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Assessment on China's Urbanization after the Implementation of Main Functional Areas Planning

Abstract: China has implemented main functional areas planning (MFAP) since 2010, which is essential for improving the efficiency of land space utilization and achieving sustainable urban development. Quantitative assessments of the urban development levels (UDLs) at the county level across China after the implementation of MFAP have not been well-documented. In this study, a unified indicator system was developed, and the UDLs of 2850 counties in China after MFAP implementation were evaluated. The results showed that MFAP played a positive role in urban development in China. The UDLs in China generally increased but showed obvious spatial differences. The higher UDLs were mostly found in the counties in the five urban belts, which reflects the overall urban layout of China. The UDLs were generally low in the western counties in comparison with those in the eastern part of China. The differences in the UDLs from east to west were greater than those from north to south. Moreover, the differences in the UDLs presented a spatial agglomeration effect. This study could offer insight into the refinement of MFAP in China and sustainable urban development in developing countries.

Key words: Urbanization; Main Functional Areas Planning; Assessment; China; Sustainable development

1. Introduction

China has experienced dramatic urbanization and extensive urban expansion since the reform and opening-up (Wang et al., 2019; Yang and Jiang, 2018) while also suffering increasing population growth and severe resource constraints in the regional environment (Bai, 2014; Gaughan et al., 2016; Li, B. et al., 2016; Li, J. et al., 2018; Long et al., 2018), which results in serious contradictions between plans and maladjusted spatial management (Zhao, Y. et al., 2018). To effectively plan the distribution of the population and economy, improve the efficiency of space utilization and realize the goal of sustainable development, China has implemented main functional areas planning (MFAP) (Fan et al., 2012b; Fan et al., 2019; Liu et al., 2017). Urban development, as one of the critical topics emphasized in MFAP, has sparked increasing attention (Du et al., 2014; Guan et al., 2018).

Urban development is mostly accompanied by population agglomeration, socioeconomic development and urban land expansion (Li, G. et al., 2018; Liu, Y. et al., 2018; Ramachandra et al., 2015; Wang et al., 2019). Researchers have been devoted to evaluating urban development from different perspectives. Numerous studies have focused on comparing the differences in urban development at different territorial levels based on data from multiple years (Bai et al., 2012; Gao et al., 2015; Kuang et al., 2016; Li, G. et al., 2018; Shu et al., 2018; Zhan et al., 2018). Methods such as the comprehensive index system, quadrant plots method, exploratory spatial data analysis, correlation analysis, stepwise regression and the McKinsey matrix have been widely adopted (Chen et al., 2013; Shen et al., 2015; Zhang, W. et al., 2018; Zhang, Y. et al., 2018; Zhao and Wang, 2018; Zhao, Y. et al., 2018). Undoubtedly, scholars have made progress in urbanization evaluations. Since administrative variables play important roles in the management of urban development in developing countries (Fang et al., 2016; Vojnovic, 2014), previous studies must be expanded to understand the strategic requirements of urban development (Fang et al., 2016; li and Liu, 2019; Wang, Z. et al., 2018; Zou et al., 2016). MFAP clearly shows that the core of county-level urban development should focus on concentrated distributions of industry, population and urban spaces (Fan et al., 2012a); however, the county-level urban development across China after MFAP was released has not been systematically quantified (Chen et al., 2013; Fan et al., 2019; Yu et al., 2018; Zhou et al., 2018). The current studies that have evaluated urban development based on county-level units have been mostly restricted to typical areas and depend on multiple indicators (Liu and Wei, 2014; Xiao et al., 2018; Yang and Jiang, 2018; Zhou et al., 2015), making county-level data collection across the whole nation difficult.

The growing interest in evaluating urban development through the consideration of policy demands is also observed worldwide and is mainly focused on the establishment of comparable indicators for sustainable urban assessments (Dhakal and Imura, 2003; Holden, 2006; Klopp and Petretta, 2017; Meijering et al., 2018; Moreno Pires et al., 2014; Yigitcanlar and Lönnqvist, 2013), creation of a global city policy database (Rozhenkova et al., 2019; Townsend, 2015), analysis of official documents (Medina and Huete García, 2019), and design of survey experiments (Pleger et al., 2018). However, quantitative evaluation of urban development across the whole nation linked to policy metrics is still challenging due to a lack of consensus on the correct approach (Hák et al., 2016; Hasan and Satterthwaite, 2005; Parnell, 2016). Given that governance management systems are relatively weak in most developing countries and that disorganized urbanization is increasingly prominent (Bren d'Amour et al., 2017), unified measurements of urban development that translate policy targets are urgently needed (Al shawabkeh et al., 2019; Colléony and Shwartz, 2019; Ouyang et al., 2016; Ramachandra et al., 2015; Yue et al., 2019; Zhang et al., 2012).

Thus, this study attempted to develop unified indicators that could be comparable at the county scale across China, adequately reveal the regional disparity in urban development, and directly inform decision-making in MFAP and the sustainable development in developing countries (Zhang et al., 2015). The specific objectives were 1) to develop an index system for the assessment of urban development levels (UDLs) to satisfy multiple needs of the county-scale spatial units, the accessibility of data and ability to depict policy targets; 2) to assess the temporal changes in the UDLs from 2009 to 2015 in China; 3) to compare multi-scale regional differences in the UDLs in the years 2009, 2012, and 2015; and 4) to propose policy recommendations to serve further urban development and spatial regulation in China.

