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Study on the Matching Degree between Land Resources Carrying Capacity and Industrial Development in Main Cities of Xinjiang, China

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Abstract: The contradiction between industrial development (ID) and land resource carrying capacity (LRCC) is increasingly intensified with the rapid advancement of urbanization globally. This typical phenomenon exists particularly in these developing countries or regions. This study investigated the matching degree (MD) between ID and LRCC by using a coupling coordination degree model (CCDM) with referring to the main cities of Xinjiang, China. The data used in this study was collected from 16 sample cities in Xinjiang for the period of 2009–2018. The research findings reveal that (1) MD average value between 16 sample cities has been gaining steady growth; (2) although MD value in all sample cities has been increasing, there still exists a big room for improvement towards a well matching state; (3) the differences in MD values among all sample cities are very small; (4) the MD performance in the northern cities in Xinjiang is better than that in southern Xinjiang. This is mainly because of the radiation effect of Urumqi in northern Xinjiang. It is therefore suggested developing such a radiation city in southern Xinjiang in order to improve MD performance in southern Xinjiang. These research findings can provide policymakers in Xinjiang and other backward cities globally with valuable references in understanding the status of MD between ID and LRCC in the local cities, thus tailor-made policy instruments can be designated for the mission of sustainable development.

Keywords: sustainable development; urbanization; land resource carrying capacity (LRCC); industry development (ID); matching degree (MD); case study

1. Introduction

Land is regarded as the most basic factor of production for supporting industrial development (ID) [1–3]. The supporting effect of land use on ID is manifested in both “quantity support” and “structural support”, that is, the amount of land (area) is the cornerstone of ID, and the change of land use structure will lead to the corresponding adjustment of industrial structure [4]. However, with the rapid advancement of urbanization, the contradiction between ID and LRCC is increasingly intensified. For example, in the process of urbanization, the rapid development of industries and the explosive growth of population has caused excessive consumption of land resources, resulting in serious resource constraints and environmental pollution problems, such as the sharp reduction of arable land, soil pollution, traffic congestion, and so on. These problems limit the economic development of a city and hinder the process of sustainable development of a city.

It is worth noting that this contradictory phenomenon is particularly serious in areas with weak resource endowment and underdeveloped economies, such as cities in Xinjiang, China. According to data from the Ministry of Land and Resources, the average urban land
The GDP index of Xinjiang was 1.532 million RMB in 2017, which is only 22.1%, 16.7%, and 36.5% of that recorded in Beijing, Shanghai, and Guangzhou, respectively [5]. However, as the strategic fulcrum of China’s “One Belt and One Road” and “Global community with a shared future”, the development of Xinjiang’s urban industry and economy has increasingly become an important cornerstone of national rejuvenation and social stability [6]. Xinjiang’s land area accounts for one-sixth of China’s [7], which means that if ID and LRCC can develop coordinately, it will promote the coordinated development between ID and LRCC throughout China. Therefore, the Chinese government pays great attention to the ID of Xinjiang and the coordination between ID and LRCC in the region. For example, according to the document of the Healthy Development of industry in Xinjiang issued by the National Development and Reform Commission in 2014, the government put great emphasis on the coordinated development of ID and LRCC of Xinjiang.

It can be seen that it is urgent to determine solutions that can enable the coordinated development between ID and LRCC in the underdeveloped cities of Xinjiang. Therefore, the study on the matching of ID and LRCC of cities in Xinjiang not only helps to promote the implementation of the major strategy of the Western development of China, but also provides guidance and reference for the sustainable development of backward border areas of Xinjiang. Furthermore, understanding matching between ID and LRCC is of great significance to regional planning and promotes the sustainable development of Xinjiang. Thus, research on the matching between ID and LRCC in Xinjiang is conducive to identify the weak matching areas, and then adequate policies can be formulated to increase the matching between ID and LRCC in Xinjiang.

Previous studies have presented various findings on ID and LRCC. The relevant research can be categorized into three groups. The first category mainly focuses on the study of ID under the constraint or support of LRCC, which mainly involves three aspects, namely, industrial scale, industrial layout, industrial structure. From the perspective of industrial scale, Millington and Millington (1973) investigated the scale of the food industry supported by Australia’s LRCC, and suggested that the maximum population size should be capped at 12 million if the standard of living of Australia is maintained at a high standard [8]. Gu et al. (2010) investigated the scale of leading industries based on the constraint of LRCC and pointed out that the appropriate industrial scale of coal mining and washing industry of Pingbao area of Henan City in China should be 39.7 billion RMB to 45.8 billion RMB in 2015 [9]. In the research on industrial layout, Guangmin (1999) studied the characteristics and historical development of land resources in Macao and considered that the industrial layout in Macao should be dominated by gambling tourism and trade service industry [10]. In referring to LRCC, Li et al. (2017) suggested that the industrial spatial pattern of Qingyang City in Gansu City in China should be dominated by energy and chemical industry in the central part of the city, industry, and agriculture in the south, and agriculture and animal husbandry in the southwest [11]. In examining industrial structure under the support of LRCC, Mendia et al. (2017) studied the status of ID from the perspective of LRCC support in Newcun, Argentina, and pointed out that it is necessary to combine the geological conditions and the differentiated characteristics of ecological resources in different areas of the city [12]. Niu et al. (2020) studied the appropriateness of the industrial structure of Tibet from the perspective of LRCC and found that the land resources severely restricted the development of Tibet’s industry [13].

