arable land abandonment mainly focused on three aspects: infrastructure, organization and management, and policies and institutions. In terms of infrastructure, the construction of water conservancy, transportation, and other facilities could help to reduce arable land abandonment [20,21]. In terms of organizational management, under the guidance of village collectives, cooperatives, and other grassroots organizations, could promote agricultural socialization services, and alleviate arable land abandonment [5,22]. In terms of policies and institutions, the confirmation of land usage rights and agricultural support policies could reduce farmer's arable land abandonment behavior[23,24]. To sum up, about the impact of non-agricultural transfer of labour and rural human settlement environment on arable land abandonment, existing literature had launched active exploration, and many valuable research conclusions have been drawn, but there are still three directions to be further explored. First of all, whereas most studies focus on the effects of non-agricultural transfer of labour or the rural human settlement environment on arable land abandonment, few studies have incorporated the rural human settlement environment, non-agricultural transfer of labour, and arable land

abandonment into the same analytical framework. And from the perspective of improving the rural human settlement environment, there is even little literature to explore effective ways for alleviating the influence of non-agricultural transfer of labour on arable land abandonment. Secondly, the current studies have focused on analyzing of the influence of a certain rural human settlement environment factor or the non-agricultural transfer of labour on arable land abandonment, whereas less attention was paid to the interaction effect of rural human settlement environment and non-agricultural transfer of labour on arable land abandonment. Finally, few studies have investigated the influence mechanism of rural human settlement environment on arable land abandonment. In-depth analysis of the differentiation feature in the influence of rural human settlement environment on the arable land abandonment, will be helpful to explore the internal mechanism which rural human settlement environment influences arable land abandonment.

Based on the above analysis, the discussion in this paper addresses three aspects. At first, in contrast to previous studies, rural human settlement environment, the non-agricultural transfer of labour and arable land abandonment are included in the same analytical framework. And how to alleviate the effects of the non-agricultural transfer of labour on arable land abandonment by improving rural human settlement environment is explored. Secondly, because the interaction effect between rural human settlement environment and non-agricultural transfer of labour on arable land abandonment is rarely considered. This paper introduces the interaction term of rural human settlement environment and non-agricultural transfer of labour to explore their interaction effect on arable land abandonment, and further test the different dimensions of human settlement environment and non-agricultural transfer of labour on arable land abandonment. At last, because few studies explore the influence mechanism of improving the rural human settlement environment on arable land abandonment. Based on the analysis of the difference characteristics of improving human settlement environment affecting farmland abandonment, this paper explores the internal mechanism of human settlement environment affecting arable land abandonment.

### 3. Theoretical framework

The rapid development of industrialization and urbanization in China has for a long time caused agricultural labour forces to migrate in large numbers to cities and towns or non-agricultural industries. Thus, the relative scarcity and price of labour to capital, land and other factors continue to escalate [25]. Increasing agricultural opportunity cost and factors prices tend to stimulate cost increases and further compress the profit margins of agricultural production. According to the principle of the maximization of household income, as rational economic decision-makers, farmers will inevitably choose to reduce agricultural production and operation times and opt to increase time spent in non-agricultural labour, if the incomes they earn by engaging in non-agriculture are higher than their earnings from agricultural production. And farmers will continue this behavior until their marginal income from farming equals their marginal income from non-agricultural employment and the entire farming family achieves the Pareto optimal [26]. During this process, the family's labour force will continually transfer to non-agricultural sectors. Ultimately, the risk of arable land abandonment would surge when the labour force that remains behind to farm cannot longer use the arable land resources. Given this scenario, the academic community has launched in-depth explorations of how arable land abandonment caused by non-agricultural labour transfer can be alleviated, and two types of effective measures were suggested. Some scholars believed that realizing factors substitution or revitalizing rural resources can promote agricultural development. Thus, they suggested replacing labour force by machine, providing agricultural socialization services and transferring arable land to effectively make use of arable land resources [27–29]. Other studies indicated that various factors can be encouraged to return to rural locations by enhancing the attractiveness of the countryside. They asserted that the endogenous power of the countryside can be activated by accelerating the return of the labour force and the fostering of new agricultural operators to accomplish large-scale agricultural management [15,30] and reduce the arable land abandonment. The human settlement environment represents surface spaces that execute numerous functions such as infrastructure building, public services, social governance, cultural inheritance and ecological conservation. Thus, human settlement environment is closely related to agricultural production, rural life and various human activities in the ecological environment [31]. Improving human settlement environment is conducive to alleviate the arable land abandonment caused by non-agricultural labour transfer. Rural human settlement environment can be divided into the hard and soft human settlement environment. The hard human settlement environment denotes the sum of all types of facilities and regional spaces closely related to production and life [7]. It includes living conditions, infrastructure and other material elements and spatial areas related to the particular ecological milieu. The soft human settlement environment represents the non-material elements of production and life [8], such as the public services, policies and systems, local customs and traditional culture as well as the cultivation of common values, the coordination of interests and other cultural and community development initiatives. The mutual penetration and interactions of hard and soft human settlement environments can accelerate the construction of diverse infrastructures and communities, strengthen the supply of public services, promote the development of agricultural mechanization and social services and accelerate land transfers. It tends to change the appearance of villages, enhance the attractiveness of the countryside, promote the return of labour forces to their hometowns for employment and entrepreneurship, speed up the cultivation of new agricultural business entities, achieve large-scale agricultural management and consequently assuage the phenomenon of arable land abandonment. In summary, enhancing rural human settlement environment can help to mitigate the phenomenon of arable land abandonment resulting from non-agricultural labour transfer. Given this background, the following research hypothesis is proposed for the present study:

**H1.** Improving the rural human settlement environment can alleviate the arable land abandonment caused by the non-agricultural transfer of labour.

The alleviative effect of rural human settlement environment on arable land abandonment resulting from non-agricultural labour transfer is associated with the objective terrain conditions and the subjective place attachment.

On the one hand, different terrain conditions cause different factor substitutions, resource consumption, land locations and other aspects of agricultural production, which lead to significant differences in the mitigation effects of the rural human settlement environments. Mountains, plateaus and hills cover a vast area of China and account for more than two-thirds of the country's total land area. The proportion of slope arable land is also substantial: arable lands sloped more than  $6^\circ$  comprise 22.75 % of the total arable land in China<sup>®</sup>. Mountainous and hilly areas present complex terrains in comparison to the plains, many constraints for mechanised operations, poor farming environment, large relief and weak infrastructure, which greatly increase the difficulties and costs of mechanical labour [32]. The fragmentation of arable land is more severe because of the rugged and steep terrains of mountains and hills and height differences is large, increasing efforts and time undertaken by farmers to travel to different land plots and consuming more fuel for machinery and equipment. It also increases the consumption and waste of production factors during the transportation of different plots (e.g. fertilizer volatilization, seed scattering, irrigation water loss, etc.) [10]. In addition, the arable land that is remotely located, less fertile or far away from a water source is more common in mountainous and hilly areas and the cost of land improvement is exorbitant. So it is difficult to effectively utilize such tracts of land for local farmers. Improving human settlement environment can accelerate the construction of rural infrastructure, and enhance the grassroots organization management level [8]. It is conducive to promote agricultural socialization services and arable land transfer, optimize the arable land endowment, and make farmer households effectively use arable land resources. At the same time, some studies have shown that the implementation of rural human settlement environment governance in mountainous and hilly areas is often more costly [33,34]. Therefore, under the constraints of objective terrain conditions, it is more difficult for farmers in mountainous and hilly areas to cope with the problem of rising agricultural production cost, which ultimately makes it more difficult to alleviate the arable land abandonment caused by the non-agricultural labour transfer by improving the rural human settlement environment in mountainous and hilly areas. Based on the above analysis, the following hypothesis is proposed:

**H2a.** The rural human settlement environment has the different mitigation effect on arable land abandonment caused by non-agricultural labour transfer between mountainous and hilly areas and plain areas.