2. Methodology

2.1 Study area

The study area included 2850 counties, districts and banners, except Hong Kong, Macao and Taiwan, which lack data in China. The "two-horizontal” spatial urbanization pattern (See Fig. S1) included the Asia-Europe and ridge passageway, which starts from Lianyungang city and ends in Alataw pass (H1), and the passageway along the Yangtze River in China (H2). The "three-longitudinal” spatial urbanization pattern included the coastal passageway (L1), the “Beijing-Harbin to Beijing-Guangzhou” passageway (L2), and the “Baotou to Kunming” passageway (L3). In MFAP, the national land was divided into four categories, which are the main functional areas (MFAs) (See Fig.1). The classification of MFAs are displayed in Fig. S2. There are four geographical great-areas in terms of provincial administrative level in China, which are eastern China covers 10 provincial level administrative units (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan), central China covers 6 provincial level administrative units (Shanxi, Henan, Anhui, Jiangxi, Hunan and Hubei), western China covers 12 provincial level administrative units (Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Gansu, Shaanxi, Inner Mongolia, Ningxia, Xinjiang, Qinghai and Xizang)and northeastern China covers 3 provincial level administrative units (Liaoning, Heilongjiang and Jilin).

2.2 Data

The GDP and urban population of each county were obtained from statistical yearbooks. The areas of each county were obtained from the Ministry of Civil Affairs of the People's Republic of China (http://www.mca.gov.cn/). The national and provincial MFAP (2010–2020) was obtained from the official government website (https://www.ndrc.gov.cn/). The construction land areas were interpreted with land use data downloaded from the Resource and Environment Data Cloud Platform, Institute of Geographic Sciences and Natural Resources Research (http://www.resdc.cn/) (see Table S1, S2 for full details). We also carried out field surveys in Ningxia, Shaanxi, Gansu, Fujian, Beijing, Zhejiang, Hainan, Inner Mongolia and Hubei.

2.3 Methods

2.3.1 Comprehensive index evaluation method

The comprehensive index evaluation method is widely used to assess the status of urban development (Bai et al., 2018; Wang et al., 2013; Yu et al., 2014; Zhou et al., 2015). Indexes can reflect the evolutionary process of urban systems that are induced by the dynamic interactions between related human activities (Zhang et al., 2019; Zhao and Wang, 2018). Currently, nationwide assessments on UDLs based on comprehensive index evaluation method is still lacking and the basic unit mostly concentrated at the municipal level and the provincial level (Shu et al., 2018; Zhao and Wang, 2018). Although UDLs assessment at county level on specific provinces have relatively systematic frameworks, it is difficult to scale up single case studies to the whole national due to the limitations on universality of the index system and availability of data (Zhou et al., 2015; Wang et al., 2019). We built on this background and performed our work, which satisfied multiple needs of the county-scale spatial units, data accessibility and the ability to depict the requirements of the UDLs in MFAP. The unified county-level evaluation system, when compared to nation-level and province-level evaluation systems, is advantageous to reflect the UDLs of county-level administrations directly, quantify the regional disparity of UDLs adequately, and realize the connection of macro scale and micro scale on management targets. The evaluation system mainly included 3 main steps.

First, the evaluation indicator system and the county-scale database were developed. Urban development is a complex dynamic process that is accompanied by multidimensional factor changes (Chen et al., 2010; Tan et al., 2018; Xiao et al., 2018; Zhao and Wang, 2018). Previous studies have shown that the evaluation of UDLs mainly focuses on the four dimensions of population growth, economic development, life improvement and spatial expansion (Addanki and Venkataraman, 2017; Chen et al., 2018; Chen et al., 2010; Michael et al., 2014). The selection of the indexes in this study was based on the literature and our repeated understanding of MFAP (Wang et al., 2019). Considering that the areas with high development levels mainly show the characteristics of providing industrial products and service products and having high degrees of population agglomeration and development degree in MFAP, a four-dimensional evaluation system was set up in this paper (see Table 1). Full details about index system can be found in Supplementary materials. Fig. S3 displays the spatial distributions of the third-level indexes. Multicollinearity diagnosis was used to exclude the problem of colinearity. All VIFs of the indicators were lower than 10, implying that there is no collinearity among the indicators (Zhao, J. et al., 2018).

Second, we normalized the indicators into comparable units and computed the weights. Considering that different indicators have different dimensions and magnitudes and different effects on performance evaluation, a normalization process was necessary. The indicators were standardized using Equations (1) and (2) so that all indicators had values between 0 and 1.

For the positive indicators, a larger value indicates an improved urbanization level.

$$X'_{ij} = f_a + (f_b - f_a)\frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}} \tag{1}$$

For the negative indicators, a smaller value indicates an improved urbanization level. Therefore, Equation (2) can be obtained as follows:

$$X'_{ij} = f_b + (f_a - f_b)\frac{X_{\max} - X_{ij}}{X_{\max} - X_{\min}} \tag{2}$$

where f_a and f_b are adjustable parameters that help the gathered distribution normalize values; n is the number of indicators; and m is the number of sample cases;

X_{ij} is the value of index j in unit i; and X_{min} and X_{max} are the minimum and maximum values of index j, respectively. X_{ij}' is the normalized value of index j and ranges from 0 to 1.

