Article

Spatio-Temporal Pattern and Vulnerability Assessment of the Human Settlements along the Beibu Gulf Coast of Guangxi, China

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Abstract: Human settlement development is intricately linked to production and life, and development quality is a partial indicator of the local community’s social, economic, cultural, and environmental progress. Furthermore, the human settlements’ vulnerability affects their sustainable development potential. Due to the “One Belt, One Road” initiative and land and sea corridor development in southwestern China, the Beibu Gulf coast in Guangxi is the sole waterway bridgehead used by China for opening trade with ASEAN. By examining the region’s human settlements and its potential for sustainable development, we established a benchmark for the region’s seaward economy and human settlements to achieve synergistic progress, as well as to enhance regional integration. Based on the systematic evaluation of the quality of human settlements along the Beibu Gulf coast in Guangxi, the vulnerability assessment model of human settlement was adopted to analyse the vulnerability and spatial–temporal patterns of nearby human settlements in 2010–2019, while the multiple linear regression model was used to explore their influencing factors. Our findings indicate that the quality of human settlements in the study area has experienced three distinct stages. In the early stage (2010–2012), we noted an overall year-on-year increase in settlement quality. However, in the middle stage (2013–2016), Fangchenggang and Beihai experienced a decline followed by an increase, while Qinzhou demonstrated a steady growth in settlement quality. Qinzhou continued to experience growth, albeit at a slower rate, while Fangchenggang’s rate of increase surpassed that of Beihai. The human settlements’ high-quality centre shifted between Qinzhou and Fangchenggang in the late stage (2017–2019). Additionally, in recent years, the settlements’ high-quality centre has shifted towards the western part of the region. The habitat’s sensitivity has grown slowly, as has the responsiveness index, but the vulnerability index continues to decline, and it is characterised by a spatial differentiation ranging from low to high values in a centre–east–west direction. The region’s human settlement quality is primarily influenced by economic development. The region’s habitat vulnerability is primarily caused by responsibility, and the primary factors affecting responsibility are regional imbalances in social service development, the population’s welfare, and employment and infrastructure.

Keywords: human settlement quality; vulnerability; spatio-temporal pattern; Guangxi Beibu Gulf coast region

1. Introduction

Human settlements are geographical spaces in which people live and interact with the natural world. They are links between humans and nature, and are closely related to our survival, production, life, and development [1]. Creating human settlements based on
residents’ needs is an important factor required for promoting regional sustainable development [2]. In 2022, the General Office of the People’s Government of the Guangxi Zhuang Autonomous Region’s Fourteenth Five-Year Plan for the High-Quality Development of the Beibu Gulf Economic Zone’ proposed constructing ecologically sound settlements superior to those of the rest of the country. The Plan’s goal is to create a beautiful, habitable, and productive bay area. The region has undergone comprehensive development in recent years, resulting in a pleasant living environment with integrated and coordinated infrastructure, high-quality public services and joined-up social governance [3]. As human settlements are crucial to regional development, their past, present, and future development, as well as potential vulnerabilities that may prevent them from growing sustainably, should be taken into account when formulating development plans. This method will ensure high-quality regional economic integration. Human settlements’ vulnerability refers to their exposure to natural and anthropogenic factors that disrupt the environment associated with housing, livelihoods, and primary production activities in rural areas, rendering them susceptible to damage [4].

Past studies’ findings on human settlements have yielded fruitful results spanning various geographical scales, including the national or provincial level [5], river basins [6], urban agglomerations [7], rural areas [8] and mountainous regions [9]. Moreover, our prior studies have also focused on practical aspects such as the management of residential areas and urban planning to ensure the sustainable development of micro-regions; these aspects have included investigations into informal settlements [10–12], indigenous communities present in protected forest areas [13], and other spatial scales. Various techniques have been adopted to assess these spatial scales, including the entropy weight method [14], the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method [15], the comprehensive evaluation method [16], the fuzzy comprehensive evaluation method [8], a questionnaire survey [17], ArcGIS spatial analysis technology [18], and the Global Sensitivity Analysis method [13]. Some scholars have used Global Human Settlements Layer (GHSL) data to quantify and analyse greening changes in urban centres [19] and to test urban systematisation’s generality and robustness [20]. B.P. Salmon differentiated actual land and simulated land by using supervised change detection perceptron (MLP) via MODIS satellites [21]. These studies primarily centred on the assessment of habitat quality [6,9,16], spatial–temporal dynamics [14,18,21–24], suitability [24], spatial variation [10,25], and other related aspects. Additionally, they examined the habitat’s effects on specific demographic groups, such as women [26] and children [27], and explored habitat evolution in urban and rural areas across various historical periods [28]. In recent years, scholars have paid more attention to the vulnerability of villages [29–31] and cities in arid zones [32] and have evaluated the health of urban settlements [33]; however, fewer studies have focused on coastal areas and border areas.

