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# Identify Optimization Type of Rural Settlements Based on "Production–Living–Ecological" Functions and Vitality: A Case Study of a Town in Northern China

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**Abstract:** Rural settlements are developing in the direction of functional diversification, driven by rapid urbanization, but also leading to a decline in their vitality as a result of the rapid concentration of rural population in cities. Therefore, this study proposed a theoretical framework to refine the optimization approach for rural settlements from the perspective of "production–living–ecological" functions (PLEF) and vitality. Taking a town in the farming–pastoral ecotone in northern China as a case, we evaluated the level of the PLEF of rural settlements. After exploring the functional requirements of villagers, we revealed the vitality of rural settlements based on social network analysis. The Tapio decoupling model was used to identify the optimization type of rural settlements considering the PLEF and vitality. The results showed that the PLEF of rural settlements was higher in areas with flat terrain, convenient transportation, and rich economies. Rural settlements closer to the central town were stronger in vitality. The PLEF of rural settlements was generally correlated with vitality, which means that rural settlements with a higher level of PLEF also had a stronger vitality. Rural settlements were classified into five types: suburban integration, characteristics protection, agglomeration and upgrading, general survival, relocation, and merger, according to the characteristics of a combination of PLEF and vitality. This study contributes to a deeper comprehension of the functional and structural characteristics of rural settlements and will be beneficial in guiding rural spatial reconstruction.

**Keywords:** rural settlements; "production–living–ecological" functions; vitality; the farming–pastoral ecotone; Tapio decoupling model

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## 1. Introduction

Rural settlements are essential carriers of the "production–living–ecological" spaces in the countryside, which provide villagers with the requirements of agricultural production, living services, ecological conservation, and other functions [1]. Urban and rural constructing land has continued to encroach on rural arable land, woodland, and grassland as a result of the rapid urbanization process [2]. This has limited production space, fragmented living space, and unbalanced ecological space in rural areas. Furthermore, the substantial outmigration of young laborers to urban centers has resulted in the hollowing out and getting older of rural areas [3]. This rural decay, characterized by rural depopulation, cultural dissipation, and ecological degradation, is a global problem. In response to the phenomenon of rural decline, various nations have embraced distinct strategies to revitalize the countryside, such as Liaison Entre Actions de Développement de l'Economie Rurale (LEADER) in the European Union, the One Village One Product (OVOP) Movement in Japan, the Saemaeul Movement in South Korea, the Rural–Urban Integration in the

United States, and Rural Revitalization in China [4–6]. The function of the countryside has gradually diversified from the basic agricultural production function to industrial production, livelihood security, ecological tourism, and other functions under the dual impetus of urbanization and rural revitalization [7]. As a result, the countryside finds itself amidst a rapid and dynamic phase of change.

Function is one of the attributes of rural space, and its change and evolution are essential characteristics of the rural land use pattern [8]. The traditional agricultural production function has been gradually degraded because of the non-cultivation of arable land and the non-farming of the population [9]. The pursuit of material and spiritual requirements of people has led to the growing prominence of rural living and ecological functions. The complex relationship among rural production, living, and ecological functions, which mutually reinforce and constrain, has a significant impact on the development and evolution of rural space [10]. Rural settlements, as an integral part of rural areas, have a "domino effect" in the process of countryside transformation and development in that they are an essential source of countryside development [11]. Throughout the course of rural transformation, the size, structure, and layout of rural settlements have changed dramatically [12]. The challenges are gaining greater prominence, which includes the scattered layout of settlements and the disorganized structure of production, living, and ecological land [13]. The countries have adopted different measures to optimize the land use layout of rural settlements in order to improve the level of PLEF. For example, in the Saemaeul Movement, the South Korean government improved the living quality of villagers by reorganizing the rural living environment [14]. In the OVOP Movement, the Japanese government enhanced the overall function of the countryside by fully utilizing local advantages [15]. And in 2012, the Chinese government initially proposed the goal of optimizing national land planning, which is to build an intensive and efficient production space, a livable and moderate living space, and a clear and beautiful ecological space. With its policy of revitalizing the countryside, the Chinese government has emphasized building a beautiful and harmonious countryside that is desirable to live and work in. This puts forward new requirements for the production, living, and ecological land use pattern of rural settlements in the new era. However, different rural settlements do not have a uniform demand for productive and ecological land due to differences in resources, culture and society. Therefore, clarifying the positioning of rural settlements and identifying the optimization type of rural settlements is an important means of realizing the comprehensive coordination and enhancement of "production–living–ecological" functions (PLEF) of settlements.

Identifying the optimization type of rural settlements is a crucial project for the spatial reconstruction of the countryside, as well as an important way of judging the current development condition and future development trends of rural settlements [16]. This approach serves as a potent remedy to counter rural decay, playing a pivotal role in integrating land resource elements, improving rural habitat, and fostering rural economic growth [17]. In the early twentieth century, French scholars such as Paul Vidal de la Blache and Jean Brunhes explored the types of rural settlements in terms of natural conditions and local geography [18]. They used historical methods to study the types of rural settlements, including fieldwork, comparative analysis, and systematic analysis. Subsequently, Albert Demangeon researched the forms of rural settlements in France and classified villages into four types: long, block, star, and scattered [19]. Scholars have devoted substantial research to identifying the optimization type of rural settlements. The majority of the literature evaluates rural settlements and classifies optimization types from the perspective of single factors, such as population density, location conditions, economic level, cultivation radius, and willingness of farmers [20–23]. Alternatively, scholars construct an evaluation index system from the perspective of multiple factors as a way of identifying the optimization type of settlements, such as PLEF, residential suitability, security resilience, and comprehensive influence [24–27]. Generalized matrix models, coupled coordination models, decoupled models, mutually exclusive combinatorial matrices, and hierarchical analysis are used in identification studies [28,29]. It is noteworthy that the intricate diversity and complexity exhibited by rural settlements impose limitations on the efficacy of classifying them through a single factor. Such an approach fails to facilitate a comprehensive grasp of their intricate form and underlying structural characteristics. The trend of settlement development is characterized by diversification of production functions, humanization of living functions, and rigidity of ecological functions [30]. Presently, both government and scholars are directing their focus toward evaluating rural settlements through the perspective of PLEF. PLEFs are the product of the interaction between the spatial environment and spatial elements. Scholars mostly evaluate rural settlements in terms of overall level, coupling degree, and coordination degree by utilizing the concept of PLEF [31–33]. However, current research commonly analyzes the PLEF of rural settlements by taking settlement patches or administrative villages as the evaluation unit. The natural village area is rarely considered as the evaluation unit. It also ignores the functional requirements of villagers as the main body, which lacks the combination of vitality to identify the optimization type of rural settlements.

The rural territorial system encompasses a geographical framework with distinct structures, functions, and interregional connections influenced by factors such as population mobility, resource endowment, and ecological environment [34,35]. Within this framework, the natural village area, comprising the settlement and surrounding land types, forms the fundamental component. The PLEF of rural settlements is cultivated through an ongoing process of adjustments in response to the available territorial resources and ecological environment of the natural village area [36]. PLEF serves as the cornerstone for meeting the material and societal needs of local inhabitants. Therefore, we evaluate the PLEF of rural settlements considering all the land within the natural village area. Regional variations, however, have led to rural settlements that vary in natural environments and resource endowment conditions [37]. Rural settlements characterized by infertile land, limited resources, and degraded ecological environments tend to exhibit low levels of PLEF [38]. Consequently, these circumstances render the sustenance of essential daily production and living standards challenging for the local villagers. In this case, villagers may seek to satisfy their specific requirements by traveling to adjacent settlements, guided by individual preferences and level of PLEF. To purchase daily necessities, for example, villagers travel to rural settlements with established living conditions, which reflects the phenomena of population mobility. This phenomenon can be construed as rural settlements catering to the functional requirements of non-local villagers. This research describes it as the vitality of rural settlements [39]. The attractiveness of settlements in the region where they are situated, which can satisfy villagers' multiple functional requirements, is denominated as vitality. It includes the attractiveness of the production function, the attractiveness of the living function, and the attractiveness of the ecological function [40]. Currently, the evaluation of PLEF is usually classified on the basis of the settlement's own conditions. It seldom considers the status and role of settlements in the region as a whole. As early as 2007, Woods proposed that the rural territory is a system of multiple settlements with intricate and dynamic rural networks, connecting rural to rural and rural to urban [41,42]. The vitality can reflect the influence of residential areas in the rural network system. Furthermore, the spatial travel behavior exhibited by villagers can be perceived as indicative manifestations of population mobility [43]. The functional requirements of villagers are quantitatively examined to indicate the vitality of settlements in the rural social network based on the spatial travel behavior of villagers. Therefore, this study evaluates rural settlements from the perspective of PLEF and vitality, which can assist the identification of the optimization type of rural settlements.

The farming–pastoral ecotone of Northern China is one of the four major farming–pastoral ecotones in the world. It is predominantly located in a transitional area characterized by dry and semi-arid climatic conditions, with a primary focus on the Inner Mongolia Autonomous Region [44]. This area serves as an important ecological defensive line in northern China, providing wind shelter and sand consolidation while also restricting desertification progress eastward and southward [45]. The biological environment in this region is sensitive and fragile, prone to changes in land use, and plagued by substantial population loss and rural hollowing-out issues.

Therefore, this study selected a town located within the farming–pastoral ecotone in China as a case study. We aimed to propose a theoretical framework from the perspective of PLEF and vitality to comprehensively understand the optimization path of rural settlements. To achieve this, an evaluation index system for rural settlements was constructed based on PLEF, and the vitality of rural settlements was assessed using social network analysis (SNA). The Tapio decoupling model was applied to identify the optimization types of settlements. The following questions will be addressed in this study: (1) What sort of decoupling relationship exists between PLEF and vitality in rural settlements? (2) How can the PLEF and vitality be used to identify the optimal types of rural settlements? The purpose of this work is to provide a scientific foundation for the implementation of rural revitalization strategies for the farming–pastoral ecotone.

## 2. Theoretical Framework

The functions of rural settlements are gradually developed in the process of continuously adapting to regional environmental endowments and requirements of local villagers, which reflect the results of the interaction between the natural village area and local villagers [46]. Land use, as the "spatial projection" of economic and social development, is an important tool for recognizing the functional spatial differentiation of rural settlements [47]. The land use types within the natural village area collectively provide for the production, living, and ecological multi-functional requirements of the villagers, including settlement land, arable land, grassland, woodland, and so on [48]. These functions are subject to constant change as the socioeconomic level develops, with some functions fading away while others develop new ones (Figure 1).

