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Geo-Environment Suitability Evaluation for Urban Construction in Rongcheng District of Xiong'an New Area, China

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Abstract: Xiong'an New Area is a national event and a project planned for a millennium of China. Its high-quality construction is of great significance to easing the noncapital functions of Beijing and the coordinated development of the Beijing-Tianjin-Hebei region. As an emerging city, the development and construction of Xiong'an New Area is bound to be restricted by geological and resource conditions. Therefore, geo-environment suitability analysis is the necessary basis of urban development and construction. Geo-environment suitability analysis of urban construction is a complex process that requires various geological indicator information, and relevant expertise to analyze their relevance. This paper focuses on the analytic hierarchy process (AHP) for the assessment of geo-environment suitability for urban construction in Rongcheng district, which is a Start Construction Region in Xiong'an New Area. Multiple factors, including the characteristic value of bearing capacity of foundation soil, land subsidence rate, geological faults, ground fissures, potential liquefied sands, quality of groundwater chemistry, quality of soil chemistry, chemical corrosion of concrete by groundwater, chemical corrosion of steel by groundwater, and enrichment of deep groundwater and geothermal resource, were used for the suitability assessments. From the evaluation achievements, the high and very high suitable lands for urban construction, with an acreage percentage of 89.2%, were located in most parts of the study area. Meanwhile, for another 9.1% of the land, the impacts of geological faults, land subsidence, and potential liquefied sands needed to be noted preferentially for urban construction.

Keywords: suitability; urban construction; geo-environment; Rongcheng; Xiong'an new area

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1. Introduction

With the acceleration of urban construction, the increasing demand for construction lands has become the key factor restricting planning development. At the same time, inappropriate utilization of the geo-environment and irrational development of geological resources were becoming increasingly significant, directly restricting urban construction [1–3]. Therefore, how to maximize the optimal allocation of urban construction and geological environment, and explore the evaluation method to effectively solve the practical dilemma, is particularly important [4–6].

Multicriteria analysis was a common tool used for complicated decision-making questions [7–11]. A pivotal step of geo-environment suitability analysis of urban construction was used to confirm the weight of each criterion or indicator [12]. For the application of weight confirming methods, scholars had not formed a unified scientific understanding. Generally speaking, various means widely used at present could be roughly divided into the following five categories: geographic information system (GIS) spatial data superposition analysis method [13], artificial neural network method [14], analytic hierarchy process (AHP) [15], grey comprehensive evaluation method [16], and fuzzy comprehensive evaluation method [17]. For examples, based on the GIS platform, Mario Mejia-Navarro et al. [18,19] established a geological disaster risk assessment system for Glenwood Springs, Colorado, evaluated the risk of geological disasters, and provided a basis for regional urban planning and construction. Mozafar et al. [20] took a waste treatment plant in Kurdistan Province of Iran as the research object, and systematically analyzed its location suitability by AHP. Liu et al. [21] evaluated the suitability of composite foundation for construction land through a fuzzy synthetic evaluation model in a city. Wang et al. [22] evaluated the suitability of urban construction land using multifactor grading weighted index in the alluvial plain of the Yellow River. Hu et al. [23] carried out land use zoning based on the principle of ecological priority and geo-environmental suitability using the AHP method in Weifang North Plain. Das et al. [24] finished the landslide susceptibility zonation mapping in and around the Kalimpong region by applying AHP method integrated with fifteen factors such as slope, lithology, elevation, thrust, and faults. Wang et al. [25] carried out the geological and ecological bearing capacity evaluation from three aspects of geological, ecological, and social attributes based on the GIS platform and evaluation index system, and determined the factor weights by using the AHP method.

In spite of the existence of various methods to identify weights of the selected criteria [26–29], the analytic hierarchy process (AHP) integrated GIS overlay analysis was regarded as one of the excellent multicriteria decision-making means [30–32]. Before that, Saaty [33] introduced AHP and how to use it, and provided many study examples.

Consequently, the objectives of this paper were (1) to establish a comprehensive evaluation frame for evaluating the geo-environmental suitability for urban construction land based on geo-environmental factors in Rongcheng district of Xiong'an New Area; (2) to identify the relationship and its contribution of geological indicators, including the characteristic value of the bearing capacity of foundation soil, land subsidence rate, geological faults, ground fissures, potential liquefied sands, quality of groundwater chemistry, quality of soil chemistry, chemical corrosion of concrete by groundwater, chemical corrosion of steel by groundwater, and enrichment of deep groundwater and geothermal resource, to urban construction land with the AHP method; and (3) to provide some significant information to improve decision-making for urban land planning according to the assessment results.

2. Study Area

The Rongcheng district, with an acreage of 314 km^2, is located northwest of Xiong'an New Area in North China [34], which is part of the alluvial plain of the Taihang Mountains [35] (Figure 1). The surface ground elevation displays a characteristic of decreasing from the northwest to the southeast, and varies from 5 m to 26 m with a gradient lower than 2‰ [36]. The research district belongs to the warm temperate zone with a semiarid climate, and the average annual precipitation is 482.7 mm. Meanwhile, it is close to the North China Plain's largest freshwater wetland, named Baiyangdian Lake [37]. Quaternary sediments are widely distributed in the surface ground, where rich geothermal and groundwater resources occur underground [38].

The recharging sources of shallow Quaternary groundwater are from precipitation, river and lake infiltration, farmland irrigation and underground lateral runoff, while the main discharging modes are artificial abstraction and underground flow. Furthermore, the deep groundwater in Quaternary and bedrock stratum has a certain hydraulic connection with shallow groundwater. Moreover, there are different geological problems, such as land subsidence, geological faults, ground fissures, potential liquefied sands, and so on.

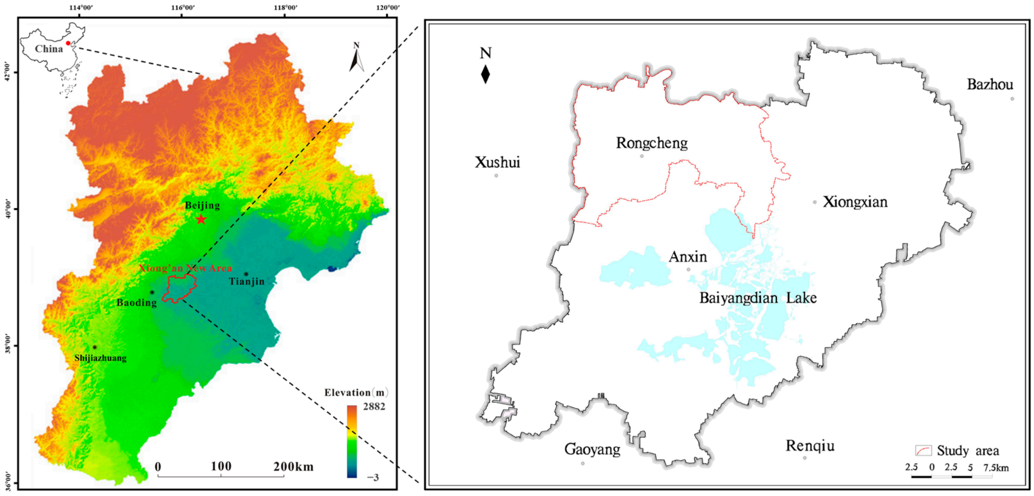

Figure 1. The study area of the Rongcheng district in Xiong'an New Area, China.