On the other hand, different level of place attachment will make farmers completely different in the aspects of hometown-related dependence and social network, so that the mitigation effect of rural human settlement environment has a significant difference. In fact, Chinese farmers have been influenced for thousands of years since ancient times by Confucianism and traditional Chinese culture. They display a compelling local complex and their hometowns often hold special status in their hearts. Spiritual beliefs such as “attach to one's native land” and “falling leaves returning to the root” construct strong attachments in Chinese people, inculcating in them a profound sense of place attachment to their hometowns [35]. Thus, an emotional bond is forged between Chinese farmers and their hometowns. Such ties are reflected in numerous aspects such as the love and identification people feel with their hometowns and their social contacts in rural communities and affect the utilization of arable land resources. However, the rapid economic development and the process of urbanization constantly impact rural social structures and traditional value systems, ushering in new ideas and concepts and diminishing some farmers' place attachment [36]. Farmers with the lower place attachment tend to yearn for work and life in cities and towns, rely less on their hometowns and do not participate in various types of village affairs. Their households often relinquish the use of part or all of their arable land because of its long distance from their non-agricultural employment place, low agricultural

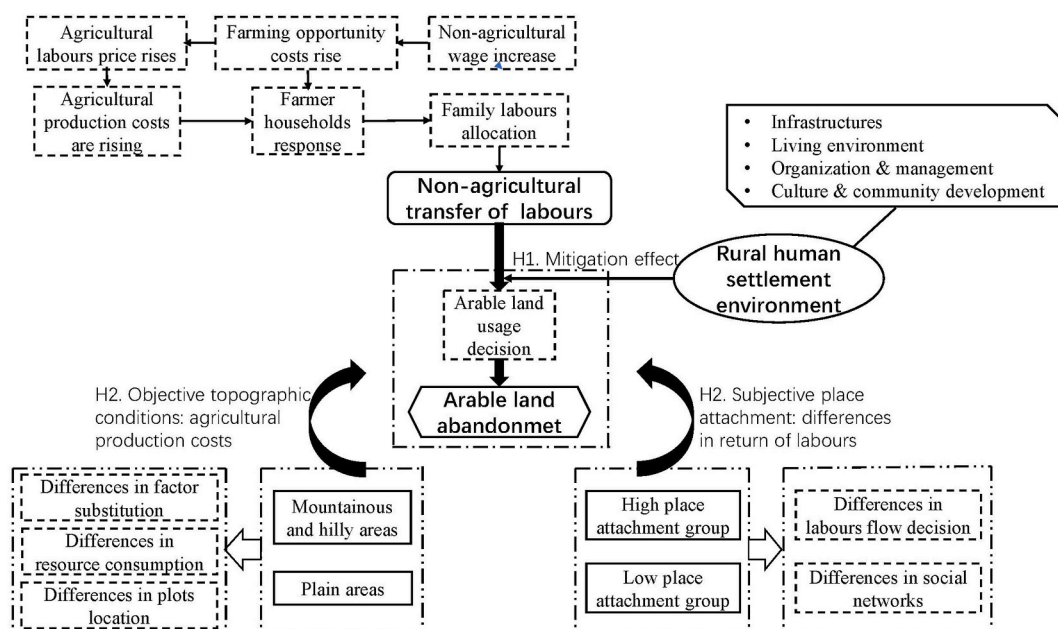


Fig. 1. The influence of rural human settlement environment and non-agricultural labour transfer on arable land abandonment.

incomes and insufficient agricultural labour forces. Farmers with the higher place attachment are more likely to be attracted by improving appearance of villages and rooting themselves in rural areas or return to their hometowns to start businesses or accept employment offers to strengthen the new type of agricultural management. The farmer households with a heightened place attachment to their villages are also inclined to utilize their rural social networks to promote agricultural socialization service, ease the transfer of arable land, achieve scale management and reduce arable land abandonment. Therefore, farmer households with the higher place attachment are more likely to be enticed by improving rural human settlement environment. They are more likely to opt to return to their hometowns and start business ventures or accept employment offers so they can make more effective use of their arable land resources and alleviate the arable land abandonment resulting from non-agricultural labour transfer. Based on the above analysis, the following hypothesis is proposed:

**H2b.** For farmer households with different place attachment level, the rural human settlement environment has the different mitigation effect on arable land abandonment caused by non-agricultural labour transfer.

In summary, the influence of rural human settlement environment and non-agricultural labour transfer on arable land abandonment is shown in Fig. 1.

## 4. Materials and methods

### 4.1. Data sources

The data used in this study were obtained from the field survey conducted by the research group from June to November 2021 in 5 provinces of China. Considering the economic and social status quo of the provinces and taking into account the characteristics of China's seven major geographical regions, the research group selected the 5 provinces of Jilin, Zhejiang, Hubei, Sichuan and Gansu for investigation. The stratified sampling method was adopted based on the level of economic development to randomly select 2–5 counties in each province and then randomly select 2–4 villages (towns) from each county as the sampled villages. The survey data were filled in by trained investigators who collected these data via face-to-face interviews with the sample of farmers to avoid errors resulting from the lack of understanding of question meaning if farmers were asked to self-report questionnaires. A total of 1439 sample farmers were randomly selected for the survey, and the missing data were supplemented via a follow-up telephone call. If the questionnaire data was missing but still could not be obtained by telephone return visit, the questionnaire is considered invalid. An aggregate of 1325 valid questionnaires were obtained after the invalidated questionnaires were eliminated and the effective rate was 92.08 %. The questionnaire included the following contents: the basic information of community (rural human settlement environment, terrain characteristic, community information) and basic information of farmer households (characteristics of household head and households; household head's place attachment; arable land information).

### 4.2. Variables setting

#### 4.2.1. Explained variable

**Arable land abandonment.** The scale of arable land abandoned can reflect the utilization of arable land resources. Therefore, referring to the study of Xie et al. [15], “arable land abandonment rate” is adopted as the proxy index for peasant households' arable land abandonment,  $\text{arable land abandonment rate} = \text{arable land abandonment area} / \text{total contracted arable land area}$ .