Although there are plenty of data on human settlements, few studies have specifically explored the present condition of human settlements and their sustainable development capacity. While the literature about human settlement is extensive, there are only a limited number of studies that consider both the present quality of human settlements and their potential for development. The study area, encompassing Qinzhou, Beihai, and Fangchenggang in the Guangxi Beibu Gulf coastal area, is a crucial component of the Beibu Gulf Economic Zone. Additionally, it serves as a key urban area within the new western land and sea corridor and the China–Zhongnan Peninsula International Economic Cooperation Corridor. A previous study stated that “giving full play to the unique advantages of land and sea neighbourhood between Guangxi and ASEAN countries, accelerating the opening up and development of the Beibu Gulf Economic Zone and the Pearl River-West River Economic Belt, and constructing international corridors for the ASEAN region. Form the 21st Century Maritime Silk Road and the Silk Road Economic Belt organic convergence of the important gateway” [34]. Within this framework, China’s National Development and Reform Commission (NDRC) issued “The Master Plan for New Western Land
and Sea Corridors”, which has aimed to establish connections between international commerce and regional economic development in western China since its creation in 2019. The Pinglu Canal, which extends from Nanning in the north to Qinzhou in the south of the Guangxi Zhuang Autonomous Region, is the primary infrastructure project outlined in this blueprint. Its purpose is to facilitate the development of a new western land and sea corridor. The Beibu Gulf coastal region in Guangxi, comprising Qinzhou, Beihai, and Fangchenggang, is a significant component of the Beibu Gulf Economic Zone. It is a crucial urban area along the new western land–sea corridor and provides a vital gateway to the China–Central South Peninsula International Economic Cooperation Corridor. Consequently, its high-quality human settlements and potential for sustainable development have attracted increasing public interest. Assessments of human settlement quality are performed not only to learn about the present state of the settlement but also to appreciate their stability and potential vulnerabilities. This study will offer guidance and ideas for the policymakers responsible for making informed decisions about regional urban development. The studied region is also vital for the integration of China’s Beibu Gulf Economic Zone. Hence, we must conduct a more extensive investigation into the vulnerability and spatial–temporal patterns of the human settlement along Guangxi’s Beibu Gulf coast via a comprehensive assessment of habitat quality along the province’s coast. We aim to offer insights to inform regional integration and the synergistic growth of the coastal economy and local human settlements.

2. Data Sources and Methods

2.1. Study Area

Guangxi’s Beibu Gulf coastal area is situated within the geographical coordinates 21°24’ N–22°43’ N and 107°27’ E–109°52’ E. It is located in the south of Guangxi, surrounded by southwestern China and Southeast Asia. Notably, this area is the sole maritime exit point for trade originating from western China (Figure 1). The region is also a strategic point for China’s relations with ASEAN member states, facilitating economic activities such as the development of Guangxi’s port sector and encouraging international trade. The region includes the cities of Beihai, Fangchenggang, and Qinzhou. Qinzhou and Fangchenggang are the primary hub cities for the Southwest Land–Sea Corridor and the Southwest International Corridor [35], whereas Beihai is renowned for its popularity with international and domestic tourists.

The study region is surrounded by the Beibu Gulf to the south, the Shiwan mountains to the northwest, and a flat landscape to the southeast. The region is located south of the Tropic of Cancer, with mild winters and hot summers, along with sufficient levels of precipitation. The average annual temperature is 23.2 °C, and the average annual precipitation rate is 1877 mm. The district has abundant water resources, with a multi-year average of 34.86 billion m³. This fact is further supported by a runoff coefficient of 0.51, signifying high water availability. In the last five years, water quality in the Beibu Gulf coastal region has generally been ranked higher than Class III [36].

The district also possesses abundant forestry, mangroves, and tourism resources. In 2021, the region’s gross domestic product (GDP) was USD 396.814 billion, while its GDP per capita was USD 63,591.99. The region experienced significant economic development from 2010 to 2021, with Qinzhou City’s gross domestic product (GDP) being the largest.
2.2. Data Sources

The economic, population, tertiary GDP, employee and wage, urban fixed-asset investment in real estate, green area, average annual temperature, and average annual precipitation data used in this study were sourced from many authoritative publications, including the *Guangxi Statistics Yearbook* (2011–2020) (http://tjj.gxzf.gov.cn/tjsj/tjnj/ (accessed on 14 January 2024)), the *Beihai Yearbook* (2011–2020) (http://www.beihai.gov.cn/xxgkbm/bhsdfzbzwyhbgs/ztzl_26/szfl/zhnj/ (accessed on 14 January 2024)), the *Fangchenggang City National Economic and Social Development Statistics Bulletin* 2011–2020 (http://www.fcgs.gov.cn/zfxxgk/jcxxgk/tjxx/ (accessed on 14 January 2024)) and the *Qinzhou Statistical Yearbook* (2011–2020). Additionally, data were collected from the Guangxi and local governments’ official websites, as well as economic-development-related statistics bulletins. Linear interpolation was employed to find specific missing data.

2.3. Methods

2.3.1. Theoretical Framework and Index Selection

Human settlements are the areas most directly associated with human production and settlement; they are also the primary locations in which people interact with and modify the natural world [37]. Human settlements are shaped by interactions between various local human activities, including socioeconomic activities, and the natural environment, such as ecology and resources, within the human–land system. This system comprises population, housing, social, support, and environmental systems, with each system containing several parts. The elements have territorial characteristics, undergo temporal evolution, and have spatial variety. They can either positively or negatively impact human settlements. The former impact is defined by coping, while the latter impact is defined by sensitivity. The connection between the two is known as human settlement vulnerability.

