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Characteristics of Urban–Rural Integration at the County-Scale Interface: The Case of Linqu County, China

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Abstract: Urban–rural integration (URI) has emerged as a crucial strategy to bridge urban and rural disparities and promote more sustained urbanisation paradigms in China and abroad. The urban–rural interface, where urban and rural spaces and daily activities are closely intertwined, reflects the complex and evolving dynamics of this integration, serves as a focal point for studying URI, and requires unique considerations in spatial planning. This study focuses on the scale of the county level and the basic spatial units for spatial planning practice in China to examine different types of urban–rural interfaces and their URI dynamics at a county level. By taking Linqu County as a case study region, land use data from Landsat remote sensing datasets were collected every 5 years from 2000 to 2020 to support the analysis of changes in the urban–rural interface. Three dimensions of land mixed-use features were employed, including the area and density, edge and shape, and aggregation and dispersion of the construction land in the region. When combined with the proportion of rural land use, the urban–rural interfaces were identified using the entropy method. This study then employed spatial analysis, the standard deviation ellipse method, and spatial autocorrelation to recognise URI dynamics, and three driving forces were identified and further analysed to support suggestions for county-level spatial planning. This research empirically enriches the understanding of the urban–rural interfaces and URI dynamics of Linqu, China. The methods and suggestions derived from the empirical study can offer potential solutions to promote URI in China and enhance urban–rural linkage in the global context to reach more sustained development.

Keywords: urban–rural integration; county level; urban–rural interface; territorial spatial planning; rural revitalisation

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1. Introduction

Reflections on urban and rural relationships have been encouraging alternative solutions and global efforts to reshape a more equivalent urban–rural relationship. Among these solutions, urban–rural integration in the Chinese context, which is also in line with the enhancing urban–rural linkage approach advocated by the UN habitat for achieving sustainable development goals (SDGs), is a practical aspect that requires imperative explorations.

Growing knowledge on the understanding of urban and rural aspects through their complex interactions and linkages (supported by tangible and intangible networks derived from urbanisation processes) represents a significant trend of exploring conceptual tools to re-capture their essence through practical approaches to reach more sustained development [1–4]. Rather than emphasising social–spatial and economic dualism, new theories have argued for the importance of conceptualising urban and rural aspects with a thorough understanding that both territories are evolving together in urbanisation [5]. This is supported by networks such as transportation, the Internet, and 'clouds', which

provide various types of flows, including water, energy, capital, waste, information, and populations circulated across the world [6]. The dual mode of defining urban and rural areas became less persuasive as these flows have made the previous 'boundaries', such as centre–periphery and big–small, less relevant; comprehensively applying these boundaries cannot reflect the essential relationships of urban and rural [7,8]. Rurbanity underlines globalising urbanisation, in which 'Endowments and Place, Flows and Connectivity, Institutions and Behaviour, and Lifestyles and Livelihoods' together characterise current urban–rural transformations and global sustainability [9]. In practice, shaping more ideal urban–rural relationships that promote integrative development has become critical. The UN habitat proposed a practical framework for enhancing urban–rural linkage to reach SDGs [10]. The representative cases were selected in 2020, 2021, and 2023 to showcase different approaches to reach more integrative development [11–13]. In China, new urban and rural relationships have always been under exploration through top-down efforts and bottom-up initiatives [14–16]; it has become clear that urban–rural integration (URI) has, in recent years, become one of the overarching approaches after a decade of practise. It aims to narrow down urban–rural differences and improve living quality through promoting and encouraging a two-way flow of urban–rural development factors [17].

In light of this, URI requires efforts across different spatial levels. At the county level, a basic unit within the national territorial spatial planning system is crucial for practising URI in terms of directly facilitating public services and resources as well as promoting industrial development in the local region to encourage the flow of two-way factors. However, due to insufficient awareness and constraints related to development stages, URI development through the formulation of integrated territorial spatial planning covering counties and rural areas has only just begun [18], and in-depth studies are in urgent need. Focusing on URI at the county level, this study was developed, and the urban–rural interface was identified as the most important area. This is because the urban–rural interface is argued to be an independent unit of territory that should be part of planning as a system that is different to the urban and rural ones; the planning of interface space must consider complicated aspects [19]. It is an area comprising urban–rural spatial fabrics mixed with urban and rural functions and stimulated by both urban and rural development and transformation dynamics. Even with a growing number of studies and practices approaching more sustained development through URI witnessed in recent years, research on the urban–rural interface still requires a lot more attention [20,21]. Therefore, we selected the county region as a basic spatial unit for our URI study, and the urban–rural interface is the object of focus. The aim is to obtain a better understanding of various types of urban–rural interfaces at the county scale and their roles in the dynamics of URI development; based on this, a more efficient URI approach can be supported, contributing to the idea of the urban–rural relationship and reaching more sustained development in China and beyond. Correspondingly, the key questions are proposed: What different types of urban–rural interfaces within a county region can be identified? What were their roles in urbanisation processes, and what were the URI dynamics affecting them? How can this knowledge contribute to the spatial planning for a more sustained development?

2. Literature Review

2.1. Urban–Rural Integration and Critical Factors

In contrast to the previous dual conceptualisation of urban and rural areas, comprehensive thinking focusing on an urban and rural interlink has become a critical knowledge trend in supporting the development of spatial solutions for problems between urban and rural areas. Enhancing urban–rural linkages promoted by the UN habitat and URI implemented by the Chinese government are urban–rural sustainable development guides resulting from this comprehensive thinking.

The UN habitat proposed principles and practical frameworks in 2019. It suggested 10 principles for urban–rural linkage, among which local grounded interventions, integrated governance, functional and spatial system-based approaches, participatory engage-

ment, and data-driven and evidence-based aspects were included [10]. It indicated that the general approach for enhancing urban–rural linkages is grounded in local evidence, which requires integration into governance, development agendas, and spatial approaches. Integrated planning goals, broad networks, and the "whole-of-government" have been further emphasised in the action framework [10]. This reflected the importance of achieving better and sustained urban and rural development from a more inclusive and integrated perspective via more comprehensive approaches, including spatial planning that involved both urban and rural development aims rather than setting them apart.

In China, URI is a national strategy that reshapes urban–rural relationships and focuses on encouraging a better flow of development factors between urban and rural aspects at different regional levels. This strategy is largely supported by rural revitalisation and a new type of urbanisation [22]. It emphasised understanding the features and trends of population mobility, promoting URI, and encouraging the integrated development of urban–rural industry, infrastructure, and public services. Integrative governance and local inclusiveness are also considered essential in supporting policy implementation.

Based on the aforementioned concepts, frameworks, and policies, exploratory practices and studies have been conducted to identify the relevant and critical factors reflecting urban–rural integration (URI). Various approaches have been proposed to encourage URI, focusing on key factors that influence it. The development of rural industries, often leading to rural-to-urban land transformation, is considered crucial for URI [23]. In studies of URI in the Yangtze River Delta, the most relevant levels identified were "economic", "social", "spatial", and "ecological" [24]. Migration flows are also regarded as significant in reflecting URI, particularly in terms of social integration [25]. Additionally, different levels of URI have been studied, as reflected by quality of life [26] and socio-spatial inequality, as well as physical and social mobility [19]. Various practices have been implemented to enhance URI. For instance, exploratory projects that respect rural culture and customs while accommodating outdoor activities (e.g., harvesting and rural art experiences) and educational programs have become one of the major trends [27]. The development of rural headquarters linked to national agricultural production is also evolving [15]. Enhancing urban–rural spatial connections and improving living conditions by providing eco-services through greenways are among the most popular approaches [16].

In this context, new functions, including industry, leisure, infrastructure, and educational programs, are key elements often practised by relevant actors to stimulate URI, many of which rely on land use changes. However, land transitions may sometimes negatively affect URI [28].