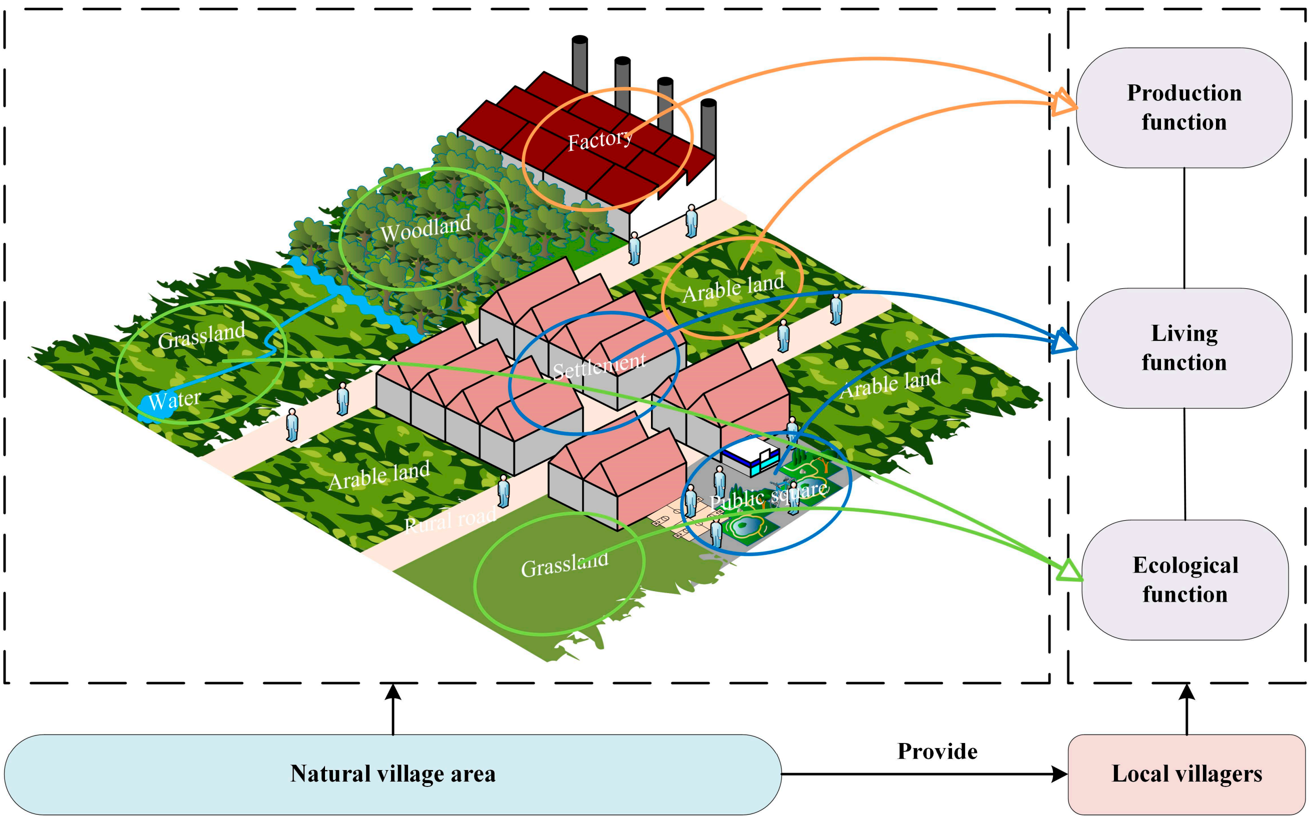


**Figure 1.** Schematic of the natural village area (note: the figure is drawn by authors).

During the pre-industrialization period, the level of social productivity was low. The land within the natural village areas was not exploited. Rural settlements were carriers of living accommodations for villagers as well as spaces for developing the agricultural production economy [49]. Functions of rural settlements show a naturally dominant and harmonious coexistence, mainly provided by arable land and settlement land within the natural village area [50]. During this period, the total volume of functions of rural settlements was small; the production function was based on agricultural production, the living function was mainly to provide living space for human beings, and the ecological function had not yet been damaged by human activities [51]. At the time of the industrialization period, accompanied by rapid urbanization, the countryside transitioned from a small peasant economic society to a modern industrial society [52]. Land within the natural village area is gradually being replaced by commercial and industrial land. The evolving structure of rural industries has resulted in changes in villagers' modes of production, living, and employment. The continuous transfer of rural labor to the cities has led to the abandonment of huge areas of arable land. The agricultural production function of the countryside has been relatively weakened [53]. Furthermore, with the increased frequency of exchanges and interaction between urban and rural areas, the trend of non-agriculturalization and diversification of rural industries is becoming more and more obvious. The rural areas that are relatively economically developed have spontaneously generated township enterprises while taking over urban industries, and the function of rural industrial production has been significantly enhanced. In the post-industrialization period, ecological problems have been associated with industrial development in the process of urbanization, such as waste of resources, environmental pollution, etc. [54]. Under the guidance of ecological concepts such as green development and sustainable development, the ecological conservation function of the countryside has been increasingly emphasized. People have also become more concerned about their living environment [55]. The government departments have provided villagers with livelihood security functions by improving public service facilities and building leisure and recreational areas. At the same time, the production, living, and ecological activities of each region are guided according to spatial planning and management model innovation [56]. It regulates the development and utilization behaviors of the stakeholders, and the multiple functions of rural areas are becoming increasingly coordinated (Figure 2).

It can be seen that with the development of the social economy, the agricultural production function of rural settlements has been gradually weakened, the living function has been prominent, and the ecological function has been increasingly valued. The PLEF has been running through the evolutionary development of rural settlements. It is an essential perspective for judging the development potential of rural settlements [57]. The level of PLEF of rural settlements varies owing to disparities in location, resource endowment, and development environment [58]. The high level of PLEF implies a rational land-use structure, comprehensive infrastructure, and flourishing industries. In this case, rural settlements cater to a spectrum of functional requirements for villagers, concurrently exhibiting elevated levels of attractiveness and vitality. Conversely, the low level of PLEF implies a single land use structure dominated by residential land use and the lack of industrial land use. And rural settlements are constrained in their capacity to address merely fundamental functional necessities for villagers, resulting in diminished levels of attractiveness and vitality. Hence, this research concludes that an increase in the level of PLEF within rural settlements corresponds to an augmented level of their vitality.

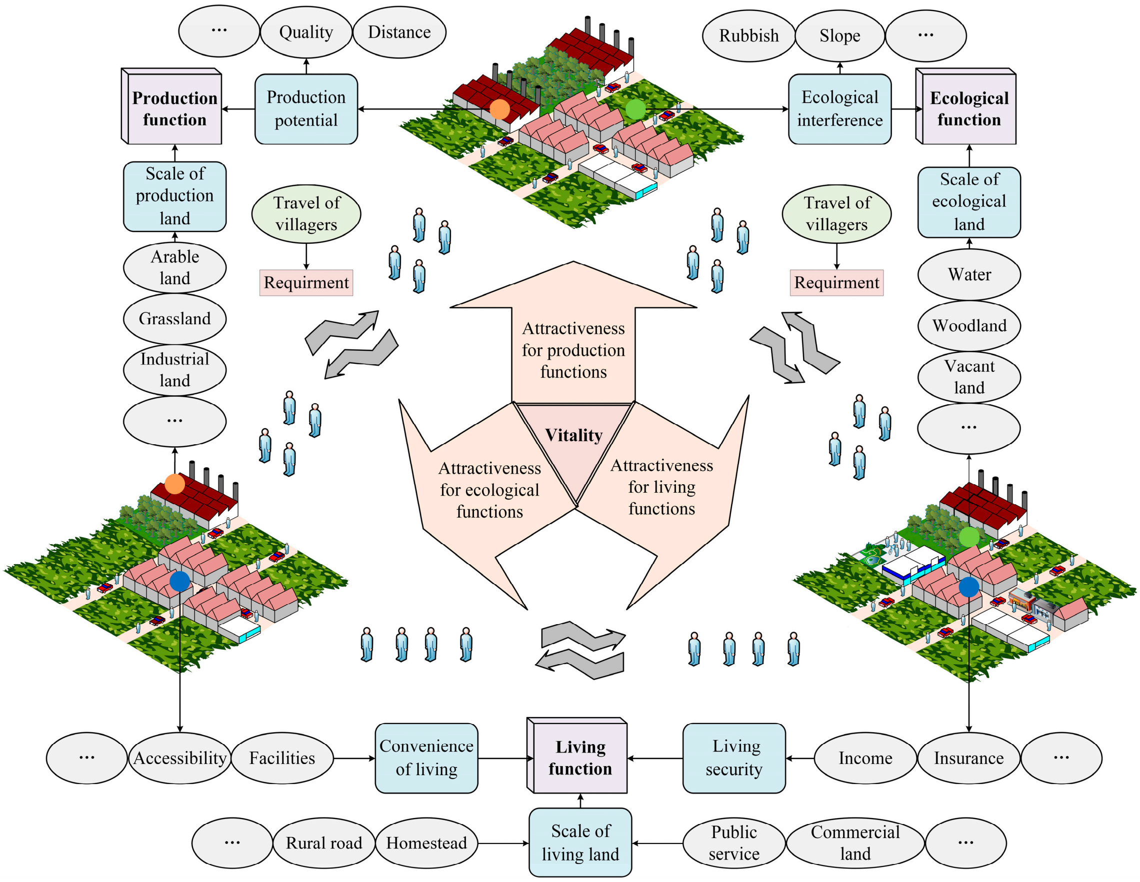


**Figure 2.** Theoretical framework for PLEF and vitality in rural settlements (note: the figure is drawn by authors).

## 3. Materials and Methods

### *3.1. Study Area*

Kekeyiligeng Town (Ke Town) is located in the Inner Mongolia Autonomous Region of China and serves as a representative farming–pastoral ecotone (Figure 3). Ke Town has high topography in the north and low topography in the south, with an average altitude of around 1500 m, a temperate continental monsoon climate, with 290~330 mm of annual precipitation. Ke Town was originally a nationwide poverty-stricken area but succeeded in escaping poverty in 2019 with an economy characterized by agriculture and animal husbandry. As of 2019, the rural population of Ke Town amounted to 4883 individuals, reflecting a decline of 7594 individuals compared to 2009. This reduction signifies a decrease of more than 60% within this decade, underscoring the notable diminishment in the vitality of settlement. Water scarcity, sparse vegetation, and poor infrastructure in Ke Town have resulted in low productivity, poor quality of life, and a terrible natural environment in rural settlements, making it impossible to accommodate the requirements of villagers for normal production and living. As a result, an urgent imperative exists to conduct a comprehensive assessment of the present condition of PLEF and the vitality of rural settlements. This research is pivotal for identifying the optimization type that can effectively foster robust and sustainable rural development.

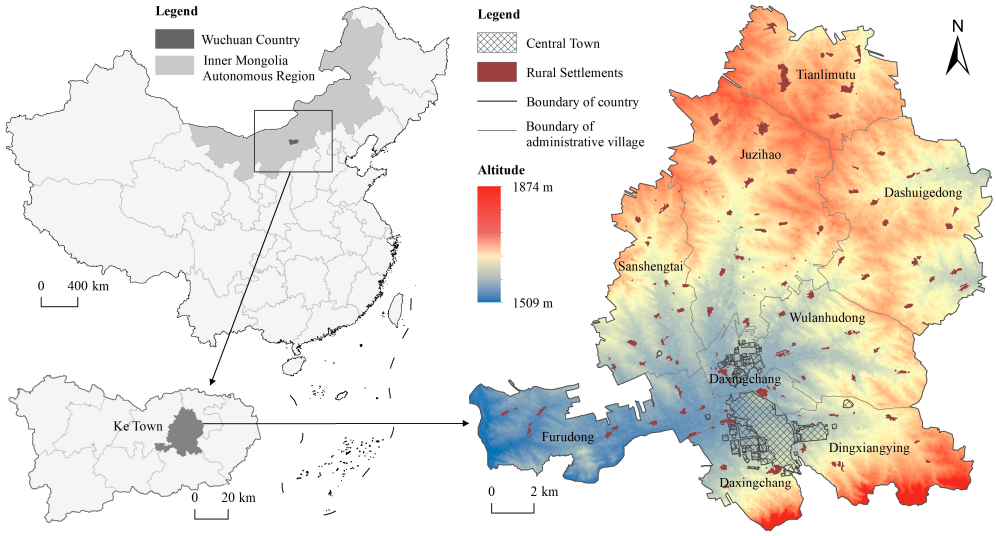


**Figure 3.** Map of the geographical location of Ke Town (note: the figure is drawn by authors).

### *3.2. Data Sources*

In this study, remote sensing image data were used to delineate natural village areas and slope extraction, including 1 m resolution remote sensing images (https://livingatlas.arcgis.com/wayback/ (accessed on 10 May 2023)) and 30 m resolution DEM (http://www.gscloud.cn/ (accessed on 12 May 2023)). Land use data (the Natural Resources Bureau, Wuchuan, Inner Mongolia Autonomous Region, China) were provided by the Wuchuan Country Natural Resources Bureau. ArcGIS software was used to obtain data on evaluation indicators based on land use data, such as the grassland area index, cropland area index, industrial and mining land area index, accessibility to town centers, and distance from main roads. Socioeconomic data (the Bureau of Statistics, Wuchuan, Inner Mongolia Autonomous Region, China) were collected from the Wuchuan Country Statistical Yearbook, including average annual household income, number of information and communication facilities, number of public service facilities, share of agricultural insurance insured, etc. Field census data were obtained using participatory rural appraisal (PRA), such as quality grade of arable land, rate of new houses built in the last five years, intensity of fertilizer application, residential travel, etc.

Several government documents have been used to identify optimization types of rural settlements, including the National Rural Revitalization Strategic Plan (2018–2022), the Overall Planning of Land Use in Kekeyiligeng Town (2009–2020), the Chinese Traditional Villages List, and the Wuchuan County Traditional Villages List. The National Rural Revitalization Strategic Plan (2018–2022) was proposed in September 2018 by the Chinese government. This is the first planning document that responds to China's rural revitalization strategy. The document makes it clear that rural revitalization will be promoted in categories according to the development status, location conditions, and resource endowments of different villages and in accordance with the ideas of suburban integration, characteristics protection, agglomeration and upgrading, and relocation and merger. The Overall Planning of Land Use in Kekeyiligeng Town (2009–2020) is the land use restructuring, regional land use regulation, and the major tasks of land use formulated by the Ke Town government based on the natural geography and socioeconomic situation. The document established the expansion boundaries for urban construction in Ke Town. The Chinese Traditional Villages List is a list of ancient villages with rich historical information and cultural backgrounds compiled by the Chinese government in 2012, with six batches now published. The villages on this list are national conservation units. The Wuchuan County Traditional Villages List is a county-level list of villages for protection compiled by the Wuchuan County Government. This list of villages has a lower level of protection but covers a wider area.

### 3.3. Research Idea

Rural settlements are spatial carriers that serve certain functions and connections in rural areas. PLEF represents the comprehensive capacity of rural settlements, whereas vitality characterizes the attractiveness of rural settlements. Both dimensions intricately intertwine, directly impacting and reflecting the socioeconomic progress within rural settlements. Therefore, this study proposed a theoretical framework from the perspective of PLEF and vitality. We took Ke Town of farming–pastoral ecotone as a case study and constructed an evaluation index system of PLEF of rural settlements based on the concept of PLEF. The entropy weight method (EWM) was employed to assign weights to each index to evaluate the level of PLEF in rural settlements. PRA was used to collect data on the spatial travel behavior of villagers, and SNA was used to assess the vitality of rural settlements. The Tapio decoupling model was used to identify the combined characteristics of the PLEF and the vitality of rural settlements. Based on the combined characteristics of both, the optimization type of rural settlements in Ke Town was defined with reference to the National Rural Revitalization Strategic Plan (2018–2022), as well as local plans and other documents (Figure 4).