The second group of research in the discipline of ID and LRCC mainly focuses on the impact of ID on LRCC. For example, Cheng et al. (2017) constructed an evaluation index system of LRCC in China’s major grain-producing areas (Heilongjiang City) and concluded that the risk factors of the LRCC system are mainly industrial structure and regional economic development [14]. Gray et al. (2018) analyzed the interrelationship between LRCC and industrial structure in Queensland, Australia, and concluded that the development of agriculture, industry, and mining has exerted varying degrees of pressure on the local LRCC [15]. In referring to 11 cities in the Harbin-Changchun urban agglomeration for the period of 2004–2015, Tang et al. (2021) investigated the index of the
ID, urban construction, social economy, suggesting that only the two cities of Harbin and Changchun present satisfactory LRCC state in the agglomeration [16].

A further group of research in the discipline of ID and LRCC focuses on the correlation and coordination between ID and LRCC. For example, Yang et al. (2020) analyzed the correlation and coordination between the LRCC and the industrial structure in referring to Zhengzhou by using the grey relational analysis model and concluded that the industrial structure of the city was unreasonable during 1998–2017 [17]. Xie et al. (2013) evaluated the coupling level of LRCC and ID in Poyang Lake Eco-economic Zone in China, and concluded that the simultaneous optimization of land resources and the economy is the best way to improve the coupling between LRCC and ID [18]. In examining the evolution of urban LRCC, in referring to 290 prefecture-level cities in China, Luo et al. (2020) suggested that the proportion of high-tech industrial land should be increased in the process of industrial transfer in these cities in order to improve urban LRCC [19].

From the above literature review, it can be seen that there are few studies on the relationship between ID and LRCC, and there is almost no research examining the match between ID and LRCC in referring to main cities in Xinjiang. Further, existing studies mainly focus on certain aspects of ID such as industrial structure and industrial scale but overlook the issue of more comprehensive aspects. This way could not provide an overall and comprehensive understanding of the matching relationship between ID and LRCC. Therefore, this article is dedicated to providing an index evaluation system related to studying the matching between ID and LRCC in the main cities of Xinjiang in China.

2. Evaluation Indicators for Measuring ID and LRCC

2.1. Evaluation Indicators for Measuring ID

ID refers to the process of the generation, growth, and evolution of an industry, including the evolution process of industries [20]. This process includes both quantitative changes in terms of the number of enterprises and output of products or services in the industry, as well as qualitative adjustments and changes of the industrial structure [21–24].

Based on the above connotation discussion, this paper constructs a multi-dimensional evaluation index system for ID. These indicators mainly include four dimensions, namely, industrial scale, industrial structure, industrial efficiency and industrial potential. Industrial scale refers to the output scale or operating scale of a specific industry, which can be represented by gross production value or output volume [25]. Industrial structure refers to the proportion of agriculture, industry, and service industries in a country [22,26]. Industrial efficiency refers to the per capita output at a certain developmental stage. Industrial potential refers to the momentum of industrial development [27], which can also be defined as the extent to which the industry can develop in a long-term effect [28,29]. By referring to indicators presented in previous studies in conducting ID evaluation from these four dimensions, a set of indicators in this study for measuring ID can be confirmed by considering the applicability and data availability, as shown in Table 1.

| Dimension          | ID Indicators                                                                 | Unit                        |
|--------------------|------------------------------------------------------------------------------|-----------------------------|
| Industrial scale   | • ID₁ Gross domestic output value                                            | 100 million RMB             |
|                    | • ID₂ The total number of employees in the primary, secondary and tertiary    | ten thousand people          |
|                    | industries                                                                   |                             |
| Industrial structure| • ID₃ Proportion of tertiary industry output to GDP                            | %                           |
|                    | • ID₄ Per capita GDP of employees in the primary industry                      | RMB/person                  |
| Industrial efficiency| • ID₅ Per capita GDP of employees in the secondary industry                   | RMB/person                  |
|                    | • ID₆ Per capita GDP of employees in the tertiary industry                     | RMB/person                  |
| Industrial potential | • ID₇ Added value of primary industry                                        | 100 million RMB             |
|                    | • ID₈ Added value of secondary industry                                      | 100 million RMB             |
|                    | • ID₉ Added value of tertiary industry                                       | 100 million RMB             |

Table 1. Indicators employed in this study for measuring ID.
2.2. Evaluation Indicators for Measuring LRCC

LRCC refers to the population scale and economic scale that land resources can accommodate in a certain period. Preliminary research on the LRCC is dated back to Malthus’s (1798) research on the principle of population [30]. Since then, the related research has expanded substantially with the study objects extending from arable land to grasslands, forests, water, construction land, and other subjects [31,32]. Accordingly, LRCC has become an important reference index for evaluating the development of the regional population, resources, economy, and ecological environment with the rise of sustainable development theory [33–35].