2.2. Conceptualisation of the Urban–Rural Interface

The urban–rural interface is where urban space and rural space are directly connected to urban and rural regions and show both urban and rural features and dynamics. It is a region where the urban and rural are directly mixed and characterised by hybridity, multifunctionality, and a rapid speed of transformations [29–31]. It is also a 'hot spot' for natural energy [32]. This type of region can be recognised distinctively in different contexts across the world [19]. At the same time, the urban–rural interface has often been identified to be unequal in resource distribution and service delivery, uneven in infrastructure, and has fragmented and intertwined spaces of agriculture, industry, and residence [33–36], which always undergo uncertainties and transformations of lifestyle, land use, ecology, power relations, and social networks [19].

The development of the urban–rural interface, connecting the edge of urban expansion and its rural hinterland, has been challenged by both urban and rural agendas and residents' needs for living, including excess industrial areas, housing problems, and land use fragmentation [37]. The urban–rural interface is not simply a region with mixed urban and rural features but shows distinct spatial layouts, everyday practices, development dynamics, and flexibility [19]. These areas are found to encounter their own precise problems and require distinctive, innovative solutions that differ from what has been applied

in urban or rural areas to cope with these complex challenges [38]. However, the research on the urban–rural interface is still insufficient. For example, although the URI has been explored in China (from institutional approaches and practical projects), communities at the urban–rural interface have been often overlooked [21].

To sum up, a variety of urban–rural interfaces are reflected in existing studies in China and beyond, and different types of urban–rural interfaces can be identified from the perspectives of locations, functions, transformation speed, and mixed aspects (Table 1) [1,20,27,31,32]. For instance, take functions: some are more related to rural functions such as agriculture [20,27,32]; some are closely related to ecological functions for biotic diversity [1,20,27,31,32]; others have played roles in complementing the functions overflowing from urban areas, most of the time in a close proximity [20,27,31,32]. Furthermore, the urban–rural interface is not simply a mixture of urban and rural aspects but has its own features and is challenged by unique problems [20,31]. Therefore, it is hard to evaluate URI by using one set of criteria and enhance urban–rural linkage using similar spatial plans. It is critical to understand the similarities and differences of URI at the urban–rural interface.

Table 1. Different types of urban–rural interface.

Location	Function	Transformation Speed	Mixed Use of Land/Space	References
In between urban regions/agglomerations	Agriculture, eco-services, energy, and serves as urban hinterland	Comparatively slow	Comparatively low level of urban–rural spatial fabrics	[20,32]
In between the urban area and rural area within a regional scale (e.g., municipality)	Complex functions of residential, industry, waste treatment, eco-services, agriculture, and informal functions	Comparatively fast; can partially be transformed into urban areas	Highly mixed use of land, and urban–rural spatial fabrics	[1,20,27,31]
At the peripheries of high-level urban centres (e.g., cities)	Complex functions of residential, industry (can be closely related to adjacent urban areas), eco-services, energy, leisure, and informal use	Depends on the local development agenda	Middle-level mixed use of land and urban–rural spatial fabrics	[20]
At the peripheries of low-level urban centres (e.g., towns, townships)	Agriculture, eco-services, residential, and informal use	Depends on the local development agenda; sometimes it can be transformed rapidly	Middle-level mixed use of land and comparatively high level of urban–rural fabrics	[20,27]
In the middle of urban areas	Mainly residential, industry, and informal use	Depends on the local development agenda; it can be hard to transform	Comparatively low level of urban–rural spatial fabrics	[20]

Source: Author's construction based on above-mentioned literature.

2.3. Methods for Identifying Urban–Rural Interfaces

In past research, the identification methods of urban–rural interfaces can be generally divided into qualitative and quantitative versions, and the latter includes methods with a single factor and those with multiple factors. The qualitative method has been used to identify urban–rural interfaces mostly based on the empirical estimation of the distance to the central area or the range of urban buffers according to the city level [39,40]. For example, Salem proposed that the ring area 15–40 km away from the urban centre should be classified as a semi-urbanised area [41], and Webster and Muller defined 50 km as a criterion for dividing the inner and outer urban–rural interfaces [42]. In general, these definitions of urban–rural interfaces are subjective and can be changed based on the scope

and level of the city [43], which is difficult to generalise in studies at various scales of urban and rural areas.

Quantitative methods that use a single factor to identify urban–rural interfaces are commonly based on remote sensing data and socio-economic data, including land cover, light remote sensing data, landscape pattern, population density, proportion of non-agricultural population, and commuting distance of residents [43,44]. For example, some scholars have proposed that if the total population of the settlement is less than 20,000 people and the average population density is at least 40 people/km, then an area should be identified as an urban–rural interface [45]; some scholars proposed that areas with a ratio of construction land to total land area of less than 30% can be identified as urban–rural interfaces according to land remote sensing data [46]; and some scholars used the brightness level of urban light remote sensing data to identify urban–rural interfaces, regarding low-level brightness areas, as defined in their research, as urban–rural interfaces [47].

Quantitative methods that use multiple factors to identify urban–rural interfaces select indicators from socio-economic data and remote sensing data and analyse and evaluate these indicators using fuzzy sets, threshold regression, spatial clustering, entropy methods, and breaking point analysis methods [48,49]. For example, scholars used population income, land type, toilet distribution density, and the vegetation distribution of administrative units to divide the whole territory of Vietnam into urban core areas, urban areas, semi-urbanised areas, and rural areas [50]; some scholars analysed 20 indicators of socio-economic aspects, such as GDP, the density of the population, and commuting distance of residents with breaking point analysis methods to identify the urban–rural interfaces on the fringe of Beijing, China [51]; and some scholars analysed urban–rural interfaces with non-agricultural construction density and land ownership characteristic data through threshold regression and spatial clustering [49]. Due to the accessibility of data, research using such multiple-factor methods in China usually take the provincial level as the research scope and the county-level or township-level administrative boundaries as the fundamental research units [48,49]. In order to further study the complexity, dynamics, and ambiguity of urban–rural integration in semi-urbanised areas, scholars have identified the spatio-temporal characteristics of urban–rural interfaces at the city level using a 1×1 km raster scale and multiple indicators [48].

To sum up, the selection of methods for identifying urban–rural interfaces in past research mainly considered data accessibility, the scope of the selected case study, and the accuracy requirements to answer the research questions.

2.4. Summery

Integrative thinking in urban–rural interactions is the trend for supporting more sustained development and guiding spatial planning. In the existing literature, the research on factors reflecting the differences in urban and rural integration is comparatively rich. Moreover, while the research on the urban–rural interface is still insufficient, so is its identification at various scales. In this study, we tried to reflect on the key questions we proposed to provide a more in-depth understanding of the urban–rural interface by identifying its distinctive features. We define the urban–rural interface as areas between the urban and rural fringe where tangible and intangible urban-to-rural transformation always takes place, directly reflecting the local urbanisation continuum. The urban–rural interface is characterised by both urban and rural factors, and its development has been driven by both dynamics. It is not taken as a simple mixture of urban and rural fragmentation in this study but as a unique dynamic space accommodating and stimulating urban–rural interactions. The county scale is selected in this research.

Drawing on existing studies, as well as reflecting on the key questions, we employed an improved multi-factor identification method which combines the calculation of construction land and the proportion of rural land as a comprehensive index, visualised and analysed it using the entropy method, and conducted spatial analysis in consideration of the key differences between urban and rural aspects in Chinese contexts, such as the type of land

uses and ownership. Multiple factors and indicators were selected for analysis; the multi-factor identification method shows a more comprehensive and accurate way to recognise urban–rural interfaces in small-scale units with land use data compared to other methods. It can be used in both other counties in China and other places worldwide if the selected cases have accessible land use data and administrative boundaries.

