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Quantitative Analysis of the Coupling Coordination Degree Between Urbanization and Eco-environment in Mongolia

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Abstract: Mongolia is an important country in the Economic Corridor of China-Mongolia-Russia, a deep understanding of the coupling relationship between urbanization and the eco-environment in Mongolia is meaningful to achieve green development of the Belt and Road. The entropy method and coupling coordination degree model were integrated to evaluate the coupling coordination degree between urbanization and the eco-environment in Mongolia during 2000−2016. The results showed that the coupling coordination degree between urbanization and the eco-environment in Mongolia was generally at the stage of seriously unbalanced development, and that the main contributor of the urbanization and the eco-environment subsystem were demographic urbanization and eco-environment endowment, respectively. The southern part of Mongolia central zone should be paid more attention due to the lower degree of coupling coordination between urbanization and the eco-environment. To promote the healthy urbanization development in Mongolia, six-layer eco-city establishing green development pattern is proposed to provide scientific support for Mongolia.

Keywords: coupling coordination degree; urbanization; eco-environment; Mongolia; six-layer eco-city

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1 Introduction

The world has experienced rapid urbanization (Liu et al., 2014; He et al., 2017). The *World Urbanization Prospects* : *The 2014 Revision* (United Nations, 2014), pointed out that 54% of the world was urbanized and predicted that 66% of the population will live in the urban area in 2050. Global urbanization put severe stress on the eco-environment. *Science* (Grimm et al., 2008) and *Nature* (Gurney et al., 2015) both proposed that urban areas are major contributors of global eco-environmental problems. In addition, the Man and the Biosphere Programme, put forward by the United Nations Educational, Scientific and Cultural Organization (UNESCO), proposed the relationship between anthropogenic activities and environment as a core scientific question (UNESCO, 2018). So far, the quantitative research on the coupling coordination degree between urbanization and the eco-environment has allured scientific interest (Liu et al., 2015; Zhang, 2016; Zhao et al., 2017; Yu et al., 2018), and has made much progress (Fang and Wang, 2013).

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The relationship between urbanization and the eco-environment is a complex interactive coupling and coercing relationship (Qiao and Fang, 2005; Xu et al., 2018). A large number of research have used various methods to investigate the coupling between urbanization and the eco-environment, such as Environmental Kuznets Curve (EKC) (Xia et al., 2014; Xu et al., 2018; Lin and Zhu, 2018), Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) (Lin et al., 2017; Effiong, 2018), Logarithmic Mean Divisia Index (LMDI) (Ding and Li, 2017), Orthogonal Least Square (OLS) (Azam and Khan, 2016; Yazdi and Shakouri, 2018) and Coupling Coordination Degree (CCD) (Tang et al., 2017; Zhao et al., 2017; Haseeb et al., 2017). However, the STIRPAT, LMDI and OLS are dedicated to the single-direction influence of urbanization and other driving forces on the eco-environment. The EKC can be used to describe the non-linear relationship of the urbanization-environment system (Fang and Wang, 2013). In addition, the interactive coupling analysis of the relationship between urbanization and the eco-environment can provide a more comprehensive understanding of the urbanization-environment compound system (He et al., 2017). Quantitative analysis of the coupling coordination degree between urbanization and eco-environment is significant to achieve the sustainable development of urbanization.

Coupling, originating from physics, is introduced to depict a phenomenon that urbanization and eco-environment have effects on each other by various interactions (Fang and Wang, 2013). A great deal of research have validated that rapid urbanization put great pressure on the atmospheric environment and water environment (Ren et al., 2014; Bao and Zou, 2017), and led to severe land use/land cover change (Martellozzo et al., 2018), urban climate change (Elliott and Clement, 2014; Sadorsky, 2014) and heat island effects (Chrysanthou et al., 2014). These research extend the comprehension on the coupling relationship between urbanization and the eco-environment. However, most previous studies focused on the coupling relationship of single-element environment and urbanization. In recent years, some scholars began to pay more attention to the coordination between the comprehensive and multi-element eco-environment and urbanization. For example, He et al. (2017) developed an index system for the urbanization-environment compound system and conducted a coupling analysis in Shanghai, China. Wang et al. (2014) examined the coupling coordination degree between urbanization and the eco-environment by a dynamic coupling degree model in the Beijing-Tianjin-Hebei (BTH) region from 1980 to 2011. The results indicated the BTH region belonged to the rudimentary symbiosis phase, and the urban environment faced great presssure.