In the evaluation indicator system, each indicator plays a role in and contributes to UDLs to varying degrees. It was necessary to determine the weight of each indicator. The entropy method has been widely used in urbanization assessment because it can eliminate expert subjectivity to a large extent (Chen et al., 2010; He et al., 2017; Li and Li, 2014; Li et al., 2012; Liu, N. et al., 2018; Zhou et al., 2015). The entropy method is based on information theory. Information entropy is the measurement of the degree of disorder within a system, which can be further applied to measure the amount of useful information of the data provided (Amiri et al., 2014). The smaller the information entropy is, the lower the degree of disorder in information, the greater the utility value of the information, and the greater the index weights (Liu and Wei, 2014; Zou et al., 2006). According to the entropy value, the weight of the index could be calculated. Thus, the entropy method was adopted to determine the weight of each indicator. The steps were as follows (formulas (3)-(6)):

$$Y_{ij} = \frac{X_{ij}'}{\sum_{i=1}^{m} X_{ij}'} \tag{3}$$

$$e_j = -k \sum_{i=1}^{m} (\mathrm{Y}_{ij} \ln \mathrm{Y}_{ij}) \tag{4}$$

$$d_j = 1 - e_j \tag{5}$$

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{6}$$

where Y_{ij} is the ratio of index j in unit i, m is the number of units to be assessed, k is a constant and $k = \frac{1}{\ln m}$. e_j is the information entropy, which represents the amount of information carried in index j. Specifically, the greater the amount of information, the higher the entropy. d_j is the redundancy of the information entropy, n is the number of indexes, w_j is the weight of each indicator and $\sum w = 1$. The weights of the indicators were listed in Table 2.

Third, we calculated the urbanization development index and assigned the classifications. F_i represents the performance of the urbanization development index, which can be obtained by the following equation:

$$F_i = \sum_{j=1}^{n} x'_{ij} \times w_j \tag{7}$$

Based on the natural breaks criterion and the real conditions of China, F_i can be classified into 5 levels (see Table 3).

2.3.2 Pearson's correlation analysis

To identify whether MFAP contributed to urban development from 2009-2015, Pearson’s correlation analysis was carried out for the correlation between F_i and ranked the urban development functional importance of 2850 counties with SPSS 21.0 software. The rank of urban development functional importance was based on the definitions and requirements of the MFAs. According to the MFAP, the importance of urban development function was generally from high to low in the order of optimal development areas (ODAs), key development areas (KDAs), major agricultural production areas (MAPAs) and important ecological functional areas (IEFAs). Consequently, the numbers “4”, “3”, “2” and “1” were adopted to represent the ranks of the urban functional importance of the ODAs, KDAs, MAPAs and IEFs, respectively. If urban development benefited from the implementation of MFAP, there should be a positive correlation from 2009 to 2015. Two significance levels (0.05 and 0.01) were set, and a two-tailed test was performed.

3. Results

3.1 The impacts of MFAP on urban development

Pearson's correlation analysis showed that there was a positive correlation between F_i and the ranking of urban functional importance of 2850 counties ($P < 0.01$). From 2009 to 2015, the correlation coefficients were listed as 0.419, 0.420 and 0.423, respectively. This indicated that the urban development of ODAs, KDAs, MAPAs and IEFAs was in line with the orientation of MFAP. The MFAP played a positive role in optimizing urban development from 2009-2015 in China.

3.2 Urban development at the national level

As illustrated in Fig. 2, the UDLs in China showed an overall increasing phase. In 2009, the number of county-level administration regions that reached Class I to Class III was 1399, which accounted for 49.09% of the regions. In 2015, this number increased to 1599, which included 56.11% of the total number. In addition, compared to 2009, the number of counties that reached Class IV and Class V decreased by 31 and 231, respectively, in 2015 (see Table S3).

Fig. 3 displays the spatial pattern of the UDLs in China from 2009 to 2015. Overall, the counties in these urban belts, which reflect the overall urban layout of China, showed higher UDLs than those of other regions. In particular, the UDLs rose obviously in the counties of Chongqing, Chengdu, Wuhan, Changsha in H2 and Chongqing, Chengdu, the central parts of Guiyang in L3. In addition, the counties located in Zhengzhou and Xi'an in H1 increased more in higher UDLs. There were no such obvious increases in the counties in Lanzhou, Sining, Urumchi in H1; Harbin, Changchun and Shenyang in L1; and Hohhot and Kunming in L3. The UDLs in county-level administrative areas from 2009-2015 were always high, while the increase in the UDLs was not apparent in the Beijing-Tianjin-Hebei region, Yangtze River delta region and Pearl River delta region in H1. It was observed that the UDLs in the western counties was obviously lower than that in the other three areas, and they were almost all grouped in Class V and had sporadic distributions in the other classes. Conversely, the eastern counties that covered most county-level administrations showed higher UDLs. The increasing rates of county-level administrative units from Class I to Class III in eastern China, central China, western China and northeastern China were 14.93%, 35.32%, 37.81% and 11.94% from 2009 to 2015, respectively.