3. Case Selection and Methodology

3.1. Case Selection

This research takes Linqu County, located in Weifang City, Shandong Province, as the study area (Figure 1). It represents a type of ordinary county that administratively belongs to a region with a comparatively positive development dynamic and strong economy, allowing us to showcase the trends, features, and role of the urban–rural interface in promoting URI. The total area of Linqu County is 1831 km^2; the northern part of the county is a plain area, and the southern part is a mountainous area. Linqu County contains four subdistricts, which are usually regarded as the central city, and six townships (including four Administrative Committees). Both subdistricts and townships contain urban areas and rural areas, leading to potential various types of urban–rural interfaces. The total population in Linqu County is 0.8 million and the urbanisation rate in Linqu County is about 55%, according to the seventh population census in 2020. In 2021, the GDP of Linqu County was CNY 38.942 billion, ranked among the top 18% of all counties in China and 46% of counties in Shandong Province [52,53], which means the economic development of Linqu County can support its rapid urbanisation and sustained development. It can be used as a universal case study and can also provide experience for late-developing areas in China.

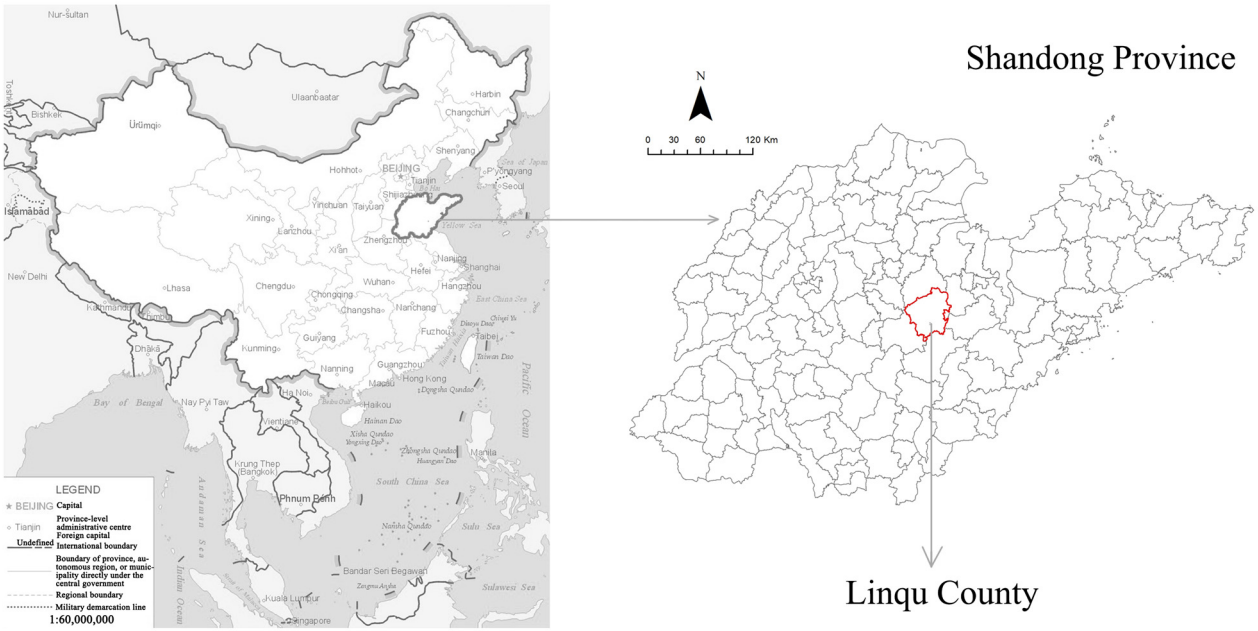


Figure 1. Location of the case study; source: the map of China was obtained from the standard map service system [54].

3.2. Methodology

By drawing on previous literature studies and field investigations, this research used 'land-mixed use' and rural land proportion to form the 'urban–rural interface index' to identify the urban–rural interfaces. The theoretical framework is shown in Figure 2. The research took Landsat-TM/ETM and Landsat 8 remote sensing monitoring data of land use in 2000, 2005, 2010, 2015, and 2020 with a resolution of 30 m and analysed the construction and rural land use change as the overall index to identify urban–rural interfaces in Linqu

County. The data were obtained from the Resource and Environmental Science Data Platform in China. Taking the study of mixed-use land's effects on resident population distribution from 600 m to 3000 m in Jiading District in Shanghai as a reference [55], the research divided the raster of Linqu County into 1 × 1 km spatial grids, which serve as the fundamental spatial units, to balance the number of spatial units and the accuracy of the change in land use.

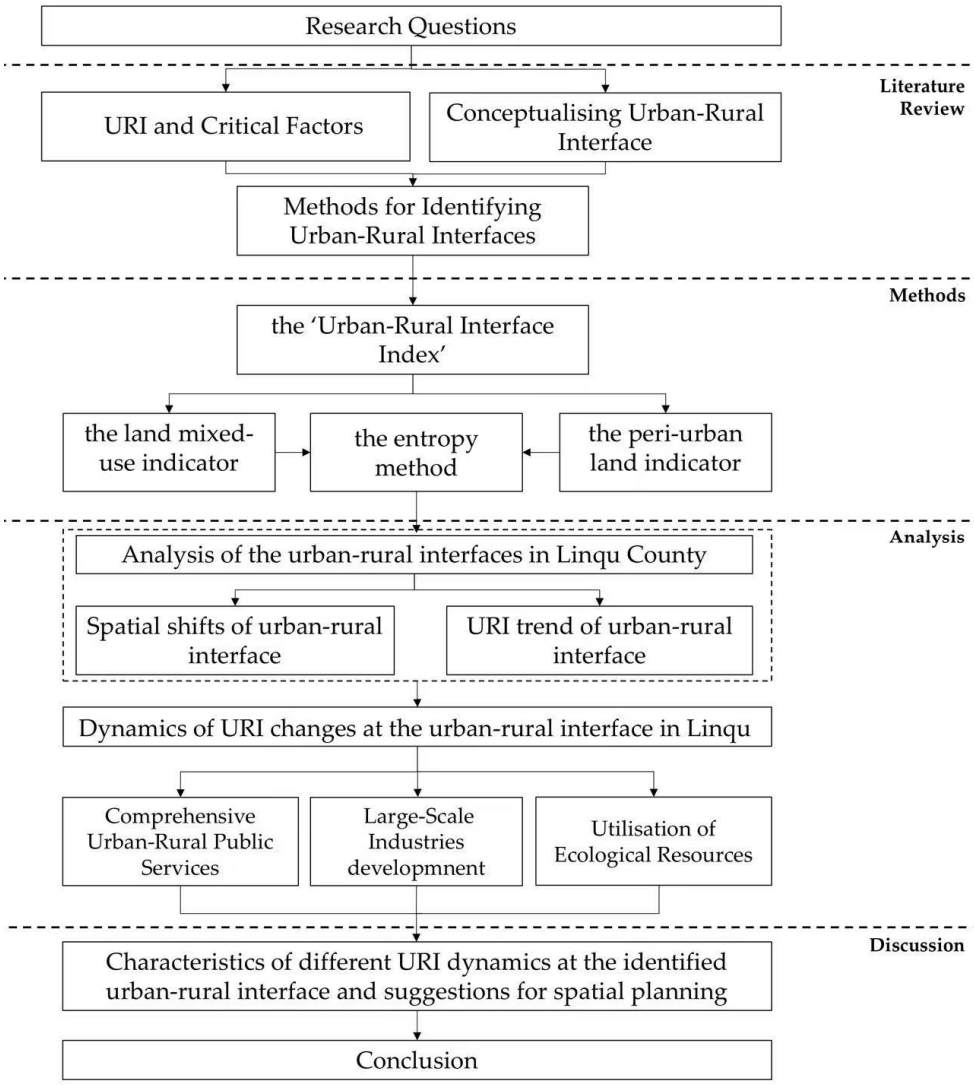


Figure 2. Theoretical framework.