Research on the index for evaluating LRCC has produced abundant results [36–40]. For example, in evaluating the LRCC in 16 cities in the Yangtze River Delta region of China, Liu (2012) established 12 evaluation indicators about LRCC [41], covering the environment, transportation, water resources, and land resources, etc. Qian et al. (2015) developed 20 indicators for measuring LRCC across the economic, social and ecological aspects [42]. Tang et al. (2021) established a comprehensive evaluation index system of LRCC including five dimensions, namely, urban construction, social economy, ID, and urban ecology [16]. By referring to the indicators adopted in previous research, a set of indicators for evaluating the comprehensive carrying capacity of land are established across economic, social, and environmental dimensions, which can be shown in Table 2.

| Dimension  | LRCC Indicators                                                                 | Unit          |
|------------|---------------------------------------------------------------------------------|---------------|
| Economic   | • LRCC1 Grain production per unit of arable land                                  | kg/ha         |
|            | • LRCC2 Secondary and tertiary industry added value per unit of construction land | 10,000 RMB   |
| Social     | • LRCC3 Residential land area per capita                                           | km²/10,000 people |
|            | • LRCC4 Public green area per capita                                              | km²/10,000 people |
| Ecological | • LRCC5 Population density                                                        | Person/km²   |
|            | • LRCC6 Road area per capita                                                      | m²           |
|            | • LRCC7 Afforestation area                                                        | Hectares     |
|            | • LRCC8 Ratio of air quality days equal to or higher than Grade II                 | %            |

3. Evaluation Method for ID and LRCC

3.1. Entropy Weight Methods for Calculating Weight Values between Indicators

The entropy weight method (EWM) is a method for comprehensive evaluation of multiple indicators. In using EWM, entropy value is adopted to judge the degree of dispersion of an indicator over a given period of time and the given study objects. The smaller the information entropy value, the greater the degree of dispersion of the indicator, and the greater the impact of the indicator on the comprehensive evaluation (which is reflected by weighting values).

The calculation procedures of indicator weight are shown in the following formulas. Firstly, the original indicator data will be standardized via the following formula:

\[
y_{ikj} = \frac{x_{ikj} - \min \{x_{kj}\}}{\max \{x_{kj}\} - \min \{x_{kj}\}}
\]  

(1)

where \(x_{ikj}\) represents the original value of ID or LRCC evaluation indicator \(j\) for city \(k\) in year \(i\), and \(y_{ikj}\) represents the standardized value of the indicator \(j\) for city \(k\) in a year.

Secondly, the weighting values of individual indicators are calculated by adopting the following formulas:

\[
p_{ikj} = \frac{y_{ikj}}{\sum_{i=1}^{m} \sum_{k=1}^{s} y_{ikj}}
\]  

(2)

\[
e_j = -\frac{1}{\ln(m \times s)} \sum_{j=1}^{m} \sum_{k=1}^{s} p_{ikj} \ln p_{ikj} (0 \leq e_j \leq 1)
\]  

(3)
where \( w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \) 

\[(4)\]

3.2. Linear Weighted Sum Methods for Calculating Evaluation Results of LRCC and ID

The linear weighted sum method (LWSM) is commonly used for evaluating the performance of a system that consists of multiple dimensions of indicators. By using this method, the evaluation results of LRCC and ID can be obtained by using the following model (5):

\[ U_i = \sum_{j=1}^{n} w_j y_{ikj} \]

\[(5)\]

where \( U_i \) represents the evaluation result of ID and LRCC, respectively.

3.3. The Model of Matching Degrees between ID and LRCC

The coupling coordination degree model is used to analyze the coordinated development level between two or more systems [42,43]. Coupling coordination degree obtained from applying the model refers to the interactive benign influence between two or more systems, which can reflect the quality of coordination [44] (Ji Zheng et al., 2020).

The coupling coordination degree model is applied in this study to investigate the MD between ID and LRCC. The value of MD between the two systems, namely, ID \((U_1)\) and LRCC \((U_2)\) can be calculated through the following formula:

\[ C = \sqrt{U_1 \times U_2 / \left( \frac{U_1 + U_2}{2} \right)^2} \]

\[(6)\]

\[ T = \alpha U_1 + \beta U_2 \]

\[(7)\]

\[ MD = \sqrt{C \times T} \quad (0 \leq MD \leq 1) \]

\[(8)\]

where \(C\) represents the coupling degree of ID and LRCC. \(T\) represents the comprehensive evaluation index of ID and LRCC. \(U_1\) represents the performance of ID, and \(U_2\) represents the performance of LRCC, both of which are calculated by applying the formula (5). \(\alpha\) and \(\beta\) denote the contribution rate of \(U_1\) and \(U_2\), respectively, and in this study, the circumstance of “\(\alpha = \beta = 1/2\)” is adopted given the fact that ID \((U_1)\) and LRCC \((U_2)\) are equally important. MD will be used to reflect the matching level between ID and LRCC, which can be well matched, barely matched, slightly matched, rarely matched. The criteria for defining the matching level are specified in Table 3.

Table 3. The criteria of MD performance.

| MD Performance Zones                    | Specification Criteria |
|-----------------------------------------|------------------------|
| Well matching zone                      | 0.8 < MD ≤ 1.0         |
| Barely matching zone                    | 0.5 < MD ≤ 0.8         |
| Slightly matching zone                  | 0.3 < MD ≤ 0.5         |
| Rarely matching zone                    | 0 < MD ≤ 0.3           |

4. Research Data

4.1. Case Cities

A total of 16 main cities in Xinjiang were selected as case objects by considering their land resources, industries, and population scales, as shown in Figure 1. According to the data in 2018, 16 case cities have urban areas of 194,996 square kilometers, accounting for 84.24% of Xinjiang’s urban area. Additionally, the GDP of the 16 research cities was
746.509 billion RMB, accounting for 61.2% of Xinjiang’s total GDP. Data about their land resources, industries, and population scales are also presented in Table 4.