Mongolia, as an important developing country of the China-Mongolia-Russia Economic Corridor, has experienced dramatic urbanization (Park et al., 2017). According to the National Statistics Office of Mongolia (2000–2017), the urbanization in Mongolia increased from 57% in 2000 to 69% in 2015, with annual average growth rate at 1.21%, higher than the growth rate of the whole world (47% in 2000, 54% in 2015, and annual average growth rate 0.99%). Meanwhile, Mongolia belongs to arid and semi-arid regions, with average annual precipitation below 400 mm or even 200 mm. With fragile environment and great pressure from human activities, the green development pattern to coordinate the development between urbanization and eco-environment is in urgent need in Mongolia. Nevertheless, the research focused on this region are relatively insufficient. China proposed the Belt and Road Initiative in 2013, and Mongolia proposed the Grassland Road Initiative in 2014. Under this background, quantitative analysis of the coupling coordination degree between urbanization and eco-environment in Mongolia is a prerequisite for the two initiatives' harmonious promotion and crucial for the realization of sustainable development of urbanization in Mongolia.

This paper aims to conduct an analysis of the coupling coordination degree between urbanization and the eco-environment in Mongolia. An integrated index system is developed in this paper to evaluate the contributions made by the indicators of the urbanization and eco-environment subsystem, respectively. The examination of the coupling coordination degree can stimulate more sustainable strategies for the urbanization development in Mongolia. Identifying the major contribution factor is important to provide a knowledge to adjust the coupling coordination degree of the urbanization and the eco-environment subsystems.

2 Materials and Methods

2.1 Study area and data source

Located between Russian Federation and People's Republic of China, Mongolia is the second largest land-locked country in the world, with a total area of 1.57 million km^2. In 2017, it has a total population of 3.18 million, a total GDP (gross domestic product) of 271.67 billion Mongolian Tugrik (Tug, equivalent to 106.63 million USD) and an urbanization level of 67% (National Statistics Office of Mongolia, 2000−2017). There are 21 *aimags* (provinces) and the capital Ulaanbaatar in Mongolia (Fig. 1). The multi-year average of precipitation during the period 2000−2016 in the 21 *aimags* and Ulaanbaatar are all below 400 mm, and more serious is that the precipitation of nearly half of the 21 *aimags* are below 200 mm. All the territory of Mongolia is belong to arid and semi-arid area, one of the most vulnerable areas in the global ecosystem. Many ecological and environmental problems exist in these area, such as desertification and soil erosion, due to the scarce water resources and sparse vegetation coverage.

According to the *World Urbanization Prospects: The 2014 Revision* (United Nations, 2014), the urbanization process will last for some time in the whole world. It predicted that the urbanization level of Mongolia will reach 84.8% in 2050, higher than most Asian countries and regions. Urbanization is a sword that has two sharp edges (He et al., 2017). On the one hand, urbanization will promote economic growth and the quality of life. On the other hand, it may reversely consume more resources and put considerable pressure on the eco-environment, even causing ecological deterioration and severe environmental pollution. The data during the period 2000−2016 covering the indexes of the urbanization subsystem and the eco-environment subsystem are all derived from the Mongolian Statistical Information Service website (National Statistics Office of Mongolia, 2000–2017).

2.2 Index system for urbanization and the eco-environment assessment

The relevant research results are thoroughly taken into account when establish the index system to better assess the coupling coordination degree between urbanization and the eco-environment in Mongolia (Ding et al., 2015; Li et al., 2019; Yao et al., 2019). Urbanization is a comprehensive development process of various aspects. It is not only presented as the migration and agglomeration of population from rural to urban area, but also including the economic structure and lifestyle transformation from rural to urban. An integrated index system of the urbanization subsystem (Table 1) includes three first grade indicators (demographic urbanization, economic urbanization and social urbanization) and seven basic indicators (percentage of urban population, population density, GDP per capita, sales of industrial production, number of vehicles per 10 000 people, number of telelines per 10 000 people and number of general education schools).