(1) The mixed-use land indicator:

The research selected eight factors from three aspects, area and density, edge and shape, and aggregation and dispersion (Table 2), to analyse all 1 × 1 km grids in Linqu County using Fragstats 4.2 and ArcGIS 10.7. It took the construction land identified using the remote sensing monitoring data of land use in 2000, 2005, 2010, 2015, and 2020 and then integrated the results of the principal component analysis metrics and normalised them to the (0,1) range, resulting in the mixed-use land index of each grid in Linqu County. According to the literature, the mixed use of land is the most prominent characteristic of urban–rural interfaces; the higher the degree of land use fragmentation, the more significant the characteristics of urban–rural interfaces [44,56]. Concluded from past research, we selected eight factors from three aspects that can comprehensively describe the spatial characteristics of the construction land in grids, reflect the degree of land use fragmentation, and are easy to integrate as indicators to analyse the degree of urban–rural interaction.

Principal component analysis is an effective method to reduce the dimensionality of factors and extract major factors [57], and it is widely used in multi-variate analysis. In order to facilitate comparison, principal component analysis was used to integrate the eight indicators into a unified visual value.

Table 2. Eight factors of the mixed-use land indicator.

Aspects	Factors	Factor Implications	Formula	Positive/ Negative
Area and density	Total (Class) area (TA/CA)	Total (Class) area presents the total area of construction land in the selected grid.	CA equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.	Negative
	Number of patches (NP)	NP is the number of patches in the 1 × 1 km grid. The larger the number, the greater the fragmentation of the construction land.	$NP = n_i$ n_i = number of patches in the grid of class type.	Positive
	Largest patch index (LPI)	The proportion of the largest area of patches in the grid to the overall 1 × 1 km unit	$LPI = \frac{\max a_{ij}}{A} \times 100$ a_{ij} = area (m^2) of patch ij. A = total grid area (m^2).	Negative
Edge and shape	Landscape shape index (LSI)	It reflects the change in patch shape in the landscape, and when the LSI value increases, the patch irregularity increases [56].	$LSI = 0.25\frac{\sum_{k=1}^{m} e_{ik}^*}{\sqrt{A}}$ e_{ik}^* = total length (m) of the edge in the grid between patch types (classes) i and k; includes the entire grid boundary and some or all background edge segments involving class i. A = total grid area (m^2).	Positive
	Shape index by area-weighted mean (AM)	It reflects the complexity of the shape of the patches in the grid.	$SHAPE = 0.25\frac{p_{ij}}{\sqrt{a_{ij}}}$ p_{ij} is the perimeter (m) of patch ij. a_{ij} is the area (m^2) of patch ij.	Positive
Aggregation and dispersion	Splitting index (SPLIT)	It reflects the degree of dispersion of the patches in the grid.	$SPLIT = \frac{A^2}{\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}^2}$ a_{ij} = area (m^2) of patch ij. A = total grid area (m^2).	Positive
	Aggregation index (AI)	It indicates the degree of dispersion of patches in the grid. The smaller the AI value is, the larger the dispersion degree of different types of patches in the grid is [56].	$AI = \left[\frac{g_{ij}}{max-g_{ij}}\right](100)$ g_{ij} = number of like adjacencies (joins) between pixels of class i based on the single-count method.	Negative
	Patch cohesion index	The higher the value, the higher the spatial connectivity within the grid.	$Cohension = \left[1 - \frac{\sum_{j=1}^{m} p_{ij}}{\sum_{j=1}^{m} p_{ij}\sqrt{a_{ij}}}\right]\left[1 - \frac{1}{\sqrt{A}}\right]^{-1} \times 100$ p_{ij} = perimeter of patch ij in terms of number of cell surfaces. a_{ij} = area of patch ij in terms of number of cells. A = total number of cells in the grid.	Negative

Sources: created by authors according to https://fragstats.org/index.php/fragstats-metrics/patch-based-metrics/aggregation-metrics/ (accessed on 26 August 2024).

(2) The peri-urban land indicator

According to the definition of urban–rural interfaces, the proportion of rural areas can represent the urbanisation of Linqu County. Theoretically, the proportion of rural land areas in the urban–rural interface between urban areas and rural areas, respectively, and approaches 50% in the standard urban–rural interface. Meanwhile, the urbanisation rate in Linqu was about 55% by the end of 2020, according to the Seventh National Population Census of Linqu County. Thus, this research identified 0.5 as the standard to evaluate the peri-urban land indicator in each grid (1 × 1 km) and took the rural land recognised by the remote sensing monitoring data in 2000, 2005, 2010, 2015, and 2020 for analysis. The proportion of rural land (prl) in each grid equals the total area of recognised rural land in one grid, including arable land, woodland, and grassland, divided by the total area, which is 1 km^2. Then, the research calculated the peri-urban land index in each grid by using the following formula and normalised it to the (0,1) range:

$$\text{The peri} - \text{urban land indicator} = (prl - 0.5)^2$$

(3) The urban–rural interface index

The above two indicators are weighted and assigned using the entropy method to calculate the overall score of each year in each grid, namely the urban–rural interface index, which was visualised using ArcGIS 10.7 software. The urban–rural interface index reflected the degree of the urban–rural interface in each grid. The following shows the process of calculating the score by using the entropy method [58].

(a) Calculate the weighting of each of the two indicators for each grid; i is the number of grids and j is number of the indicators.

$$P_{ij} = \frac{u_{ij}}{\sum_{i=1}^{n} u_{ij}}, \mathrm{i} = 1, 2 \ldots \mathrm{n}; \mathrm{j} = 1, 2$$

(b) Calculate the entropy value of the j-th indicator as e_j:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \text{and } k = \frac{1}{\ln n}$$

(c) Calculate the weights of each indicator $W(E_j)$:

$$W(E_j) = \frac{1 - e_j}{\sum_{j=1}^{m} (1 - e_j)}$$

(d) Calculate the score for each grid Q_i:

$$Q_i = \sum_{j=1}^{m} u_{ij} W_{E_J}$$

(4) Analysing the characteristics of urban–rural interfaces

(a) The spatial development direction of urban–rural interfaces

The standard deviation ellipse method is one of the classical methods used to analyse the directional characteristics of spatial distribution, and it can be used to quantitatively explain the spatial direction, morphology, and centrality of the distribution of factors from a global and spatial perspective [59]. The research used ArcGIS 10.7 to analyse and present the results according to this method.

(b) Spatial pattern characteristics of urban–rural interfaces

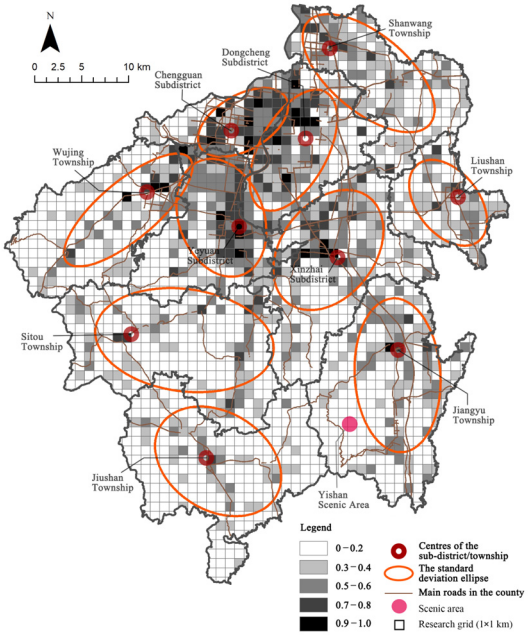
Spatial autocorrelation was used to measure spatial pattern characteristics. The correlation between the property values of different spatial areas is due to the spatial location of these areas. Local spatial autocorrelation can reflect the spatial connection degree of all

units in the study area and describe the relative characteristics of urban–rural interfaces, which is commonly represented by LISA local autocorrelation Moran's I [60]. Its formula is shown below. The research used ArcGIS 10.7 to analyse and present the results according to this method.

$$I = \frac{x_i - \overline{x}}{S^2} \sum_{i=1}^{n} \left(W_{ij}(x_i - \overline{x}) \right)$$

4. Analysis of Urban–Rural Interface of the Case Study Region and the Results

The research integrated the land use and the proportion of rural areas in Linqu County from 2000 to 2020 as an urban–rural interface index to identify the urban–rural interfaces and analyse their transformation with spatial analysis in ArcGIS 10.7, as shown in Figure 3a–e.