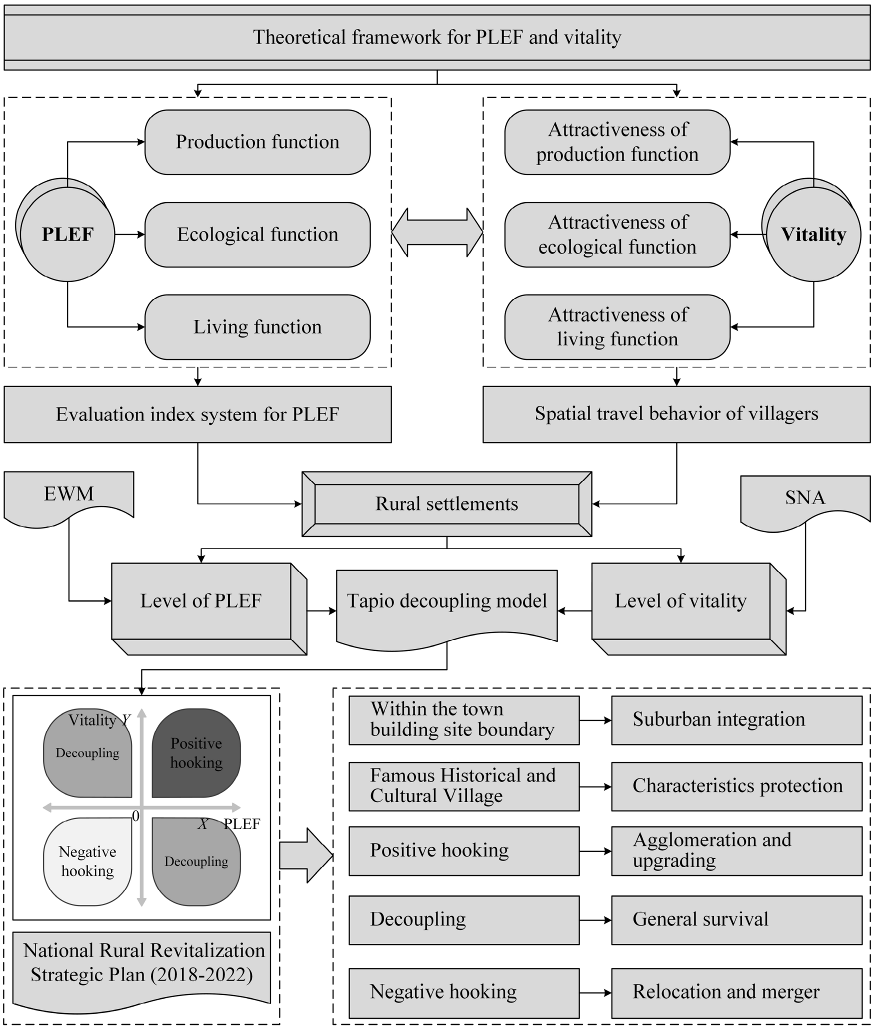


**Figure 4.** Technology roadmap (note: the figure is drawn by authors).

### 3.4. Methodology

#### 3.4.1. Participatory Rural Appraisal (PRA)

PRA is a method of gaining information on local realities through informal interviews with villagers [59]. This study mainly used a combination of questionnaires and semistructured interviews [60]. In the actual survey, we adopted the open-ended questioning method and conducted the interviews according to the survey topic and the survey outline prepared in advance. Moreover, we enabled the surveyed villagers to express their views and wishes on agricultural production, the condition of human habitats, and the relocation of migrants in a harmonious atmosphere.

In August 2019, we conducted a full census of Ke Town. We first visited the village council of each administrative village to obtain basic information about the village to fill out the questionnaire designed in advance. Afterward, we consulted the villagers at their homes and communicated with them face-to-face according to the interview outline to obtain their most realistic ideas. We mainly used this method to obtain data on the indicators in the evaluation index system of PLEF, including the number of information and communication facilities, the number of public service facilities, the average annual household income, the percentage of insured persons in agricultural insurance, the diversity of income sources of villagers, the ecological facilities completeness, the rubbish and wastewater outflow, and the fertilizer application intensity. Furthermore, we obtained data on the spatial travel behavior of villagers during a week through interviews.

#### 3.4.2. Delineation of Natural Village Areas Based on a Remote Sensing Image

The natural village area is developed naturally as a result of the production and living process of villagers. It is the basic unit that provides for the multiple functional requirements of villagers [61]. Hence, this study took the natural village area as the evaluation unit to analyze the PLEF of rural settlements. In the current system of classification of land use status, there is no specific scope of natural village areas. Furthermore, the various types of land within the rural settlements are coarsened into a whole plot. This leads to difficulties in revealing the various land use types and their functions within the natural village area. So, we first need to define the scope of the natural village area. At present, the local villagers have ownership of the land within the natural village area. Conversely, they do not have the ownership of land in other natural village areas [62]. Therefore, we delineated the scope of the natural village area and interpreted the internal land use of rural settlements, which was helped via remote sensing images and PRA.

In Ke Town, rural settlements are characterized by a single mode of production and living and a bad ecological environment. The natural village area is defined by a huge area and a small number of settlements. Arable land and grassland within the natural village area are the main production land for villagers. Residential land and vacant land within settlements are the living land of villagers. All land within the natural village area, including woodlands, grasslands, and rivers, provides ecological space for villagers. The scope of the natural village area includes production land, living land, and ecological land. Mountains, water systems, highways, and other features played a significant role in defining the scope of natural village areas in previous studies. But now that there is a clear ownership relationship among each land, the natural village area can be delimited by acquiring data on ownership of each category through PRA. Therefore, visual interpretation of the geomorphology of Ke Town is performed with the help of remote sensing images. The scope of the natural village area was delineated based on on-site investigation data. Finally, the ArcGIS program was utilized to outline the natural village area with clear land class differentiation using data from the land use change survey (Figures 5 and 6).

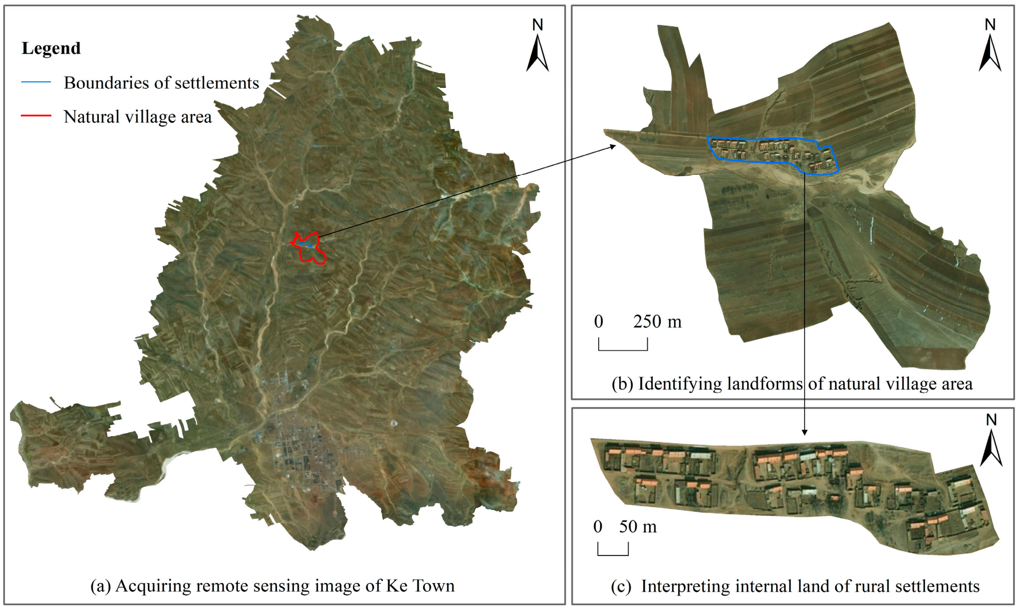


**Figure 5.** Visual interpretation of land use types (note: the figure is drawn by authors).

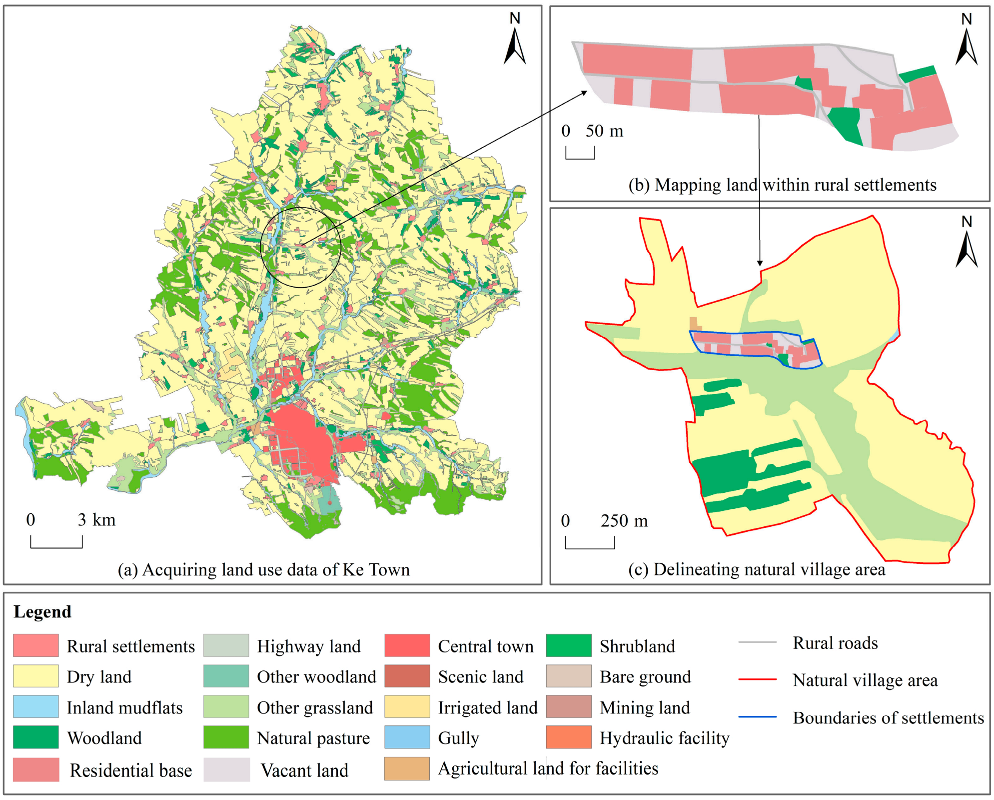


**Figure 6.** Delineation of Ke Town natural village area (note: the figure is drawn by authors).

### 3.4.3. Construction of the Evaluation Index System for the PLEF of Rural Settlements

After referring to the existing research results and combining them with the characteristics of the natural villages in Ke Town, this study constructed the evaluation index system of PLEF of rural settlements from three dimensions of the production function, living function, and ecological function [1,13,31,48], as follows (Table 1).