![Figure 1. The location of the case cities in this paper.](image-url)

**Table 4.** The main industries, land scales, and population scales of the 16 main cities in Xinjiang for the year 2018.

| Case Cities | Distance to Urumqi (km) | Main Industries | Land Scale (km²) | Population Size (10,000 People) |
|-------------|-------------------------|-----------------|-----------------|-------------------------------|
| Urumqi      | 0                       | Petrochemical, metallurgy, textile, food, medicine machinery, building materials light, electronic | 13,787.9 | 217 |
| Karamay     | 280                     | Oil industry    | 7735.2          | 30.7 |
| Shihezi     | 130                     | Non-ferrous metal processing, chemical manufacturing industry | 460 | 36.1 |
| Turpan      | 180                     | Crop farming    | 15,729.2        | 29.2 |
| Hami        | 490                     | Melons, fruits  | 85,035          | 43.2 |
| Changji     | 35                      | Tourism, non-ferrous metal processing, chemical manufacturing, non-metallic products, agricultural and sideline food processing | 7971 | 36.3 |
| Yining      | 70                      | Planting industry, tourism | 644 | 57.1 |
| Kuytun      | 24                      | Agriculture, animal husbandry, grain, oil cotton | 1109.9 | 13.5 |
| Tower       | 650                     | Foreign trade   | 4356.6          | 16.4 |
| Altay       | 667                     | Tourism         | 10,826          | 16.4 |
| Bole        | 448                     | Industry, commerce, tourism, real estate development | 7956 | 26.8 |
| Korla       | 600                     | Transportation, logistics | 7267.3 | 48.7 |
| Aksu        | 1126                    | Long-staple cotton, textile, cement, chemical industry | 14,400 | 51.3 |
| Artux       | 1553                    | Melons and fruits | 16,151 | 28.6 |
| Kashgar     | 1588                    | Foreign trade, export | 1056.8 | 65.2 |
| Hetian      | 2073                    | Silk, wool carpet, Hetian jade, Uighur medicine | 510.2 | 40.9 |
| Xinjiang cities | —                     | — | 231,488 | 885 |
| Percentage (%) | —                     | — | 84.24 | 85.58 |
4.2. Data

The sources of original data for all the LRCC and ID evaluation indicators listed in Tables 1 and 2 are shown in Table 5, and the data is collected across a 10-year time period from 2009 to 2018.

Table 5. Data sources for LRCC and ID indicators.

| Indicators | Data Sources |
|------------|--------------|
| LRCC1, LRCC2, LRCC4, LRCC6, ID1, ID3, ID4, ID5, ID6, ID7, ID8, ID9 | Xinjiang Statistical Yearbook (2010–2019) |
| LRCC2, LRCC5, LRCC6 | China Urban Construction Statistical Yearbook (2010–2019) |
| LRCC7 | China Forestry Statistical Yearbook (2010–2019) |
| ID2 | Xinjiang Survey Yearbook (2010–2019), Statistical Yearbook of China’s Regional Economy (2010–2019) |
| LRCC8 | Statistical Yearbook of Chinese Cities (2010–2019) |
| ID4, ID5, ID6 | China County Statistical Yearbook (2010–2019) |

However, the data for some indicators cannot be obtained directly from the official statistics, such as ID4 (per capita GDP of employees in the primary industry), ID5 (per capita GDP of employees in the secondary industry), ID6 (per capita GDP of employees in the tertiary industry). Therefore, certain data processing calculations are needed:

\[ ID4 = \frac{\text{Primary industry output value}}{\text{Practitioners in the primary industry}} \]  
\[ ID5 = \frac{\text{Secondary industry output value}}{\text{Practitioners in the secondary industry}} \]  
\[ ID6 = \frac{\text{Tertiary industry output value}}{\text{Practitioners in the tertiary industry}} \]

Furthermore, there is some missing data for some indicators in certain years such as the indicator ID2 in 2013, and LRCC1 in 2009. All the missing data are complemented by using the linear interpolation method or linear extrapolation method.

Follow the above data processing process, the research data of 16 cities in Xinjiang from 2009 to 2018 were obtained. As the complete database of the 16 cities is too large to be included in the paper, only the data for a sample case city of Urumqi is shown in Table 6.

Table 6. Research data for the case city of Urumqi from 2009 to 2018.