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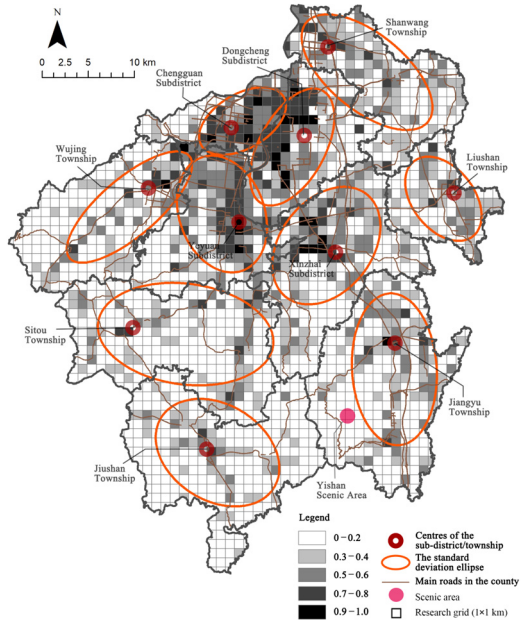

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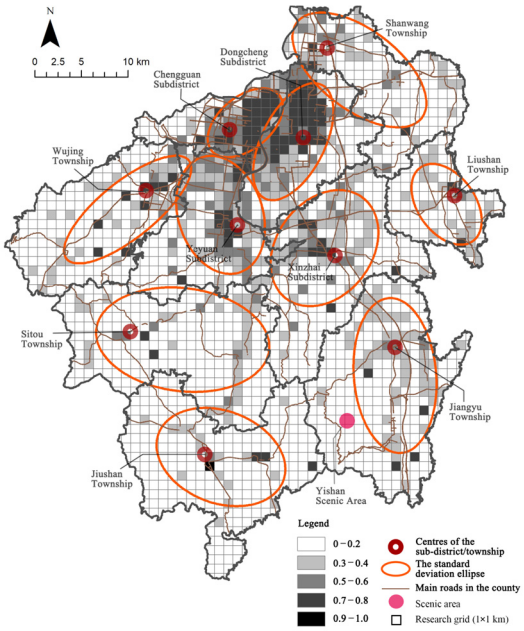
Figure 3. *Cont.*



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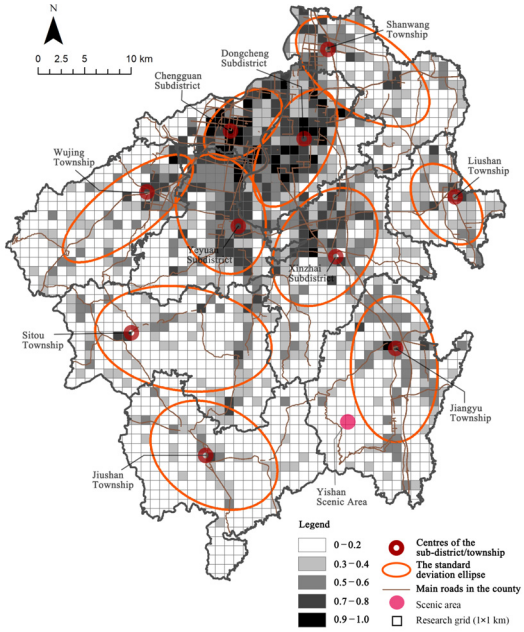

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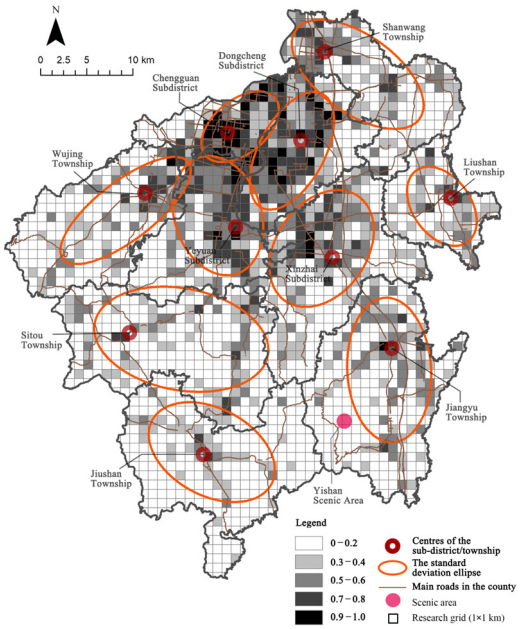
Figure 3. *Cont*.



(**e**)

Figure 3. (**a**) The spatial distribution of the urban–rural interface index in 2000 in Linqu County. (**b**) The spatial distribution of the urban–rural interface index in 2005 in Linqu County. (**c**) The spatial distribution of the urban–rural interface index in 2010 in Linqu County. (**d**) The spatial distribution of the urban–rural interface index in 2015 in Linqu County. (**e**) The spatial distribution of the urban–rural interface index in 2020 in Linqu County.

The figure shows the five degrees of the urban–rural interfaces in Linqu County; the lighter the colour, the higher the score of the urban–rural interface index, which means the grid is more likely to be the urban–rural interfaces in Linqu County. Based on the results of the standard deviation ellipse method, the ovals in each year show the direction of the extent of the urban–rural interface.

4.1. The Spatial Distribution of Urban–Rural Interfaces

In general, the spatial distribution of the urban–rural interfaces of Linqu County showed more interfaces in the north and a few in the south (continuous in the north and scattered in the south), resulting from the urban centre located in north Linqu, attracting greater flows of urban–rural factors countywide. Figure 3a–e show that urban–rural interfaces are obviously located adjacent to the urban centres of the main subdistricts, which are located in northern Linqu and are more continuous due to the urbanisation process at the county level during the past 20 years. In contrast, the urban–rural interfaces around townships were few and scattered where there was a low urbanisation rate (located in southern Linqu). From 2005 to 2015 (Figure 3c,d), the urban–rural interface index in central areas of the Chengguan and Dongcheng Subdistricts changed obviously. From 2005 to 2010, there was a low peak value, but with a small variance, and from 2010 to 2015, the high and low values were more obvious. This illustrates that with the increase in the urbanisation rate in Linqu County, the boundary between urban and rural areas is becoming increasingly clear, which means urban–rural factors first gathered in central urban areas and then overflowed to the rural areas around them. Additionally, in the past 20 years, the development direction of urban–rural interfaces in all subdistricts and townships has been relatively consistent.

Urban centres in Linqu have evolved from a single subdistrict to a broader range, mainly including the central areas of Chengguan and Dongcheng Substricts, leading to the extension of urban–rural interfaces around urban centres and along the transportation infrastructure between them. From 2000 to 2020, the urban centre in Linqu County

expanded from Chengguan Subdistrict to a broader range, mainly including the centre of Chengguan and Dongcheng Subdistricts. Although the urban area of Linqu County still showed a single-centre structure over the 20 years, the spatial range of this "single centre" has largely increased when comparing between 2020 (Figure 3e) and 2000 (Figure 3a). Along with the extension of urban centres, the area and scope of urban–rural interfaces have also increased, and so has the degree of mixed-use land, which further accelerated the gathering of urban–rural factors in this area. Meanwhile, with the gathering of urban–rural factors in urban–rural interfaces in north Linqu, urban–rural interfaces (shown as spatial axes connected into continuous urban areas), such as the urban centres of Yeyuan and Xinzhai Subdisricts, have become more significant during the past 20 years when comparing Figure 3a,e. These urban–rural interfaces, usually situated along well-constructed transportation infrastructure and around urban centres, mainly contain residential areas and small rural industries.