**Table 1.** Evaluation index system of PLEF of rural settlements (Note: The table is drawn by authors).

| Target Layer | Guideline Layer | Indicator Layer | Calculation Instructions | Properties | Weights |
| --- | --- | --- | --- | --- | --- |
| Production function | Scale of production land | Area of grassland | Size of grassland in natural village | Positive | 0.0145 |
| | | Area of arable land | The size of arable land in natural village | Positive | 0.0400 |
| | | Area of industrial and mining land | The size of industrial and mining land in natural village | Positive | 0.0674 |
| | Production potential | Quality grade of arable land | Quality of arable land | Positive | 0.0288 |
| | | Quality grade of grassland | Quality of grassland | Positive | 0.0084 |
| | | Distance from mining sites | Distance from rural settlements to mining sites | Negative | 0.0756 |
| Living function | Scale of living land | Per capita homestead area | Total homestead area/total population | Positive | 0.0290 |
| | | Percentage of traffic area | Area of roads/area of settlement | Positive | 0.0534 |
| | | New housing construction rate in the past five years | New houses in the past five years/total houses of settlement | Positive | 0.0289 |
| | | Housing utilization rate in the past five years | Houses used in settlements in the past five years/total houses of settlement | Positive | 0.0170 |
| | Convenience of living | Accessibility of central town | Distance from central town to settlement | Negative | 0.0459 |
| | | Distance to main roads | Distance from the main road to settlement | Negative | 0.0636 |
| | | Number of information and communication facilities | Number of telecommunications, cable TV, and computer within settlement | Positive | 0.0249 |
| | | Number of public service facilities | Number of clinics, fitness facilities, cultural stations in natural village | Positive | 0.0076 |
| | Living security | Average annual household income | Average annual household income of settlement | Positive | 0.0257 |
| | | Percentage of insured persons in agricultural insurance | Population insured by agricultural insurance/total population of settlement | Positive | 0.0313 |
| | | Diversity of income sources of villagers | Sources of income of households in settlement | Positive | 0.0101 |
| Ecological function | Scale of ecological land | Area of woodland | Area of woodland in natural village | Positive | 0.1141 |
| | | Area of water | Area of water in natural village | Positive | 0.1399 |
| | | Ecological facilities completeness | Whether to centralize domestic garbage and wastewater treatment | Positive | 0.0412 |
| | Ecological interference | Rubbish and wastewater outflow | Amount of domestic waste and wastewater discharged in settlement | Negative | 0.0395 |
| | | Fertilizer application intensity | Intensity of fertilizer application | Negative | 0.0388 |
| | | Slope | Slope of settlement | Negative | 0.0544 |

The production function is the ability of villagers to engage in productive labor to obtain economic benefits and is provided by land for agricultural and livestock production, industrial production, and so on. Ke Town is located in an economically underdeveloped agricultural and pastoral area where traditional agriculture and animal husbandry are still the primary sources of income for farmers and herders, and only a few individuals work in the mining industry. As a result, this study chose two primary guideline layers of the scale of production land and production potential to evaluate the production function of the village area. The scale of productive land reflects the maximum limit of citizens' access to economic benefits, and the degree of grain production is determined by the production potential. Three indicators are included in the productive land scale: the area index of grassland, the area index of arable land, and the area index of industrial and mining land. They reflect the size of the territory available to citizens for agriculture, animal husbandry, and industry, respectively. Three variables are used to determine production potential: the quality grade of arable land, the quality grade of grassland, and the distance from industrial and mining locations. The town is sparsely populated, and agricultural land and pasture are mostly found on the outskirts of the villages. The distance is so close that it is difficult to reflect differences in the production conditions of settlements in terms of distance. However, the quality of farmland and grassland has a direct impact on crop growth and determines the level of product returns. Environmental pollution is present at industrial and mining sites with mining operations. The closer to the settlement, the more polluted it is. The distance can represent the citizens' convenience in engaging in mining operations while also reflecting the pollution level of industrial and mining sites.

Living function is the ability of villagers to live and drink daily and to engage in interpersonal activities. The major living land for villagers is rural roads and house-building amenities. This study chose three guideline layers to evaluate the living function of the village area: the scale of living land, the convenience of living, and the living security. The scale of living land represents the extent of the area in which villagers engage in everyday interpersonal interactions. The higher the scale, the broader the range of activities available to citizens. The degree of convenience for inhabitants to engage in live activities is reflected in their level of living convenience. Living security refers to the ability of villagers to maintain a regular life in the case of a natural disaster. The scale of living land includes four indicators: housing area per capita, percentage of traffic area, new housing construction rate in the past five years, and housing utilization rate in the past five years. The most significant place for the daily life of villagers is residential land. The rate of newly built dwellings in the last five years, as well as the rate of housing utilization in the last five years, show the vitality of settlement. The newer houses created and the greater the rate of house usage, the more dynamic the settlement and the stronger the agglomeration. Accessibility to the central town, distance to important roads, amount of information and communication facilities, and number of public service facilities are all indicators of life convenience. The greater the accessibility of settlements and proximity to the main road, the greater the impact of the central town on settlements and the more convenient it is to carry out social and economic activities. Villagers are in the most contact with information, communication, and public service facilities in their daily lives. The greater the facilities, the more diverse the range of life activities available to inhabitants. The average annual household income, the percentage of insured persons in agricultural insurance, and the diversity of income sources of villagers are all indicators of living security. The more disposable income villagers have, the higher the average annual household income. The lower the proportion of the employed population of settlements, the more significant the problem of aging in the settlement and the worse the prospects for village economic development. Agricultural insurance compensates villagers for natural disasters that occur while they are engaged in agriculture. The more diverse the income sources of farmers, the more secure the economic income of villagers.

The ecological function is the ability to provide villagers with ecological services and maintain ecosystem stability. The principal ecological land is grassland, woodland, and other vegetation. Two primary guideline layers of the scale of ecological land and ecological disturbance were used in this study to evaluate the ecological function. The robustness of a natural village ecosystem's ability to tolerate external damage and govern self-recovery is determined by the ecological land size. The degree of harm to the ecosystems of natural settlements is reflected in ecological disturbance. The scale of ecological land incorporates three indicators: the area index of woodland, the area index of water, and the ecological facilities' completeness. The size of the village ecology is affected by the size of the woodland and water area, and the larger the area, the stronger the stability. The ecological facilities' completeness refers to whether inhabitants centralize residential rubbish and wastewater treatment. Indicators of ecological interference include rubbish and wastewater outflow, fertilizer application intensity, and slope. The rubbish and wastewater outflow are generated by villagers engaged in production and living activities. The more pollution there is in the village environment, the higher the emissions. Fertilizer application intensity is the amount of fertilizer used by inhabitants to produce goods. The greater the amount of fertilizer utilized, the more serious the soil pollution problem. The amount of the slope influences the convenience of villagers' productivity and lifestyle.

#### 3.4.4. Evaluation of the Vitality of Rural Settlements

There are numerous types of travel due to the necessities of daily production and life, such as shopping, visiting relatives, amusement, and so on [63]. Economic, cultural, and social differences in rural settlements influence travel destinations. This constitutes the social network of rural settlements based on the travel behavior of villagers. The breadth and frequency of excursions taken by villagers reflect the spatial linkages that exist among rural settlements [64]. The range denotes the travel destination, and the frequency is the number of travels. The greater the variety and frequency of trips, the stronger the spatial relationship and the more active the rural settlements.

SNA is a means of depicting the morphology, features, and structure of a network as a whole [65]. The node symmetry index is one of them, and it is used to determine the relevance of nodes in a social network. Nodes refer to rural settlements in the social network of rural settlements, while edges connecting nodes correspond to the spatial travel behavior of villagers. According to travel demand, the spatial travel behavior of villagers is classified into six categories: study, work, medical care, socializing, shopping, and tourism. The expert scoring system is used to determine the weight of each type of travel. Using social network analysis, the node symmetry index is utilized to indicate the vitality of rural settlements using the one-week travel data of villagers. The following is the calculating formula:

$$L = \frac{L_{in} - L_{out}}{L_{in} + L_{out}} \tag{1}$$

$$L_{in} = \sum_{i=1}^{n} \frac{w_i \cdot P_a}{P_A} \tag{2}$$

$$L_{out} = \sum_{i=1}^{n} \frac{w_i \cdot P_b}{P_B} \tag{3}$$

where $L$ is the vitality of rural settlements; $L_{in}$ is the vitality of rural settlements visited; $L_{out}$ is the vitality of rural settlement trips; $P_a$ is the number of people visited in a week for the $i$ trip type of rural settlements; $P_A$ is the total number of people visited in a week for all trip types of rural settlements; $P_b$ is the number of trips in a week for the $i$ trip type of rural settlements; $P_B$ is the total number of trips in a week for all trip types of rural settlements; $w_i$ is the weight of $i$ trip type, and $i$ is the trip type.

#### 3.4.5. Tapio Decoupling Model

Decoupling is a physics concept that is used to examine two or more connected states that have interrelationships [66]. The most common decoupling models are the OECD (organization for economic co-operation and development) model, the Tapio model, the IPAT (environmental impact = population × affluence × technology) equation, and so on [67]. The coefficient of variation is used in this study to calculate the correlation index of the PLEF and the vitality of rural settlements. The Tapio model is designed to assess the decoupling relationship between PLEF and vitality. The relative elasticity value is used as the basis for classifying the optimization type of rural settlements, and the model is defined as follows (Table 2):

$$\overline{F} = \frac{\sum_{j=1}^{n} F_j}{n} \tag{4}$$

$$\overline{L} = \frac{\sum_{j=1}^{n} L_j}{n} \tag{5}$$

$$\sigma_F = \sqrt{\frac{\sum_{j=1}^{n} \left(F_j - \overline{F}\right)^2}{n-1}} \tag{6}$$

$$\sigma_L = \sqrt{\frac{\sum_{j=1}^{n} \left(L_j - \overline{L}\right)^2}{n-1}} \tag{7}$$

$$R = \frac{F_j'}{L_j'} = \left(\frac{F_j - \overline{F}}{\sigma_F}\right) / \left(\frac{L_j - \overline{L}}{\sigma_L}\right) \tag{8}$$

where $\overline{F}$ and $\overline{L}$ are the mean value of PLEF and the mean value of vitality of rural settlements, respectively; $\sigma_F$ and $\sigma_L$ are the standard deviation of PLEF and vitality of rural settlements, respectively; $R$ represents the relative elasticity value of PLEF and vitality of rural settlements; $F_j'$ is the correction index of PLEF; $L_j'$ is the correction index of vitality.

**Table 2.** Tapio decoupling model of PLEF and vitality (note: the table is drawn by authors).

| Optimization Type | Relative Elasticity Value | Relationship | Attribute | Meaning |
|---|---|---|---|---|
| Agglomeration and upgrading ($F_j' > 0$ and $L_j' > 0$) | $0 < R \leq 0.8$ | $F_j' < L_j'$ | Positive hook (strong in *L*) | Both *F* and *L* are at high level, with stronger in L |
| | $0.8 < R \leq 1.2$ | $F_j' \approx L_j'$ | Positive hook (strong both $F - L$) | Both *F* and *L* are at high level, and both are highly coordinated |
| | $R > 1.2$ | $F_j' > L_j'$ | Positive hook (strong in *F*) | Both *F* and *L* are at a high level, with stronger in F |
| General survival ($F_j' > 0$ or $L_j' > 0$) | $R < 0$ | $F_j' > 0 > L_j'$ | Decoupling (weak in *L*) | *F* is at a high level, *L* is at a low level |
| | | $L_j' > 0 > F_j'$ | Decoupling (weak in *F*) | *L* is at a high level, *F* is at a low level |
| Relocation and merger ($F_j' < 0$ and $L_j' < 0$) | $0 < R \leq 0.8$ | $F_j' > L_j'$ | Negative hook (weak in *L*) | Both *F* and *L* are at low level, with weaker in L |
| | $0.8 < R \leq 1.2$ | $F_j' \approx L_j'$ | Negative hook (weak both $F - L$) | Both *F* and *L* are at the low level, and both are highly coordinated |
| | $R > 1.2$ | $F_j' < L_j'$ | Negative hook (weak in *F*) | Both *F* and *L* are at low level, with weaker in F |

## 4. Results

### *4.1. Evaluation Results of PLEF*

The scores of the three key indicators of production, living, and ecological functions are determined using the assessment index system of PLEF of rural settlements. Each dimension is classified into three levels using the natural breakpoint technique, which is as follows (Table 3; Figure 7):

**Table 3.** Evaluation results of PLEF of rural settlements (note: the table is drawn by authors).

| Village | Production Function | | | Living Function | | | Ecological Function | | | PLEF | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H | M | L | H | M | L | H | M | L | H | M | L |
| Dashuigedong | 0 | 12 | 14 | 1 | 1 | 24 | 5 | 15 | 6 | 3 | 7 | 16 |
| Daxingchang | 27 | 4 | 4 | 13 | 21 | 1 | 3 | 9 | 23 | 15 | 20 | 0 |
| Dingxiangying | 0 | 6 | 8 | 4 | 7 | 3 | 5 | 5 | 4 | 4 | 6 | 4 |
| Furudong | 8 | 10 | 2 | 8 | 12 | 0 | 4 | 11 | 5 | 10 | 10 | 0 |
| Juzihao | 11 | 14 | 5 | 8 | 12 | 10 | 2 | 14 | 14 | 8 | 17 | 5 |
| Sanshengtai | 5 | 9 | 12 | 6 | 11 | 9 | 0 | 9 | 17 | 2 | 17 | 7 |
| Tianlimutu | 4 | 5 | 0 | 1 | 4 | 4 | 3 | 4 | 2 | 4 | 5 | 0 |
| Wulanhudong | 10 | 8 | 2 | 10 | 8 | 2 | 1 | 5 | 14 | 7 | 13 | 0 |
| Total | 65 | 68 | 47 | 51 | 76 | 53 | 23 | 72 | 85 | 53 | 95 | 32 |
| Total area/$hm^2$ | 134.18 | 268.62 | 134.72 | 199.60 | 178.70 | 159.23 | 179.94 | 235.22 | 122.35 | 256.78 | 220.22 | 60.52 |
| Average area/$hm^2$ | 2.06 | 3.95 | 2.87 | 3.91 | 2.35 | 3.00 | 7.82 | 3.27 | 1.44 | 4.84 | 2.32 | 1.89 |