Vulnerability, which was first employed to examine risks and hazards, is the extent to which a system, subsystem, or system component is prone to suffering damage due to exposure to danger, which might be in the form of a disturbance or a stressor [38]. Human settlement vulnerability is the extent to which the environment in which people live, work, and depend on is compromised by the severe natural of human-induced disturbances or pressures. Sensitivity is the vulnerability of a site to hazards or disturbances, while
coping capacity involves the various strategies used in human settlements to mitigate or eliminate any adverse effects on settlements resulting from heightened exposure and sensitivity [24].

Understanding the current state of development (e.g., via a liveability assessment [6,9,16] or quality assessment [24]) and the potential for future development (e.g., via a vulnerability assessment [29–32]) is essential for human settlements to achieve sustainable development. Concurrently, we took into account the fact that sustainability is a useful reference point for establishing healthy and productive socioeconomic environments, developing comfortable living spaces, and promoting ecologically sustainable progress [39]. We intentionally used the same indicators for assessing both the quality and vulnerability of human settlements to determine their current foundations and future development potential (Figure 2). In conjunction with prior research [30,38,40], five main systems, namely demographic, residential, social, support, and environmental systems, were utilised to assess human settlement quality.

Figure 2. Theoretical analysis framework.

Based on previous studies [22,30], we selected individual people-oriented, contextual indicators. Specifically, 27 indicators were chosen based on their relevance to people’s daily lives. The weights of these indicators (Table 1) were calculated using Equations (1)–(3).

Furthermore, the indicators were categorised into two groups based on their impacts on human settlements: sensitivity and responsibility indicators (Table 2). The sensitivity indicators included economic indicators such as GDP per capita and the proportion of tertiary sector GDP, selected to characterise the degree of disturbance to human settlements caused by economic activities, and social indicators such as the urban registered unemployment rate, the gender ratio, the population’s natural growth rate, the proportion of the population engaged in non-agricultural economic activities, the urban population density, and the urban road area per capita, selected to characterise the disturbance to human settlements caused by internal activities and structures. Additionally, the ecological environment was regarded as the disturbance to human settlements caused by the average annual temperature, the average annual precipitation, and the green park area per capita. Coping indicators assessed the adaptive capacity of the system to cope with multiple perturbations, including indicators about the life and use of savings deposits, urban residents’ annual disposable incomes, real estate investment in urban fixed assets, and employed workers’ average annual wages, as well as the share of public financial expenditure allocated to education, such as the number of books in public libraries per 100 people, beds per 1000 population, practising physicians per 1000 population and full-time teachers per 100 primary and secondary school students, and infrastructure, such as the centralised sewage treatment rate, the domestic rubbish harmlessness treatment rate, the water penetration rate, per capita daily water consumption, and the gas consumption penetration rate. Finally, the indicators were graded using the natural breakpoint method.

Table 1. Indicator systems and weights for human settlement quality.
<table>
<thead>
<tr>
<th>Target Layer</th>
<th>System Layer</th>
<th>Index Level</th>
<th>Stats (Positive Impact (+)/Negative Impact (-))</th>
<th>Index Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population System (0.1705)</td>
<td>X1: Gender ratio (%)</td>
<td>-</td>
<td>0.0852</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X2: Natural rate of population growth (%)</td>
<td>-</td>
<td>0.0123</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X3: Proportion of non-agricultural population (%)</td>
<td>+</td>
<td>0.0730</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X4: Urban population density (Person /km²)</td>
<td>-</td>
<td>0.0128</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X5: Urban fixed assets investment in real estate development (CNY 100 million)</td>
<td>+</td>
<td>0.0274</td>
<td></td>
</tr>
<tr>
<td>Dwelling System (0.0402)</td>
<td>X6: GDP per capita (CNY)</td>
<td>+</td>
<td>0.0395</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X7: Proportion of tertiary industry GDP (%)</td>
<td>+</td>
<td>0.0556</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X8: Average annual salary of working staff (CNY)</td>
<td>+</td>
<td>0.0534</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X9: Urban registered unemployment rate (%)</td>
<td>-</td>
<td>0.0309</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X10: Household savings deposits (CNY 100 million)</td>
<td>+</td>
<td>0.0393</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X11: Annual disposable income of urban residents (CNY)</td>
<td>+</td>
<td>0.0266</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X2: Education as a proportion of public expenditure (%)</td>
<td>+</td>
<td>0.0411</td>
<td></td>
</tr>
<tr>
<td>Social System (0.2864)</td>
<td>X13: Water penetration rate (%)</td>
<td>+</td>
<td>0.0111</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X14: Daily domestic water consumption per capita (L)</td>
<td>+</td>
<td>0.0404</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X15: Gas penetration rate (%)</td>
<td>+</td>
<td>0.0143</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X16: Per capita urban road area (m²)</td>
<td>+</td>
<td>0.0515</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X17: Public library holdings per 100 people</td>
<td>+</td>
<td>0.0445</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X18: Number of beds per 1000 people</td>
<td>+</td>
<td>0.0338</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X19: Number of medical practitioners per 1000 people</td>
<td>+</td>
<td>0.0249</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X20: Number of full-time teachers per 100 primary and secondary school students</td>
<td>+</td>
<td>0.0163</td>
<td></td>
</tr>
<tr>
<td>Support System (0.2368)</td>
<td>X21: Annual mean temperature (°C)</td>
<td>+</td>
<td>0.0375</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X22: Mean annual precipitation (mm)</td>
<td>+</td>
<td>0.0408</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X23: Per capita green park area (m²)</td>
<td>+</td>
<td>0.0971</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X24: Green land rate in built-up area (%)</td>
<td>+</td>
<td>0.0141</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X25: Green coverage rate of built-up area (%)</td>
<td>+</td>
<td>0.0147</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X26: Sewage treatment centralised treatment rate (%)</td>
<td>+</td>
<td>0.0531</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X27: Harmless treatment rate of household garbage (%)</td>
<td>+</td>
<td>0.0087</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Indicator system of human settlement vulnerability.