The urban–rural interfaces and the administrative boundary do not overlap; in fact, the urban administrative boundary contains urban areas, urban–rural interfaces, and rural areas in Linqu County. From Figure 3c–e, during the past 20 years, each central area of subdistricts has occupied part of their administrative boundary, and the urban–rural interfaces around it are also mainly contained in the boundary. In townships, centre areas and urban–rural interfaces adjacent to them occupied a smaller part of the administrative region, leaving a large range of the region as rural areas.

4.2. The Spatial Evolution of Urban–Rural Interfaces

In the past 20 years, the urban–rural interfaces of Linqu County have emerged and developed with the expansion of the central urban area, mainly due to the development of industries. The research takes Dongcheng District as an example. Due to the rise and development of aluminium trading in the 1990s, in the past 30 years, upstream and downstream industries of the aluminium industry have continued to gather in Dongcheng Subdistrict, leading to the agglomeration of urban–rural factors in Dongcheng, including labour, information, technology, and capital, which accelerated the urbanisation process in Linqu County. Because of that, villages surrounding the centre of Dongcheng gradually changed into communities, and the urban centre of the county expanded from Chengguan Subdistrict to Dongcheng Subdistrict. Moreover, with the accelerating flow of urban–rural factors, areas adjacent to the central part of the subdistrict had become the pioneer area of the flow of urban–rural factors, which emerged and developed as urban–rural interfaces.

Urban–rural interfaces not only expanded at the edge of the central urban area but also show an expansion trend along the transportation arteries. As analysed in Section 4.1, with the gathering of urban–rural factors in urban centres, these factors had overflowed to surrounding areas. Initially, they gathered in the areas around the urban centres and then developed along the main transportation arteries to other noncontinuous urban centres or townships, such as the central areas of Yeyuan and Xinzhai Subdisricts. This phenomenon mainly occurred because of the population mobility caused by employment and residence between urban and rural areas. During the past 20 years (Figure 3a–e), the trend of this expansion of urban–rural interfaces were gradually significant along the connection of Chengguan and Dongcheng, the main urban centre, and Yeyuan and Xinzhai, noncontinuous urban centres and Wujing Township. Meanwhile, with the tighter connection among the northern part of Linqu, more sufficient industries, transportation infrastructure, and public services have been planned and constructed; this led to the further gathering of urban–rural factors and the continuous spatial layout of urban–rural interfaces as axes.

In the southern part of the county, urban–rural interfaces are few and scattered due to deviating from urban centres, which means they have difficulty accessing the spillover of urban–rural factors in central areas. Most of the townships in southern Linqu are responsible for agricultural planting and residence. Over the past 20 years, their centres have lacked large-scale industries and mainly provide community-level public service

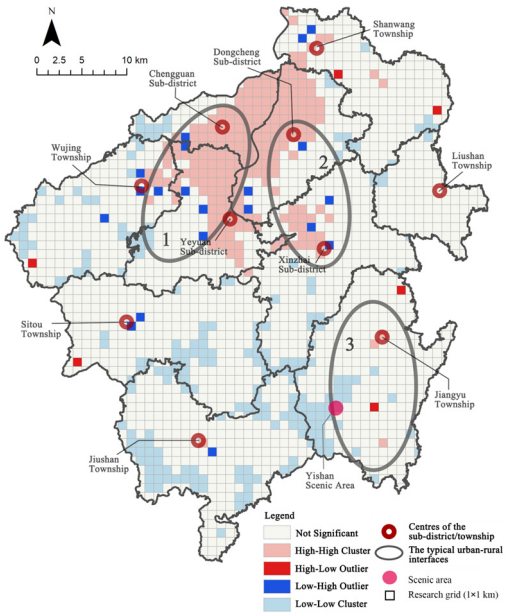
facilities, making it difficult to gather urban and rural factors. Therefore, the urban–rural interface area only exists around the residents' activity centres, showing few and scattered characteristics in spatial distribution.

4.3. The Categories of Urban–Rural Interfaces and Their Characteristics of URI

Based on the above analysis in Sections 4.1 and 4.2, the research found that urban–rural interfaces both around central areas of subdistricts and townships, and along the urban–rural axes in Linqu County, had undertaken similar functions, which is the pioneering area of the two-way flow of urban–rural factors. However, the driving forces of the urban–rural integration process of these interfaces were different, which can be used to classify the categories of urban–rural interfaces in Linqu County. Thus, the research combines a local autocorrelation analysis of the urban–rural integration index in Linqu County in 2010 and 2020, which showed obvious differences in the evolution process; qualitative in-depth interviews; and field investigations to summarise the driving development forces of typical urban–rural interfaces and their characteristics of URI.

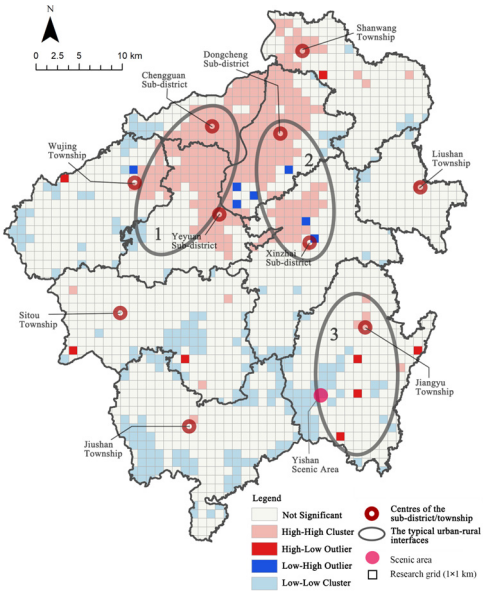
4.3.1. Urban–Rural Integration Driven by Comprehensive Urban–Rural Public Services

The first category is that the form and expansion of urban–rural interfaces have relied on the well-constructed and comprehensive public services and infrastructure in central urban areas and adjacent rural areas. This category usually exists in and around central subdistricts at the county level. For example, the local autocorrelation score of the urban–rural interface index in Chengguan and Yeyuan Subdistricts showed that high–high clusters increased while low–high clusters decreased in the peripheral area of the two subdistricts from 2010 to 2020, according to area 1 in Figure 4a,b. In central urban areas, well-constructed and comprehensive public services and infrastructure have attracted the increasing flow of urban–rural factors during the past 10 years, and urban–rural interfaces around them formed and strengthened as carriers for the outflow of gathered urban–rural factors. Thus, both central urban areas and adjacent rural areas acted as an active space for local residence, and the daily life activities of residents in Linqu County, in turn, improved the development of public services and infrastructure in these areas.



(**a**)

Figure 4. *Cont.*



(**b**)

Figure 4. (**a**) Local autocorrelation for Moran's I of the index in 2010 of Linqu County. (**b**) Local autocorrelation for Moran's I of the index in 2020 of Linqu County.

Urban–rural integration driven by comprehensive public services and infrastructure is reflected in urban–rural interfaces with continuous spatial distribution. They are located among the boundaries of urban centres formed by the two-way flow of urban–rural factors but not necessarily located around administrative boundaries of subdistricts, according to Figure 4a,b. Well-constructed and comprehensive public services and infrastructure in the urban centre provides opportunities for industrial development, job hunting and residents' daily-life activities, attracting labour, information, and technology from both urban and rural areas to gather around urban centres, thus forming urban–rural interfaces. For instance, the cherry planting industry in Yuezhuang Village, located at the urban–rural interface in Chengguan Subdistrict, has benefited from the well-developed public services and infrastructure of the subdistrict. It extended its industrial chain from the initial planting industry to multiple industrial activities, such as planning, trading, and transporting and formed a regional "employment center", attracting regional urban–rural factors in urban–rural interfaces [61].