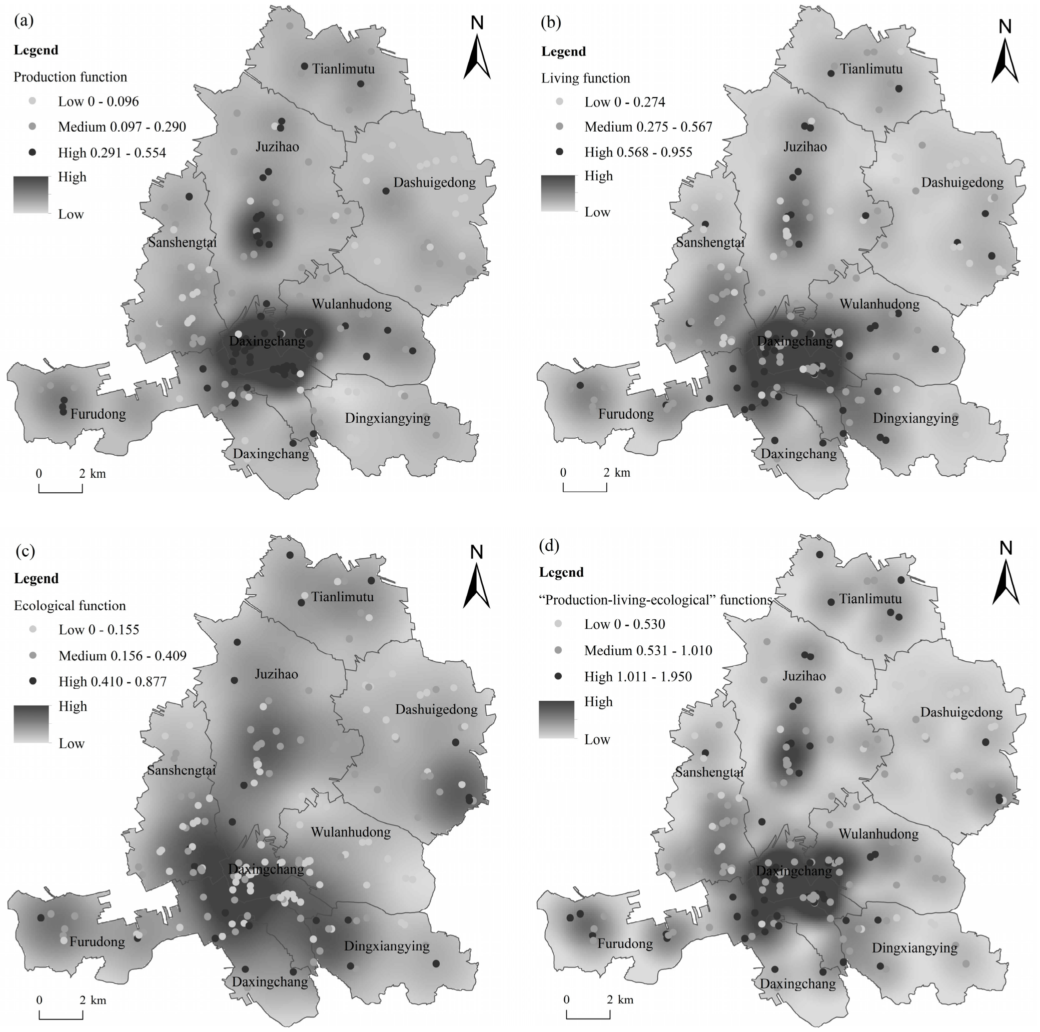


**Figure 7.** Evaluation results of PLEF of rural settlements. (**a**) is the result of the evaluation of production function of rural settlements, (**b**) is the result of the evaluation of living function of rural settlements, (**c**) is the result of the evaluation of ecological function of rural settlements, (**d**) is the result of the evaluation of PLEF of rural settlements (note: the figure is drawn by authors).

In terms of production function, there are 65 rural settlements with high-level production functions, with a total patch area of 134.18 hm2 and an average patch area of 2.06 hm2, mainly distributed around the central town. There are 68 rural settlements with medium-level production functions, with a total patch area of 268.62 $hm^2$ and an average patch area of 3.95 $hm^2$, and their distribution is relatively decentralized, with distribution in every administrative village. There are 47 rural settlements with low-level production functions, with a total patch area of 134.72 $hm^2$ and an average patch area of 2.87 $hm^2$, mainly distributed in Dashuigedong, Sanshengtai, and Dingxiangying villages. It can be seen that the production function of rural settlements in Ke Town is high, and the proportion of low-level production function is low. The production function of settlements gradually decreases with the increase in distance from the central town. The economic development of the central town is relatively good, with perfect infrastructure and richer production systems. As a result, settlements around the center have stronger production functions due to its influence. The settlements that are farther away, such as Dashuigedong Village, have more settlements with low-level production functions.

In terms of living function, there are 51 rural settlements with high-level living functions, with a total patch area of 199.60 $hm^2$ and an average patch area of 3.91 $hm^2$, mainly distributed in the southern part of Ke Town and closer to the central town. There are 76 rural settlements with a total area of 178.70 $hm^2$ and an average patch area of 2.35 $hm^2$, which are scattered. There are 53 rural settlements with low-level living functions, with a total patch area of 159.23 $hm^2$ and an average patch area of 3.00 $hm^2$, mainly distributed in the villages of Dashuigedong, Sanshengtai, and Juzihao. It can be seen that the characteristics of the living function of rural settlements in Ke Town are similar to the production function. The living function is gradually weakened with the increase in distance from the central town. However, unlike the production function, rural settlements with a high level of living function are concentrated in the southern part of Ke Town. This is because the topography of Ke Town is high in the north and low in the south, and the northern part is hilly and mountainous, making it inconvenient for villagers to travel.

In terms of ecological function, there are 23 rural settlements with high-level ecological function, with a total patch area of 179.94 $hm^2$ and an average patch area of 7.82 $hm^2$, which are mainly distributed in the villages of Tianlimutu, Juzihao, and Daxingchang. There are 72 rural settlements with medium-level ecological function, with a total patch area of 235.22 $hm^2$ and an average patch area of 3.27 $hm^2$, which are more dispersed, with a higher distribution ratio in the villages of Juzihao and Dashuigedong. There are 85 rural settlements with low-level ecological function, with a total patch area of 122.35 $hm^2$ and an average patch area of 1.44 $hm^2$, which are mainly distributed in the settlements around the central town, such as Wulanhudong Village and Sanshengtai Village. It can be seen that the ecological environment of rural settlements in Ke Town is poor, with low-level ecological functions accounting for nearly half of the area. Most high-level ecological functions are located in the border zone far from the central town. This indicates that settlements in remote areas suffer less human damage, and the ecological environment is effectively protected. The strength of the ecological functions of settlements decreases with the size of settlements. Larger settlements have more land and can better maintain the stability of the ecological environment.

From the perspective of PLEF, there are 53 rural settlements with high levels of PLEF, with a total patch area of 256.78 $hm^2$ and an average patch area of 4.84 $hm^2$, which are mainly distributed in the southern part of Ke Town. At the same time, the proportion of Tianlimutu Village is higher, and the number of settlements in this administrative village is small, but the scale is large. There are 95 rural settlements with medium-level PLEF, with a total patch area of 220.22 $hm^2$ and an average patch area of 2.32 $hm^2$, which are widely distributed. There are 32 rural settlements with a low level of PLEF, with a total patch area of 60.52 $hm^2$ and an average patch area of 1.89 $hm^2$, mainly distributed in Sanshengtai and Dashuigedong villages. It can be seen that the overall level of PLEF of rural settlements in Ke Town is good. There are few settlements with low levels of PLEF, and nearly 82% of the settlements belong to the intermediate level or above. Most of the rural settlements with low levels of PLEF are located in the border area, which is far away from the central town. In the southern region, where the terrain is flat and close to the central town, the level of PLEF is stronger.

### *4.2. Vitality of Rural Settlements*

We measured the vitality of settlements based on the data on the spatial travel behavior of villagers. Then, the natural breakpoint method was used to classify the vitality of settlements into three levels: I (Low), II (Medium), and III (High), as follows (Table 4; Figure 8).

**Table 4.** Evaluation results of the vitality of rural settlements (note: the table is drawn by authors).

| Village | I | | II | | III | |
|---|---|---|---|---|---|---|
| | **Area/hm$^2$** | **Rural Settlements** | **Area/hm$^2$** | **Rural Settlements** | **Area/hm$^2$** | **Rural Settlements** |
| Dashuigedong | 54.81 | 18 | 30.57 | 8 | 0 | 0 |
| Daxingchang | 4.81 | 5 | 60.28 | 22 | 3.50 | 8 |
| Dingxiangying | 4.88 | 4 | 19.94 | 9 | 6.93 | 1 |
| Furudong | 17.47 | 7 | 26.78 | 9 | 8.72 | 4 |
| Juzihao | 26.87 | 10 | 49.65 | 13 | 34.44 | 7 |
| Sanshengtai | 27.57 | 9 | 24.43 | 15 | 3.78 | 2 |
| Tianlimutu | 59.62 | 4 | 12.83 | 4 | 15.02 | 1 |
| Wulanhudong | 4.41 | 3 | 34.92 | 14 | 5.29 | 3 |
| Total | 200.43 | 60 | 259.40 | 94 | 77.69 | 26 |

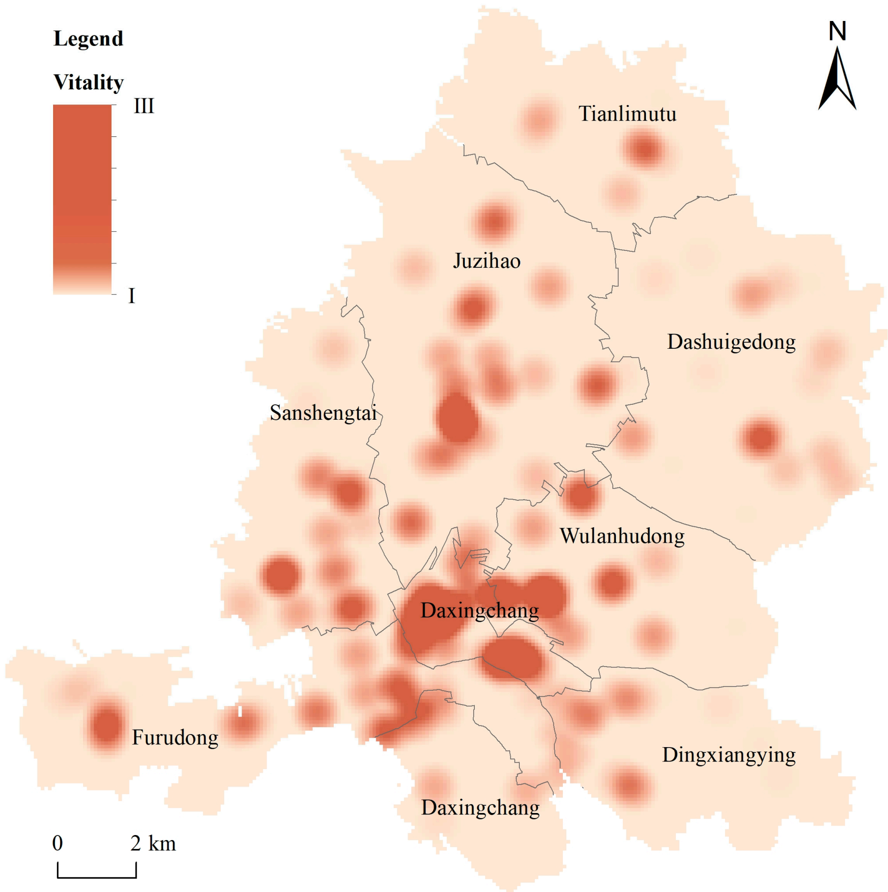


**Figure 8.** Evaluation results of the vitality of rural settlements (note: the figure is drawn by authors).

The calculation obtained the vitality of rural settlements in Ke Town between 0 and 85, which is categorized into three levels: I level (0~15), II level (16~43), and III level (44~85). There are 60 rural settlements belonging to Grade I vitality, with a total patch area of 200.43 hm$^2$ and an average patch area of 3.34 hm$^2$, which are mainly distributed in the villages of

Dashuigedong, Tianlimutu, Sanshengtai, and Dingxiangying. And most of them are far away from the central town in the border zone. There are 94 rural settlements with grade II vitality, with a large number and wide distribution, with a total patch area of 259.40 $hm^2$ and an average patch area of 2.76 $hm^2$. There are only 26 rural settlements with grade III vitality, with a total patch area of 77.69 $hm^2$ and an average patch area of 2.99 $hm^2$, mainly distributed around the central town. It can be seen that the closer to the central town, the higher the settlement vitality. This is due to the fact that the central town is in areas where social and economic activities are concentrated, with large flows of people and sufficient resources, which can provide villagers with more employment opportunities and is the main place for villagers to interact with each other.

### 4.3. Decoupling Characteristics of PLEF and Vitality in Rural Settlements

We calculated the modification index of PLEF and the vitality of rural settlements in Ke Town. Then, we explored the characteristics of the decoupling of PLEF and vitality by constructing a Tapio decoupling model, and the results are as follows (Table 5).