| 2009       | 2010       | 2011       | 2012       | 2013       | 2014       | 2015       | 2016       | 2017       | 2018       |
|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| ID1        | 10,727,645 | 13,027,147 | 16,215,843 | 18,954,206 | 20,584,716 | 22,646,800 | 23,873,124 | 24,589,766 | 27,306,455 | 30,997,659 |
| ID2        | 132.50     | 135.30     | 139.95     | 142.62     | 145.44     | 165.25     | 174.48     | 181.22     | 189.99     | 194.93     |
| ID3        | 55.54      | 53.00      | 53.76      | 57.34      | 59.08      | 62.10      | 67.10      | 70.20      | 68.90      | 68.50      |
| ID4        | 13,334.58  | 14,941.49  | 18,788.38  | 20,769.77  | 24,012.09  | 24,459.23  | 27,234.29  | 30,253.01  | 27,000.11  | 27,877.95  |
| ID5        | 130,775.83 | 165,780.87 | 5762.91    | 6149.68    | 6609.28    | 6872.25    | 211,501.17 | 194,122.88 | 214,642.55 | 239,958.49 |
| ID6        | 69,706.93  | 79,380.09  | 90,908.04  | 110,138.24 | 116,541.57 | 124,335.05 | 127,295.07 | 132,198.48 | 145,362.78 | 155,871.92 |
| ID7        | 160,015    | 186,918    | 202,163    | 218,498    | 226,434    | 235,787    | 265,262    | 281,353    | 250,021    | 257,871    |
| ID8        | 4,642,542  | 5,934,955  | 7,458,323  | 8,099,657  | 8,500,177  | 8,755,677  | 7,582,317  | 7,040,837  | 8,237,981  | 9,509,555  |
| ID9        | 5,925,089  | 6,905,274  | 8,555,356  | 10,636,050 | 11,858,110 | 13,655,540 | 15,025,350 | 17,267,580 | 18,818,450 | 21,230,230 |
| LRCC2      | 6422       | 6089       | 6619       | 6955       | 7681       | 7543       | 7661       | 7532       | 7993       | 7993       |
| LRCC3      | 31,151.82  | 37,471.12  | 41,724.02  | 50,856.97  | 52,040.61  | 54,361.37  | 54,907.12  | 55,753.25  | 61,764.21  | 68,560.50  |
| LRCC4      | 0.41       | 0.41       | 0.40       | 0.50       | 0.52       | 0.54       | 0.56       | 0.57       | 0.57       | 0.58       |
| LRCC5      | 0.14       | 0.13       | 0.15       | 0.14       | 0.15       | 0.16       | 0.16       | 0.16       | 0.18       | 0.19       |
| LRCC6      | 8230       | 8148       | 7972       | 8111       | 7784       | 7466       | 2123       | 2043       | 1929       | 1874       |
| LRCC7      | 6.88       | 7.18       | 7.42       | 7.45       | 9.57       | 10.08      | 10.54      | 10.71      | 10.53      | 11.76      |
| LRCC8      | 2868       | 2092       | 2975       | 4096       | 2729       | 3231       | 1853       | 894        | 1797       | 3028       |
| LRCC9      | 71.80      | 72.90      | 75.60      | 80.80      | 83.30      | 84.90      | 65.20      | 67.20      | 66.00      | 74.19      |
5. Results

5.1. Performance Value for ID and LRCC

By applying the research data specified in the previous section to Equations (1)–(5) in the evaluation method part, the performance values of ID and LRCC of 16 case cities can be obtained, as shown in Tables 7 and 8, respectively.

Table 7. Industry development (ID) performance values of 16 case cities in Xinjiang.

| City     | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Urumqi   | 0.3403 | 0.3839 | 0.4412 | 0.4929 | 0.5247 | 0.5816 | 0.6200 | 0.6413 | 0.6938 | 0.7624 |
| Karamay  | 0.1109 | 0.1540 | 0.1714 | 0.1751 | 0.1844 | 0.1920 | 0.1858 | 0.1573 | 0.1786 | 0.2043 |
| Shihezi  | 0.0491 | 0.0569 | 0.0646 | 0.0719 | 0.0839 | 0.0878 | 0.0953 | 0.0939 | 0.0988 | 0.1077 |
| Turpan   | 0.0376 | 0.0429 | 0.0443 | 0.0571 | 0.0604 | 0.0606 | 0.1070 | 0.1136 | 0.1214 | 0.1370 |
| Hami     | 0.0819 | 0.0951 | 0.0685 | 0.0785 | 0.0906 | 0.1013 | 0.0993 | 0.1289 | 0.1422 | 0.1539 |
| Changji  | 0.1030 | 0.1220 | 0.1328 | 0.1570 | 0.1703 | 0.1927 | 0.2077 | 0.2137 | 0.2169 | 0.2338 |
| Yining   | 0.0840 | 0.0862 | 0.0545 | 0.0621 | 0.0628 | 0.0690 | 0.0694 | 0.0713 | 0.0754 | 0.0781 |
| Kuytun   | 0.0439 | 0.0468 | 0.0631 | 0.0669 | 0.0606 | 0.0583 | 0.0648 | 0.0624 | 0.0678 | 0.0729 |
| Tower    | 0.0323 | 0.0344 | 0.0394 | 0.0469 | 0.0484 | 0.0724 | 0.0651 | 0.0582 | 0.0710 | 0.0762 |
| Altay    | 0.0744 | 0.0890 | 0.0345 | 0.0361 | 0.0396 | 0.0360 | 0.0377 | 0.0381 | 0.0364 | 0.0580 |
| Bole     | 0.0661 | 0.0725 | 0.0938 | 0.0981 | 0.0516 | 0.0769 | 0.1117 | 0.1358 | 0.0994 | 0.1009 |
| Korla    | 0.1175 | 0.1354 | 0.1351 | 0.1662 | 0.1788 | 0.1944 | 0.1840 | 0.1633 | 0.1661 | 0.1762 |
| Aksu     | 0.0543 | 0.0636 | 0.0698 | 0.0768 | 0.0819 | 0.0874 | 0.0922 | 0.0997 | 0.1083 | 0.1083 |
| Artux    | 0.0275 | 0.0323 | 0.0312 | 0.0336 | 0.0293 | 0.0501 | 0.0330 | 0.0346 | 0.0680 | 0.0680 |
| Kashgar  | 0.0479 | 0.0523 | 0.0543 | 0.0883 | 0.0838 | 0.0732 | 0.0741 | 0.0706 | 0.0731 | 0.0766 |
| Hetian   | 0.0481 | 0.0706 | 0.0835 | 0.0964 | 0.1019 | 0.1119 | 0.1140 | 0.1192 | 0.1495 | 0.1606 |

It can be seen from Tables 7 and 8 that the performance for both ID and LRCC has been improving across the study period for the majority sample cities. In exception, Altay and Yining experienced a decline in ID performance, and Karamay, Changji, Yining, Kuytun, Bole, and Hetian experienced a decline in LRCC performance.