3. Methods

3.1. Field Survey and Data Collection

Geological factors play a significant role in urban construction. One such example is the bearing capacity of foundation soils, which determines the natural load-bearing capacity for buildings. Other factors such as land subsidence, geological faults, ground fissures, potential liquefaction of sands, and chemical corrosion of concrete and steel by groundwater can increase the risk of building deformation. On the other hand, the enrichment of deep groundwater and geothermal resources can provide residents in buildings with drinking water and heating. According to the data of the standard penetration test, shear test, and geotechnical test from engineering geological boreholes, the characteristic value of the bearing capacity of a single soil layer was determined. Characteristic values of the bearing capacity of foundation soils at different depths were calculated, including 0–5 m (meter), 5–10 m, 10–15 m, 15–30 m, and 30–50 m, through the data integration of single soil layers by the weighted average method. At the same time, the land subsidence rate was measured with the PS-InSAR remote sensing method, while ground fissures were investigated by high-density resistivity prospecting to depth, manual measurement to length, and compass measurement to direction. Enrichment of deep groundwater and geothermal resource distribution was analyzed by using the collected data. Meanwhile, geological faults were measured by multigeophysical exploration with controlled source audio-frequency magnetotelluric and resistivity tomography methods. Potential liquefied sands were identified on the basis of the sand liquefaction index calculated from the standard penetration test. Based on groundwater chemical and soil chemical experiments, the quality of groundwater chemistry, quality of soil chemistry, chemical corrosion of concrete by groundwater and chemical corrosion of steel by groundwater were evaluated.

3.2. Comprehensive Evaluation Frame

In view of the characteristics of the geological environment in Rongcheng district, based on suggestions from local geologists, the indicators closely related to geo-environment suitability for urban construction were chosen, and a comprehensive evaluation index system was established. As exhibited in Figure 2, two criteria, consisting of geological conditions and resource conditions, were taken into consideration for the suitability evaluation, including four subcriteria, i.e., engineering geological status, environmental geological status, hydrogeological status, and resource guarantee status. A total of 15 indicators were involved in the system. The engineering geological status included five indicators, such as the bearing capacity of the foundation soils at depths of 0~5 m, 5~10 m, 10~15 m, 15~30 m, and 30~50 m. The environmental geological status included six indicators, such as land subsidence rate, geological faults, ground fissures, potential liquefied sands, quality of groundwater chemistry, and quality of soil chemistry. The hydrogeological status included two indicators, such as chemical corrosion of concrete by groundwater and chemical corrosion of steel by groundwater. The resource guarantee status included two indicators, such as enrichment of deep groundwater and geothermal resource/geothermal gradient. Furthermore, the analytic hierarchy process (AHP), which was a decision-making method combining qualitative and quantitative analysis, was employed to identify the relations among various indicators or criteria, and to obtain final evaluation results. Obviously, the grading and weights of the abovementioned 15 indicators should be defined before evaluation, where the weights displayed the importance of different indicators. Furthermore, the comprehensive suitability index was calculated. Afterwards, final grading evaluation of geo-environment suitability for urban construction was achieved with ArcGIS 10.8 software.

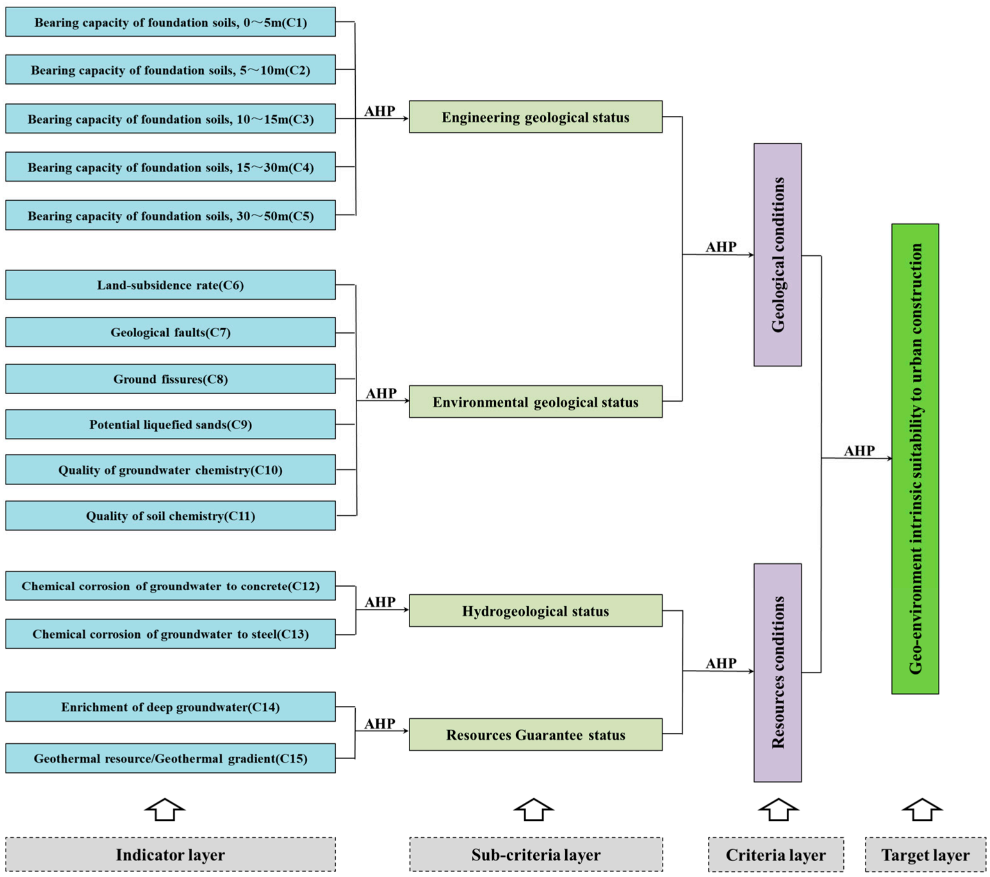

Figure 2. Comprehensive evaluation frame of geo-environment suitability.

3.3. Evaluation Method

By constructing the hierarchical structure model and its importance judgment matrix, the weight value of each evaluation indicator was obtained with the modified scaling method, and then the comprehensive index was calculated.

(1) Establish an importance matrix, A.

$$A = \begin{bmatrix} C_{11} & \cdots & C_{1n} \\ \vdots & \ddots & \vdots \\ C_{n1} & \cdots & C_{nn} \end{bmatrix}$$

where n is the number of indicators, and the relative importance is checked from Table 1.