<table>
<thead>
<tr>
<th>Target Layer</th>
<th>Standardised Layer</th>
<th>Element Layer</th>
<th>Index Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Settlement Vulnerability</td>
<td>Sensitivity</td>
<td>Economic environment</td>
<td>GDP per capita, share of GDP in tertiary industry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social environment</td>
<td>Urban registered unemployment rate, gender ratio, natural population growth rate, share of non-agricultural population, urban population density, urban road area per capita</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ecological environment</td>
<td>Average annual temperature, average annual precipitation, park green space per capita</td>
</tr>
<tr>
<td></td>
<td>Coping</td>
<td>Residents’ livelihood and employment</td>
<td>Residents’ savings deposits, annual disposable income of urban residents, urban fixed-asset investment in real estate, annual average salaries of on-the-job workers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social public service</td>
<td>Education as a share of public expenditure, centralised sewage treatment rate, rate of harmless treatment of domestic garbage, Number of books in public libraries per 100 inhabitants, number of beds per 1000 people, number of practicing physicians per 1000 people, number of full-time teachers per 100 primary and secondary students</td>
</tr>
</tbody>
</table>

2.3.2. Human Settlement Quality Assessment (HQA)

Using the entropy weight method allowed for identifying and emphasising localised variations, and successfully addressing the limitations associated with artificial enhancement and mitigating redundancy observed in intricate large-scale systems’ index characteristics [40]. The entropy weight technique to determine the weights for human settlement evaluation has been used by researchers such as Li Xueming [41] and Li Shuai [42] for many years.

The indicators were standardised using a normalisation method, followed by using the entropy weight method to assess the quality of the human environment. The procedural sequence comprises the following steps:

\[
P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}
\]

\[
e_j = -k \sum_{i=1}^{m} (P_{ij} \ln P_{ij}), \quad k = \frac{1}{\ln m}
\]

\[
w_j = \frac{(1-e_j)}{\sum_{j=1}^{m} (1-e_j)}
\]

where \(m\) is the product of the length of the evaluation period (measured in years) and the number of cities. Additionally, \(n\) is the number of indicators, \(i\) is the \(i\)th city, and \(j\) is the \(j\)th indicator (\(i = 1,2,3,\ldots; j = 1,2,3,\ldots\)). Moreover, \(e_j\) is the entropy value associated with the \(j\)th indicator, while \(w_j\) is the weight assigned to that indicator.

The human settlement quality was determined using Equations (4) and (5) based on the entropy-weighting-method-determined indicator weight values.

\[
S_i = \sum_{j=1}^{n} w_j \times P_{ij}
\]

\[
Y_i = \sum_{i=1}^{n} S_i
\]

In the formula, the quality index for each system layer is \(S_i\), and the human settlement quality index for city-\(i\) is \(Y_i\).
2.3.3. Human Settlement Vulnerability Assessment

Based on [30], the vulnerability of human settlements was assessed by examining the association between sensitivity and coping capacity. The former measure positively correlates with vulnerability, while the latter measure negatively correlates with vulnerability [43]. The results were assessed as follows:

\[ V_n = \frac{W_j}{C_i} \]  
(6)

\[ W_j = \frac{w_j}{\sum_{j=1}^{11} w_j} \]  
(7)

\[ C_i = \frac{c_i}{\sum_{i=1}^{14} c_i} \]  
(8)

In the formula, the quality index for each system layer is \( S_i \), and the human settlement quality index for city-\( i \) is \( Y_i \).

2.3.4. Human Settlement Vulnerability Assessment

Based on [30], the vulnerability of human settlements was assessed by examining the association between sensitivity and coping capacity. The former measure positively correlates with vulnerability, while the latter measure negatively correlates with vulnerability [43]. The results were assessed as follows:

\[ V_n = \frac{W_j}{C_i} \]  
(9)

\[ W_j = \frac{w_j}{\sum_{j=1}^{11} w_j} \]  
(10)

\[ C_i = \frac{c_i}{\sum_{i=1}^{14} c_i} \]  
(11)

where \( V_n \) is human settlement vulnerability, \( W_j \) is the sensitivity index, \( C_i \) is the coping index, \( w_j \) is the weight of the jth indicator \((j = 1,2,3,\ldots,11)\), and \( c_i \) is the weight of ith indicator \((i = 1,2,3,\ldots,14)\).