Every aspect of urbanization may exert influence and pressure on the eco-environment. Meanwhile, urban development may be reversely in the grip of the eco-environment. The eco-environment index system (Table 2) is made up of three first grade indicators (eco-environment level, eco-environment endowment and

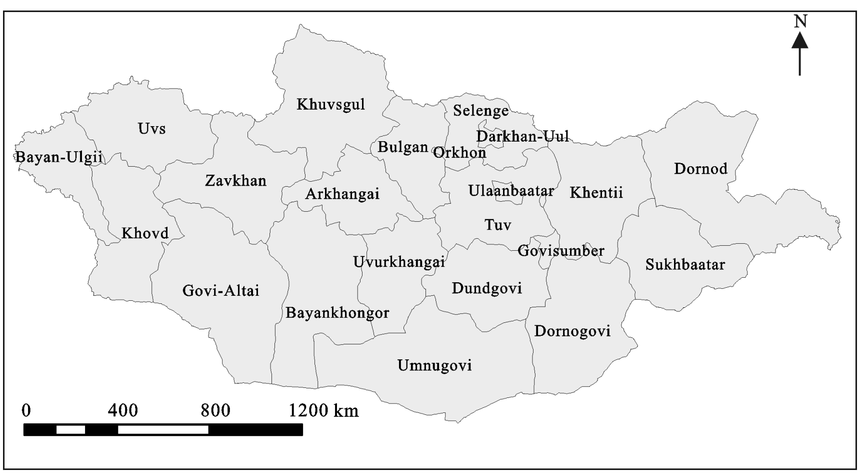

Fig. 1 Administrative division of Mongolia

Table 1 Urbanization index system and the weight of each indicator

First grade indicators	Weight (%)	Indicators	Weight (%)
Demographic urbanization	63.73	Percentage of urban population (%)	1.45
		Population density (people/km^2)	62.28
Economic urbanization	28.67	GDP per capita (1000 MNT, Tug)	4.98
		Sales of industrial production (Tug)	23.69
Social urbanization	7.60	Number of vehicles per 10000 people	1.52
		Number of telelines per 10000 people	2.77
		Number of general education schools	3.31

Table 2 Eco-environment index system and the weight of each indicator

First grade indicators	Weight (%)	Indicators	Weight (%)
Eco-environment level	29.39	Annual precipitation (mm)	2.22
		Number of rivers	11.20
		Number of lakes	15.97
Eco-environment endowment	54.97	Sown areas per capita (m^2)	36.17
		Forest harvest volume per capita (m^3)	18.80
Eco-environment response	15.64	Solid waste disposal trucks	15.64

eco-environment response). Considering that Mongolia belongs to the arid and semi-arid area, indicators related to water resource, the most important constraint for the study area, are introduced into the eco-environment index system. Owing to the limitation of the environmental data, the eco-environment index system consists of six basic indicators (annual precipitation, number of rivers, number of lakes, sown areas per capita, forest harvest volume per capita and solid waste disposal trucks).

Entropy method is applied to determine the weight of each indicator in the urbanization index system and eco-environment index system. To achieve the comparison during different years, the entropy model is modified in this paper. The modified entropy model is as follows:

Normalization treatment was calculated by Equation (1):

$$x'_{\theta ij} = x_{\theta ij} / x_{i\max} \tag{1}$$

where $x_{\theta ij}$ denotes the value of the indicator j of province i in year θ, $x'_{\theta ij}$ denotes the normalized value of the indicator j of province i in year θ, x_j max denotes the maximum of the indicator j.