It is shown in Fig. 4 that the county-level administrations with the Class I urban development level (UDL) were mostly distributed in H2, L1 and L2. Class II was mainly distributed on H1, L1 and L2. Class III covered most regions of H2, L1 and L2. Class IV was mainly distributed in H2 and L2. For Class V, only those in L3 were relatively obvious in 2009. The number of counties whose UDLs belonged to Class

I~III was obviously greater than that in Class IV~V in these five belts. As displayed in Fig. 5, the percentage that the first three levels occupied of the total area of H1, H2, L1, L2 and L3 were 73.52%, 78.78%, 82.35%, 81.78% and 60.00%, respectively, in 2015. When compared to 2009, the increases were 4.07%, 12.17%, 5.93%, 7.32% and 12.91% in Class I to Class III for H1, H2, L1, L2 and L3, respectively (see Table S4).

Fig.6 demonstrates the class variations of the UDLs in the 31 provinces in China from 2009 to 2015. The county-level administrativons that regularly included most of the first UDLs were mainly in Guangdong, Henan, Shandong and Jiangsu. The counties that covered the second UDL were mostly distributed in Hebei, Henan, Shandong, Jiangsu and Anhui. The counties that covered the third UDL were mostly distributed in Sichuan, Hebei, Anhui and Hunan. Class IV was mainly present in Guangxi, Henan and Jiangxi. Class V was mainly distributed in Gansu, Guangxi, Guizhou, Heilongjiang, Qinghai, Shanxi, Shaanxi, Sichuan, Xizang, Xinjiang and Yunnan. In addition, the UDLs in 2015 in some provinces, such as Ningxia and Hainan, increased obviously when compared to those in 2009.

3.3 Urban development at the MFA level

3.3.1 Optimal development areas

The ODAs are an important part of the "two-horizontal" and "three-longitudinal" spatial urbanization patterns in China. Fig. 7 illustrates the UDLs of the optimal development zones in China. From 2009 to 2015, the amount variation in the county-scale administrative units with UDLs ranging from Class I and Class III were 31, -16 and -15, respectively. The corresponding proportional variations were 12.70%, -6.56%

and -6.15%.

3.3.2 Key development areas

The KDAs are the regions distributed in the new spatial pattern of urbanization and have been planned to focus on industrialization and urbanization. As displayed in Fig. 7, the amount of variation in the county scale administrative units with UDLs changing from Class I and Class V was 57, 2, -11, -23 and -25, respectively. The corresponding proportional variations were 9.86%, 0.35%, -1.90%, -3.98% and -4.33%, respectively.

4. Discussion

4.1 Assessment of the UDLs from 2009 to 2015 in China

An evaluation of the policy-related outcomes can shed light on the policy's effectiveness and inform further refinements and management (Al shawabkeh et al., 2019; Liu et al., 2010). The national MFAP indicates that China's spatial governance has transformed towards functional control and upgrades (Fan et al., 2019; Fan et al., 2013). Chinese urbanization processes are facing practical and theoretical challenges that might be more complex than what has been seen previously. Fan et al. (2019) comprehensively described the division process of MFAs and emphasized a timely assessment for responding to the adjustment of MFAP. In this study, we successfully developed a comparable index to facilitate comparisons between counties and to inform the urban management focus for MFAP. County-level administration is an important component of the socio-economic structure and is the basic unit in MFAP in China. MFAP proposed that each county included urban, agricultural, or ecological land space, which determined its corresponding function (Wang, J. et al., 2018). Quantitative evaluation of the UDLs in 2850 counties in this study intuitively reflected the urban functional status and supplemented our understanding of urbanization.

Generally, MFAP has played a positive role in urban development in China. Counties in the "two-horizontal & three-longitudinal” spatial urbanization pattern showed higher UDLs than those of the other regions, implying that the ODAS and KDAs specifically made contributions to urban development (Li et al., 2017; Shahtahmassebi et al., 2018). Land economic density, the degree of population agglomeration, spatial development intensity and UDLs in the five belts in two directions showed different increases from 2009 to 2015, further suggesting that a noticeable and centralized urban pattern has primarily been constructed in China. However, differences among the regional scales still need to be addressed.

The differences in the UDLs in the east-west direction were greater than those in the north-south direction in China. The proportions of UDLs ranging from Class I to Class III in the five belts in MFAP from the maximum to minimum were L1, L2, H1, H2 and L3 in 2015, while the corresponding increments were L3, H2, L2, L1 and H1 from 2009 to 2015. More efforts would be made in MFAP to narrow the gaps between the UDLs, especially in L3 and H2. The land economic density on H1 increased more apparently than the degree of population agglomeration and spatial development intensity in H1 from 2009 to 2015. This was likely due to the optimization of the population distribution and the control of built-up area expansion in the ODAs, which was consistent with the requirements in MFAP. This aligned with Liu et al. (2017a).