5.2. Performance of MD

By applying data in Tables 7 and 8 to Formulas (6)–(8), values of MD between ID and LRCC in reference to the 16 case cities are shown in Table 9.
Table 9. Matching degree (MD) between ID and RECC of 16 case cities in Xinjiang.

| City     | 2009    | 2010    | 2011    | 2012    | 2013    | 2014    | 2015    | 2016    | 2017    | 2018    |
|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Urumqi   | 0.5303  | 0.5389  | 0.5756  | 0.6206  | 0.6161  | 0.6416  | 0.5987  | 0.5869  | 0.6224  | 0.6710  |
| Karamay  | 0.4986  | 0.5007  | 0.5189  | 0.5169  | 0.5207  | 0.5207  | 0.5204  | 0.4882  | 0.5194  | 0.5414  |
| Shihezi  | 0.2952  | 0.3093  | 0.3273  | 0.3488  | 0.3647  | 0.3755  | 0.3790  | 0.3756  | 0.3774  | 0.3823  |
| Turpan   | 0.2947  | 0.3050  | 0.3112  | 0.3466  | 0.3538  | 0.3686  | 0.4539  | 0.4782  | 0.5046  | 0.5428  |
| Hami     | 0.3470  | 0.3667  | 0.3461  | 0.3576  | 0.3713  | 0.3846  | 0.3725  | 0.4292  | 0.4511  | 0.4677  |
| Changji  | 0.4248  | 0.4127  | 0.4200  | 0.4449  | 0.4605  | 0.4814  | 0.4816  | 0.4715  | 0.4652  | 0.4807  |
| Yining   | 0.3612  | 0.3597  | 0.3335  | 0.3444  | 0.3472  | 0.3553  | 0.3303  | 0.3380  | 0.3499  | 0.3513  |
| Kuytun   | 0.2905  | 0.2883  | 0.3323  | 0.3384  | 0.3346  | 0.3320  | 0.3265  | 0.3115  | 0.3143  | 0.3245  |
| Tower    | 0.2747  | 0.2776  | 0.2990  | 0.3255  | 0.3231  | 0.3596  | 0.3334  | 0.3203  | 0.3437  | 0.3580  |
| Altay    | 0.3499  | 0.3422  | 0.2862  | 0.3016  | 0.3109  | 0.3071  | 0.3024  | 0.2961  | 0.2991  | 0.3362  |
| Bole     | 0.3425  | 0.4135  | 0.3968  | 0.3809  | 0.3133  | 0.3639  | 0.3855  | 0.3991  | 0.3695  | 0.3699  |
| Korla    | 0.3987  | 0.3720  | 0.4494  | 0.4684  | 0.4703  | 0.4749  | 0.4709  | 0.4407  | 0.4710  | 0.4839  |
| Aksu     | 0.3119  | 0.3231  | 0.3520  | 0.3418  | 0.3481  | 0.3655  | 0.3579  | 0.3501  | 0.3872  | 0.3983  |
| Artux    | 0.2639  | 0.2747  | 0.2630  | 0.2841  | 0.2648  | 0.3061  | 0.2692  | 0.2651  | 0.2846  | 0.3388  |
| Kashgar  | 0.2966  | 0.2879  | 0.3037  | 0.3445  | 0.3402  | 0.3320  | 0.3334  | 0.3231  | 0.3313  | 0.3405  |
| Hetian   | 0.2687  | 0.2931  | 0.3149  | 0.3304  | 0.3338  | 0.3378  | 0.3262  | 0.3183  | 0.3271  | 0.3356  |
| Average value | 0.3468  | 0.3541  | 0.3644  | 0.3810  | 0.3796  | 0.3942  | 0.3901  | 0.3870  | 0.4011  | 0.4202  |

The data in Table 9 can also be presented graphically, as shown in Figures 2 and 3. According to the criteria in Table 3, the matching zone can also be defined in Figure 3. By using the GIS technique, the MD values of 16 cities in Xinjiang in 2009 and 2018 can be presented graphically for further discussion, as shown in Figure 4.

![Figure 2](image-url)
By using the GIS technique, the MD values of 16 cities in Xinjiang in 2009 and 2018 can be presented graphically for further discussion, as shown in Figure 4.

Figure 3. MD performance of the 16 cities in Xinjiang from 2009 to 2018.
Figure 4. (a) The MD values of the 16 cities in Xinjiang for the year of 2009. (b) The MD values of the 16 cities in Xinjiang for the year of 2018.