#### 4.2.2. Core explanatory variables

- (1) **Rural human settlement environment.** After referring to existing studies [8,9,11] specific indicators are selected from the four dimensions of infrastructure, living environment, organization and management and culture and community development to construct the index system of rural human settlement environment. In the term of infrastructure, every village is deemed to have “electricity, drinking water, roads, cable TV, Internet” and other modern facilities according to the standards of the national “Village-village Access” project. This study focuses on the village Internet usage and the road hardening rates because electricity and drinking water have essentially been fully covered. Express logistics coverage was also included in the infrastructure dimension considering the rapid development of rural e-commerce and its significant impact on agriculture and rural development. The living environment is determined according to the relevant requirements of “rural toilet retrofitting, garbage and sewage treatment and village appearance improvement” in the “Five-years Action Plan for Improving Rural Human Settlement Environment (2021–2025)”. Considering the reality of the relatively popular sanitary toilets in rural areas and the availability of data, the proportion of brick-concrete housing, the domestic waste treatment rate and the domestic sewage treatment rate are selected as specific indicators. In terms of organization and management, the educational condition, medical condition and agricultural specialized cooperatives are selected as specific indicators to reflect the level of rural organization and management services from the three aspects of education, medical care and cooperative organizations. In terms of culture and community development, the number of cultural and sports activities and the number of activity centers in the village are used to reflect rural culture and village development. After constructing the index system of rural human settlement environment, this paper draws on the research of Wei & Li [37] and uses entropy weight TOPSIS method to evaluate the comprehensive index and scores of various dimensions of rural human settlement environment.



- (2) **Non-agricultural transfer of labour.** With reference to the study of Xie et al. [15], the non-agricultural transfer of labour is represented by the proportion of the non-agricultural transfer of labour in the total household labour force<sup>®</sup>.

#### 4.2.3. Instrumental variables

- (1) **The relationship between village cadres and villagers.** In China, improving the rural human settlement environment depends on government promotion, and grassroots workers are required to implement relevant policies. The harmonious relationship between village cadres and villagers can make villagers build trust in government policies, it will be helpful to promote the human settlement environment policies [38]. This satisfies the correlation requirement for instrumental variable. Meanwhile, arable land abandonment is the decision of the peasant household itself, which has nothing to do with the relationship between village cadres and villagers. The exogenous conditions of variable can be satisfied to a certain extent.
- (2) **Environmental pollution petition.** The event of “environmental pollution petition” is determined by complex economic and social factors, whereas arable land abandonment is mainly affected by the cost and income of agricultural production and operation, and there is not the direct relation between them. After environmental pollution petition, the local human settlement environment will be changed. It indicates that environmental pollution petition can only influence the arable land abandonment by improving rural human settlement environment. Therefore, the “environmental pollution petition” is selected as the instrumental variable to satisfy the exogeneity and exclusivity hypothesis.

#### 4.2.4. Control variables

Combined with the actual situation and related literature, this paper has selected some indicators as control variables.

- (1) **Personal characteristics.** The factors such as gender, age, education level and experience of village cadres have been proved to influence on arable land abandonment [10–12]. Therefore, in this study, the individual characteristic variables include: gender of household head, age of household head, education level of household head, and the village cadres experience of household head.
- (2) **Family characteristics.** Previous studies have found that household size, the characteristics of labour force, income level, the characteristics of arable land can affect farmers’ arable land abandonment decisions [5,15,30,32]. Therefore, the selected variables of household characteristics include: household size, proportion of family members who were supported and brought up, health status, total family income, arable land scale, fragmentation of arable land, arable land quality, arable land transfer, distance from the house to the nearest market.
- (3) **Community characteristics.** According to existed literature, the factors such as agricultural policies, natural condition can also affect the arable land abandonment [4,12,15]. In this paper, the community characteristic variables are selected as: land ownership confirmation, agricultural production subsidies and natural disaster.

In addition, in order to distinguish the influence of external factors such as natural geographical conditions, economic and social development, policy differences, customs and habits among different regions [7], dummy variable of provinces is adopted to control the influence by regional differences (see Table 1).

The meaning, assignment and descriptive statistics of the variables are shown in Table 2.

**Table 1**  
The rural human settlement environment index system.

Dimensions	Indicators	Specification	Mean	Standard deviation
Infrastructures	Internet usage rate	The proportion of households using the Internet in the sample of farmers	0.532	0.633
	Village road hardening rate	The proportion of hardened pavement area in total area of village roads	0.724	0.597
	Express coverage rate	The proportion of households who can receive express delivery in the sample of farmers	0.239	0.358
Living environment	Proportion of brick-concrete housing	The proportion of households with brick-concrete housing in the sample of peasant households	0.748	0.693
	Domestic waste disposal rate	The proportion of households dealing with domestic waste in the sample of farmer households	0.353	0.414
	Domestic sewage treatment rate	The proportion of households treating domestic sewage in the sample of farmer households	0.268	0.338
Organization & management	Educational condition	The number of primary schools per 100 households	0.457	0.433
	Medical condition	The number of village health centers per 100 households	0.641	0.562
	Coverage rate of agricultural cooperatives	The proportion of households participating in specialized agricultural cooperatives among the sample of farmer household	0.715	0.631
Culture & community development	The number of annual community cultural & sports activities	The number of cultural or sporting events held in the village	2.233	3.264
	The number of community activity centers	The number of activity centers owned by the village	0.732	0.896

### 4.3. Research method

Because of the Tobit model is unbiased when dealing with the variables which have non-negative truncation characteristics, its estimation coefficient is far better than ordinary least squares (OLS) estimation. Therefore, the Tobit model is selected to analyze the effects of rural human settlement environment and non-agricultural transfer of labour on arable land abandonment.

First, the influence of rural human settlement environment and non-agricultural transfer of labour on arable land abandonment is investigated, and the baseline model is established as follows:

$$Y_{it} = \alpha + \beta_1 X_{it} + \beta_2 E_{it} + \gamma C_{it} + \varepsilon_{it} \quad (1)$$

in Equation (1),  $Y_{it}$  is arable land abandonment,  $X_{it}$  and  $E_{it}$  are rural human settlement environment and non-agricultural transfer of labour,  $C_{it}$  is the control variables. And the subscript  $i$  represents a farmer household,  $t$  is the year.  $\alpha$  is the constant term,  $\beta_1$ ,  $\beta_2$  and  $\gamma$  respectively represent the estimated coefficients of the variables;  $\varepsilon_{it}$  is a random disturbance term.

In order to explore the interaction effect, the interaction term between rural human settlement environment and non-agricultural transfer of labour  $X \times E$  is introduced, and the model is as follows:

$$Y_{it} = \alpha + \beta_1 X_{it} + \beta_2 E_{it} + \beta_3 X_{it} \times E_{it} + \gamma C_{it} + \varepsilon_{it} \quad (2)$$

in Equation (2),  $\beta_3$  is the estimated coefficient of the interaction term, and other coefficients and variables are the same as in Equation (1).

**Table 2**

The descriptive analysis of the main variables.