4.3.2. Urban–Rural Integration Driven by Introduced Large-Scale Industries

The second category is that the form and expansion of urban–rural interfaces have relied on introducing large-scale industries in central urban areas. For example, the local autocorrelation score of the urban–rural interface index in Dongcheng and Xinzhai Subdistricts showed that high–high clusters increased around urban centres of the two subdistricts from 2010 to 2020, according to area 2 in Figure 4a,b. In Linqu County, the aluminium industry had been introduced since 1980s in Dongcheng Subdistrict, attracting investment and large production enterprises surrounding the urban centre. Initially, the introduced industries usually belonged to the secondary industry, located in the peripheral area of urban centres. This increased regional employment opportunities, and caused the flow of labour between residential and working areas, and further drove the construction of surrounding public service facilities and infrastructure, gradually attracting the flow of other urban–rural factors, such as information, technology, and capital, to this area. With the development of introduced industries and the peripheral area they belonged to, the former peripheral area was urbanised and connected to existing urban centres, turning the adjacent rural areas into new peripheral areas of urban areas. Additionally, it has caused

the transformation of rural land in surrounding villages to state-owned land to meet the need of the development of introduced industries during the past 20 years.

Urban–rural integration driven by introduced large-scale industries is reflected in urban–rural interfaces around urban centres, where the industrial parks or big companies are located, and they are not necessarily shown continuously in the spatial distribution. According to area 2 in Figure 4a,b, urban–rural interfaces formed by large-scale, introduced industries located separately in the Dongcheng and Xinzhai Subdistricts in 2010, and with the development of industries and infrastructures led by the gathered urban–rural factors, there was a trend of connection and spatial continuity between the two subdistricts in 2020.

4.3.3. Urban–Rural Integration Driven by the Utilisation of Ecological Resources

The third category is that the form of urban–rural interfaces has relied on the utilisation of ecological resources. Localised tourist resorts can naturally attract the agglomeration of urban and rural factors through the utilisation of ecological resources, which leads to the improvement of the transportation infrastructure and public service facilities, forming urban–rural interfaces around it. In this case, the Yishan Scenic area located in southern Jiangyu Township attracted tourists inside and outside the county. Although it is far from the central urban areas in Linqu County, the areas around the Yishan Scenic area still formed public service centres; this is shown in high–low outliers that separately occurred and increased in Jiangyu Township from 2010 to 2020, according to the local autocorrelation score of the urban–rural interface index of area 3 in Figure 4a,b, which acted as new urban–rural interfaces in the township. In addition, the gathered regional population flow and consumption can offer job opportunities and increase the need for public services in the central township. The central area of Jiangyu has also developed and formed urban–rural interfaces around it.

Urban–rural integration driven by the utilisation of ecological resources is reflected in the urban–rural interfaces around these resources or the centre of their administrative boundary and the spatial characteristics related to ecological resources. The utilisation of ecological resources can be limited by protection policies and their own environmental carrying capacity, so the tourism and public services relying on the resources cannot be developed unlimitedly. Thus, the range and completeness of urban–rural interfaces formed around ecological resources depend on the characteristics of the ecological resources and the degree of their utilisation.

5. Discussion

Building on the above analysis and results, along with existing studies on urban–rural interface development, this research identifies three aspects warranting further discussion. The first aspect concerns the different types of urban–rural interfaces identified in the empirical study. The second aspect involves understanding the URI dynamics of these interfaces and discussing the primary driving forces—whether they are top-down plans or bottom-up initiatives. This leads to the final aspect: understanding the development factors stimulated or organized by these dynamics. Based on these discussions, suggestions for spatial planning are derived.

(1) Four types of urban–rural interfaces have been identified in the county, which showed distinctive features in transformation speed, hybridity, and the dynamics of URI.

Existing studies suggest that urban–rural interfaces are influenced by various factors and can be understood differently across contexts and spatial scales. For example, at a national scale, three types of urban–rural interfaces have been identified: urban–rural continuities, discontinuities, and ambiguous situations [62]. At the municipal scale, three types are recognized: urban-dominant interfaces, intertwined interfaces, and rural-dominant interfaces [63]. Similarly, empirical evidence from Linqu shows that the development of urban–rural interfaces varies based on geographic location, function, and transformation process, with both continuities and discontinuities identified. However, at the county level, urban and rural areas are mostly intertwined. Differences in urban functions and

levels of development further differentiate the interfaces at urban peripheries, revealing distinct dynamics (see Table 3). For example, the peripheries of urban centres of subdistricts (e.g., Chengguan and Dongcheng Sub-district) that transformed rapidly partially became urban areas and also showed a high level of mixed-use land for accommodating complex functions. They also comprised highly mixed urban and rural spatial fabrics. The peripheries of town centres of townships (e.g., Jiangyu Township) transformed slowly and remained as rural areas with less mixed land uses and showed little mixture of urban and rural spatial fabrics. These mainly supported agricultural and ecological functions. Although the former type of urban–rural interface reflected a clear trajectory of rural-to-urban transformation and various statuses and phases within the transformation process, the latter one has remained still for a long period of time and did not show the spatial development pattern known as the urban–rural continuum [64]. In this light, the URI, defined by the two-way flow of urban–rural development factors, at the urban–rural interfaces showed diversified features, which are nonlinear. Two main types of flows that formed these distinctions can be identified in Linqu County. The first type is characterised by national/regional flows (e.g., highly mixed floating populations, also known as migrant workers, which, in many cases, was led by public and private investments that introduced industries and provided potential job opportunities). The second type is the URI supported by local development flows characterised by public services, narrowing down differences between urban and rural areas.

Therefore, to respond to a more sustained URI development, a higher requirement was put forward for spatial planning to fully understand the transformation and take the urban–rural interface as a space that distinguishes between urban and rural areas.

(2) URI dynamics at the urban–rural interface can be led by using both top-down agendas and bottom-up initiatives.

Many studies suggest that the development of the urban–rural interface is shaped by both top-down and bottom-up initiatives and planning. In many cases, top-down development, representing urban forces [63], affects growth primarily through policies related to land transfer [19]. Conversely, some studies show that bottom-up planning, focusing on local priorities, can outweigh top-down planning in its impact on natural resource management [65]. Evidence from Linqu confirms the influence of both driving forces in shaping the urban–rural interface at the county level. It demonstrates that top-down and bottom-up initiatives impact different types of URI dynamics. The location, functions, and URI dynamics in various urban and rural areas have led to diverse driving forces, with some dynamics shaped more by top-down plans and others involving more bottom-up initiatives. For example, in the case of Linqu, urban–rural interfaces that were characterised by delivering public services usually emerged at the peripheries of those urban areas (e.g., the interface of Chengguan subdistrict and Yeyuan subdistrict), which mainly relied on top-down support. The interfaces driven by industries closely linked to local pillar industries mostly appeared to be a certain distance away from the central urban area of the county (e.g., 6–10 km in the case of Linqu). This type of development was characterised by less land investment, transportation convenience, affordable labour costs, and avoiding impacts of environmental pollution on residential areas. This type of development can be initiated by local bottom-up initiatives. There were also interfaces characterised by major ecological functions, which were supported by natural environmental resources, and regional agendas relied on both top-down and bottom-up efforts. They mainly experience different dynamics. For example, the urban–rural interface driven by public services relies on the flow of resources from the city to the countryside (e.g., the interfaces of Jiangyu township), bringing adjacent rural areas into the scope of the urban–rural interface, while the urban–rural interface driven by natural resources/eco-services needs to first form or strengthen the "urban function", and then form the urban–rural interface within a certain range around it.