The proportion of the indicator j of province i in year θ was calculated by Equation (2):

$$y_{\theta ij} = x'_{\theta ij} \Big/ \sum_{\theta}\sum_{i} x'_{\theta ij} \tag{2}$$

Information entropy (e_j) of the indicator was calculated by Equation (3):

$$e_j = -\frac{1}{k}\sum_{\theta}\sum_{i} y_{\theta ij}\ln(y_{\theta ij}),\quad k>0,\quad k=\ln(rn) \tag{3}$$

where r is the number of years, n is the number of aimag, Entropy redundancy (g_j) was calculated by Equation (4):

$$g_j = 1 - e_j \tag{4}$$

Weight of the indicator (w_j) was calculated by Equation (5):

$$w_j = g_j \Big/ \sum_{j} g_j \tag{5}$$

Evaluation of the indicator ($H_{\theta i}$) was calculated by Equation (6):

$$H_{\theta i} = \sum_{j}\left(w_j x'_{\theta ij}\right) \tag{6}$$

2.3 The coupling coordination degree model

Since urbanization subsystem and eco-environment subsystem influence each other through interactive mechanisms, the system can be defined as a coupling system. And the coordination of the coupling relationship between the two subsystems is significant for sustainable development through the urbanization process. The coupling degree of urbanization and eco-environment can be calculated by Equation (7):

$$C = (f(U) \cdot g(E) \big/ ((f(U) + g(E))/2)^2)^{1/2} \quad (7)$$

where C is the coupling degree of urbanization and the eco-environment, $f(U)$ is the urbanization system, and $g(E)$ is the eco-environment system. The coupling coordination degree of urbanization and eco-environment is calculated by Equation (8):

$$T = \alpha f(U) + \beta g(E); \quad D = \sqrt{C \times T} \quad (8)$$

where D is the degree of coupling coordination between urbanization and the eco-environment, T represents the level of effect of urbanization on the eco-environment, α and β illustrate the contribution of urbanization and the eco-environment to the system.

The comprehensive index of the development stages of coupling between urbanization and the eco-environment (Wang et al., 2014; He et al., 2017) is shown in Table 3.

3 Results

3.1 Analysis of the urbanization and eco-environment system

The weight coefficients of the first grade indicators and the basic indicators of the comprehensive index system, including the urbanization subsystem and the eco-environment subsystem were presented in Table 1 and Table 2, respectively. The weight of each indicator in both the two subsystems was evaluated by the entropy method. The three first grade indicators: demographic urbanization, economic urbanization and social urbanization, were ranked by their weight value as follows: demographic urbanization (63.73%) > economic urbanization (28.67%) > social urbanization (7.60%). Demographic urbanization was weighted the highest and it was considered to have the greatest impact on the comprehensive urbanization. The basic indicators of the urbanization subsystem were ranked by the weight value as follows: population density (62.28%) > sales of industrial production (23.69%) > GDP per capita (4.98%) > number of general education schools (3.31%) > number of telelines per 10 000 people (2.77%) > number of vehicles per 10 000 people (1.52%) > percentage of urban population (1.45%). The population density accounted for more than a half and sales of industrial production accounted for nearly one quarter of the total impact. This result supports the view that the comprehensive urbanization in Mongolia mainly reflects in the urban population concentration during the study period. This result is consistent with the previous research in Ulaanbaatar, Mongolia (Park et al., 2017) that also proposed the importance of the urban population agglomeration and economic development in the process of urbanization development.

Table 3 Comprehensive index of the development stages of coupling between urbanization and the eco-environment