Variables	Indicators	Assignment and indicators specification	Mean	Standard deviation
<b>Explained variable</b>				
Arable land abandonment	Arable land abandonment rate	Arable land abandonment area of peasant households/total contracted arable land	0.159	0.231
<b>Explanatory variables</b>				
Rural human settlement environment	The level of rural human settlement environment	The comprehensive development index of rural human settlement environment	0.443	0.524
Non-agricultural transfer of labour	The proportion of non-agricultural transfer of labour	The number of non-agricultural transfer of labour/Total labour force of rural households	0.627	0.320
<b>Instrumental variables</b>				
The relationship between village cadres and villagers	The harmonious degree of the relationship between village cadres and villagers	1 = Very poor; 2 = Relatively poor; 3 = General; 4 = Relatively good; 5 = Very good	0.373	0.326
Environmental pollution petition	Whether to petition for environmental pollution	Whether to petition for environmental pollution: 1 = Yes, 0 = No	0.088	0.132
<b>Control variables</b>				
Personal characteristics	Gender	Gender of household head: 1 = Male, 0 = Female	0.763	0.352
	Age	Age of household head (Years-old)	54.604	13.258
	Education level	Education level of household head (Years)	7.526	3.274
	Village cadre experience	Whether household head has village cadre experience: 1 = Yes, 0 = No	0.055	0.083
Family characteristics	Household size	Total population of peasant household (People)	2.560	1.219
	The proportion of family members who are supported and brought up	The number of old people and children/Total population of rural households (hm <sup>2</sup> )	0.322	0.448
	Health status of labour force	The proportion of households with poor health in the labour force	0.138	0.228
	Total family income	Total family income last year (Ten thousand yuan)	8.753	10.164
	Arable land scale	The total area of land actually cultivated by peasant households (hm <sup>2</sup> )	0.310	0.414
	Fragmentation of arable land	Total plots of arable land	8.142	8.725
	Arable land quality	Soil fertility: 1 = very poor, 2 = relatively poor, 3 = fair, 4 = relatively good, 5 = very good	3.369	0.833
	Whether to participate in the arable land transfer	1 = Yes, 0 = No	0.428	0.385
	Distance from the house to the nearest market	km	8.597	6.432
	Land ownership confirmation certificate	0 = Not received, 1 = Have obtained the "Land Contract Management Right Certificate"	0.672	0.558
Community characteristics	Agricultural production subsidies	Whether to receive subsidies for agricultural production: 1 = Obtained, 0 = Not obtained	0.526	0.440
	Natural disaster	Whether have there been any natural disaster 1 = Yes, 0 = No	0.431	0.483
	Provincial code	N/A	–	–
<b>Regional variable</b>				

## 5. Results

### 5.1. Baseline results

Table 3 presents the baseline regression results of rural human settlement environment and non-agricultural labour transfers affecting arable land abandonment: Columns (1) and (2) represent the regression results of the overall level of rural human settlement environment, Columns (3) to (6) denote the regression results of the different dimensions of rural human settlement environment. Specifically, Column (1) displays the estimation result obtained using Equation (1). It is easily deduced that the coefficient of variable rural human settlement environment is negative and passes the significance test of 10 %, when the interaction effect is not considered. The coefficient of variable non-agricultural transfer of labour is significantly positive at the level of 1 %, indicating that improving rural human settlement environment can reduce the arable land abandonment. Conversely, it means that non-agricultural transfer of labour can aggravate the arable land abandonment. Column (2) lists the estimation result of attained using Equation (2). This result shows that the coefficient of rural human settlement environment is significantly negative at the 5 % level after the interaction effect is considered. The interaction term between rural human settlement environment and non-agricultural labour transfer is negative and passes the significance test of 1 %, and the coefficient of variable non-agricultural labour transfer has decreased. It signs that improving human settlement environment can alleviate arable land abandonment caused by the non-agricultural labour transfer. Thus, H1 has been verified. Columns (3) to (6) respectively exhibit the regression results of infrastructure, living environment, organisational management and culture and community development. It is evident that only the coefficients of infrastructure and organization management presented in Columns (3) and (5) are significantly negative at the level of 1 %. Their interaction terms with the non-agricultural transfer of labour are also negative and pass the significance test of 1 % and 5 % respectively, and the coefficients of variable non-agricultural labour transfer have decreased<sup>④</sup>. These outcomes imply that infrastructure and organisation management in rural human settlement environment can alleviate the arable land abandonment caused by the non-agricultural labour transfer. This result also confirms the views in the research of Xiang et al. [39] & Krocak et al. [40]: improving the infrastructure construction and strengthening the management of residential areas were conducive to the arable land utilization.

### 5.2. Endogenetic analysis

In general, endogeneity is mainly from missing variables, measurement errors and mutual causation. First of all, various control

**Table 3**

The regression results of the influence of rural human settlement environment and non-agricultural transfer of labour on arable land abandonment.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Rural human settlement environment	−0.021 <sup>c</sup> (0.013)	−0.025 <sup>b</sup> (0.011)				
Infrastructure			−0.034 <sup>a</sup> (0.009)			
Living environment				0.007 (0.006)		
Organization management					−0.024 <sup>a</sup> (0.007)	
Culture & community development						−0.018 <sup>c</sup> (0.011)
Non-agricultural transfer of labour	0.167 <sup>a</sup> (0.047)	0.133 <sup>b</sup> (0.063)	0.128 <sup>a</sup> (0.035)	0.075 <sup>b</sup> (0.035)	0.104 <sup>a</sup> (0.029)	0.081 <sup>b</sup> (0.038)
Rural human settlement environment × Non-agricultural transfer of labour		−0.055 <sup>a</sup> (0.015)				
Infrastructure × Non-agricultural transfer of labour			−0.065 <sup>a</sup> (0.018)			
Living environment × Non-agricultural transfer of labour				0.022 (0.029)		
Organization management × Non-agricultural transfer of labour					−0.048 <sup>b</sup> (0.022)	
Culture & community development × Non-agricultural transfer of labour						−0.030 (0.041)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Regional variable	Yes	Yes	Yes	Yes	Yes	Yes
Constants	−0.251 <sup>b</sup> (0.114)	−0.284 <sup>a</sup> (0.078)	0.308 <sup>a</sup> (0.083)	0.275 <sup>b</sup> (0.124)	−0.247 <sup>b</sup> (0.110)	−0.225 <sup>a</sup> (0.062)
Log-likelihood	574.38	591.46	537.24	489.37	612.59	554.73
Observations	1325	1325	1325	1325	1325	1325

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.



variables are included can reduce the interference of missing variables on the regression results. At the same time, by controlling the regional variable, the interference of missing variables on regression results is reduced to a certain extent. Secondly, in terms of measurement error, after replacing the explained variable “arable land abandonment” with the indicator “whether there is arable land abandonment behavior”, the estimated result is not greatly affected<sup>⑥</sup>. At last, there may be a mutual causal relation between the core explanatory variable and explained variable, that is, arable land abandonment may in turn affect rural human settlements. For mitigating the endogeneity, the IV–Tobit method is used for estimation. “The relationship between village cadres and villagers” and “whether to petition for environmental pollution” are selected as the instrumental variables. These two variables are not only closely related to rural human settlement environment, but also have no direct influence on arable land abandonment. Therefore, they can be used as the instrumental variables to explore the endogeneity problem (see Table 4). The results show that “The relationship between village cadres and villagers” and “whether to petition for environmental pollution” are valid instrumental variables.

Table 4(A) presents the estimation results based on the “the relationship between village cadres and villagers” as an instrumental variable. Column (1) is the result of the first stage, and the instrumental variable is positively correlated with rural human settlement environment at the significance level of 5 %. Column (2) is the result of the second stage: rural human settlement environment is negatively correlated with arable land abandonment, and the coefficient of variable rural human settlement environment is significant at the 5 % level. It indicates that improving rural human settlement environment is conducive to reducing arable land abandonment. According to the test result, the value of the  $F$ -statistic is much higher than 10, so the hypothesis of weak instrumental variable is rejected; it means that this instrumental variable is not a weak instrumental variable. In the second stage, the exogenous Wald test ( $\chi^2$ ) is significant at the 1 % level, indicating that the instrumental variable is reasonable. In conclusion, “the relationship between village cadres and villagers” is an effective instrumental variable.