Table 3. Urban–rural interfaces identified in Linqu and URI dynamics.

Location	Function	Transformation Processes	Mixed Use of Land/Space	URI Dynamics/Two-Way Flow of Development Factors Within Linqu County	URI Supported by Factors Beyond Administrative Boundaries
At the peripheries of urban centres of sub-districts.	Complex functions of residential, different types of industries, public services and facilities, agricultural activities.	Transformed fast and partially into urban areas.	High level of mixed use of land, and urban–rural spatial fabrics	Industries, public services and infrastructure/capital, labour, in-flow of raw material and out-flow of products.	The industry linked to national/regional development dynamics.
Between two urban centres of sub-districts that are far away from both centres.	Mainly residential, public services and facilities, agricultural activities.	Transformed at a medium speed and remain as mainly rural areas.	Middle-level mixed use of land, and comparatively high level of urban–rural fabrics	Industries, public services and infrastructure/labour, land.	Transportation linked to regions.
Between the peripheries of the urban administrative boundaries of sub-districts and town centres (e.g., rural areas in Wujing and Shanwang townships).	Mainly residential, industrial.	Transformed at a medium speed and partially into urban areas.	Middle-level mixed use of land, and comparatively low level of urban–rural fabrics.	Industries/capital, labour, in-flow of raw material and out-flow of products.	The industry linked to both regional and local development and everyday needs.
At the peripheries of town centres of townships.	Mainly residential, agricultural, and ecological services.	Transformed slowly and remain as mainly rural areas.	Low level of mixed use of land, and comparatively low level of urban–rural spatial fabrics.	Tourism/labour, consumption, land.	Transportation linked to regions.

By drawing on this knowledge, spatial planning should provide more possibilities for broader inclusiveness that can reflect both top-down agendas and bottom-up initiatives so that spatial planning can really play its role in practise.

(3) URI supported by industries and eco-services showed an obvious feature that the two-way development factor flows are beyond the local urban hinterland.

The territories extended between urban and rural are being seen as new locations for industries as well as large leisure facilities in European countries and the USA [66]. Our empirical study in Linqu also reflected that the industries and leisure activities related to eco-services play an important role in the form of URI at the urban–rural interface. Meanwhile, current discussions on urban and rural development also emphasize the importance of contextualizing this development within the urbanization process. This approach highlights the need to view the development of a place through an interconnected lens, acknowledging that the flow of various development factors is complex and not always confined to neighbouring spaces [1]. Distinctive landscapes observed worldwide further illustrate this, as the visible features can originate from human activities and developments occurring far from where they are identified [3]. The empirical evidence in this study supports these theories, demonstrating that the understanding of the urban–rural interface

also requires the perspective that it is not only affected by urban areas and their spatially linked hinterlands but also regions beyond. For example, the urban–rural interfaces identified in Linqu were, of course, affected more or less by their directly adjacent urban areas; however, the URI development dynamics that are characterised by the two-way flow of urban–rural development factors were not limited to the area. Industries showed the most obvious trend. Take the interface located between Chengguan Subdistrict and Wujing Township as an example; small rural industries, such as agricultural and sideline product processing and trading industries, serve local everyday needs as well as the regional agenda. They attracted investments and talents from both Linqu County and the city and even the broader province the county belongs to, and the products were mainly sold to Shandong Province. Moreover, the urban–rural interface of Jiangyu Township, in which the URI dynamics are mainly characterised by the function of providing eco-services, also reflected factor flows beyond Linqu County; it serves visitors in Linqu and the adjacent cities and counties. However, the investment in this area was mainly from the local government and stakeholders inside Linqu. It is critical to realise and identify these URI developments that are supported by flows from other areas beyond the region. It is common sense that county-level urban and rural resources can easily be attracted by higher-level urban areas and flow out to other economically developed provinces, cities, and counties, and vice versa, especially in the areas with better transportation and infrastructure networks. This leads to a loss of resources in the county and slows down the local URI. The evidence also showed that more developed urban areas that are not in the spatially connected region could also support the local URI of the urban–rural interface, taking the local factories and eco-services that are linked to the regional resources, for instance. These two opposing forces between an urban area and its hinterland and beyond work together to promote the formation and evolution of the urban–rural interfaces in the county.

This provides us with a crucial insight for spatial planning, which is that a URI that emphasises the two-way flow of development factors between urban and rural aspects may not be limited to the urban and rural aspects that are directly adjacent, but the flow can cross administrative boundaries and even be global flows. Combined with the fact that some types of urban–rural interfaces are also characterised by comparatively rapid transformation speed, the key is to identify local needs and initiatives and link them to the development agendas of broader regions. This can be an important approach to encourage and emphasise the URI dynamic, making it more sustainable, and further support the approach of practising a more integrated, inclusive, and adaptive development and governance model in the urban–rural interface against the background of globalisation and industrialisation [29].

6. Conclusions

Urban–rural integration is a national policy in China that also echoes the enhancement of urban–rural linkage promoted by the UN habitat, which aims to create more equivalent urban–rural relationships and sustained development. Taking the URI of urban–rural interfaces at a county scale as the research subject, this research aims to support more ideal urban–rural relationships and obtain sustainable development. An ordinary county named Linqu that administratively belongs to a comparatively developed province was selected as the case area to identify different types of urban and rural interfaces and the URI dynamics.

Urban–rural interfaces are shaped by various processes, including urban transitions, rural restructuring, and the evolution of multifunctional rural spaces, which are key to understanding their current and future status [67]. These interfaces are considered independent territorial units distinct from purely urban or rural areas [18]. The empirical study in Linqu verified this and further suggested the existence of more complex types of urban–rural interfaces, and one of the dominate factors is the level of urban functionality. Urban–rural interfaces exhibited distinct dynamics; those related to market-driven industries often involve more local initiatives, while others, such as public services and eco-services, require initial top-down efforts. The study also emphasizes the importance of

a perspective that extends beyond administrative boundaries to encompass the continuous and discontinuous spatial connections between urban areas and their hinterlands, capturing the essence of urban–rural interfaces. Factor flows, shaping these dynamics, in these areas are more complex, and may be related to regional and national agendas, relying on various networks, including transportation, information, and production chains. Building on the knowledge above, the research proposes that for interfaces located on the peripheries of higher-level urban areas accommodating industries tied to regional/national agendas, spatial planning for URI should emphasize flexibility and inclusiveness to integrate various initiatives. For interfaces primarily serving ecological structures, public services, and infrastructure near less-developed towns, URI development may be constrained by fewer growth factors, necessitating prioritization in spatial planning. Furthermore, the development of planning tools to identify and promote factor flows within and beyond the region is urgently needed to support URI development and avoid rigid, uniform delineation approaches.

Additionally, this research provided a comprehensive methodology for identifying urban–rural interfaces and analysing their features at the county level, taking spatial and temporal factors into account. Quantitative methods were applied in this research, depending on both the spatial scope of the case area and the characteristics of accessible land use remote sensing data. The grid unit segmentation of county-level subdistricts and townships provided a relatively accurate identification result of urban–rural interfaces considering the difference in URI development in each subdistrict or township. This methodology can be used in the identification of urban–rural interfaces in both other counties in China and other places worldwide if they have accessible land use data and similar administrative boundaries.

The research evidence contributed to a better understanding of the urban–rural interface and provided practical tools for identifying it, as well as aiding planning guided under URI aims to reach sustainable development. Admittedly, this study only tested one ordinary county that shows the trend of URI development in China, which limits its application. Thus, we plan to proceed with our research and to develop our approach to identifying and analysing the urban–rural interface and its URI features further and enrich empirical studies in the future.

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Data Availability Statement: The raw data supporting the conclusions of this article are unavailable due to privacy restrictions, and further inquiries can be directed to the corresponding author.

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