**Table 5.** The decoupling features between PLEF and vitality of rural settlements (note: the table is drawn by authors).

| Village | Positive Hooking | | | Decoupling | | Negative Hooking | | |
|---|---|---|---|---|---|---|---|---|
| | Strong in F | Strong Both | Strong in L | Weak in F | Weak in L | Weak in F | Weak Both | Weak in L |
| Dashuigedong | 0 | 0 | 0 | 5 | 3 | 12 | 2 | 4 |
| Daxingchang | 3 | 3 | 10 | 5 | 8 | 3 | 0 | 3 |
| Dingxiangying | 1 | 1 | 1 | 2 | 3 | 4 | 0 | 2 |
| Furudong | 5 | 1 | 3 | 3 | 6 | 0 | 0 | 2 |
| Juzihao | 4 | 1 | 2 | 7 | 5 | 4 | 6 | 1 |
| Sanshengtai | 1 | 0 | 1 | 6 | 3 | 10 | 1 | 4 |
| Tianlimutu | 0 | 0 | 1 | 0 | 6 | 1 | 0 | 1 |
| Wulanhudong | 5 | 3 | 4 | 3 | 4 | 0 | 0 | 1 |
| Total | 19 | 9 | 22 | 31 | 38 | 34 | 9 | 18 |

There are 50 rural settlements in Ke Town with a positive relationship between the PLEF and the vitality. The PLEF and vitality are at a high level, mainly distributed in the villages of Daxingchang, Wulanhudong, and so on. Among them, 19 rural settlements are strong in PLEF, 22 rural settlements are strong in vitality, and 9 rural settlements are as strong as both. The number of the decoupled relationship is 69, and the PLEF and the vitality show the decoupling status of "one high and one low". The distribution of rural settlements in this state is wide, of which the PLEF of rural settlements is weak (31) and vitality is weak (38). The number of negative relationships is 61, with PLEF and vitality levels at a low level, mainly in the villages of Dashuigedong, Sanshengtai, and Juzihao. Among them, 19 rural settlements are weak in PLEF, 22 rural settlements are weak in vitality, and 9 rural settlements are as weak as both. We find that PLEF is correlated with vitality in Ke Town. Daxingchang Village and Wulanhudong Village, which have sufficient resources, are close to the central town and have convenient transportation, are at a high level in terms of the PLEF and vitality. However, Dashuigedong Village, which is resource poor, far away from the central town, and with poor transportation, has a low level of PLEF and vitality.

### 4.4. Identification of Optimization Type of Rural Settlements

With reference to the document "The National Rural Revitalization Strategic Plan (2018–2022)", the optimization types of rural settlements in Ke Town are determined to be of five types: suburban integration, characteristic protection, agglomeration and upgrading, general survival and relocation, and merger. Firstly, regarding the urban construction land use boundary delineated in the document "The Overall Planning of Land Use in

Kekeyiligeng Town (2009–2020)", the rural settlements within the boundary are categorized as suburban integration type. Secondly, with reference to the "Chinese Traditional Villages List", "Wuchuan County Traditional Villages List", and other documents, the traditional villages with historical and cultural value in Ke Town are classified as characteristic protection types. Finally, we constructed a decoupling model between the PLEF of rural settlements and the vitality. Based on the combination of the two features, the optimization types of rural settlements in Ke Town are identified as agglomeration and upgrading, general survival and relocation, and merger. The details are as follows (Table 6; Figure 9):

(1) Rural settlements (20) are classified into suburban integration types. This type is located around the central town, most of which are distributed in the village of Daxingchang and a few in the villages of Dingxiangying, Furudong, and Wulanhudong. And it has the advantage of becoming the backyard of the central town. This type of rural settlement should be properly prepared for the development of arable land and grassland into industrial and commercial land because the town expands outward. Simultaneously, the integrated growth of urban and rural industries, infrastructure connectivity, and public service sharing must be accelerated. The original rural landscape should be kept in form as much as feasible, and governance should reflect the urban level. Prepare to receive the spillover of urban functions and meet the consumption needs of the town;

(2) Rural settlements (9) are classified into characteristic protection types. This type is distributed in the villages of Dashuigedong, Furudong, Sanshengtai, and Wulanhudong. This type of rural settlement is an important carrier for the manifestation and inheritance of excellent traditional Chinese culture. To construct a complete set of traditional cultural protection systems, it is important to perform a good job of traditional siting of settlements, patterns, natural landscapes and its exquisite scenery of the overall spatial form, and environmental protection. Completely safeguard historical sites, traditional structures, and cultural peculiarities. It also uses its cultural characteristics to strengthen and build infrastructure to facilitate the development of rural tourism and specific industries. Create a traditional rural settlement that integrates rural tourism development with rural protection;

(3) Rural settlements (42) are classified into agglomeration and upgrading types. Rural settlements with a positive relationship between the PLEF and the vitality are classified as this type. This type is distributed in the villages of Daxingchang, Furudong, Juzihao, and Wulanhudong. This type of rural settlement is large in scale, rich in natural resources, and has a good ecological environment and frequent population movement, making it a key area for rural revitalization. The government and citizens must develop village development plans in a scientific and rational manner, capitalize on their own resource advantages, and improve the backing of leading enterprises. They should continue to improve the village's production and living circumstances, optimize the ecological environment, boost population concentration and vitality, and construct a livable, workable, and beautiful village;

(4) Rural settlements (53) are classified into general survival types. Rural settlements with a decoupled relationship between the PLEF and the vitality are categorized as this type. This type is widely distributed in Ke town. This type of rural settlement should continue to maintain its original characteristics, improve the ecological environment, strengthen industrial development, and attract the return of the population. The path of rational function optimization is formulated by identifying the major functions of the settlements. To develop livable and functional villages with industrial benefits and healthy ecology and actively form tight relations with the agglomeration and enhancement type of rural settlements;

(5) Rural settlements (56) are classified into relocation and merger types. Rural settlements with a negative correlation between the PLEF and the vitality are categorized as this type. This type is distributed in the villages of Dashuigedong, Juzihao, Sanshengtai, etc. This type of rural settlement has a poor ecological environment and

backward infrastructure, and the relocation and annexation of the village should be completed as soon as possible. The total relocation and annexation of settlements is carried out under the premise of providing full respect to the citizens' own interests through poverty alleviation relocation, ecological and livable relocation, and rural agglomeration relocation. The original characteristics of relocated settlements should be preserved, and ecological space and ecosystems should be developed and improved in accordance with local conditions.

**Table 6.** Optimization type of rural settlements (note: the table is drawn by authors).

| Village | Suburban Integration | Characteristics Protection | Agglomeration and Upgrading | General Survival | Relocation and Merger |
|---|---|---|---|---|---|
| Dashuigedong | 0 | 3 | 0 | 7 | 16 |
| Daxingchang | 13 | 0 | 12 | 5 | 5 |
| Dingxiangying | 2 | 0 | 3 | 4 | 5 |
| Furudong | 2 | 2 | 8 | 6 | 2 |
| Juzihao | 0 | 0 | 7 | 12 | 11 |
| Sanshengtai | 0 | 3 | 2 | 7 | 14 |
| Tianlimutu | 0 | 0 | 1 | 6 | 2 |
| Wulanhudong | 3 | 1 | 9 | 6 | 1 |
| Total | 20 | 9 | 42 | 53 | 56 |

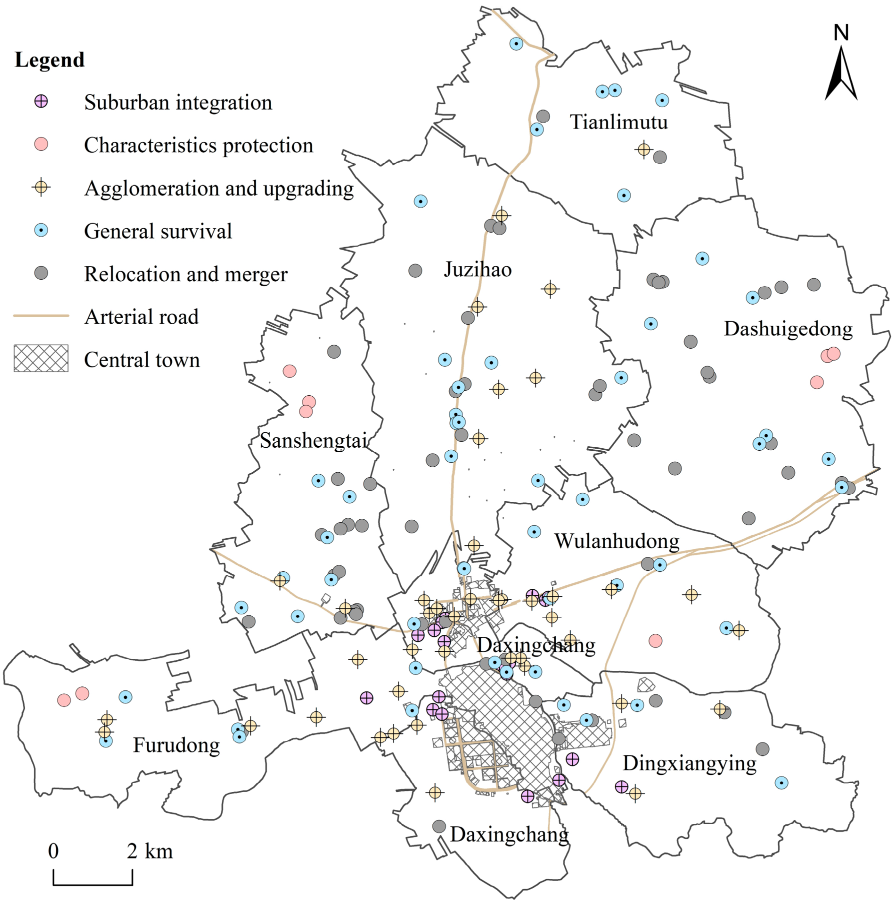


**Figure 9.** Optimization type of rural settlements (note: the figure is drawn by authors).

## 5. Discussion

### *5.1. Relationship between PLEF and Vitality of Rural Settlements*

We found that the level of PLEF of rural settlements has significant regional differences in Ke Town. The settlements around the central towns have a higher level of PLEF than the remote mountainous areas [68]. This result is consistent with the results of previous research [69]. Central town emerges as a pivotal nexus that intricately links rural settlements, thereby exerting discernible influence characterized by radiation-driven dynamics and demonstrative leadership within the adjacent areas. These neighboring villages have access to public service facilities such as educational and medical services in the town. At the same time, the scale and proportion of productive land for industry, warehousing, and logistics within the countryside are increasing rapidly, which is influenced by the expansion of land for urban construction. In remote mountainous areas, however, the topography dramatically restricts the productive and living activities of villagers. In addition, the results of the evaluation of vitality showed the same characteristics as the PLEF. The vitality is stronger where rural settlements are located close to towns or transportation routes. This demonstrates that PLEF is associated with vitality in some way.

This study verifies the relationship between PLEF and vitality through the Tapio decoupling model. The improvement of PLEF is beneficial to enhancing the vitality of rural settlements. The settlements adjacent to the central town are distinguished by their intricate network of infrastructure, comprehensive industry, and sophisticated transportation systems, which can satisfy the economic, cultural, social, and ecological requirements of villagers. Most importantly, the whole industrial system provides villagers with substantial employment opportunities and stimulates the vitality of the settlement. The promotion of vitality driven by PLEF is more evident in specialized tourism villages [70]. These regions are rapidly deriving new non-agricultural functions of tourism services, cultural creativity, and commerce, such as regions rich with landscape resources, historical and cultural heritage, and special ecological agricultural resources. An array of specialized tourism villages has emerged featuring leisure agriculture and cultural tourism. The specialized tourism villages adjust the layout of settlements, improve public infrastructure, and complete the deficiency of public services. The rural areas are divided into clearer zones for production, living, and ecological functions. This type of village, driven by rural tourism, attracts masses of villagers for tourism, employment, and living, which stimulates the vitality of the countryside.

### *5.2. Implications for the Rural Spatial Reconstruction*

Rural spatial reconstruction refers to the process of rural transformation and development under the background of urbanization, which is influenced by multiple factors, such as city-driven, self-renewal, and government regulation [71,72]. In this process, different optimization types of rural settlements play various roles [73]. Taking into account the five types of rural settlements classified in this study, we should accurately formulate the respective optimization paths to achieve the enhancement of rural structure and function. The suburban integration type should improve the industrial structure and service functions to promote the development of neighboring settlements. The characteristic protection type should deal with the relationship between the optimization and improvement of rural settlements and the preservation of characteristic culture. Policymakers need to sufficiently develop the existing characteristic industries in the village area and strengthen the level of industrial linkage so as to realize the virtuous circle of village protection, cultural inheritance, and economic development. The agglomeration and upgrading type should be expanded moderately to increase the degree of agglomeration of rural settlements and improve infrastructure construction. The general survival type should further strengthen control and planning of rural land to enhance the efficiency of land use in future development. More importantly, this type needs to ameliorate the problem of hollowing out by integrating rural landscapes and living environments for villagers. The relocation and merger type should formulate a rational relocation program to address the livelihoods of farmers and ecological protection in an integrated manner (Figure 10).