Table 4(B) reports the estimation results using “whether to petition for environmental pollution” as an instrumental variable. As shown in Column (1), the instrumental variable is significantly positively correlated with rural human settlement environment at the 1 % level. The result in Column (2) also shows that rural human settlement environment can reduce arable land abandonment. The results of the correlation test on the instrumental variable also show that it is valid, in the same way as in Table 4(A).

### 5.3. Robustness test

In order to ensure the robustness of the baseline regression, this paper adopts two methods for the robustness test: screening sample data and replacing explained variables (see Table 5). The results show that the baseline regression is robust.

#### 5.3.1. Screening the sample data

By screening the sample data, the robustness of the baseline regression result can be tested. For avoiding the influence of the extreme values, the research samples of arable land abandonment are truncated by 5 %. The result is shown in Column (1) of Table 5. It is not difficult to see that after removing extreme values, the estimated coefficients and significance of each variable is basically consistent with the baseline regression results in Table 3. It indicates that the baseline regression result is robust.

#### 5.3.2. Replacing the explained variable

The indicator “whether there is arable land abandonment behavior” is selected to replace the original explained variable, and the Binary Probit model is chosen to test the robustness of the baseline regression. The Column (2) of Table 5 shows the estimated result of replacing the explained variable. The result also shows that rural human settlement environment can alleviate the influence of non-agricultural transfer of labour on arable land abandonment, which also means that the result of baseline regression is robust.

**Table 4**  
Endogenetic analysis: IV–Tobit.

	(1)	(2)
	The first stage	The second stage
<b>Variables</b>	<b>A. IV: The relationship between village cadres and villagers</b>	
The relationship between village cadres and villagers	0.170**(0.080)	
Rural human settlement environment		−0.022**(0.10)
$F$ -statistic value	42.286***	
Wald $\chi^2$		361.39***
Observations	1325	1325
<b>Variables</b>	<b>B. IV: Whether to petition for environmental pollution</b>	
Whether to petition for environmental pollution	0.353*** (0.098)	
Rural human settlement environment		−0.025** (0.012)
$F$ -statistic value	47.403***	
Wald $\chi^2$		387.42***
Observations	1325	1325

Note: \*\*\* denotes 1 % significance level, \*\* denotes 5 % significance level, \* denotes 10 % significance level; values in brackets are the standard error.

**Table 5**  
Robustness test.

Variables	(1)	(2)
	Screening sample data	Replacing the explained variable
	Truncated 5 %	Whether there is arable land abandonment behavior
Rural human settlement environment	−0.029 <sup>**</sup> (0.013)	−0.035 <sup>**</sup> (0.016)
Non-agricultural transfer of labour	0.118 <sup>***</sup> (0.033)	0.129 <sup>***</sup> (0.035)
Rural human settlement environment × Non-agricultural transfer of labour	−0.044 <sup>***</sup> (0.012)	−0.059 <sup>**</sup> (0.028)
Control variables	Yes	Yes
Regional variable	Yes	Yes
Constants	−0.206 <sup>***</sup> (0.058)	−0.239 <sup>**</sup> (0.111)
Log-likelihood	452.09	479.36
Observations	1264	1325

Note: \*\*\* denotes 1 % significance level, \*\* denotes 5 % significance level, \* denotes 10 % significance level; values in brackets are the standard error.

#### 5.4. Heterogeneity analysis

The aforementioned baseline regression result shows that improving the rural human settlement environment can help to assuage arable land abandonment caused by non-agricultural labour transfer. In fact, whether improved rural human settlement environment can function to mitigate arable land abandonment depends on objective terrain conditions and the subjective place attachment. Terrain conditions determine differences in agricultural production costs caused by topographic conditions and manifest primarily as factor substitution, resource consumption and land location [3,6]. The difference in place attachment encompasses differences in labour flows and social networks emanating from the subjective place attachment to the hometown, which further affects the utilization of arable land resources [35]. place attachment, it is assumed that farmer households with a heightened place attachment to their villages are more likely to realize labour return or use their social networks to actualize agricultural socialization services and arable usage their arable land resources. On the basis of this presumption, this study explores the internal mechanisms and testimonies related to rural human settlement environment and probes their roles in alleviating arable land abandonment caused by non-agricultural labour transfer.

##### 5.4.1. The regional comparison with different terrain conditions: the mechanism of agricultural production cost

The significant differences in agricultural production and management costs in different terrain areas result in differential effects of non-agricultural labour transfer on arable land abandonment in mountainous and hilly areas and the plains areas. At the same time, the higher cost of promoting the improvement of human settlement environment in mountainous and hilly areas must be taken into account. Therefore, farmer households in mountainous and hilly areas may find it more difficult than the rural residents of the plains areas to reduce factor waste, save costs and improve land endowments by improving their human settlement environment in mountainous to decelerate arable land abandonment because of non-agricultural labour transfers. In this study, assumes that differences in terrain conditions between mountainous and hilly areas and the plains would result in differences in agricultural production and management costs. Thus, improving rural human settlement environment would more evidently alleviate farmer households' arable land abandonment behaviours in the plain areas.

This study refers to the relevant extant literature to define terrains with altitudes less than 200m and relief degrees less than 30m as the plains; terrains with altitudes more than 200m or relief degrees more than 30m are defined as mountainous and hilly areas [41,42]. Then, the heterogeneity of rural human settlements and non-agricultural labour transfer influencing arable land abandonment under different terrain conditions was compared and analysed.

**Table 6**  
The regional heterogeneity results of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment.

Variables	(1)	(2)
	Mountainous and hilly areas	Plain areas
Rural human settlement environment	−0.014(0.012)	−0.039 <sup>b</sup> (0.018)
Non-agricultural transfer of labour	0.190 <sup>a</sup> (0.054)	0.072 <sup>b</sup> (0.033)
Rural human settlement environment × Non-agricultural transfer of labour	0.043(0.069)	−0.069 <sup>a</sup> (0.020)
Control variables	Yes	Yes
Regional variable	Yes	Yes
Constants	−0.198 <sup>c</sup> (0.123)	−0.204 <sup>c</sup> (0.055)
Log-likelihood	312.85	239.74
Observations	822	503

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.

Table 6 displays the regional heterogeneity results of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment. Column (1) and (2) exhibit the estimated result in mountainous and hilly areas and the plain areas, respectively. In Column (1), the result shows that the coefficients of variable of rural human settlement environment and its interaction term with non-agricultural labour force transfer are not significant. In Column (2), the result shows that the coefficients of the variable of rural human settlement environment and its interaction term with non-agricultural labour transfer is significantly negative at 5 % and 1 % level, respectively. The coefficient of variable non-agricultural transfer of labour has decreased<sup>⑦</sup>. The above results indicate that in the plain areas, promoting the human settlement environment can significantly alleviate the arable land abandonment caused by the non-agricultural labour transfer. However, this mitigation effect is not evident in mountainous and hilly areas. Therefore, compared with mountainous and hilly areas, farmer households in plain areas are more likely to use the construction of human settlement environment to alleviate the arable land abandonment caused by the non-agricultural labour transfer, supporting H2a.