Table 1. Scale of relative importance between different indicators.

Scale	Meaning of the Scale
Scale = 1	Equal importance, two indicators contribute equally to the object
Scale = 1/9	Extreme unimportance, the evidence favoring one indicator over another is of the lowest possible order of affirmation
1/9 < Scale < 1, 1 < Scale < 9	More and more importance, judgment more and more strongly favors one indicator over another
Scale = 9	Extreme importance, the evidence favoring one indicator over another is of the highest possible order of affirmation

Annotation: the relative importance of the indicators being compared is closer together when the scale is equal to 1 [33].

(2) Identify the weights

Based on the importance judgment matrix, the maximum eigenvalue and eigenvector were obtained [39], and then the eigenvector was normalized to calculate the weight value of different indicators [40,41]. Moreover, a consistency test of the judgment matrix should be carried out.

The calculation equation of the product of each row element (M_i) is:

$$M_i = \Pi_{j=1}^{n} C_{ij}$$

The calculation equation of normalized eigenvector (W_i) is:

$$W_i = \frac{\sqrt[n]{M_i}}{\sum_{i=1}^{n} \sqrt[n]{M_i}}$$

The calculation equation of eigenvalue (λ_i) is:

$$\lambda_i = \sum_{j=1}^{n} C_{ij} W_j$$

The calculation equation of maximum eigenvalue (λ_{max}) is:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{\lambda_i}{nW_i}$$

The calculation equation of consistency ratio (CR) is:

$$CR = \frac{(\lambda_{max} - n)/(n-1)}{RI} \tag{1}$$

where RI is the mean random consistency index, which can be checked from Table 2. Meanwhile, CR needs to be less than 0.1.

Table 2. Mean random consistency index (RI) values of 11–15 order judgment matrix.

Order-Number	11	12	13	14	15
RI value	1.51	1.48	1.56	1.57	1.59

(3) Calculate the suitability comprehensive index, *SI*.

$$SI = \sum_{i=1}^{n} u_i \cdot w_i, i = 1, 2, \ldots, n \tag{2}$$

where u_i is the score value of each indicator, w_i is the weight of each indicator, n is total number of indicators.

4. Results and Discussion

4.1. Results and Discussion of Geo-Environment Indicator Distribution

4.1.1. Bearing Capacity of Foundation Soils

The bearing capacity of foundation soils in different depths showed dissimilar characteristic values, varying from 105 kpa to 280 kpa, with an increasing trend from lower to deeper layers in Rongcheng County (Figure 3).

The bearing capacity of foundation soils for suitability for urban construction between 0–5 m, making 115 kpa and 125 kpa as the grading standards, could be divided into three grades, corresponding to very high (125–130 kpa), high (115–125 kpa), and moderate (105–115 kpa) (Table 3). The bearing capacity of foundation soils between 5–10 m, making 120 kpa, 130 kpa, and 140 kpa as the grading standards, could be divided into four grades, corresponding to very high (140–180 kpa), high (130–140 kpa), moderate (120–130 kpa), and low (110–120 kpa) (Table 3). The bearing capacity of foundation soils between 10–15 m, making 150 kpa, 170 kpa, and 190 kpa as the grading standards, could be divided into four grades, corresponding to very high (190–250 kpa), high (170–190 kpa), moderate (150–170 kpa), and low (110–150 kpa) (Table 3). The bearing capacity of foundation soils between 15–30 m, making 165 kpa, 175 kpa, and 185 kpa as the grading standards, could be divided into four grades, corresponding to very high (185–240 kpa), high (175–185 kpa), moderate (165–175 kpa), and low (155–165 kpa) (Table 3). The bearing capacity of foundation soils between 30–50 m, making 200 kpa, 210 kpa, and 220 kpa as the grading standards, could be divided into four grades, corresponding to very high (220–280 kpa), high (210–220 kpa), moderate (200–210 kpa), and low (190–200 kpa) (Table 3).