6. Discussion

6.1. The Overall MD Performance of the 16 Cities

According to Figure 2, the average MD of the 16 cities in Xinjiang has experienced steady growth from 0.35 to 0.42 during the 10 surveyed years, indicating that the MD between LRCC and ID in Xinjiang cities has been gradually improving. This is mainly due to the implementation of strategies such as the development of the western region of China. For example, the central government of China had supported 331 ID projects in Xinjiang with a fund of 845 million RMB from 2011 to 2015. The implication of these projects requests for adjusting the traditional industrial structure by incorporating more recycling resource industries. These projects also pointed out to promote tertiary industries such as cultural tourism based on the level of LRCC. On the other hand, the 13th Five-Year Plan of Xinjiang also requires speeding up the construction of a green industrial economy and a land resource-saving society. These strategic measures have helped the ID in Xinjiang cities achieve good results with the decrease of the secondary industry by 10.8% from 2009 to 2018, and the increase of tertiary industry by 22.8%. As a result, the level of ID and LRCC becomes more in harmony with each other. Therefore, the MD level of 16 cities in Xinjiang ID and LRCC was gradually improving from 2009 to 2018.

It can be seen from the above analysis that the Xinjiang government has been playing an important role in improving the matching development of ID and LRCC. However, the data in Fig 3 shows that the level of MD is relatively low, with the max level of 0.42 in 2018, indicating there is still significant room for improvement. Thus, it is considered that the Xinjiang government should enhance the overall development speed and level of the industry, such as strengthening the development of characteristic tourism industries.
Meanwhile, the Xinjiang government can also give priority to the supply of construction land for key industries by scientifically arranging the total quantity, structure, layout, timing, and method of the land. With reference to the findings in this study, cities in backward regions globally should pay attention to the transformation and upgrading of their traditional industries to improve the matching degree between ID and LRCC. On the other hand, they can develop more green industries such as tourism to protect the local environment. This research finding is also consistent with the research by [45], who pointed out that the development of tourism in a certain area can contribute more to the improvement of LRCC.

6.2. The MD Performance Comparison Analysis between Case Cities

The comparison analysis will be conducted in three aspects. Namely, the overall analysis, good and poor performance analysis, and radiation analysis.

6.2.1. Overall Analysis

As shown in Figure 2, the overall level of MD performances of 16 sample cities in Xinjiang is relatively poor. Only two of the 16 sample cities (Urumqi and Karamay) achieve barely matching MD performance, the others are located in the slightly matching zone, except for the city Atushi that is always in the rarely matching zone. Furthermore, differences in MD performance levels between the 16 cities are very small. The main reason for this is that the central government’s policies on LRCC and ID are highly consistent across Xinjiang in promoting industry across all cities, without reflecting differentiation. For example, both city governments of Changji and Korla adopt similar policies to support key industrial enterprises [46]. These policies have similar effects in both cities in promoting the release of land use space within the cities and improving land utilization and industrial output rate per unit area. It can be seen from Figure 3 that the MD values of both Changji and Korla have increased in parallel after the policies were enacted in 2009–2012 [47–49].

Another interesting phenomenon is that all cities have maintained improvement in MD during 2009–2018 although the MD performance level in 16 case cities is still not very satisfactory. The main reason is that the central government has been continuously introducing policies on LRCC and ID, which has driven a continuous increase in the MD performance of Xinjiang cities. For example, the Xinjiang government in recent years has been continuously devoted to promoting the transformation of agricultural operations by incorporating a number of large-scale and characteristic agricultural projects, aiming to improve agricultural land use efficiency. In the period of 2002–2011, Xinjiang invested 1.9 billion RMB to carry out greening and transformation projects in the eastern Xinjiang industrial zone to prevent the destruction of desert sandstorms. These policy measures are effective to ensure normal operation of local enterprises and the healthy development of agriculture and animal husbandry [50]. In 2014, the Xinjiang government emphasized that both the quality and quantity of cultivated land should not be reduced while developing the construction industry [51].

From the findings in this study, it can be found that the support from city governors for key industries plays a very important role in improving ID performances. At the same time, the government’s policies for strengthening ecological environment protection and land resources will further enhance the coordination between LRCC and ID. Additionally, this proposition is echoed with the study by [52], who pointed out that industry should be developed based on land carrying capacity. The experience can be extended to other cities globally.

6.2.2. Good and Poor Performance Analysis

As showed in Figure 3, Urumqi city and Karamay city performed the best MD among the 16 cities, locating in the barely matching zone. The MD performance value of Urumqi city is the highest among the 16 cities, rising from 0.53 in 2009 to 0.67 in 2018, and the performance by Karamay rose from 0.5 to 0.54 in the same period. As the capital of
Xinjiang, Urumqi has the largest industrial base and the most reasonable industrial structure due to better policy supports and ID conditions, such as better infrastructure, accessible information exchange mechanism and better supply of high-end talents, etc. Accordingly, the industrial efficiency is relatively high in Urumqi. Furthermore, Urumqi pays great attention to promoting ID by using its LRCC. For example, Urumqi develops the agriculture industry through the control of land desertification. It has established a strict ecological protection system for the development of the construction industry by requesting that “the trees excavated on construction land shall be transplanted to other places equally” [53]. In addition, Urumqi also pays attention to the development of high-tech industries such as the electronics industry to increase the added value of its land resources. Therefore, its ID and LRCC have a better matching degree. On the other hand, as an emerging industrial city, Karamay has achieved a high level of industrialization. Industries in Karamay have a high degree of relevance, thus the agglomeration effect can be gained, especially in processing and commercial industries. At the same time, Karamay has a higher degree of land intensification, which has contributed to the improvement of LRCC level [54]. This is why the MD performance between ID and LRCC is relatively high in the city. The experience of Urumqi can be promoted to other cities globally for improving MD. In line with this, city governments should promote a more reasonable industrial structure based on local conditions, enhance the development of high-tech industries or green industries, and continue to protect the ecological environment. On the other hand, local enterprises and the government should work together to strengthen the management of key industries. Furthermore, the government should provide guarantees and corresponding subsidies for green industries.