Types	Comprehensive index		Sub-types
		$g(E) - f(U) > 0.1$	Superiorly balanced development with lagging urbanization
Superior balanced development	$0.8 < D \le 1$	$f(U) - g(E) > 0.1$	Superiorly balanced development with a lagging environment
		$0 \le \lvert f(U) - g(E) \rvert \le 0.1$	Superiorly balanced development of urbanization and eco-environment
		$g(E) - f(U) > 0.1$	Barely balanced development with lagging urbanization
Barely balanced development	$0.5 < D \le 0.8$	$f(U) - g(E) > 0.1$	Barely balanced development with a lagging environment
		$0 \le \lvert f(U) - g(E) \rvert \le 0.1$	Barely balanced development of urbanization and eco-environment
		$g(E) - f(U) > 0.1$	Slightly unbalanced development with hindered urbanization
Slightly unbalanced development	$0.3 < D \le 0.5$	$f(U) - g(E) > 0.1$	Slightly unbalanced development with a hindered environment
		$0 \le \lvert f(U) - g(E) \rvert \le 0.1$	Slightly unbalanced development of urbanization and eco-environment
		$g(E) - f(U) > 0.1$	Seriously unbalanced development with hindered urbanization
Seriously unbalanced development	$0 < D \le 0.3$	$f(U) - g(E) > 0.1$	Seriously unbalanced development with a hindered environment
		$0 \le \lvert f(U) - g(E) \rvert \le 0.1$	Seriously unbalanced development of urbanization and eco-environment

As shown in Table 2, the three first grade indicators in the eco-environment subsystem were ranked by their weight value as follows: eco-environment endowment (54.97%) > eco-environment level (29.39%) > eco-environment response (15.64%). The eco-environment endowment was the key factor influencing the eco-environment subsystem. Sown areas per capita (36.17%), forest harvest volume per capita (18.80%), number of lakes (15.97%) and solid waste disposal trucks (15.64%) had the greatest influence on the eco-environment, accounting for more than 80% in total. The cultivated land resources, forest resources and water resources should be given more protection to maintain the eco-environment subsystem. In Mongolia, more environment monitoring work and environment protection policies are in urgent demand to support the healthy development of economy and urbanization.

The above results indicated that the demographic urbanization and the eco-environment endowment have greater contributions to the comprehensive urbanization subsystem and the eco-environment subsystem than other indicators, respectively.

3.2 Spatiotemporal pattern of the comprehensive urbanization level

The comprehensive urbanization scores of 21 *aimags* and Ulaanbaatar in Mongolia in 2000, 2005, 2010, 2015 and 2016 were shown in Table 4. From 2000 to 2016, the comprehensive urbanization level in Mongolia showed an increasing trend. The comprehensive urbanization scores of all the 21 *aimags* and Ulaanbaatar in Mongolia were higher in 2016 than 2000. In 2000, the comprehensive urbanization scores of most regions (15 *aimags*) were lower than 0.02. The seven *aimags*, where the comprehensive urbanization score were above 0.02, were ranked as follows: Ulaanbaatar (0.3967) > Uvurkhangai (0.2066) > Dundgovi (0.0652) > Orkhon (0.0353) > Darkhan-Uul (0.0319) > Dornogovi (0.0212) > Govisumber (0.0207). These seven *aimags* all located around the capital Ulaanbaatar and in the central region of Mongolia. In 2016, the comprehensive urbanization scores of all 21 *aimags* and Ulaanbaatar were higher than 0.02. Rounding up the top 10 comprehensive urbanization level were Ulaanbaatar (0.7433), Uvurkhangai (0.2803), Dundgovi (0.0896), Orkhon (0.0622), Dornod

Table 4 Comprehensive urbanization score in Mongolia during 2000–2016

Aimag	2000	2005	2010	2015	2016
Bayan-Ulgii	0.0172	0.0208	0.0255	0.0309	0.0301
Govi-Altai	0.0144	0.0176	0.0172	0.0273	0.0272
Zavkhan	0.0142	0.0267	0.0177	0.0273	0.0265
Uvs	0.0144	0.0184	0.0200	0.0283	0.0268
Khovd	0.0147	0.0179	0.0185	0.0260	0.0249
Arkhangai	0.0145	0.0167	0.0178	0.0290	0.0267
Bayankhongor	0.0133	0.0160	0.0191	0.0289	0.0279
Bulgan	0.0155	0.0183	0.0221	0.0299	0.0279
Uvurkhangai	0.2066	0.2217	0.2465	0.2794	0.2803
Khuvsgul	0.0171	0.0204	0.0219	0.0292	0.0286
Orkhon	0.0353	0.0503	0.0668	0.0651	0.0622
Dornogovi	0.0212	0.0300	0.0313	0.0390	0.0379
Dundgovi	0.0652	0.0716	0.0749	0.0914	0.0896
Umnugovi	0.0142	0.0181	0.0290	0.0289	0.0368
Selenge	0.0154	0.0161	0.0302	0.0359	0.0353
Tuv	0.0133	0.0145	0.0179	0.0317	0.0300
Darkhan-Uul	0.0319	0.0425	0.0414	0.0415	0.0413
Govisumber	0.0207	0.0216	0.0261	0.0361	0.0323
Dornod	0.0168	0.0199	0.0229	0.0434	0.0462
Sukhbaatar	0.0105	0.0138	0.0203	0.0305	0.0296
Khentii	0.0175	0.0199	0.0214	0.0301	0.0290
Ulaanbaatar	0.3967	0.5029	0.6157	0.7188	0.7433