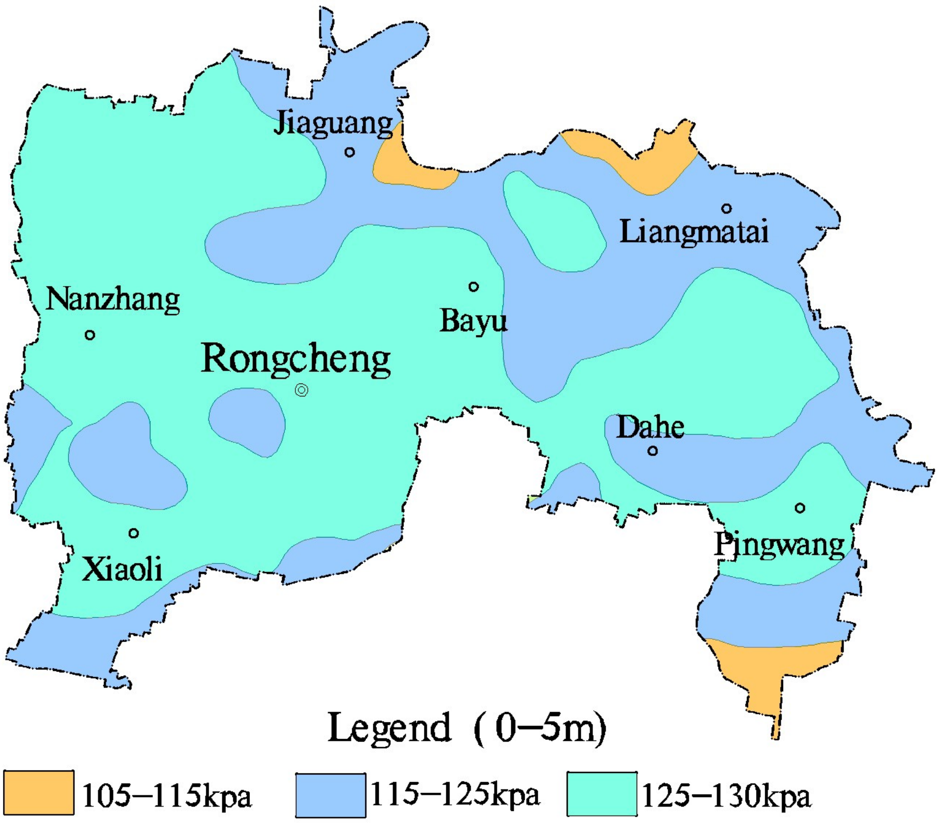

Figure 3. *Cont.*

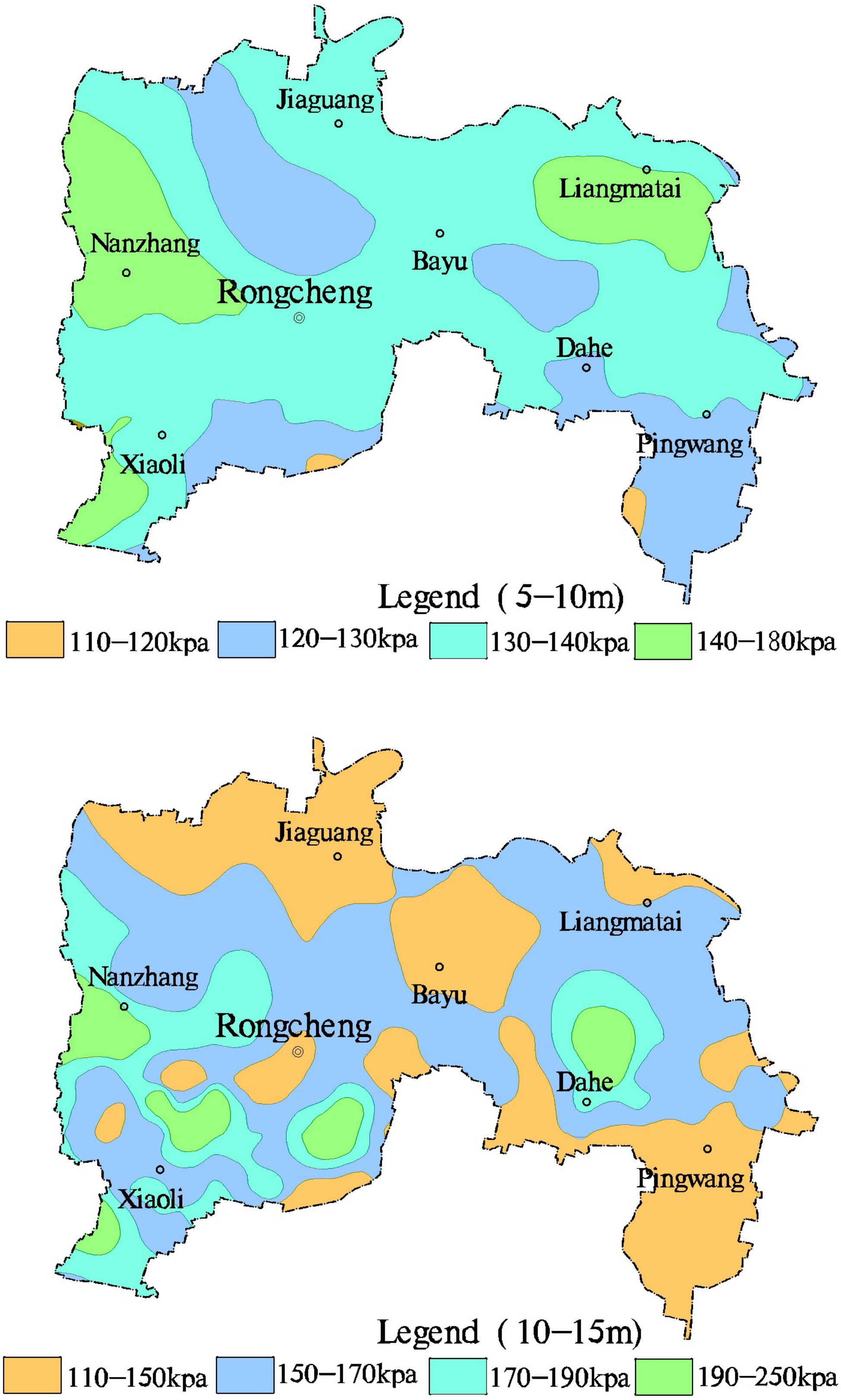

Figure 3. *Cont.*

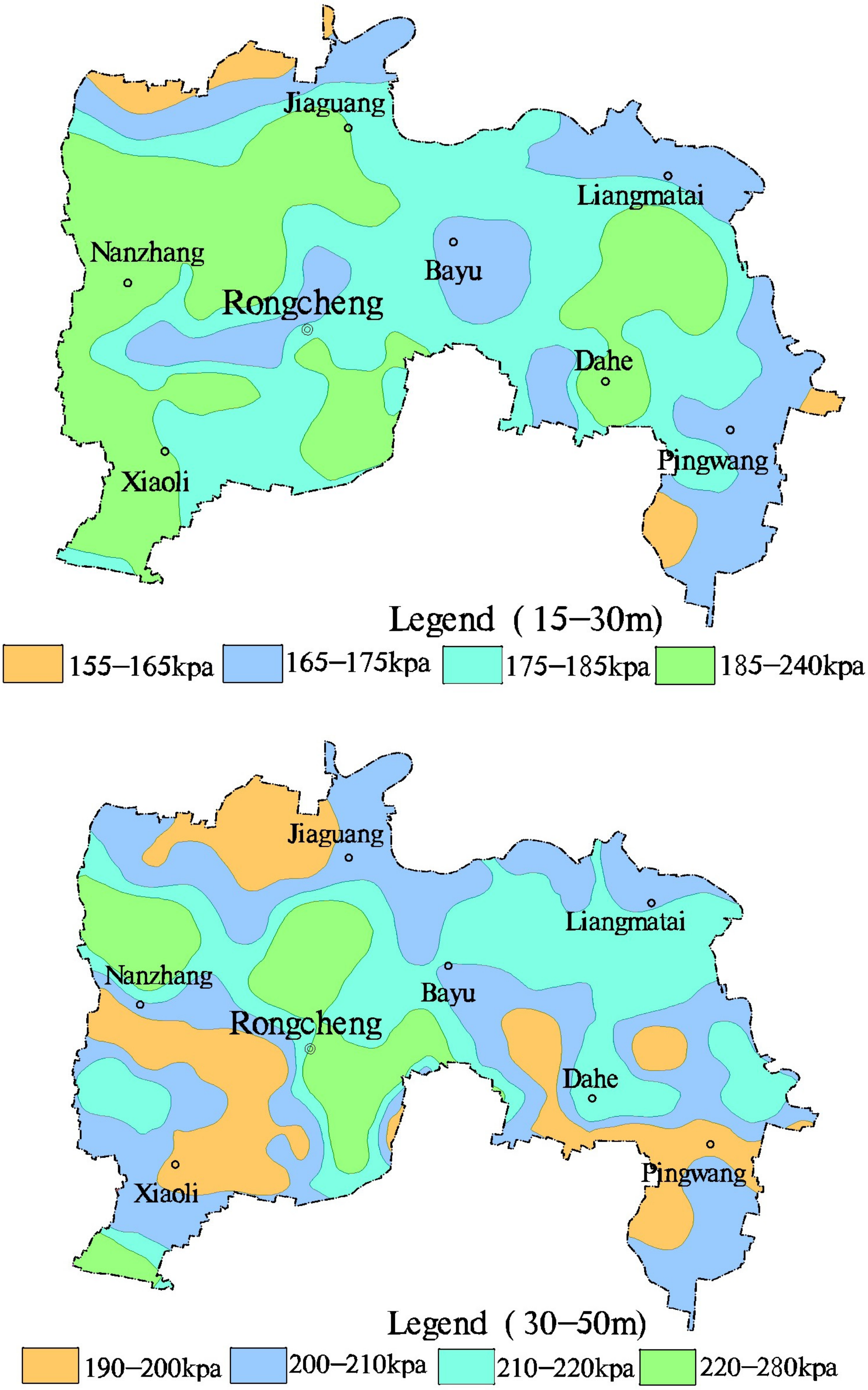

Figure 3. Spatial distributions of characteristic values of bearing capacity of foundation soils at different depths.