2.3.5. Natural Breakpoint Spatial Analysis Method

We selected human settlement quality data from 2010, 2013, 2016, and 2019 for the Beibu Gulf coast in Guangxi as samples for spatial analysis. Moreover, the natural breakpoint grading method in ArcGIS [23] was employed to examine the spatial differentiation in human settlement quality at the municipal level.
2.3.6. Multiple Linear Regression Analysis

We analysed the effects of sensitivity and adaptability on human settlement vulnerability using multiple linear regression based on the calculated indices. The resulting regression model is presented below:

\[ V_i = 3.226W_i - 3.759C_i + 1.195 \]  \( (R^2 = 0.969, F = 111.704, p = 0.00001) \)

where \( V_i, W_i, \) and \( C_i \) denote the indices for human settlement vulnerability, sensitivity, and adaptability, respectively.

3. Results

3.1. The Spatial–Temporal Variability in Human Settlement Quality in the Coastal Areas of the Beibu Gulf

3.1.1. Temporal Variation

During 2010–2019, the quality of human settlements along the Beibu Gulf coast in Guangxi generally grew, although a small dip was observed in 2013 (Figure 2). Between 2010 and 2016, human settlements exhibited the greatest quality in Beihai, the largest growth rate in Fangchenggang, and a steady growth rate in Qinzhou. After 2016, Fangchenggang saw the most substantial growth and had the highest settlement quality score in the region. In contrast, Beihai exhibited a higher growth rate, while Qinzhou grew at a comparatively slower pace.

The qualitative performances of human settlements in Beihai and Fangchenggang declined in 2013. However, in 2017, Fangchenggang surpassed Beihai to become the leading city in the region in terms of growth, while Beihai and Qinzhou exhibited sluggish growth. The years 2013 and 2017 were significant milestones for the growth of regional human settlement quality. Accordingly, the study period was divided into three developmental periods: phase 1 (2010–2012), phase 2 (2013–2017), and phase 3 (2018–2019) (Figure 3).

Figure 3. Quality index of the human settlement environment in the Beibu Gulf coastal area in Guangxi.


During this period, there was a concurrent, synchronised advancement in the quality of human settlements located in the Beibu Gulf coastal regions in Guangxi. Qinzhou’s score was below the mean value, whereas Fangchenggang experienced a subsequent increase and surpassed Qinzhou, securing second position. The growth rates of Qinzhou
and Beihai exhibited a degree of similarity, whereas Fangchenggang experienced the largest development increase rate.

Phase II (2013–2016): Beihai and Fangchenggang experienced an initial decrease followed by a subsequent increase in growth, whereas Qinzhou achieved stable growth.

In 2013, there was a decline in human settlement quality in both Beihai and Fangchenggang. Subsequently, Beihai experienced consistent growth and maintained its position as the top-ranking region in terms of human settlement quality. Conversely, Fangchenggang, which initially ranked at the bottom in 2013, experienced gradual development in 2014 and achieved substantial growth in 2015–2016.

Phase III (2017–2019): Fangchenggang developed at a faster rate than Beihai, whereas Qinzhou’s growth rate decreased.

In this period, human settlement quality in the region exhibited distinct characteristics. Notably, Fangchenggang experienced significant development, surpassing Beihai in 2017 to become the most developed district. Conversely, Beihai’s growth rate declined, aligning with the average growth rate. Similarly, Qinzhou experienced slower growth, falling below the regional average to the lowest position in the region.

3.1.2. Spatial Divergence

The years 2010, 2013, 2016, and 2019, indicative of the improvement in the coastal human settlement quality in Guangxi’s Beibu Gulf, were chosen as the analytical samples to examine the spatial differentiation of human settlements based on the characteristics of spatial analysis. The spatial disparity in human settlement quality along the Beibu Gulf coast in Guangxi is shown in Figure 4 and was defined as follows:

(1) Human settlement quality varied between the east, west, and centre of the study area in 2010, with Beihai having the highest quality, followed by Fangchenggang, with Qinzhou having the lowest quality (Figure 4a).

(2) Human settlement quality varied between Beihai, Qinzhou, and Fangchenggang in 2013 and 2016. Beihai still had the highest human settlement quality score, while Fangchenggang lagged behind (Figures 4b,c). Beihai was strongest for several residential system indicators, including the average annual wages of on-the-job workers, the unemployment rate of urban workers, the gender ratio, and the share of non-agricultural workers in the population. Furthermore, it led Qinzhou and Fangchenggang in terms of per capita daily water consumption and the number of beds per 1000 people in the support system.

(3) In 2019, the Fangchenggang–Beihai–Qinzhou region was characterised by a westward shift in the distribution of high-quality human settlements (Figure 4d).
In 2017–2019, Fangchenggang notably departed from the prevailing trend and emerged as a prominent regional hub for human settlement quality, surpassing Beihai. This transformation may be attributed to the implementation of social systems. Among the aforementioned factors, Fangchenggang had the highest per capita GDP, with Beihai and Qinzhou ranking second and last, respectively. In terms of per capita gas consumption, Qinzhou and Beihai held the lead before 2016, but Fangchenggang caught up thereafter. Regarding per capita urban road area, Qinzhou and Fangchenggang differ, with Beihai ranking lowest. Finally, in terms of per capita green space in parks, Fangchenggang demonstrated significant growth and secured the top position in the region.