Class I was mostly distributed in the relatively developed H2, L1 and L2 in the five belts. H2 covers three urban agglomerations in the Yangtze River delta, the middle Yangtze River basin and the Chengdu-Chongqing region, where the counties with Class I UDLs in 2015 accounted for 52.4%, 22.79% and 17.69%, respectively. The gradual development of the Yangtze River Economic Belt, which accounts for 21% of the total area and more than 40% of the total population and GDP in China, was an important contribution (Liu, Y. et al., 2018). The developed eastern provinces, such as Beijing, Tianjin, Shandong, Shanghai and Jiangsu, that were included in H2, L1 and L2 also offer insights into the highest UDLs (Zhang, W. et al., 2018); the respective proportions of the counties with Class I UDLs were 62.5%, 75%, 100%, and 56.25%. The counties in H2, L1 and L2 contain the majority of the ODAs and KDAs. Even though there were also KDAs on H1 and L3, no ODAs were found, and coupling effects are lacking. The Class II UDLs cover most of the regions in H1, L1 and L2. Unlike H2, H1 covers a longer distance across the east and west, and apparent spatial disparities were present in the UDLs. Class III was mostly distributed in H2 and L2, especially the counties in Harbin, Shenyang and Changchun in the northeast and Chongqing, Chengdu, Wuhan, Changsha and Nanchang. The decrease in the proportion of Class IV on L2 further indicated that the cities, where the horizontal and vertical axes intersected, played key roles in the promotion of the UDLs. The decrease in Class V in L3 after 2009 implied a faster pace of urbanization in the central and western counties. This was consistent with the results of similar studies that supported of urban expansion (Zhao et al., 2015).

There was a gradual reduction in the distribution with a narrowing gap between the UDLs in the east and those in the west. The proportions of the top three levels of UDLs in the four regions from the maximum to minimum were the eastern counties, central counties, western counties and northeast counties in 2015, while the corresponding increments were listed as the western counties, central counties, eastern counties and northeast counties from 2009 to 2015. Because of the greater area and long-term backward urban development of the western region, more efforts need to be devoted to improving the UDLs in the KDAs of the Lanzhou-Xining area, the northern hillslope area of the Tian Shan Mountains and central-southern Tibet, central Yunnan Province and the "Hohhot, Baotou and Ordos" region. The UDLs in provinces with the top three UDLs were distributed in coastal areas. This was likely due to the existence of a relatively long development history of urbanization in the eastern counties in the ODAs (Fang et al., 2016). However, the concomitant small increment further indicated that although massive urban development has been controlled in the ODAs, the overpopulation and economic volumes still cannot be neglected (Chen et al., 2018). The percentage of counties in the top three UDLs in the KDAs of the Harbin-Changchun area decreased by 11.43% from 2009 to 2015. Although China has made efforts to revitalize the northeastern provinces in recent years, improving the traditional industrial structures in KDAs remains challenging (Mao et al., 2019). The county-level administrative units in capital cities such as Xi'an, Wuhan, Changsha, Zhengzhou and Chengdu played important roles in contributing to the rise in the UDLs (Bai et al., 2018). Meanwhile, these counties were KDAs as well as nodes in the "two-horizontal & three-longitudinal" urbanization spatial pattern, and the induced effect of radiation became obvious. This was consistent with the idea in MFAP and the new urbanization plan released in 2014 by China's National Development and Reform Commission (li and Liu, 2019). The apparent increase in the UDLs in Ningxia and Hainan also indicates that the pilot provinces in MFAP had made progress. Urban-rural development gaps still exist in provinces such as Sichuan, Henan and Anhui.

The regions were not isolated, and the differences in the UDLs among regions presented a spatial agglomeration effect (Li, H. et al., 2016), which was closely related to spatial distance, traffic conditions, and population flow. Without sound transportation networks, it may take longer for materials and the population to flow between distant regions, which restrains the development of regional linkages (Chandra and Vadali, 2014). However, the agglomeration features are unidirectional and polarizing. The land economic density, degree of population agglomeration and spatial development intensity were highly concentrated in the eastern counties, such as the Beijing-Tianjin-Hebei region, Yangtze River delta and Pearl River Delta. The area around these regions presents moderate population concentration levels. For instance, H2 is an important part of the Yangtze River Economic Belt, and an obvious core-periphery spatial structure exists in the Yangtze River delta and the Chengdu-Chongqing region. However, the structure could not be clearly captured in the urban agglomeration in the middle reaches of the Yangtze River. Jin et al. (2018) also found that urbanization efficiency presented a “bar-like” distribution across the Yangtze River Economic Belt and suggested a balanced level of development within the middle and lower reaches of this economic region. In western regions far from coastal areas, the agglomeration effect was either very weak or not concentrated. The depressed economic and infrastructural conditions, along with the greater employment opportunities in cities, induced mass population migration from rural to urban areas (Fang et al., 2016; Li, Y. et al., 2018). This further suggests that efforts for traffic improvement can potentially promote the development of transportation networks (Luo and Shen, 2009).

In terms of governance, an extremely important aspect for nationwide environmental management is the efficient implementation of rigid macro-strategic targets in micro-administrative cells, which has still been a longstanding challenge in China. This study offered insights into filling this gap and developed links between county level management and national or provincial governance. Managers can not only recognize the quality of urbanization nationwide but also can identify the problem at the county level, and make timely adjustment to adapting the national intent. However, the limitations of the environmental management is that this kind of assessment mechanism is still not perfect yet and needs to be developed in a regular manner to respond to future urban development trends in China. This study used China as a case study, and it also provided insights into the achievement of sustainable urbanization that could guide other developing countries. Problems caused by rapid urbanization commonly exist in cities in the developing world, such as India (Ramachandra et al., 2015), Brazil (De Oliveira et al., 2019) and Egypt (Abd-Elmabod et al., 2019). Although the specifics will probably differ between countries and spatial scales, the demand for detailed nation-scale assessments on the UDLs to support target setting are likely to be common. Hence, the idea and proposed method can help comprehensively evaluate the urbanization process, recognize the cause of depressed urbanization practices, and inform decision-making to develop suitable strategies towards orderly urban development in these countries.