It can be further seen from Figure 3 that the MD performance in Turpan City and Hami City have experienced a high level of increase, spanning three zones, from rarely matching zone in 2009 to slightly matching zone in 2009–2017, and rose to the barely matching zone in 2018. This is because Turpan is very good at making use of the locally abundant arable land resources to vigorously develop agriculture and tourism industries, which in turn has promoted the development of both industry and LRCC, thus MD is significantly improved. As for Hami City, it has a relatively high level of tertiary industries such as tourism and business services. Hami City government has also been actively supporting the supply of construction land required for the development of tertiary industrial enterprises, which created a good investment environment for tertiary industries such as tourism and commerce and service industries. Therefore, the level of MD in Hami City has increased gradually.

In contrast, the MD performance in Altay City and Yining City showed a downward trend during the study period. This is mainly because the traditional industry in the two cities used to be agriculture dominated. However, the land for agriculture has been used in recent years for other types of industries such as the ski industry. However, the ski industry in these cities has not developed successfully, instead, a large amount of pastoral land has been eaten, leading to a decrease in LRCC [55].

6.2.3. Radiation Analysis

Figure 4 shows the spatial evolution of MD in the case cities in Xinjiang from 2009 to 2018. It can be seen that the level of MD in northern Xinjiang is better than that in southern Xinjiang. The major reasons for this spatial difference are in two aspects. On one hand, the city Urumqi, as a core city in northern Xinjiang, has a radiation effect in promoting MD performance of other cities in northern Xinjiang. For example, Urumqi has the largest transit hub in Xinjiang, which provides very essential conditions for industrial development between cities around Urumqi. Urumqi also tends to develop industrial cooperation with the surrounding cities, which have also driven the ID and promoted the efficient use of LRCC in other surrounding cities [56]. On the other hand, there is no leading city in southern Xinjiang where the natural environment is very harsh and the economic condition is very weak [57]. Therefore, it suggests that southern Xinjiang should
focus on developing leading cities. In order to develop such a radiation city, a favorable policy environment should be carried out for its industrial development, especially in investment, credit, finance, priority supply of land, and preferential land prices in the city. For example, by developing Aksu city as the core radiation city in the southern Xinjiang region, the MD level in the southern region of Xinjiang can be improved. It can be seen that the development of transportation hub cities in backward areas is essential to help strengthen industrial cooperation with surrounding regions, which can lead to the formation of industrial clusters through the radiation function.

7. Conclusions

This study investigated the matching state between industrial development (ID) and land resource carrying capacity (LRCC) in main cities of Xinjiang in China for the period of 2009–2018. A multi-dimensional evaluation index system is established to measure ID by considering industrial scale, industrial structure, industrial efficiency and industrial potential. On the other hand, a comprehensive evaluation index system is developed to measure LRCC by incorporating economic, social, and environmental elements.

The main research findings can be summarized as follows:

1. Overall MD performance of the main cities in Xinjiang has been gaining steady growth, although the level of MD values is located in the slightly matching zone in the study period.
2. The differences in MD performance levels between the 16 sample cities are very small. Even the two best MD performers, namely, Urumqi city and Karamay, are still in the barely matching zone.
3. The level of MD in the northern cities in Xinjiang is better than that in southern Xinjiang. This is mainly because of the radiation effect of Urumqi in northern cities. It is therefore suggested developing such a radiation city in southern Xinjiang in order to improve MD performance in southern Xinjiang.

By drawing upon the research findings, policy recommendations can be proposed as follows: firstly, it is suggested that backward areas like Xinjiang of China should adopt proper policies to promote the environment-friendly industries as their key industries based on the local conditions. Secondly, it is recommended to strengthen the role of government in these backward areas to support the development of key industries such as tourism and strengthen land resource protection. Thus, coordinated development between ID and LRCC can be promoted. Thirdly, it is recommended to promote the radiation-driven effect of key cities such as Urumqi and Karamay in Xinjiang, through establishing transportation networks between main cities. By this way, an advantageous industrial cluster can be formed, and LRCC can be improved as well. The application of these recommended policies can help improve the matching degree between ID and LRCC at both national and global level.

This study contributes to literature development in studying the relationship between ID and LRCC. Practically, the empirical results can provide policymakers in Xinjiang and other backward cities globally with valuable references in understanding the status of MD between ID and LRCC in the local cities. Thus, tailor-made policy instruments can be formulated to improve the performance of MD for the mission of sustainable development. The research results are also very conducive to ensure the stability of the region by improving the social and economic development level of Xinjiang.

The limitations of this study are appreciated. Although the study examines the MD performance level of sample cities in Xinjiang, there is no in-depth analysis of MD influencing factors. This is a recommendation for studying in future research. Furthermore, more case cities can be incorporated for comparative study.
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