Table 7 shows the regional heterogeneity results of different dimensions of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment. Columns (1) to (4) and (5) to (8) display the estimated results of the infrastructure, living environment, organization management, culture and community development in mountainous and hilly areas and the plains, respectively. In Column (1), the result shows that the coefficients of the variable of infrastructure and its interaction term with non-agricultural transfer of labour are significantly negative at the levels of 10 % and 5 %, respectively. In Columns (5) and (7), the results show that the coefficients of the variables infrastructure and organisational management and their interaction terms with non-agricultural transfer of labour are significantly negative at least 5 % level. The coefficients of variable non-agricultural transfer of labour have decreased<sup>⑦</sup>. These results reveal that in the plains, improving the grassroots organisation and management level could significantly lessen the arable land abandonment resulting from non-agricultural labour transfer. The mitigation effect of improving infrastructure is weaker in mountainous and hilly areas. Therefore, H2a is further tested. The existing literature affirms this conclusion. Numerous studies have reported that strengthening the construction of infrastructure such as transportation, communication and logistics can reduce diverse costs and mitigate losses [43,44] accruing to agricultural production and operations. Strengthening the development of village organizations and cooperatives is also conducive to the promotion of agricultural socialization services and arable land transfer, and alleviate the of arable land abandonment. In particular, it is necessary to strengthen policy support in remote mountainous areas and make up for infrastructure-based shortcomings to promote the effective use of local resources [45].

**Table 7**

The regional heterogeneity results of different dimensions of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Mountainous and hilly areas				Plain areas			
Infrastructure	−0.012 <sup>c</sup> (0.007)				−0.044 <sup>a</sup> (0.012)			
Living environment		0.017 (0.015)				−0.008 (0.007)		
Organization management			−0.016 (0.023)				−0.042 <sup>a</sup> (0.012)	
Culture & community development				−0.008 (0.007)				−0.015 (0.021)
Non-agricultural transfer of labour	0.185 <sup>b</sup> (0.083)	0.157 <sup>b</sup> (0.073)	0.199 <sup>a</sup> (0.055)	0.096 <sup>b</sup> (0.046)	0.136 <sup>a</sup> (0.038)	0.129 <sup>b</sup> (0.057)	0.119 <sup>b</sup> (0.055)	0.078 <sup>a</sup> (0.022)
Infrastructure × Non-agricultural transfer of labour	−0.050 <sup>**</sup> (0.024)				−0.069 <sup>***</sup> (0.019)			
Living environment × Non-agricultural transfer of labour		−0.032 (0.047)				−0.022 (0.018)		
Organization management × Non-agricultural transfer of labour			0.047 (0.067)				−0.058 <sup>***</sup> (0.016)	
Culture & community development × Non-agricultural transfer of labour				0.010 (0.009)				−0.026 (0.041)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constants	−0.157 <sup>a</sup> (0.043)	−0.138 <sup>b</sup> (0.062)	0.130 <sup>b</sup> (0.061)	0.117 <sup>a</sup> (0.033)	−0.145 <sup>b</sup> (0.066)	−0.137 <sup>b</sup> (0.063)	0.094 <sup>a</sup> (0.026)	−0.085 <sup>a</sup> (0.023)
Log-likelihood	339.56	321.74	308.49	316.93	256.42	244.38	251.64	237.15
Observations	822	822	822	822	503	503	503	503

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.

#### 5.4.2. The groups of comparison with different level of place attachment: the mechanism of the return of labour

The differences in the place attachment exhibited by different groups also influence arable land abandonment caused by non-agricultural labour transfer. In general, improving rural human settlement environment and increasing the attractiveness of the countryside would entice farmer households with a heightened place attachment to become the new management entity taking root in rural locales. It can prompt the farmer households to use arable land resources and simultaneously promote arable land transfer through rural social networks to achieve scale management and thus alleviate the arable land abandonment. Therefore, from the perspective of attracting the return of labour force, this paper explores the differentiated characteristics which the rural human settlement environment influences the arable land abandonment caused by non-agricultural labour transfer in different place attachment level groups.

According to the research of Kasarda et al. [46], Gerson et al. [47] and Li et al. [48], and combining with the current actual situation of farmers to set the specific indicators. The indicators were selected from five aspects: “farmers’ sense of ownership”, “sense of identity with the village”, “degree of love for the village”, “degree of concern for village affairs”, “degree of attachment to the village”, and then assigned values according to the Five-component Likert Scale (see [Supplementary Table 1](#)). The indicators representing the place attachment were then aggregated with equal weights to obtain an average value and the place attachment level of farmers to their village was finally obtained. Finally, the farmer households were classified according to the median of the sample’s value of place attachment to their village into two groups designating “high place attachment group” and “low place attachment group”. Subsequently, the heterogeneity of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment under different place attachment level was compared and analysed.

[Table 8](#) exhibits the group heterogeneity results of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment. Columns (1) and (2) respectively display the estimated results of the two groups classified as high and low place attachment group. In Column (1), the result show that the coefficients of the variable of rural human settlement environment and its interaction term with non-agricultural labour transfer is significantly negative at the levels of 10 % and 5 %, respectively. The coefficient of variable non-agricultural transfer of labour has decreased<sup>®</sup>. In Column (2), the result shows that the coefficients of the variable of rural human settlement environment and its interaction term with non-agricultural labour transfer is not significant. These results indicate that improving rural human settlement environment could significantly alleviate arable land abandonment caused by non-agricultural labour transfer for the farmer households who display the high place attachment to their village. However, the mitigation effect is not significant for the farmer households exhibiting low place attachment. Therefore, compared with the low place attachment farmer households, high place attachment farmer households are more susceptible to the improvement of human settlement environment, thus alleviating the arable land abandonment caused by the non-agricultural labour transfer, supporting [H2b](#).

[Table 9](#) shows the group heterogeneity results of different dimensions of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment. Columns (1) to (4) and (5) to (8) respectively exhibit the estimated results of infrastructure, living environment, organisation and management, culture and community development in the high place attachment group and low place attachment group. It is easily clarified that the coefficients of the variables of infrastructure, organisational management and culture and community development displayed in Columns (1), (3) and (4), respectively, and their interaction term with non-agricultural labour transfer are all significantly negative at least at the level of 10 %. The coefficients of variable non-agricultural transfer of labour have decreased<sup>®</sup>. This result indicates that improving infrastructure, raising the level of grassroots organisation and management and promoting cultural and community development can significantly alleviate the arable land abandonment caused by non-agricultural labour transfer in high place attachment group. However, this mitigation effect is not obvious in low place attachment group. [H2b](#) is further verified. Similar results can be found in research conducted in related domains. Some studies have evidenced that promoting rural construction tends to entice the farmer households of high place attachment to return to their villages for employment and life [8,31,35], become the new type of agricultural management, promote eland transfer, achieve large-scale management and reduce the arable land abandonment [24].

**Table 8**

The group heterogeneity results of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment.