4.2 Policy recommendations

To elevate the construction of the "two-horizontal” spatial urbanization pattern and to improve the effectiveness of MFAP, future decision-makers should adequately consider county-level differences in the UDLs of the MFAs. Policy recommendations to help end the traditional “one size fits all” policies for China’s urban development and land space management:

(1) It is suggested to promote industrial and spatial optimization in the coastal passageway (L1), especially in the ODAs. The Chinese government should relieve stress from excessive agglomeration of the population and economy of the ODAs in the Beijing-Tianjin-Hebei region, the Yangtze River delta and the Pearl River delta. It is imperative that high-tech industries and advanced manufacturing bases be constructed to attract labor transfers in the counties near Beijing, Shanghai and Guangzhou. To strictly control the expansion of new built-up areas, demarcation of the boundaries of urban development is urgently needed. A list of areas where industrial access is banned is considered a feasible supplement to promote the upgrading of the industrial structure.

(2) Regional cooperation and linkages must be improved in the passage along the Yangtze River (H2). To foster the rise of the central region, the KDAs in the middle reaches of the Yangtze River in H2 still need more inter-province cooperation among Hubei, Hunan and Jiangxi. Constructing a three-dimensional traffic network is

suggested to promote interconnected development among the urban agglomerations. It is highly recommended to speed up the construction of the ports in Wuhan, Changsha, Hefei and Nanchang along the Yangtze River waterway.

(3) Strengthen the external investment and infrastructural construction in the KDAs in the western Asia-Europe land bridge (H1) and the endpoints of the "Baotou to Kunming" passageway (L3). An "overall protection and local development" mode should also be developed. It is imperative to improve the construction of infrastructure and public service facilities in the western KDAs. Government investments in the industrial development of the KDAs should focus on the processing of agricultural and livestock products in the central-southern region of Tibet, energy trading with central Asia in the northern hillslope area of the Tian Shan Mountains, new material processing in the Lanzhou-Xining area, tourism in central Yunnan Province, etc.

(4) Attention should be paid to the development transformation of the old northeastern industrial base in the "Beijing-Kazakhstan to Beijing-Guangzhou" passageway (L2). The combination of new technologies such as big data and artificial intelligence with the traditional manufacturing industry and new industries such as ecological agriculture are recommended for the KDAs in the Harbin-Changchun area. Economic cooperation between Northeast China and the other countries in Northeast Asia and the economic corridor among China-Mongolia-Russia are also suggested.

5. Conclusions

In this study, a comprehensive evaluation system reflecting the UDLs reflecting the UDLs throughout the 2850 county-level administrations in China was successfully developed. UDLs from 2009-2015 after the implementation of MFAP was assessed. The main conclusions were as follows. The UDLs in China showed a generally increasing trend from 2009 to 2015. The regions in the five main urban belts presented higher UDLs under the combined action of population, space and the economy. The counties in the nodes of the urbanization spatial pattern, especially the ODAs and KDAs, significantly contributed to urban development. However, there were obvious spatial differences in the UDLs. The differences in the UDLs in the east-west direction were greater than those in the north-south direction in China. The proportion of counties whose UDLs ranged from Class I to Class III in the five belts and 31 provinces indicated a gradual reduction in the distribution but a narrowing of the differences between the east and the west. Moreover, the differences in the UDLs were linked to a spatial agglomeration effect, especially in the Yangtze River Economic Belt. This was mainly attributed to the effects of transportation and infrastructure. Finally, important policy implications for China's further urban development and land space management were inferred.

Overall, the implementation of MFAP has met its objectives in improving urban development in China. However, regional disparities in the UDLs still need to be addressed. Measures to refine management in MFAP should continue to advance to lead to fundamental improvement in China's sustainable urban development. The limitations of this study lie in data acquisition. Due to the availability of county-level data, indicators reflecting environmental elements such as wastewater discharge volume and air quality index were not included. In addition, because the publication of the statistical yearbooks lags behind the current time period, an efficient data mining method should be developed to reflect the dynamic changes in the UDLs in future studies. The development of an information platform combining a database and evaluation method is suggested for periodic assessment of urban development.