Table 3. The evaluation criteria for geo-environment suitability for urban construction.

Criteria Layer	Subcriteria Layer	Indicator Layer		Grading Criteria of Suitability: Very High	High	Moderate	Low
Geological conditions	Engineering geological status	Bearing capacity of foundation soils	0~5 m (C1)	125~130 kpa	115~125 kpa	105~115 kpa	/
			5~10 m (C2)	140~180 kpa	130~140 kpa	120~130 kpa	110~120 kpa
			10~15 m (C3)	190~250 kpa	170~190 kpa	150~170 kpa	110~150 kpa
			15~30 m (C4)	185~240 kpa	175~185 kpa	165~175 kpa	155~165 kpa
			30~50 m (C5)	220~280 kpa	210~220 kpa	200~210 kpa	190~200 kpa
	Environmental geological status	Land subsidence rate (C6)		<0 mm/a	0~10 mm/a	10~30 mm/a	>30 mm/a
		Geological faults (C7)		None	Away	Near	Existing
		Ground fissures (C8)		None	Away	Near	Existing
		Potential liquefied sands (C9)		None		Slight	Moderate
		Quality of groundwater chemistry (C10)		Can be used as a source of drinking water		Can be used as drinking water after proper treatment	Not suitable to be a source of drinking water
		Quality of soil chemistry (C11)		Very clean	Clean	Mildly polluted	Serious polluted
Resource conditions	Hydrogeological status	Chemical corrosion of concrete by groundwater (C12)		Slight			
		Chemical corrosion of steel by groundwater (C13)		Slight		A little	
	Resource Guarantee status	Enrichment of deep groundwater (C14)		>5000 m^3/d	3000–5000 m^3/d	1000–3000 m^3/d	<1000 m^3/d
		Geothermal resource/Geothermal gradient (C15)		≥6 °C/100 m	≥5 °C/100 m	≥3 °C/100 m	<3 °C/100 m

4.1.2. Land Subsidence

According to the statistics data with PS-InSAR measurements from January to December in 2016, the land subsidence rate in most areas was between 30 mm/a and 10 mm/a, except the urban district and the northern area of Rongcheng County, Jiaguang, Bayu, and the western area of Dahe, with a rate of 30–40 mm/a, and the southern area of Pingwang, with a rate of less than 10 mm/a (Figure 4). The land subsidence rate for suitability for urban construction, making 0 mm/a, 10mm/a, and 30 mm/a as grading standards [42], could be divided into four grades, corresponding to very high (<0 mm/a), high (0–10 mm/a), moderate (10–30 mm/a), and low (>30 mm/a) (Table 3).

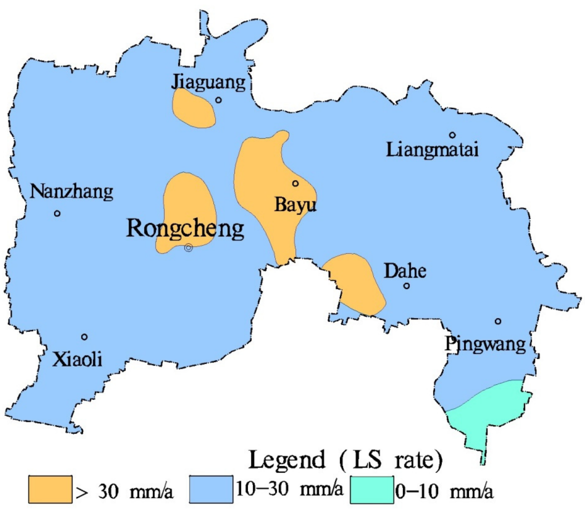

Figure 4. Zonal distributions of land subsidence rate.

4.1.3. Geological Faults

On the basis of geophysical exploration data, there were four geological faults, mainly distributed in Rongcheng, named Rongdong (RD) fault, Shunyi-Gaobeidian (SG) fault, Xushui-Anxin (XA) fault, and Qianxi-Jixian-Baoding-Shijiazhuang (QJBS) fault, which are inactive faults (Figure 5). It is worth noting that although the geological faults are currently inactive, they would lose stability with the reinjection of groundwater during deep geothermal resource exploitation in Rongcheng district of Xiong'an New Area [43]. Therefore, geological faults were also selected as an evaluation indicator for suitability evaluation. Based on the influence degree of distance to faults [44], geological faults for suitability for urban construction could be divided into four grades, corresponding to very high (none), high (away), moderate (near), and low (existing) (Table 3).

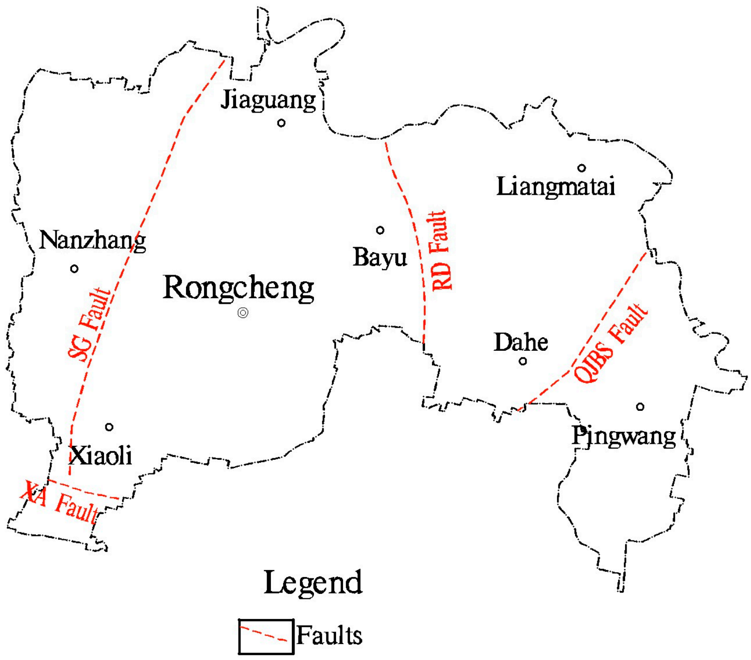

Figure 5. Distributions of geological faults.