Variables	(1)	(2)
	High place attachment group	Low place attachment group
Rural human settlement environment	−0.032 <sup>c</sup> (0.019)	−0.016(0.014)
Non-agricultural transfer of labour	0.128 <sup>b</sup> (0.060)	0.147 <sup>b</sup> (0.069)
Rural human settlement environment × Non-agricultural transfer of labour	−0.043 <sup>b</sup> (0.019)	0.023(0.036)
Control variables	Yes	Yes
Regional variable	Yes	Yes
Constants	−0.139 <sup>b</sup> (0.065)	−0.069 <sup>a</sup> (0.019)
Log-likelihood	348.92	198.15
Observations	468	857

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.

**Table 9**

The group heterogeneity results of different dimensions of rural human settlement environment and non-agricultural labour transfer affecting arable land abandonment.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	High place attachment group				Low place attachment group			
Infrastructure	−0.041 <sup>a</sup> (0.011)				0.022 <sup>b</sup> (0.010)			
Living environment		0.013 (0.018)				−0.008 (0.007)		
Organization management			−0.028 <sup>b</sup> (0.013)				−0.010 <sup>c</sup> (0.006)	
Cultural & community development				−0.010 <sup>a</sup> (0.005)				0.011 (0.015)
Non-agricultural transfer of labour	0.109 <sup>b</sup> (0.048)	0.127 <sup>a</sup> (0.036)	0.120 <sup>a</sup> (0.032)	0.085 <sup>b</sup> (0.038)	0.168 <sup>a</sup> (0.047)	0.158 <sup>b</sup> (0.073)	0.1358 <sup>b</sup> (0.0646)	0.117 <sup>a</sup> (0.032)
Infrastructure × non-agricultural transfer of labour	−0.053 <sup>a</sup> (0.015)				−0.043 (0.038)			
Living environment × non-agricultural transfer of labour		−0.047 (0.040)				0.021 (0.018)		
Organization management × non-agricultural transfer of labour			−0.045 <sup>b</sup> (0.021)				−0.025 (0.021)	
Cultural & community development × non-agricultural transfer of labour				−0.028 <sup>c</sup> (0.016)				−0.009 (0.013)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constants	−0.114 <sup>a</sup> (0.031)	0.085 <sup>c</sup> (0.051)	0.056 <sup>b</sup> (0.026)	−0.103 <sup>a</sup> (0.028)	−0.089 <sup>b</sup> (0.043)	0.056 <sup>c</sup> (0.034)	−0.042 (0.037)	−0.073 <sup>a</sup> (0.020)
Log-likelihood	183.87	192.64	203.19	188.52	346.72	350.28	348.35	332.46
Observations	468	468	468	468	857	857	857	857

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.

## 6. Further research

China is a country with great internal differences. The terrain is high in the western and low in the eastern; the climate is very different between northern and southern. There is a big gap in economic development between coastal areas and inland areas; and there are significant differences in agricultural production methods, cultural custom and social development among different regions [49]. Therefore, it is necessary to further explore the differences of arable land abandonment and its driving factors in different regions.

Table 10 reports the regression results of rural human settlement environment, non-agricultural transfer of labour affecting arable land abandonment in different provinces. Columns (1) to (5) show the estimated results for Zhejiang, Hubei, Jilin, Sichuan and Gansu, in turn. It can be seen that only in Columns (1), (2) and (3), the coefficients of rural human settlement environment are significantly negative at least on the 5 % level; the interaction terms are significantly negative at the levels of 5 %, 10 % and 5 % respectively. And after adding the interaction item, the coefficients of the variable non-agricultural transfer of labour have decreased<sup>®</sup>. It also means that in Zhejiang, Hubei and Jilin provinces, the mitigation effect of improving rural human settlements is significant. This result can be confirmed by existing literature. For example, some studies have shown that in the eastern and central plains or major grain-producing areas, infrastructure construction and grassroots organization development can promote local arable land usage [4,12].

In terms of control variables, education level, health status of the labour force, arable land scale and fragmentation of arable land affect the decision of arable land abandonment in the whole sample. For different regions, household size, arable land quality, arable land transfer and land ownership certification are the factors that affect land abandonment in Zhejiang, Hubei and Jilin provinces. However, the proportion of family members who are supported and brought up and natural disasters can affect the utilization of arable land resources by farmer households in Sichuan and Gansu provinces. Above results are also supported by existing literature: some scholars believe that improving rural human capital, accelerating the construction of high-standard arable land and promoting large-scale management in plain areas or major grain-producing areas are important ways to alleviate local arable land abandonment [4,10,24].

## 7. Conclusions and policy implications

### 7.1. Conclusions

This study utilised micro-survey data obtained from 1325 households in 5 provinces in China and took the “relationship between village cadres and villagers” and “environmental pollution petition” as the instrumental variables. It employed the Tobit model to

**Table 10**

The regression results of rural human settlement environment and non-agricultural transfer of labour affecting arable land abandonment in different provinces.

Variables	(1)	(2)	(3)	(4)	(5)
Rural human settlement environment	−0.036 <sup>a</sup> (0.010)	−0.026 <sup>b</sup> (0.012)	−0.021 <sup>b</sup> (0.010)	−0.012 <sup>c</sup> (0.007)	−0.009 (0.010)
Non-agricultural transfer of labour	0.083 <sup>b</sup> (0.037)	0.126 <sup>a</sup> (0.035)	0.107 <sup>b</sup> (0.049)	0.162 <sup>a</sup> (0.046)	0.184 <sup>a</sup> (0.052)
Rural human settlement environment × Non-agricultural transfer of labour	−0.022 <sup>b</sup> (0.010)	−0.039 <sup>a</sup> (0.011)	−0.025 <sup>b</sup> (0.012)	−0.028 (0.022)	−0.013 (0.015)
Gender	−0.012 (0.009)	−0.017 (0.013)	−0.008 (0.006)	−0.007 (0.005)	−0.003 (0.002)
Age	0.004 (0.003)	0.003 (0.002)	−0.002 (0.002)	0.003 (0.003)	0.005 (0.004)
Education level	−0.011 <sup>c</sup> (0.006)	−0.014 <sup>b</sup> (0.007)	−0.016 <sup>b</sup> (0.007)	0.005 <sup>c</sup> (0.004)	0.004 <sup>c</sup> (0.003)
Village cadre experience	−0.027 (0.021)	−0.029 (0.024)	−0.032 (0.028)	−0.016 (0.019)	−0.008* (0.005)
Household size	−0.023 <sup>b</sup> (0.010)	−0.024 <sup>c</sup> (0.015)	−0.013 <sup>c</sup> (0.007)	0.008 (0.009)	0.011 (0.014)
The proportion of family members who are supported and brought up	0.019 (0.017)	0.032 (0.027)	0.009 (0.010)	0.015* (0.009)	0.007* (0.004)
Health status of labour force	0.006 <sup>b</sup> (0.003)	0.008 <sup>a</sup> (0.002)	0.011 <sup>a</sup> (0.003)	0.004 <sup>b</sup> (0.002)	0.005 <sup>c</sup> (0.003)
Total family income	−0.003 (0.002)	−0.005 (0.006)	−0.004 (0.005)	−0.002 (0.001)	−0.003 (0.002)
Arable land scale	−0.018 <sup>a</sup> (0.005)	−0.027 <sup>a</sup> (0.007)	−0.022 <sup>a</sup> (0.006)	−0.016 <sup>b</sup> (0.007)	−0.006 <sup>b</sup> (0.003)
Fragmentation of arable land	0.015 <sup>b</sup> (0.007)	0.021 <sup>a</sup> (0.006)	0.017 <sup>b</sup> (0.007)	0.023 <sup>a</sup> (0.007)	0.025 <sup>b</sup> (0.011)
Arable land quality	−0.014 <sup>b</sup> (0.006)	−0.022 <sup>a</sup> (0.006)	−0.028 <sup>a</sup> (0.008)	−0.011 (0.009)	−0.014 (0.0012)
Whether to participate in the arable land transfer	−0.045 <sup>c</sup> (0.026)	−0.056 <sup>b</sup> (0.025)	−0.063 <sup>c</sup> (0.037)	−0.029 (0.034)	−0.038 (0.044)
Distance from the house to the nearest market	0.007 (0.006)	0.004 (0.005)	0.005 (0.006)	0.003 (0.002)	0.001 (0.001)
Land ownership confirmation certificate	−0.018 <sup>b</sup> (0.008)	−0.015 <sup>c</sup> (0.009)	−0.026 <sup>b</sup> (0.011)	−0.012 (0.010)	−0.003 (0.002)
Agricultural production subsidies	−0.004 (0.005)	−0.008 <sup>c</sup> (0.005)	−0.007 <sup>b</sup> (0.003)	−0.003 (0.003)	−0.002 (0.002)
Natural disaster	0.024 (0.020)	0.023 (0.019)	0.026 (0.022)	0.028 <sup>c</sup> (0.017)	0.035 <sup>b</sup> (0.016)
Log-likelihood	148.96	165.27	124.35	103.17	92.68
Observations	281	303	278	259	204