### 3.2. Human Settlement Vulnerability Evolution

#### 3.2.1. Evolution of the Human Settlement Vulnerability Process

Except for a decline in 2013, the sensitivity of human settlements ranged from 0.406 to 0.656, indicating that the influence of internal and external factors on the disruption of human settlements increased gradually. The gradual increase in responsibility from 0.257 to 0.622 suggests that the region’s human settlements have become more capable of managing disruptions brought about by both internal and external factors along the Beibu Gulf coast in Guangxi from 2010 to 2019. With the aforementioned limitations in sensitivity and coping, the numerical values representing the vulnerability of the region’s human settlements persistently declined. Prior to 2013, the vulnerability of the human settlements
was relatively high (1.579–1.663), highlighting their fragile nature. However, it subsequently dropped to a low level (1.231–1.054) for an extended period and has since continued to decline, indicating the region’s human settlement vulnerability (Figure 5).

Figure 5. The evolution and regional variations in human settlement vulnerability in the Beibu Gulf.

3.2.2. Spatial Evolution of Human Settlement Vulnerability

(1) Human Settlement Sensitivity

The sensitivity of human settlements notably varied in Fangchenggang, while it was more robust and consistent in Beihai and comparatively low in Qinzhou (Figure 6), demonstrating that internal and external factors had greater impacts on human settlement volatility in Fangchenggang; the factors limiting human settlements in Beihai had been present for a long time and had a relatively stable influence, while the human settlements in Qinzhou were stable and only marginally impacted by internal and external factors.

Figure 6. Sensitivity index of the human settlement environment in the Beibu Gulf coastal area in Guangxi.

The sensitivity of human settlements in Beihai is primarily determined by economic factors, as the area is heavily reliant on tourism. Prior to 2017, Fangchenggang faced significant limitations due to economic and environmental issues, resulting in high human settlement sensitivity. However, after 2017, the improvement in ecological and environmental conditions led to a significant reduction in its human settlements’ sensitivity. Fangchenggang’s environmental system outperformed the other two cities between 2017 and
2019, gaining a substantial lead. Notably, in 2017, Fangchenggang experienced significant progress compared to the previous year. This progress was evident in the expansion of green space within parks by 8.33 square meters, a 13.7% increase in the rate of green space expansion in built-up areas, and a 15.12% increase in the rate of green coverage in built-up areas. Qinzhou’s growth reduced its reliance on external variables to improve its economy, society, and environment, decreasing the sensitivity of human settlements and increasing resilience.

(2) Human Settlement coping capacity

The mean value of the human settlement coping index throughout the Beibu Gulf coast region in Guangxi grew from 0.086 to 0.207 (Figure 7), a clear improvement in its coping capacity. Before 2013, the highest values for human settlement coping capacity were distributed in Beihai. Subsequently, between 2014 and 2018, the high-value region shifted to Qinzhou. Fangchenggang, on the other hand, consistently occupied the position of the low-value region for a long period. However, after 2018, Beihai surpassed Qinzhou to reclaim its status as the high-value region. Notably, in 2019, Fangchenggang and Qinzhou exhibited comparable levels of coping capacity.

![Figure 7. Coping index of human settlements in the Beibu Gulf coastal area in Guangxi.](image)

The coping indices of the region’s human settlements were influenced by several elements. Of these characteristics, social utilities had the most significant impact, followed by population employment and, lastly, infrastructure. In 2015 and 2018, Qinzhou exhibited the highest values for public utilities. However, in subsequent years, Beihai became the high-value district in this field. Conversely, Fangchenggang experienced delay but shown rapid growth thereafter. For residential life and employment, Qinzhou consistently held the lead position and exhibited higher growth, while Beihai and Fangchenggang demonstrated comparable performance. For infrastructure, Beihai had the highest development, followed by Qinzhou, whereas Fangchenggang initially grew at a slower pace but later experienced rapid growth. Infrastructure development in Qinzhou and Beihai has experienced slower growth in recent years.

(3) Human Settlement Vulnerability

In general, the human settlement vulnerability index along the Beibu Gulf coast region in Guangxi saw its average value decline from 0.526 to 0.352 (Figure 8). The lowest-value areas were located in Qinzhou, while the highest-value areas were located in Fangchenggang and the central region of Beihai. The city of Fangchenggang has experienced strong variations in its human settlements’ vulnerability.
The vulnerability index of human settlements in the Beibu Gulf coastal area in Guangxi can be described by the following multiple linear regression model:

\[ V_i = 3.226W_i - 3.759C_i + 1.195 \]  \( (R^2 = 0.969, F = 111.704, p = 0.00001) \)

where variables \( V_i, W_i, \) and \( C_i \) denote the indices for the vulnerability, sensitivity, and coping capacity of human settlements, respectively. A unitary increase in the sensitivity index led to a 3.226 increase in the regional human settlement vulnerability index, whereas a unitary increase in the coping index led to a 3.759 decrease in the vulnerability index. Based on the available data, we observed that the correlation between coping capacity and vulnerability was stronger than that for sensitivity. This finding implies that coping capacity has a greater influence on vulnerability than sensitivity. Consequently, to enhance the coping capacity of the Beibu Gulf coastal human settlements system, it is vital to reinforce the key role of coping capacity.