4.1.4. Ground Fissures

There were about 20 discovered ground fissures, with a general distribution along the NW–SE direction. Most of the fissures appeared in forests and farmland, without endangering or damaging lives or property. Moreover, these fissures appeared in short lengths, most of which were less than 1000 m. The buried depth of the surface cracks were shallow, with depths of less than 20 m (Figure 6). Depending on the influence degree of distance to fissures [45], ground fissures for suitability for urban construction could be divided into four grades, corresponding to very high (none), high (away), moderate (near), and low (existing) (Table 3).

4.1.5. Potential Liquefied Sands

There were silty and fine sand layers distributed within 20 m of depth underground, which might result in liquefaction of seismic sands. According to the relevant provisions of the Code for Seismic Design of Buildings, the seismic intensity in this area was 7 degrees, the basic seismic acceleration was 0.10 g, and belonged to the second seismic group. According to the requirements of the general planning of this region, this evaluation of sand liquefaction was made according to the seismic intensity of 7.5 degrees, the designed basic seismic acceleration of 0.15 g, and 2 m of groundwater level, within a depth of 20 m.

Depending on the risk of liquefaction, potential liquefied sands for suitability for urban construction could be divided into four grades, corresponding to very high and high (none), moderate (slight liquefied), and low (moderate liquefied) (Figure 6, Table 3).

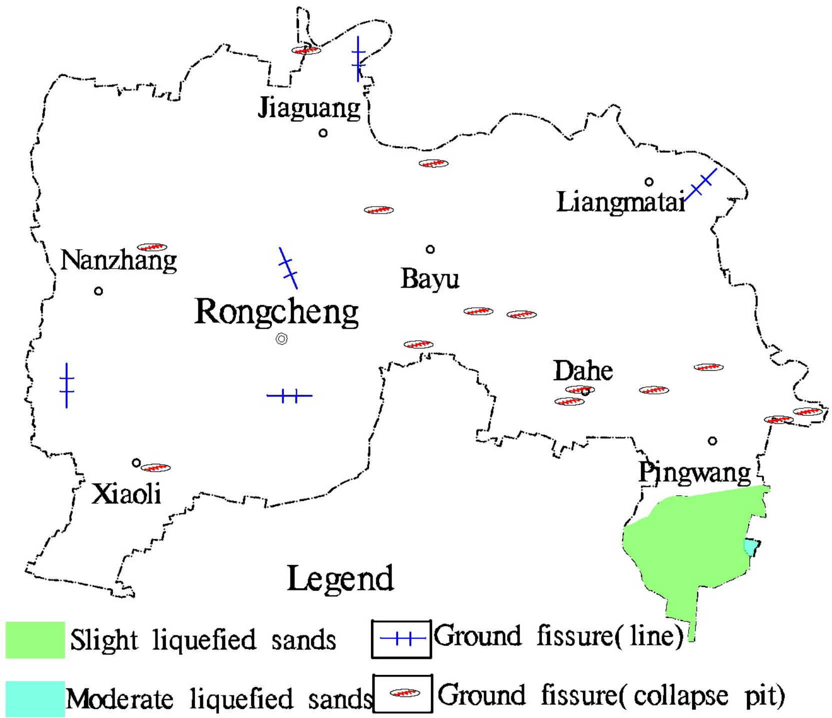

Figure 6. Distributions of ground fissures and potential liquefied sands.

4.1.6. Qualities of Groundwater and Soil Chemistry

Based on the qualities of groundwater and soil chemistry in 2017, groundwater in most areas could be used as a source of drinking water directly or after proper treatment, except the area of northeast Liangmatai (Figure 7). In addition, soils in most districts were clean and very clean, except areas such as Dongniubei, Xujiayuan, Wufangdong, Dongli, and Zanzhuang.

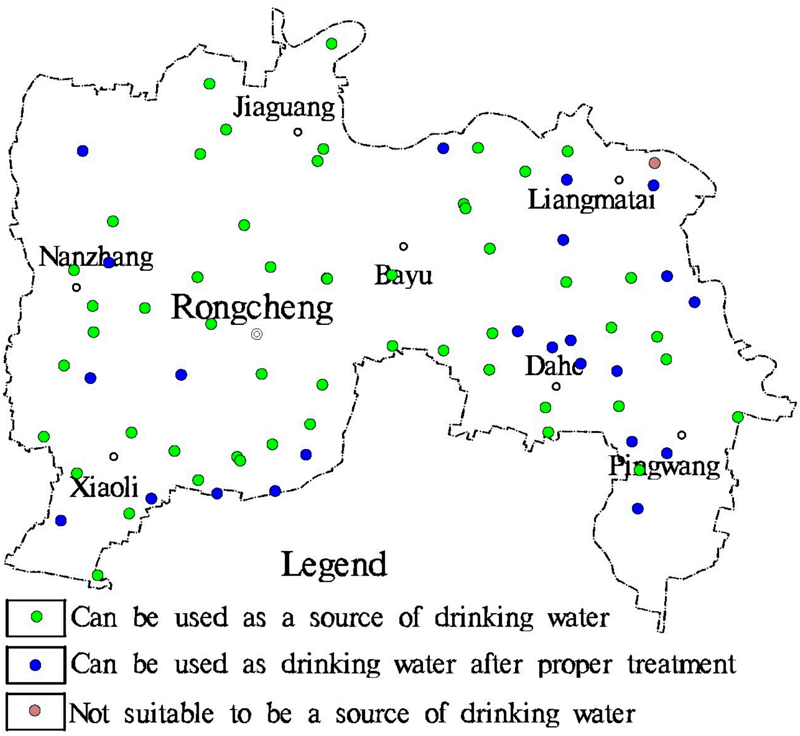

Figure 7. Quality distribution of groundwater chemistry samples.

Depending on the difference of categories, the quality of groundwater chemistry for suitability for urban construction could be divided into four grades, corresponding to very high, high, moderate, and low (Table 3). Meanwhile, the quality of soil chemistry could be divided into four grades, corresponding to very high (very clean), high (clean), moderate (mildly polluted), and low (serious polluted) [46] (Table 3).

4.1.7. Chemical Corrosion of Concrete and Steel by Groundwater

The chemical corrosion of concrete by groundwater in Rongcheng all belonged to a slight grade, and the chemical corrosion of steel by groundwater in most areas was in the slight category, except northeastern Xiaoli and southern Pingwang (Figure 8).