(0.0462), Darkhan-Uul (0.0413), Dornogovi (0.0379), Umnugovi (0.0368), Selenge (0.0353) and Govisumber (0.0323).

All the *aimags* with higher level of comprehensive urbanization were located in the central part of Mongolia. The spatial pattern of the comprehensive urbanization level in Mongolia showed an inverse U-shape pattern: higher in the central region and lower in the edge regions. In addition, there were five *aimags* (including Uvurkhangai, Dornod, Orkhon, Dundgovi and Umnugovi) and Ulaanbaatar, where the comprehensive urbanization scores increased more than 0.02 during 2000–2016, and most of these six *aimags*' urbanization level are relatively higher. Therefore, Ulaanbaatar, Uvurkhangai, Orkhon, Dundgovi and Umnugovi should be paid more attention in the process of urbanization development in the future.

3.3 Comprehensive eco-environmental level in Mongolia

Table 5 showed the comprehensive level of the eco-environment subsystem of the 21 *aimags* and Ulaanbaatar in Mongolia from 2000 to 2016. The comprehensive level of eco-environment in Mongolia didn't change so much during 2000–2016. In addition, it showed a north-south differentiation spatial pattern. The comprehensive eco-environment level was higher in the north and lower in the south of Mongolia. In 2016, rounding up the top 10 were Govisumber (0.3559), Khuvsgul (0.2870), Bulgan (0.2628), Arkhangai (0.2376), Ulaanbaatar (0.1746), Selenge (0.1692), Khentii (0.1572), Zavkhan (0.1569), Dornod (0.1430) and Darkhan-Uul (0.1273). The top 10 *aimags*, where the comprehensive eco-environment level were higher, were all located in the north part of Mongolia.

The above analysis of the comprehensive level of the urbanization subsystem and the eco-environment subsystem indicated that five *aimags* (including Uvurkhangai, Orkhon, Dundgovi, Umnugovi and Dornogovi), with higher level of urbanization and lower level of eco-environment, should be paid more attention from the government and researchers since the rapid urbanization put strict pressure on the originally fragile eco-environment in these regions.

Table 5 Comprehensive eco-environmental score in Mongolia during 2000–2016

Aimag	2000	2005	2010	2015	2016
Bayan-Ulgii	0.1979	0.2041	0.1395	0.1045	0.0890
Govi-Altai	0.0418	0.0523	0.0659	0.0636	0.0556
Zavkhan	0.1279	0.1221	0.0734	0.1314	0.1569
Uvs	0.0821	0.0739	0.0803	0.0683	0.0731
Khovd	0.0486	0.0450	0.0593	0.0612	0.0573
Arkhangai	0.1435	0.2025	0.2201	0.2529	0.2376
Bayankhongor	0.0595	0.0373	0.0567	0.0710	0.0670
Bulgan	0.1323	0.2427	0.2461	0.2678	0.2628
Uvurkhangai	0.0685	0.0685	0.0864	0.0863	0.0812
Khuvsgul	0.2347	0.2271	0.3000	0.2748	0.2870
Orkhon	0.0218	0.0317	0.0290	0.0387	0.0370
Dornogovi	0.0134	0.0181	0.0186	0.0234	0.0247
Dundgovi	0.0226	0.0198	0.0319	0.0394	0.0353
Umnugovi	0.0137	0.0209	0.0152	0.0241	0.0269
Selenge	0.1094	0.1529	0.2040	0.1441	0.1692
Tuv	0.1314	0.1206	0.1373	0.1222	0.1024
Darkhan-Uul	0.0999	0.0701	0.1070	0.1461	0.1273
Govisumber	0.1396	0.1351	0.2711	0.3799	0.3559
Dornod	0.1006	0.1147	0.1136	0.1091	0.1430
Sukhbaatar	0.0203	0.0204	0.0417	0.0548	0.0583
Khentii	0.0778	0.1108	0.2527	0.1346	0.1572
Ulaanbaatar	0.0906	0.1097	0.1329	0.1662	0.1746