4. Discussion and Recommendations

4.1. Discussion

The Beibu Gulf coastal region in Guangxi, as the sole coastal region in China characterised by an undeveloped economy, has historically achieved slower human settlement development than other coastal locations. In recent years, this district has gained prominence due to the implementation of “the Belt and Road Initiative” and the establishment of land and sea corridors in southwestern China. As a result, it is now a crucial waterway bridgehead for China’s engagement with the Association of Southeast Asian Nations (ASEAN). The district has distinctive economic attributes and is a hub for special economic activities. To provide a reference point for the development of “One Belt, One Road” gateway cities and regional integration, we must examine not only the temporal process and spatial pattern of regional human settlement quality but also the spatial and temporal distribution of vulnerability, defining its sustainable development potential.

4.1.1. Analysis of Spatial and Temporal Variability in Human Settlement Quality

The central core of human settlements along the coastal sections of the Beibu Gulf in Guangxi is slowly expanding in Qinzhou City. The urban core alternates between Beihai City and Fangchenggang City, with a recent shift towards the west. Human settlements are limited by the industrial framework, infrastructure, and the level of synchronisation between economic progress and the ecological surroundings. The substantial variations in human population concentrations among the three cities can be attributed to their distinct economic structures. The greatest degree of variation is observed in the quality of
human settlements in Fangchenggang City. As of 2020, industrial-dominated secondary industry will continue to be dominant in Fangchenggang. The human environment will be constrained by the industrial structure of the secondary industry, resulting in greater variations and changes in the water and air quality environments. The tertiary industry in Qinzhou constituted over 50% of the total, emerging as the most important economic sector, while the tertiary industry in Beihai City does not exceed 50%, but its contribution to economic growth surpasses that of the primary and secondary industries [44]. Thus, variations in human settlements in the two cities were not significant.

The installation of high-speed railways has had a substantial and beneficial impact on both the economic growth of the Beibu Gulf Economic Zone [45] and the establishment of human settlements. For the integration of Qin-Bei-Fang, Qinzhou and Beihai are important cities that are connected by high-speed railways. However, Fangchenggang City does not have a high-speed railway. The quality of medical facilities is also a significant factor influencing the living environment. Qinzhou has six third-rate A hospitals, while Fangchenggang City and Beihai City only have two each. From 2011 to 2018, Qinzhou City demonstrated greater coordination between its economic development and ecological and environmental systems than Beihai City and Fangchenggang City. Additionally, Qinzhou City exhibited greater coordination between its ecological and environmental systems than Beihai City and Fangchenggang. As a result, human settlements in Qinzhou are achieving steady growth.

4.1.2. Analysis of Spatial and Temporal Variability in Regional Human Settlement Vulnerability

We observed an overall decline in regional human settlement vulnerability that tended to be robust. However, both the elements affecting human settlement vulnerability, namely sensitivity and responsiveness, increased slowly, though responsiveness increased at a faster rate than sensitivity. The relationship between the sensitivity and vulnerability indices of regional human settlements is such that a 1-unit increase in sensitivity leads to a 3.226-unit increase in vulnerability. On the other hand, a 1-unit increase in the adaptability index results in a 3.759-unit decrease in vulnerability. Thus, the correlation between adaptability and vulnerability is stronger than that for sensitivity. Therefore, adaptability has a greater impact on vulnerability than sensitivity. This association aligns with previous research [30], although the degree of correlation differs between diverse rural and urban locations.

The variation in human settlement vulnerability in Fangchenggang City is restricted by its human settlements’ sensitivity and coping ability. Between 2010 and 2013, Fangchenggang City’s human settlements were characterised by various factors, making them more vulnerable than the two other cities during the same period. Specifically, the economic environment factor was highest in 2010, the social environment factor was highest in 2011, and both the economic and social environment factors were highest in 2012. Additionally, in 2012, the ecological environment factor had the highest vulnerability. On the other hand, the coping factors in Fangchenggang City, such as the employment of residents, social public services, and infrastructure, were lower than those in the other two cities for the same period. As a result, Fangchenggang City had a stronger vulnerability.

4.2. Recommendations

In conclusion, the integrated development of human settlements in Qin-Bei-Fenghuang should be promoted synergistically within the framework of the “Belt and Road” initiative, regional integration, and the construction of western land and sea corridors to enhance the capacity for sustainable human settlement development by reducing human settlements’ sensitivity and improving their capacity, as follows.

(1) Optimising industrial structures and developing a green economy to reduce the disturbance of the human settlements by economic factors.
Relying on new development opportunities, adhering to staggered development, and using synergy to promote the development of the green economy are useful strategies. The three cities implemented a staggered development approach: Beihai has been transformed into an exemplar city of maritime-based economic progress, Qinzhou City has been strategically positioned to grow the western land–sea corridor, and Fangchenggang has developed into a modern port industrial city to establish a maritime economic corridor to enhance overall efficiency and development. Simultaneously, efforts have been made to innovate rail–sea intermodal transportation, actively promote the growth of the tertiary sector, and optimise industrial structures. Regarding the current industrial structure of Fangchenggang, which is primarily focused on the secondary industry, it is advisable to prioritise the development of high-end, energy-efficient products with high-value-added characteristics. This approach will minimise economic activities’ negative effects on local human settlements.

(2) Balancing environmental preservation and maritime economic expansion is important to lessen human settlements’ ecological sensitivity.