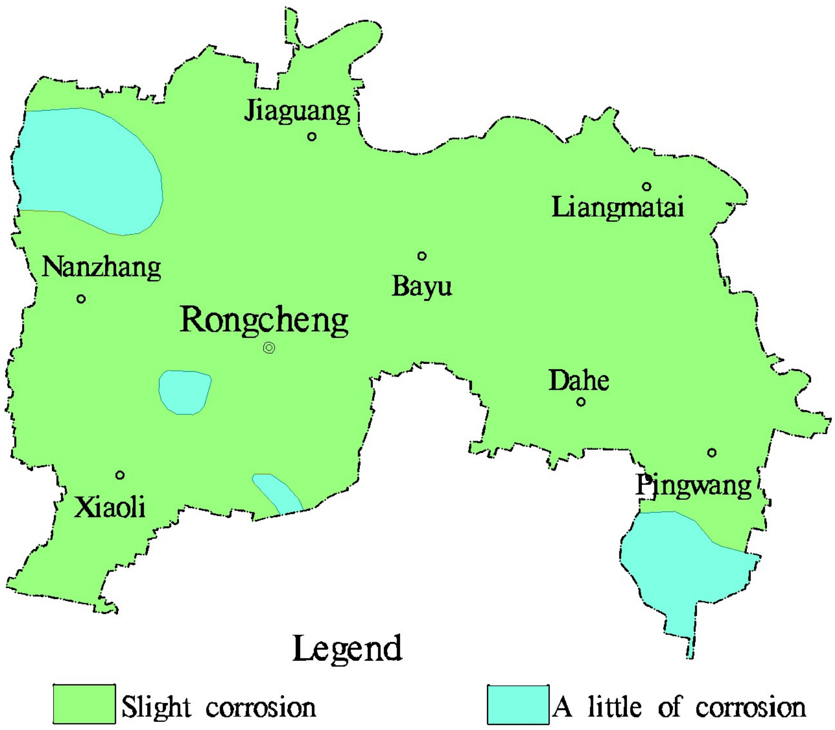

Figure 8. Zonal distributions of chemical corrosion of steel by groundwater.

According to the difference of categories, the chemical corrosion of concrete by groundwater was suitable for urban construction (Table 1). Simultaneously, chemical corrosion of steel by groundwater could be divided into four grades, corresponding to very high and high (slight corrosion), moderate, and low (a little corrosion) (Table 3).

4.1.8. Enrichment of Deep Groundwater and Geothermal Resource

Based on the available data, groundwater and geothermal resources were relatively abundant in Rongcheng, and showed certain zonation characteristics (Figures 9 and 10).

The enrichment of deep groundwater for suitability for urban construction, making 1000 m^3/d, 3000 m^3/d, and 5000 m^3/d as grading standards [47], could be divided into four grades, corresponding to very high (>5000 m^3/d), high (3000–5000 m^3/d), moderate (1000–3000 m^3/d), and low (<1000 m^3/d) (Figure 9) (Table 3). Meanwhile, geothermal resources, according to the difference of geothermal gradient, could be divided into four grades, corresponding to very high ($\geq$6 °C/100 m), high ($\geq$5 °C/100 m), moderate ($\geq$3 °C/100 m), and low (<3 °C/100 m) (Figure 10) (Table 3).

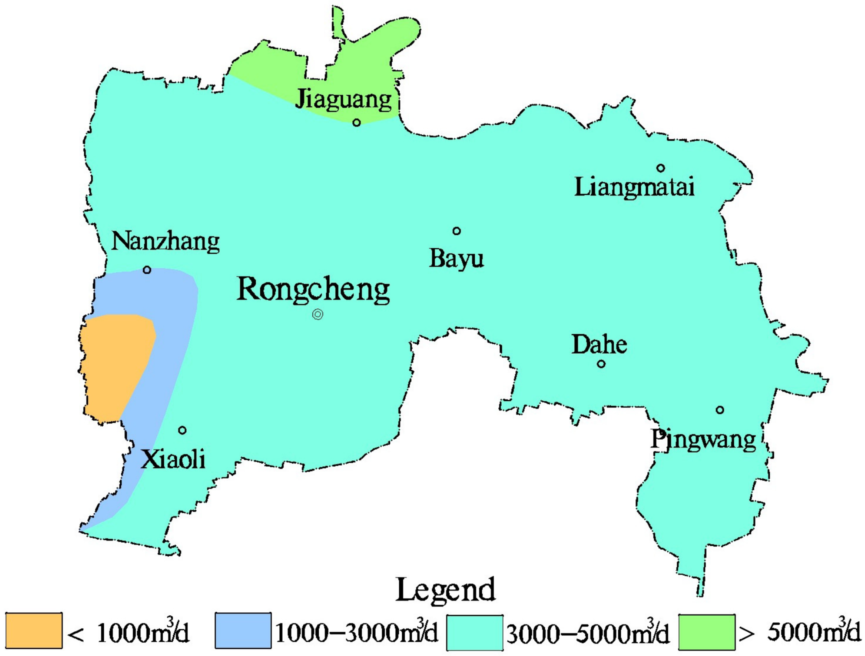

Figure 9. Zonal distributions of enrichment of deep groundwater.

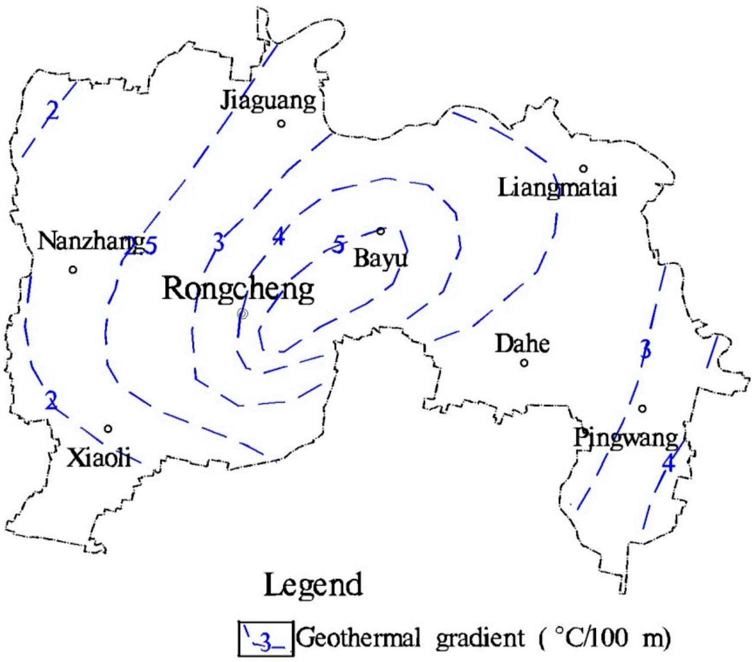

Figure 10. Distributions of geothermal gradient.

4.2. Results and Discussion of Geo-Environment Suitability for Urban Construction

According to the judgment matrix and weights of geo-environment indicators (Tables 3 and 4), the comprehensive evaluation indexes were calculated. The evaluation results showed that geo-environment suitability for urban construction in most areas of Rongcheng were in the high and very high grades, of which the very high zone covered an area of about 98 km^2, and the high zone was nearly 182 km^2 (Figure 11). The acreage of the moderate grade was approximately 5.5 km^2, and the low grade was close to 28.5 km^2. Meanwhile, the main affecting factors were dissimilar (Table 5); the impacts of geological faults, land subsidence rate, and potential liquefied sands should be noted preferentially for urban construction.

Table 4. Index judgment matrix and weights of geo-environment indicators.