3.4 Coupling coordination degree of urbanization and the eco-environment

Based on the index system of the compound urbanization and eco-environment system, we examined the coupling coordination degree of each aimag in Mongolia from 2000 to 2016. The results are shown in Table 6. The coupling coordination degree in Mongolia during 2000–2016 showed an overall increasing trend. The degree of coordinated coupling between urbanization and the eco-environment of all *aimags* in 2016 were higher than in 2000, except Baya-Ulgii. The degree of coordinated coupling between urbanization and the eco-environment in Baya-Ulgii fluctuated around 0.240 during the study period, and it was 0.242 in 2000 and 0.227 in 2016. The *aimags*, with higher coupling coordination degree, were mainly located in the northern part of Mongolia central zone, such as Ulaanbaatar (0.600), Uvurkhangai (0.388) and Govisumber (0.327), etc.. The endowment of the eco-environment was better in the northern part of Mongolia. In addition, the region, closed to the capital Ulaanbaatar, gathered more people, investment and technology etc., and had higher urbanization level. Therefore, the coupling coordination degree of the northern part of Mongolia central zone were higher than other regions.

Although the coupling coordination degree kept improving from 2000 to 2016, more than 80% region in Mongolia were still at the stage of seriously unbalanced development, with the degree of coordinated coupling between urbanization and the eco-environment below 0.3 in 2016. There were only three *aimags* and Ulaanbaatar where the coupling coordination degree were above 0.3. Uvurkhangai, Govisumber and Khuvsgul were at the stage of slightly unbalanced development, with the coupling coordination degree as 0.388, 0.327 and 0.301, respectively. Only Ulaanbaatar, the capital of Mongolia, achieved balanced development of urbanization and the eco-environment. However, Ulaanbaatar was just at the stage of barely balanced development with the coupling coordination degree being 0.600 in 2016. No superior balanced development of urbanization and eco-environment was achieved in Mongolia.

Table 6 Coupling coordination degree of urbanization and the eco-environment of in Mongolia during 2000–2016

Aimag	2000	2005	2010	2015	2016
Bayan-Ulgii	0.242	0.255	0.244	0.238	0.227
Govi-Altai	0.157	0.174	0.183	0.204	0.197
Zavkhan	0.206	0.212	0.190	0.245	0.254
Uvs	0.185	0.192	0.200	0.210	0.210
Khovd	0.163	0.168	0.182	0.200	0.194
Arkhangai	0.214	0.241	0.250	0.293	0.282
Bayankhongor	0.168	0.156	0.181	0.213	0.208
Bulgan	0.213	0.258	0.272	0.299	0.293
Uvurkhangai	0.345	0.351	0.382	0.394	0.388
Khuvsgul	0.252	0.261	0.285	0.299	0.301
Orkhon	0.167	0.200	0.210	0.224	0.219
Dornogovi	0.130	0.153	0.155	0.174	0.175
Dundgovi	0.196	0.194	0.221	0.245	0.237
Umnugovi	0.118	0.140	0.145	0.162	0.177
Selenge	0.203	0.223	0.280	0.268	0.278
Tuv	0.204	0.205	0.223	0.249	0.236
Darkhan-Uul	0.238	0.234	0.258	0.279	0.269
Govisumber	0.232	0.233	0.290	0.342	0.327
Dornod	0.203	0.219	0.226	0.262	0.285
Sukhbaatar	0.121	0.130	0.171	0.202	0.204
Khentii	0.192	0.217	0.271	0.252	0.260
Ulaanbaatar	0.435	0.485	0.535	0.588	0.600