Based on the regional resources and the environment’s capacity, we recommend adopting an integrated approach to land–sea management. This approach will improve the quality and stability of land and sea ecosystems. Additionally, efforts should be made to enhance collaborative measures for preventing and controlling pollution in the air, water, and soil. Establishing a comprehensive blue–green ecological barrier is crucial. Furthermore, promoting industrial ecology and eco-industrialisation, along with the vigorous development of the eco-economy, should be prioritised.

(3) Comprehensive advocacy, integrating public and infrastructure services in Qin–Bei–Fang to bolster the social environment’s coping capacity.

Vulnerability is more notably influenced by the district’s human settlements’ coping capacity than sensitivity. Thus, to improve the resilience of human settlements, it is necessary to focus on improving transport connectivity, fostering cooperation and linkages and optimizing investment in social and public services, as well as enhancing living and employment services. Implementing strategies to enhance the responsiveness of human settlements in a differentiated fashion, taking into consideration the integrated construction plans and current make-up of each municipality, is also essential. Qinzhou should accelerate the construction of the China–ASEAN Information Port, 5G Huawei Digital Town and other information technology infrastructure, and also improve the capacity of social public services and leverage the advantages of investment in social public services such as medical care, education, etc.; Fangchenggang City should prioritise the construction of clean and low-carbon energy infrastructure, such as wind power, nuclear power, and photovoltaic power, and construct medical care, transportation, and other infrastructure, and also improve the quality of social public services; and Beihai City should vigorously develop its tertiary industry based on coastal tourism and pension services to optimise its industrial structure, while at the same time strengthening human settlements and enabling political remediation.

4.3. Limits and Potential

While analysing their spatial and temporal distribution patterns, we evaluated the human settlement environments’ quality and vulnerability using the entropy weight method and the Human Settlements Vulnerability Assessment Model. Nevertheless, this study’s methodology, which is comparatively objective, prioritised the “quantity” over the “quality” of indicators when constructing the system. For instance, to illustrate or characterise the medical conditions underpinning the system, only two indicators were employed: the ratio of practicing physicians to beds per 1000 people and the number of beds per 1000 people. Quality indicators, such as the classification of a hospital as third-class, were not taken into account, impeding our ability to comprehensively depict the regional human environment’s evolution. Moreover, corresponding changes in statistical
data acquisition and the calibre of the statistics led to errors or missing data, affecting the results’ precision, and thus the measurements’ results in some areas may be biased. Furthermore, our examination of the spatial differentiation in human settlement quality did not differentiate between urban and rural areas, resulting in a relatively uniform performance. However, if this information is to be utilised for regional integration, it must be meticulously subdivided to enhance its practical referential value.

Thus, subsequent research into human settlements in economic zones (urban agglomerations) with small and medium-sized cities should employ an urban–rural perspective [46], concentrating on both urban areas and rural regions. Secondly, in addition to evaluating human settlements, their influencing factors [47] and driving forces must be further explored [48]. Thirdly, for normalizing urban–rural population migration and to account for China’s aging population, the appeal of the urban environment in small and medium-sized cities should be considered [49]. Finally, combining indicator evaluation with an intelligent human settlement system [50] and big data [51] prevents the homogenisation of research methods, and combining geographic information technology such as remote sensing and GIS to extract and visualise the data improves its accuracy.

5. Conclusions

We investigated the spatial–temporal distribution pattern of human settlement quality and vulnerability in the cities along the Beibu Gulf coast in Guangxi. This study specifically focused on the impact of the “One Belt, One Road” initiative and regional integration in the Beibu Gulf in Guangxi, as follows:

(1) Regarding the quality of human settlements, there have been varying increases in Beihai and Fangchenggang over time, while Qinzhou has shown consistent improvement. In terms of spatial differentiation, the area with the highest quality varies between Beihai and Fangchenggang, but growth remains more stable in Qinzhou.

(2) Regarding the vulnerability of human settlements, the overall regional human settlement vulnerability index has been decreasing annually, indicating a decrease in vulnerability and increased resilience. Additionally, spatial differentiation has been observed, with Qinzhou being the most stable, Fangchenggang showing the highest volatility and Beihai falling in the middle. Furthermore, enhancing the ability to cope is the primary indicator of resilience against local human settlement vulnerability.

(3) Human settlements’ responsiveness levels have a higher impact on their vulnerability than their sensitivity. Therefore, upgrading the coping capacity is the main measure for the sustainable development of regional human settlements.

Author Contributions: Conceptualisation, H.C.; methodology, H.C.; software, J.Y.; validation, H.C. and J.W.; formal analysis, H.C.; resources, H.C.; data curation, H.C.; writing—original draft preparation, H.C.; writing—review and editing, J.Y.; visualisation, H.C.; supervision, J.W.; funding acquisition, H.C. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the Basic Ability Enhancement Project for Young and Middle-aged Teachers in Guangxi Universities, grant number 2018KY0588.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study have been made openly available by the Guangxi Zhuang Autonomous Region Bureau of Statistics (GBS) via this link: http://tjj.gxzf.gov.cn/tjsj/ (accessed on 15 December 2023).

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; the collection, analyses, or interpretation of data; the writing of the manuscript; or the decision to publish the results.
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