Note: values in brackets are the standard error.

<sup>a</sup> denotes 1 % significance level.

<sup>b</sup> denotes 5 % significance level.

<sup>c</sup> denotes 10 % significance level.

empirically test the mitigation effect of rural human settlement environment on arable land abandonment caused by non-agricultural labour transfers. The major conclusions of this study are outlined as follows:

- (1) Improving rural human settlement environment can alleviate arable land abandonment resulting from non-agricultural labour transfer. This deduction remains valid after the endogeneity problem is considered. The mitigation effects of the different dimensions of rural human settlement environment are significantly different. Specifically, infrastructure and organisational management can significantly alleviate the arable land abandonment caused by non-agricultural labour transfer.
- (2) Terrain differences between mountainous and hilly areas and the plain areas lead to the divergences in the mitigation effects of rural human settlement environment on arable land abandonment caused by non-agricultural labour transfer. The mitigation effect of rural human settlement environment in the plain areas is more obvious than in mountainous and hilly areas. In terms of the different dimensions of human settlement environment, ameliorations in infrastructure and organisational management levels can alleviate the arable land abandonment in the plains.
- (3) Farmer households with different place attachment levels have different decisions on labour migration, which makes the mitigation effect of rural human settlement environment on arable land abandonment caused by labour non-agricultural transfer significantly different. Compared to farmer households with low place attachment, the farmer households with high place attachment to their village are more likely to be attracted by improved village appearance, become the new types of agricultural production and management, and take root in the countryside, so as to alleviate the phenomenon of arable land abandonment caused by the non-agricultural labour transfer. For different dimensions of human settlement environment, improving infrastructure, elevating organizational management level, and promoting cultural and community development will be more conducive to promoting the usage of arable land resources by farmer households with high place attachment.
- (4) There are significant differences in arable land abandonment and its driving factors in different regions. In the east and central plain or the main grain producing areas, improving rural human settlement environment has a significant mitigation effect on



arable land abandonment. Household size, arable land quality, arable land transfer and land ownership certification are also the factors affecting the reduction of arable land abandonment in these areas. In addition to the education level, health status of labour force, arable land scale, fragmentation of arable land; the proportion of family members who are supported and brought up and natural disasters can affect the arable land abandonment decision of western farmer households’.

## 7.2. Policy implications

The conclusions provide the following policy implications: First, for improving rural human settlement environment, we should pay attention to the construction of both hard and soft human settlement environment. On the one hand, it should further strengthen the construction of hard human settlement environment such as the infrastructure and ecological environment. On the other hand, it is more necessary to promote the positive role of soft human settlement environment such as grassroots governance. Second, based on the principle of adapting to local conditions, the government should take full account of the local natural geographical environment and social and economic development, strives to improve the rural human settlement environment and enhances the attractiveness of rural areas. It does not only improve people’s well-being, but also promote the flow and optimization of social and economic factors between urban and rural areas. Third, more supportive policies should be tilted to the mountainous and hilly areas and farmer households of high place attachment. It could promote the local nonagricultural employment and agricultural socialization services, accelerate the arable land transfer, and thus reduce arable land abandonment.

## 7.3. Limitations of the study and future research

This study is not without limitations. First, due to financial and capacity constraints, this paper only obtained cross-sectional data and failed to continuously observe the farmer households’ arable land abandonment behavior. In the future work, efforts will be made to carry out continuous research on fixed observation points or make use of panel data in open databases to explore effective ways to alleviate arable land abandonment. Second, this paper has selected representative variables to establish the index system to measure the quality of rural human settlement environment. But it is worth noting that rural human settlement environment is a complex system. In the future research, the index system will be continuously improved. Third, improving rural human settlement environment can not only enhance the well-being of rural residents, but also increase the attractiveness of the countryside, and attract various factors to return to the countryside. The resource allocation effect of improving rural human settlement environment is the important topic that needs to be explored constantly.

## Annotation

- ① The data comes from [https://www.gov.cn/xinwen/2020-04/30/content\\_5507849.htm](https://www.gov.cn/xinwen/2020-04/30/content_5507849.htm).
- ② The mountainous and hilly area data are derived from [https://www.gov.cn/test/2005-05/25/content\\_591.htm](https://www.gov.cn/test/2005-05/25/content_591.htm); The slope arable land data comes from the “Third National Land Census” [https://m.mnr.gov.cn/dt/ywbb/202108/t20210826\\_2678340.html](https://m.mnr.gov.cn/dt/ywbb/202108/t20210826_2678340.html).
- ③ The labour force studied in this paper referred to the labour force population aged 16 or above in the rural population, excepted for school students and other people who had no willingness to work.
- ④ Due to the limitation of the length of the article, the regression results with only two core explanatory variables are not shown here. Compared with the regression results with only two core explanatory variables, after adding the interaction term, the coefficients of the variable “non-agricultural transfer of labour” have decreased. If the readers need the regression results of the two explanatory variables, could ask the author for them.
- ⑤ The specific result was shown in Column (2) of the robustness test in Table 5 below.
- ⑥⑦⑧⑨⑩ The same interpretation as ④.

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## Data availability statement

Due to the involvement of several public institutions and research groups, some research is still ongoing; the data has not been allowed to be publicly available.

## CRediT authorship contribution statement

**Xin Zheng:** Writing – original draft, Data curation, Conceptualization. **Fuxia Yang:** Validation, Supervision, Funding acquisition, Formal analysis. **Dongshou Fan:** Supervision, Methodology, Formal analysis. **Yutong Yan:** Software, 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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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2024.e36418>.

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