During the study period, urbanization and the eco-environment were not coordinated. The results revealed that as an important country of the Belt and Road Initiative, it's greatly important and urgent for Mongolia to achieve sustainable urbanization development, and shifting the stage of being 'unbalanced development' to 'superior balanced development' of urbanization and the eco-environment.

4 Discussion

The results of this study revealed that the coupling coordination degree between urbanization and eco-environment in Mongolia was generally at the stage of seriously unbalanced development, and that the main contributor of the urbanization and the eco-environment subsystem were demographic urbanization and eco-environment endowment, respectively. This finding suggested that it was necessary to relieve the pressure of population agglomeration and improve the utilization efficiency of resource in Mongolia.

To achieve the healthy and sustainable urbanization development and the superiorly balanced of urbanization and the eco-environment in the future, we proposed six-layer eco-city establishing green development mode for Mongolia. Eco-city contains six layers, which are safe city, convenient city, circular city, green city, innovation city and harmony city. The safe city is the basic requirement. And the water resource safety is very important for cities to guarantee the production and living of more and more people gathering in urban areas in Mongolia. The core of the convenient city is the traffic and communication convenience. According to the above analysis, the contributions of the traffic and communication to the comprehensive urbanization were relatively less in Mongolia at present. We suggested that the government in Mongolia can strengthen the cooperation with China in the construction of transportation and communication infrastructure under the background of the Belt and Road. The core of circular city is to improve the efficiency of resources. Mongolia should develop modern ecological agriculture, circular industry park and ecological service industry. The core of green city is to enforce the reduction of waste emissions and improve waste disposal to establish the beautiful environment of living. The innovation city is high level of eco-city requirements. Science and technology, high concentration of talent, and the development of high-tech industries are included the construction of innovative cities. The harmony city is the highest level of requirements, the core is a high level of ecological and cultural and social civilization.

In addition, the comprehensive eco-environment index system is somewhat rough due to the environment relevant data limitation in Mongolia. More environment monitoring and evaluating work should be conducted in Mongolia to provide scientific support to the construction of the Belt and Road and the Grassland Silk Road and the healthy urbanization development in Mongolia. The cooperation between Mongolia and China should not only focus on the infrastructure construction, minerals and resources, but also the science and technology field.

5 Conclusions

An empirical quantitative analysis of the coupling coordination degree between urbanization and eco-environment in Mongolia during the period 2000−2016 was conducted in this paper, and it can provide a meaningful insight to achieve the harmonious development of urbanization and the eco-environment in Mongolia. Six-layer eco-city establishing mode was proposed in this paper to provide scientific support for healthy urbanization development in Mongolia.

The results of this study indicated that the coupling coordination between urbanization and the eco-environment in 21 *aimags* provinces of Mongolia are all at the stage of unbalanced development. Only Ulaanbaatar achieved balanced development of urbanization and the eco-environment, but the coupling coordination degree in Ulaanbaatar was just at the stage of barely balanced development. More efforts should be made to transform the 'unbalanced development' into 'superior balanced development' in Mongolia. The southern part of Mongolia central zone should be paid more attention due to the lower degree of coordinated coupling between urbanization and the eco-environment. This region has worse eco-environment endowment and heavier human activities pressure. More pollution reduction and environment protection policies should be implied to develop green urban areas. The demographic urbanization and the eco-environment endowment have greater contributions to the urbanization and the eco-environment. It was urgent eco-environment. It was urgent to improve the utilization efficiency of resource and reduce the pollution emissions. The Belt and Road Initiative and the Grassland Silk Road Initiative are both good opportunities for Mongolia to make cooperation with China in many fields, such as resource and science, to achieve sustainable urbanization development.

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