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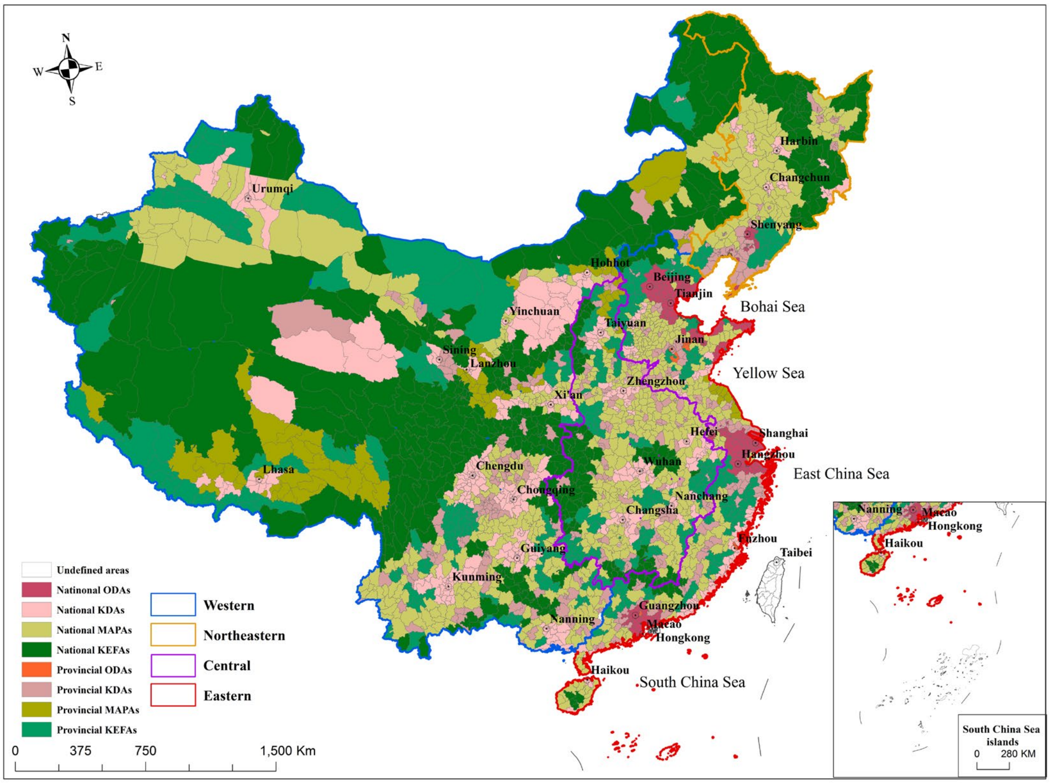

Fig.1. Main Functional Areas in China (Note: ODAs, KDAs, MAPAs, KEFAs represent Optimize development areas, Key development areas, Major agricultural production areas, and Key ecological functional areas in MFAP). *(TIFF format, 140 mm * 105 mm, 1000 dpi, 1.5 column fitting image)*

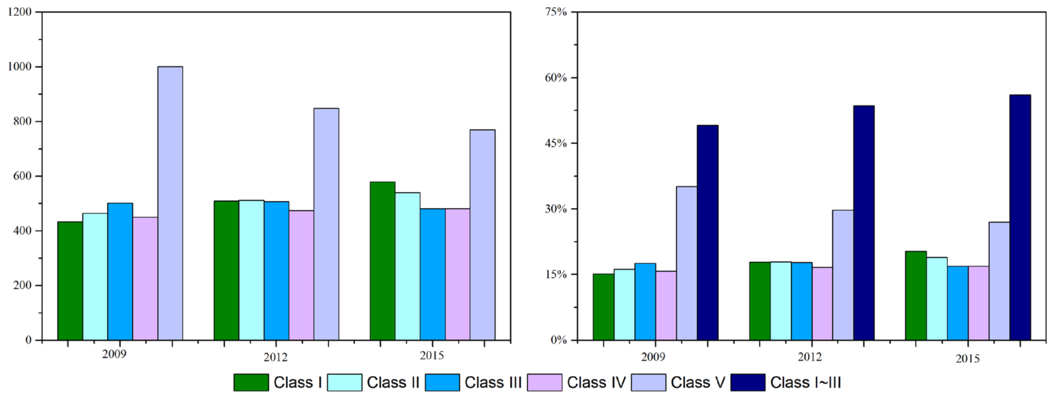

Fig. 2. UDLs from 2009 to 2015 in China. *(TIFF format, 140 mm * 54 mm, 600 dpi, 1.5 column fitting image)*

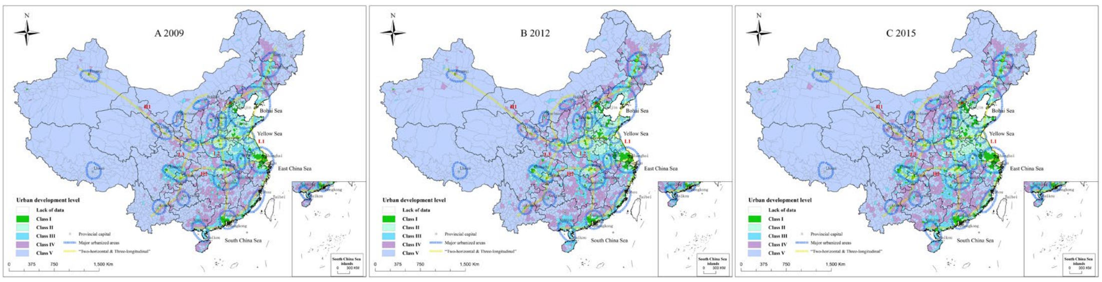

Fig. 3. Spatial distribution of UDLs from 2009-2015 in China. （Note: The notifications on the map expressed as “H1”, “H2”, “L1”, “L2”, “L3” represent the five belts in horizontal and vertical directions of the “two-horizontal and three-longitudinal” urbanization spatial pattern）*(TIFF format, 190 mm * 50 mm, 1000 dpi, 2.0 column fitting image)*