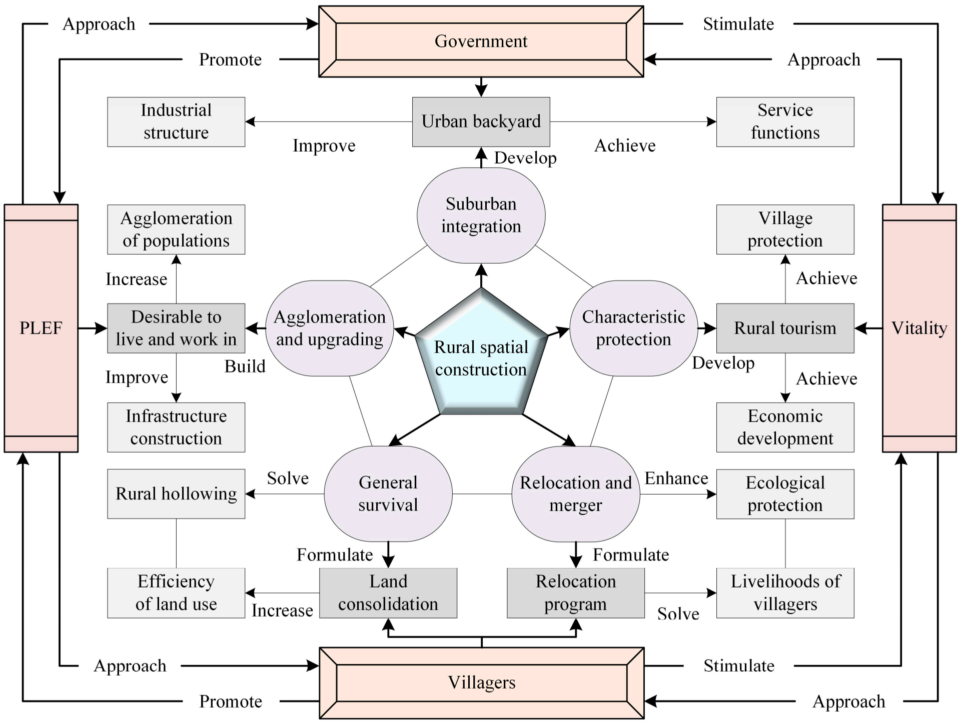


**Figure 10.** Pathways for rural spatial reconstruction (note: the figure is drawn by authors).

Presently, the majority of rural areas globally contend with inadequate infrastructure and backward industrial development, which leads to population outflows and diminishing vitality [74]. In the practice of rural spatial reconstruction, the government predominantly designs the establishment of new villages configured as singular-function residential districts [75]. However, these strategies often neglect the incorporation of comprehensive planning for rural production land, which has significantly diverged from the functional attributes of settlement production and living. In this context, the government should be directed towards the establishment of villages that embody attributes of livability, functionality, and aesthetic appeal, and utilize village planning as the means to guide the rational layout of land for rural settlements. Also, the government guides the strategic concentration of population, industry, and capital within settlements that stimulate endogenous rural development dynamics. This approach promotes industrial upgrading, facilitates the diversification and interaction of rural resource elements, and realizes the comprehensive enhancement and coordination of production, living, and ecological functions. Consequently, the government takes responsibility for fostering sustainable rural socioeconomic development by bolstering the vitality and attractiveness of rural settlements.

### *5.3. Limitation and Future Work*

The vitality exhibited by rural settlements emanates from apprehensions regarding the potential diminishment of socioeconomic development within rural areas, including demographic attractiveness, land development attractiveness, and industrial development attractiveness [76,77]. This heightened concern has been prompted by the experience of developed nations, where the significance of the agricultural production sector has undergone a decline [78]. In addition, the functional requirements of villagers are also expressed as vitality. The functional requirements of villagers, on the other hand, lead to human-centered socioeconomic activity, namely the spatial travel behavior of villagers. It refers to the social activities carried out by villagers who go to other settlements to satisfy their requirements. These social activities evolve in response to changes in the physical environment, economic development, and technological advancement. Advances in science and technology have engendered transformative shifts in socioeconomic activities, such as shopping, socializing, traveling, and so on. Considering the data obtainability, this research exposes the vitality of rural settlements by investigating the characteristics of villagers' travel behavior inside the rural settlement social network system.

The quantification of the vitality of rural settlements finds its efficacy through the scrutiny of villagers' travel data. However, the extent of influence exerted by towns and other urban centers on rural settlements within their vicinity is not comprehensively addressed. According to Woods' research, the global countryside is a rural realm that consists of rural-to-rural and rural-to-urban connections. The Taobao logistics village, for example, has established close co-operation with other cities and villages around the globe [79]. However, this study only explores inter-rural relationships within regions. Cities and villages form the urban–rural system in the regional environment. The geographic configuration of this urban–rural system is grounded in the interplay of transportation and information networks, thereby engendering the generation of information, population movements, and material flows between urban and rural areas [80]. Cities and villages are intrinsically interconnected, giving rise to the hierarchical urban–rural system encompassing cities, towns, and villages. Within this framework, the central town emerges as a densely populated locale characterized by robust economic advancement and a vibrant cultural milieu. The towns exert a discernible siphoning effect upon rural settlements, and the geographical interaction exists between the two. However, owing to limitations in data collection, this study mainly investigates the spatial interactions among rural settlements. Future research endeavors should delve into the interrelationship between towns and rural settlements to improve the optimization strategy of rural settlements.

## 6. Conclusions

Identifying the optimization type of rural settlements has evolved into an important approach aimed at augmenting land use efficiency, optimizing spatial layout, and enhancing rural habitat environment, which serve as essential conduits for the sustenance of production and livelihood of villagers. It is part of the preliminary work in the rural reconstruction system. Rural settlements, as intricate amalgamations engendered through the interplay of manifold interactions, have gradually evolved from single functions to composite functions. This transformation is driven by the diversification of land use and the multifaceted requirements of villagers. Therefore, identifying the optimized types of rural settlements requires an accurate judgment of their development trends and current status. This study comprehensively accounted for the development vitality of rural settlements within the rural social network system in conjunction with the functional requirements of villagers. We proposed a theoretical framework from the perspective of PLEF and vitality, which is then employed to identify the optimization type of rural settlements in the northern farming–pastoral ecotone in China. The findings indicated a definite correlation between the PLEF and the vitality exhibited by rural settlements. Central towns emerge as the most densely inhabited zones, fostering heightened mobility, interpersonal engagements, and trade activities. Proximity to these central towns is associated with elevated PLEF levels and amplified vitality within rural settlements. This research augments the comprehension of the spatial relationships among rural settlements and serves as an exploratory tool for policymakers and rural planners to build reasonable and optimal solutions.

The purpose of identifying settlement types is to optimize the allocation of rural people, land, industry, and other aspects. Within the constraints of policies, rural planners must design realistic settlement optimization strategies in terms of function optimization, industry enhancement, and population clustering. This process must, however, duly recognize the inherent requirements of villagers. Policy regulators conduct the reconstruction of rural settlements while addressing the social requirements of villagers and respecting their genuine intentions.

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## References

1. Liao, G.; He, P.; Gao, X.; Lin, Z.; Huang, C.; Zhou, W.; Deng, O.; Xu, C.; Deng, L. Land use optimization of rural production–living–ecological space at different scales based on the BP–ANN and CLUE–S models. *Ecol. Indic.* **2022**, *137*, 108710. [CrossRef]
2. Gao, M.; Ma, K.; Yu, J. The characteristics and drivers of China's city-level urban-rural activity sectors' carbon intensity gap during urban land expansion. *Energy Policy* **2023**, *181*, 113725. [CrossRef]
3. Chen, C.; LeGates, R.; Zhao, M.; Fang, C. The changing rural-urban divide in China's megacities. *Cities* **2018**, *81*, 81–90. [CrossRef]
4. Chatzichristos, G.; Perimenis, A. Evaluating the social added value of LEADER: Evidence from a marginalised rural region. *J. Rural Stud.* **2022**, *94*, 366–374. [CrossRef]
5. Noble, V. Mobilities of the One-Product policy from Japan to Thailand: A critical policy study of OVOP and OTOP. *Territ. Politics Gov.* **2019**, *7*, 455–473. [CrossRef]
6. Qu, Y.; Jiang, G.; Zhao, Q.; Ma, W.; Zhang, R.; Yang, Y. Geographic identification, spatial differentiation, and formation mechanism of multifunction of rural settlements: A case study of 804 typical villages in Shandong Province, China. *J. Clean. Prod.* **2017**, *166*, 1202–1215. [CrossRef]
7. Jiang, G.; He, X.; Qu, Y.; Zhang, R.; Meng, Y. Functional evolution of rural housing land: A comparative analysis across four typical areas representing different stages of industrialization in China. *Land Use Policy* **2016**, *57*, 645–654. [CrossRef]
8. Wang, X.; Wang, D.; Wu, S.; Yan, Z.; Han, J. Cultivated land multifunctionality in undeveloped peri-urban agriculture areas in China: Implications for sustainable land management. *J. Environ. Manag.* **2023**, *325*, 116500. [CrossRef]
9. Zhang, B.; Zhang, R.; Jiang, G.; Cai, W.; Su, K. Improvement in the quality of living environment with mixed land use of rural settlements: A case study of 18 villages in Hebei, China. *Appl. Geogr.* **2023**, *157*, 103016. [CrossRef]
10. Bański, J.; Wesołowska, M. Transformations in housing construction in rural areas of Poland's Lublin region—Influence on the spatial settlement structure and landscape aesthetics. *Landsc. Urban Plan.* **2010**, *94*, 116–126. [CrossRef]
11. Chen, Z.; Liu, X.; Lu, Z.; Li, Y. The Expansion Mechanism of Rural Residential Land and Implications for Sustainable Regional Development: Evidence from the Baota District in China's Loess Plateau. *Land* **2021**, *10*, 172. [CrossRef]
12. Zhou, G.; He, Y.; Tang, C.; Yu, T.; Xiao, G.; Zhong, T. Dynamic mechanism and present situation of rural settlement evolution in China. *J. Geogr. Sci.* **2013**, *23*, 513–524. [CrossRef]
13. Rao, Y.; Zou, Y.; Yi, C.; Luo, F.; Song, Y.; Wu, P. Optimization of rural settlements based on rural revitalization elements and rural residents' social mobility: A case study of a township in western China. *Habitat Int.* **2023**, *137*, 102851. [CrossRef]
14. Yang, Y. Community participation for sustainable rural development: Revisiting South Korean rural modernization of the 1970s. *Community Dev. J.* **2018**, *53*, 61–77. [CrossRef]
15. Hoang Thanh, L.; Ta Nhat, L.; Nguyen Dang, H.; Ho, T.M.; Lebailly, P. One Village One Product (OVOP)—A Rural Development Strategy and the Early Adaption in Vietnam, the Case of Quang Ninh Province. *Sustainability* **2018**, *10*, 4485. [CrossRef]
16. Wang, Z.; Ou, L.; Chen, M. Evolution characteristics, drivers and trends of rural residential land in mountainous economic circle: A case study of Chengdu-Chongqing area, China. *Ecol. Indic.* **2023**, *154*, 110585. [CrossRef]
17. Zhang, Q. Building productivism in rural China: The case of residential restructuring in Chengdu. *Geoforum* **2022**, *128*, 103–114. [CrossRef]
18. Clout, H. In the shadow of Vidal de la Blache: Letters to Albert Demangeon and the social dynamics of French geography in the early twentieth century. *J. Hist. Geogr.* **2003**, *29*, 336–355. [CrossRef]
19. Clout, H. Visions of La "Géographie Humaine" in Twentieth-Century France. *Geogr. Rev.* **2003**, *93*, 370–393. [CrossRef]
20. Kong, Y.; Ntarmah, A. Developing a rural ecological assessment index for Jiangsu Province, China. *J. Nat. Conserv.* **2021**, *64*, 126093. [CrossRef]