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**Weights**
C1	1	1	1	5/4	5/4	5/8	5/9	5/4	5/7	5/3	5/1	5/4	5/4	6/5	5/4	0.07
C2		1	1	5/4	5/4	5/8	5/9	5/4	5/7	5/3	5/1	5/4	5/4	6/5	5/4	0.07
C3			1	5/4	5/4	5/8	5/9	5/4	5/7	5/3	5/1	5/4	5/4	6/5	5/4	0.07
C4				1	1	1/2	4/9	6/5	2/3	3/2	4/1	6/5	6/5	7/6	6/5	0.06
C5					1	1/2	4/9	6/5	2/3	3/2	4/1	6/5	6/5	7/6	6/5	0.06
C6						1	7/9	2/1	8/7	4/1	5/1	8/3	8/3	8/3	4/1	0.12
C7							1	9/4	9/7	9/4	6/1	3/1	8/3	9/4	3/1	0.13
C8								1	4/7	2/1	2/1	4/5	4/5	5/2	5/3	0.06
C9									1	7/3	7/3	7/4	7/4	2/1	7/3	0.09
C10										1	8/7	1/2	1/2	7/9	7/8	0.04
C11											1	1/4	1/4	1/3	1/2	0.02
C12												1	1	5/4	5/3	0.06
C13													1	5/4	5/3	0.06
C14														1	4/3	0.05
C15															1	0.04

Annotation: the consistency ratio is 0.02.

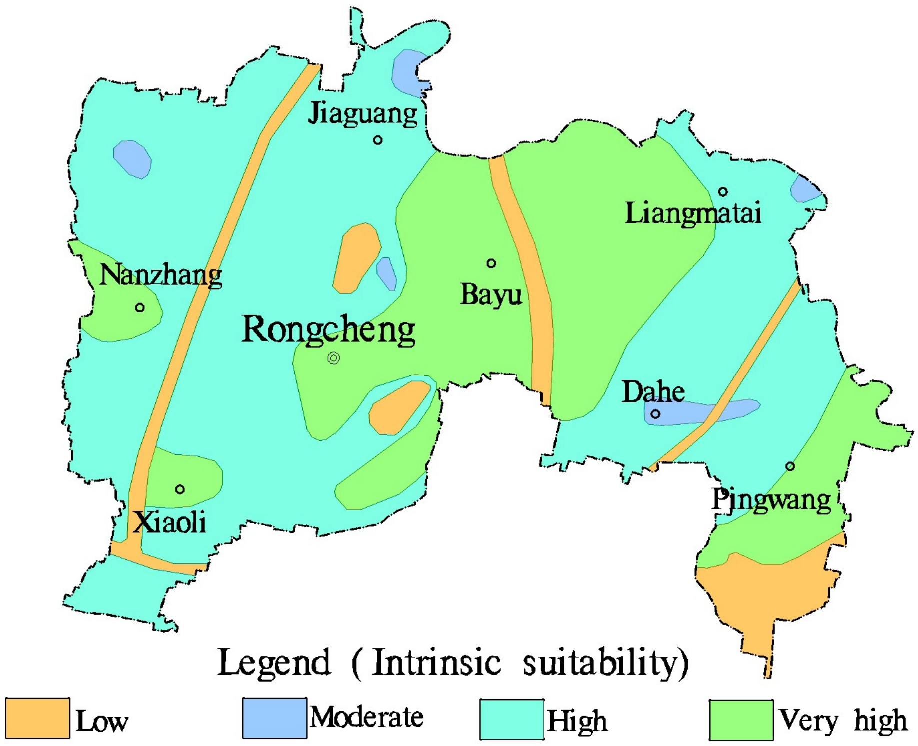

Figure 11. Zonal distributions of geo-environment suitability for urban construction.

Generally, it is a gradual process for the planning and construction of Rongcheng as a Start Construction Region in Xiong'an New Area; however, the geo-environment suitability evaluation for urban construction should be regarded as preliminary work. This paper selected as many geological indicators as possible to analyze the geo-environment suitability for urban construction. Nevertheless, it focused on geo-environment characteristics, and other socioeconomic features were not included. In future studies, population quantity and industrial structure should be considered, in order to improve decision-making for precise urban land planning.

Table 5. The evaluation results for geo-environment suitability for urban construction in Rongcheng.

Grade	Acreage (sq.km.)	Percentage	Main Affecting Factors
Very high	98	31.2%	Geothermal resource
			Enrichment of deep groundwater
			Characteristic value of bearing capacity of foundation soil
High	182	58%	Characteristic value of bearing capacity of foundation soil
			Quality of groundwater chemistry
Moderate	5.5	1.7%	Ground fissures
			Chemical corrosion of concrete by groundwater
			Chemical corrosion of steel by groundwater
			Quality of soil chemistry
Low	28.5	9.1%	Geological faults
			Land subsidence rate
			Potential liquefied sands

5. Conclusions

(1) In order to evaluate the geo-environment suitability for urban construction in Rongcheng district of Xiong'an New Area, the analytic hierarchy process (AHP) integrated GIS overlay analysis was used, based on the construction of a comprehensive evaluation frame. Moreover, two criteria, consisting of geological conditions and resource conditions, were taken into consideration for suitability evaluation, including four subcriteria, i.e., engineering geological status, environmental geological status, hydrogeological status, and resource guarantee status, which involved 15 indicators. Regrettably, the evaluation did not include the compressibility indicator of foundation soils due to a lack of data. When evaluating the suitability of the geo-environment for urban construction in other areas with the AHP method, more indicators of foundation soils could be taken into consideration. Furthermore, the analytic hierarchy process has certain advantages compared to other methods, such as the artificial neural network method and grey comprehensive evaluation method. It not only provides a quantitative mathematical calculation, but also incorporates the comparative judgment of geological experts regarding the importance of different geological indicators.

(2) The evaluation results showed that the geo-environment suitability for urban construction in most areas was in high and very high grades, of which, the very high zone covered an area of about 98 km^2, and the high zone was nearly 182 km^2. The acreage of the moderate grade was approximately 5.5 km^2, and the low grade was close to 28.5 km^2. The most suitable areas for urban construction, with an acreage percentage of 31.2%, were mainly located in the central parts of the study area. In the meantime, the least suitable areas, with an acreage percentage of 9.1%, were situated in the southeast corner and three linear belts.

(3) It is crucial to emphasize that faults, land subsidence rate, and potential liquefied sands are the primary factors that influence decision-making regarding future construction activities. When urban construction takes place in areas close to faults, buildings should maintain a certain distance from them, and these areas should be designated as green spaces. In regions experiencing a land subsidence rate of more than 30 mm/a, it is advisable to reduce groundwater extraction and lower the height of planned buildings. Additionally, engineering protection measures should be implemented in areas with potential liquefied sands. By addressing these issues, the study area can reduce infrastructure construction costs, and minimize the risk of geological disasters.

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