21. Zou, L.; Liu, Y.; Wang, J.; Yang, Y.; Wang, Y. Land use conflict identification and sustainable development scenario simulation on China's southeast coast. *J. Clean. Prod.* **2019**, *238*, 117899. [CrossRef]
22. Shi, Z.; Ma, L.; Zhang, W.; Gong, M. Differentiation and correlation of spatial pattern and multifunction in rural settlements considering topographic gradients: Evidence from Loess Hilly Region, China. *J. Environ. Manag.* **2022**, *315*, 115127. [CrossRef]
23. Gong, J.; Jian, Y.; Chen, W.; Liu, Y.; Hu, Y. Transitions in rural settlements and implications for rural revitalization in Guangdong Province. *J. Rural Stud.* **2022**, *93*, 359–366. [CrossRef]
24. Liu, Y.; Yang, Y.; Li, Y.; Li, J. Conversion from rural settlements and arable land under rapid urbanization in Beijing during 1985–2010. *J. Rural Stud.* **2017**, *51*, 141–150. [CrossRef]
25. Guo, P.; Zhang, F.; Wang, H.; Qin, F. Suitability evaluation and layout optimization of the spatial distribution of rural residential areas. *Sustainability* **2020**, *12*, 2409. [CrossRef]
26. Li, J.; Lo, K.; Zhang, P.; Guo, M. Reclaiming small to fill large: A novel approach to rural residential land consolidation in China. *Land Use Policy* **2021**, *109*, 105706. [CrossRef]
27. Zhang, Z.; Li, J. Spatial suitability and multi-scenarios for land use: Simulation and policy insights from the production-living-ecological perspective. *Land Use Policy* **2022**, *119*, 106219. [CrossRef]
28. Zhao, X.; Sun, H.; Chen, B.; Xia, X.; Li, P. China's rural human settlements: Qualitative evaluation, quantitative analysis and policy implications. *Ecol. Indic.* **2019**, *105*, 398–405. [CrossRef]
29. Zhang, Q.; Qu, Y.; Zhan, L. Great transition and new pattern: Agriculture and rural area green development and its coordinated relationship with economic growth in China. *J. Environ. Manag.* **2023**, *344*, 118563. [CrossRef] [PubMed]
30. Ma, W.; Jiang, G.; Wang, D.; Li, W.; Guo, H.; Zheng, Q. Rural settlements transition (RST) in a suburban area of metropolis: Internal structure perspectives. *Sci. Total Environ.* **2018**, *615*, 672–680. [CrossRef]
31. Kong, X.; Liu, D.; Tian, Y.; Liu, Y. Multi-objective spatial reconstruction of rural settlements considering intervillage social connections. *J. Rural Stud.* **2021**, *84*, 254–264. [CrossRef]
32. Qu, Y.; Jiang, G.-h.; Li, Z.; Tian, Y.; Wei, S. Understanding rural land use transition and regional consolidation implications in China. *Land Use Policy* **2019**, *82*, 742–753. [CrossRef]
33. Mtero, F. Rural livelihoods, large-scale mining and agrarian change in Mapela, Limpopo, South Africa. *Resour. Policy* **2017**, *53*, 190–200. [CrossRef]
34. Wang, C.; Zhou, T.; Ren, M. Driving spatial network connections in rural settlements: The role of e-commerce. *Appl. Geogr.* **2023**, *159*, 103067. [CrossRef]
35. Ma, L.; Liu, S.; Tao, T.; Gong, M.; Bai, J. Spatial reconstruction of rural settlements based on livability and population flow. *Habitat Int.* **2022**, *126*, 102614. [CrossRef]
36. Rahman, M.; Paatero, J.; Poudyal, A.; Lahdelma, R. Driving and hindering factors for rural electrification in developing countries: Lessons from Bangladesh. *Energy Policy* **2013**, *61*, 840–851. [CrossRef]
37. Ziaul Hoque, M.; Islam, I.; Ahmed, M.; Shamim Hasan, S.; Ahmed Prodhan, F. Spatio-temporal changes of land use land cover and ecosystem service values in coastal Bangladesh. *Egypt. J. Remote Sens. Space Sci.* **2022**, *25*, 173–180. [CrossRef]
38. Li, M.; Zhou, S. Pollutive cooking fuels and rural labor supply: Evidence from a large-scale population census in China. *Energy Policy* **2023**, *183*, 113780. [CrossRef]
39. Chen, C.; Fan, C. Rural-urban circularity in China: Analysis of longitudinal surveys in Anhui, 1980–2009. *Geoforum* **2018**, *93*, 97–104. [CrossRef]
40. Cheng, M.; Yansui, L.; Zhou, Y. Measuring the symbiotic development of rural housing and industry: A case study of Fuping County in the Taihang Mountains in China. *Land Use Policy* **2019**, *82*, 307–316. [CrossRef]
41. Woods, M. Engaging the global countryside: Globalization, hybridity and the reconstitution of rural place. *Prog. Hum. Geogr.* **2007**, *31*, 485–507. [CrossRef]
42. Woods, M. Rural geography III: Rural futures and the future of rural geography. *Prog. Hum. Geogr.* **2011**, *36*, 125–134. [CrossRef]
43. Tan, M.; Li, X. The changing settlements in rural areas under urban pressure in China: Patterns, driving forces and policy implications. *Landsc. Urban Plan.* **2013**, *120*, 170–177. [CrossRef]
44. Zhou, H.; Na, X.; Li, L.; Ning, X.; Bai, Y.; Wu, X.; Zang, S. Suitability evaluation of the rural settlements in a farming-pastoral ecotone area based on machine learning maximum entropy. *Ecol. Indic.* **2023**, *154*, 110794. [CrossRef]
45. Wen, Q.; Li, J.; Ding, J.; Wang, J. Evolutionary process and mechanism of population hollowing out in rural villages in the farming-pastoral ecotone of Northern China: A case study of Yanchi County, Ningxia. *Land Use Policy* **2023**, *125*, 106506. [CrossRef]
46. Zhang, Q.; Wu, J. Political dynamics in land commodification: Commodifying rural land development rights in Chengdu, China. *Geoforum* **2017**, *78*, 98–109. [CrossRef]
47. Chaudhary, A.; Kastner, T. Land use biodiversity impacts embodied in international food trade. *Glob. Environ. Change* **2016**, *38*, 195–204. [CrossRef]
48. Yanbo, Q.; Guanghui, J.; Wenqiu, M.; Zitong, L. How does the rural settlement transition contribute to shaping sustainable rural development? Evidence from Shandong, China. *J. Rural Stud.* **2021**, *82*, 279–293. [CrossRef]
49. Rosner, A.; Wesołowska, M. Deagrarianisation of the Economic Structure and the Evolution of Rural Settlement Patterns in Poland. *Land* **2020**, *9*, 523. [CrossRef]
50. Phillips, M.; Dickie, J. Moving to or from a carbon dependent countryside. *J. Transp. Geogr.* **2019**, *74*, 253–268. [CrossRef]

51. Lin, L.; Zhu, Y. Types and determinants of migrants' settlement intention in China's new phase of urbanization: A multi-dimensional perspective. *Cities* **2022**, *124*, 103622. [CrossRef]
52. Chen, W.; Li, A.; Hu, Y.; Li, L.; Zhao, H.; Han, X.; Yang, B. Exploring the long-term vegetation dynamics of different ecological zones in the farming-pastoral ecotone in northern China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 27914–27932. [CrossRef] [PubMed]
53. Zhou, T.; Jiang, G.; Zhang, R.; Zheng, Q.; Ma, W.; Zhao, Q.; Li, Y. Addressing the rural in situ urbanization (RISU) in the Beijing–Tianjin–Hebei region: Spatio-temporal pattern and driving mechanism. *Cities* **2018**, *75*, 59–71. [CrossRef]
54. Su, X.; Liu, P.; Mei, Y.; Chen, J. The role of rural cooperatives in the development of rural household photovoltaics: An evolutionary game study. *Energy Econ.* **2023**, *126*, 106962. [CrossRef]
55. Jiang, M.; Paudel, K.; Mi, Y.; Li, J. Farmland transfer and rural financial structure: Evidence from China. *Int. Rev. Financ. Anal.* **2023**, *90*, 102897. [CrossRef]
56. Yang, J.; Yang, R.; Chen, M.-H.; Su, C.-H.; Zhi, Y.; Xi, J. Effects of rural revitalization on rural tourism. *J. Hosp. Tour. Manag.* **2021**, *47*, 35–45. [CrossRef]
57. Liu, W.; Henneberry, S.R.; Ni, J.; Radmehr, R.; Wei, C. Socio-cultural roots of rural settlement dispersion in Sichuan Basin: The perspective of Chinese lineage. *Land Use Policy* **2019**, *88*, 104162. [CrossRef]
58. Kassie, M.; Jaleta, M.; Shiferaw, B.; Mmbando, F.; Mekuria, M. Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technol. Forecast. Soc. Change* **2013**, *80*, 525–540. [CrossRef]
59. Chambers, R. The origins and practice of participatory rural appraisal. *World Dev.* **1994**, *22*, 953–969. [CrossRef]
60. Koutra, C. Rapid Situation Analysis: A hybrid, multi-methods, qualitative, participatory approach to researching tourism development phenomena. *J. Sustain. Tour.* **2010**, *18*, 1015–1033. [CrossRef]
61. Li, H.; Song, W. Pattern of spatial evolution of rural settlements in the Jizhou District of China during 1962–2030. *Appl. Geogr.* **2020**, *122*, 102247. [CrossRef]
62. Ye, X.; Chuai, X. Have rural settlement changes harmed ecosystem carbon in China? *Appl. Geogr.* **2023**, *153*, 102917. [CrossRef]
63. Wang, W.; Gong, H.; Yao, L.; Yu, L. Preference heterogeneity and payment willingness within rural households' participation in rural human settlement improvement. *J. Clean. Prod.* **2021**, *312*, 127529. [CrossRef]
64. Yu, Z.; Yuan, D.; Zhao, P.; Lyu, D.; Zhao, Z. The role of small towns in rural villagers' use of public services in China: Evidence from a national-level survey. *J. Rural Stud.* **2023**, *100*, 103011. [CrossRef]
65. Selod, H.; Shilpi, F. Rural-urban migration in developing countries: Lessons from the literature. *Reg. Sci. Urban Econ.* **2021**, *91*, 103713. [CrossRef]
66. Yang, Y.; Jia, J.; Devlin, A.T.; Zhou, Y.; Xie, D.; Ju, M. Decoupling and Decomposition Analysis of Residential Energy Consumption from Economic Growth during 2000–2017: A Comparative Study of Urban and Rural Guangdong, China. *Energies* **2020**, *13*, 4461. [CrossRef]
67. Jiang, J.; Zhao, T.; Wang, J. Decoupling analysis and scenario prediction of agricultural CO2 emissions: An empirical analysis of 30 provinces in China. *J. Clean. Prod.* **2021**, *320*, 128798. [CrossRef]
68. Cattaneo, A.; Adukia, A.; Brown, D.L.; Christiaensen, L.; Evans, D.K.; Haakenstad, A.; McMenomy, T.; Partridge, M.; Vaz, S.; Weiss, D.J. Economic and social development along the urban–rural continuum: New opportunities to inform policy. *World Dev.* **2022**, *157*, 105941. [CrossRef]
69. Li, G.; Jiang, C.; Du, J.; Jia, Y.; Bai, J. Spatial differentiation characteristics of internal ecological land structure in rural settlements and its response to natural and socio-economic conditions in the Central Plains, China. *Sci. Total Environ.* **2020**, *709*, 135932. [CrossRef]
70. Martínez-Graña, A.; Serrano, L.; González-Delgado, J.; Dabrio, C.; Legoinha, P. Sustainable geotourism using digital technologies along a rural georoute in Monsagro (Salamanca, Spain). *Int. J. Digit. Earth* **2017**, *10*, 121–138. [CrossRef]
71. Dai, M.; Fan, D.; Wang, R.; Ou, Y.; Ma, X. Does rural tourism revitalize the countryside? An exploration of the spatial reconstruction through the lens of cultural connotations of rurality. *J. Destin. Mark. Manag.* **2023**, *29*, 100801. [CrossRef]
72. Ye, Y.; Fang, X. Expansion of cropland area and formation of the eastern farming-pastoral ecotone in northern China during the twentieth century. *Reg. Environ. Change* **2012**, *12*, 923–934. [CrossRef]
73. He, Q.; Tan, S.; Yin, C.; Zhou, M. Collaborative optimization of rural residential land consolidation and urban construction land expansion: A case study of Huangpi in Wuhan, China. *Comput. Environ. Urban Syst.* **2019**, *74*, 218–228. [CrossRef]
74. Johnson, K.; Lichter, D. Rural depopulation: Growth and decline processes over the past century. *Rural Sociol.* **2019**, *84*, 3–27. [CrossRef]
75. Porta, J.; Parapar, J.; Doallo, R.; Barbosa, V.; Santé, I.; Crecente, R.; Díaz, C. A population-based iterated greedy algorithm for the delimitation and zoning of rural settlements. *Comput. Environ. Urban Syst.* **2013**, *39*, 12–26. [CrossRef]
76. Zhang, L.; Zhao, Y.; Zhang, X.; Du, H. Effect Mechanisms of Peasant Relocation Decision-making Behaviours in the Process of Rural Spatial Restructuring: The case of Hotan region, China. *Sustain. Cities Soc.* **2020**, *63*, 102429. [CrossRef]
77. Torabi, Z.; Rezvani, M.; Hall, C.; Allam, Z. On the post-pandemic travel boom: How capacity building and smart tourism technologies in rural areas can help—Evidence from Iran. *Technol. Forecast. Soc. Change* **2023**, *193*, 122633. [CrossRef]
78. Lun, Y.; Jing, S.; Moucheng, L.; Qingwen, M. Agricultural production under rural tourism on the Qinghai-Tibet Plateau: From the perspective of smallholder farmers. *Land Use Policy* **2021**, *103*, 105329. [CrossRef]

79. Lin, G.; Xie, X.; Lv, Z. Taobao practices, everyday life and emerging hybrid rurality in contemporary China. *J. Rural Stud.* **2016**, *47*, 514–523. [CrossRef]
80. Pot, F.; Koster, S.; Tillema, T. Perceived accessibility in Dutch rural areas: Bridging the gap with accessibility based on spatial data. *Transp. Policy* **2023**, *138*, 170–184. [CrossRef]