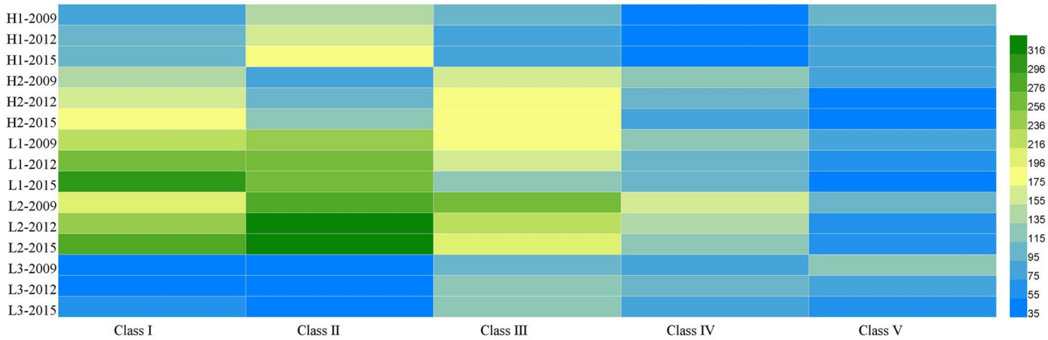

Fig. 4. Number distribution of UDLs in the spatial pattern of “two-horizontal and three-longitudinal” urbanization during 2009-2015 in China. *(TIFF format, 140 mm * 47 mm, 600 dpi, 1.5 column fitting image)*

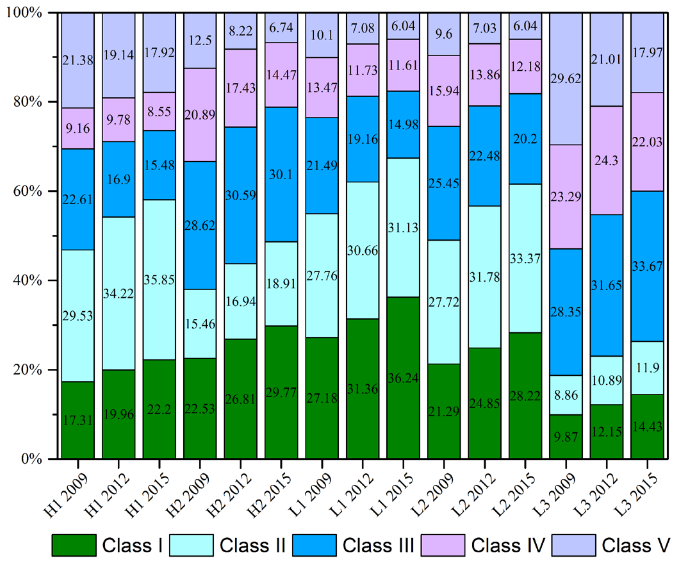

Fig. 5. Percentage distribution of UDLs in the spatial pattern of “two-horizontal” and “three-longitudinal” urbanization during 2009-2015 in China. *(TIFF format, 90 mm * 75 mm, 600 dpi, single column fitting image)*

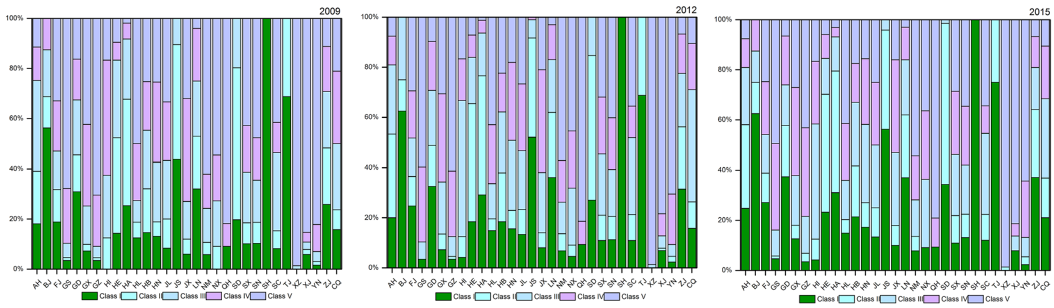

Fig. 6. Ratio variations of UDLs in the 31 provinces.

（BJ=Beijing, TJ=Tianjin, HE=Hebei, SD=Shandong, LN=Liaoning, JL=Jilin, HL=Heilongjiang, SH=Shanghai, JS=Jiangsu, ZJ=Zhejiang, FJ=Fujian, GD=Guangdong, HI=Hainan, AH=Anhui, SX=Shanxi, JX=Jiangxi, HA=Henan, HB=Hubei, HN=Hunan, GX=Guangxi, CQ=Chongqing, SC=Sichuan, GZ=Guizhou, YN=Yunnan, NM= Inner Mongolia, SN=Shaanxi, GS=Gansu, QH=Qinghai, NX=Ningxia, XJ=Xinjiang）*(TIFF format, 140 mm * 41 mm, 600 dpi, 1.5 column fitting image)*

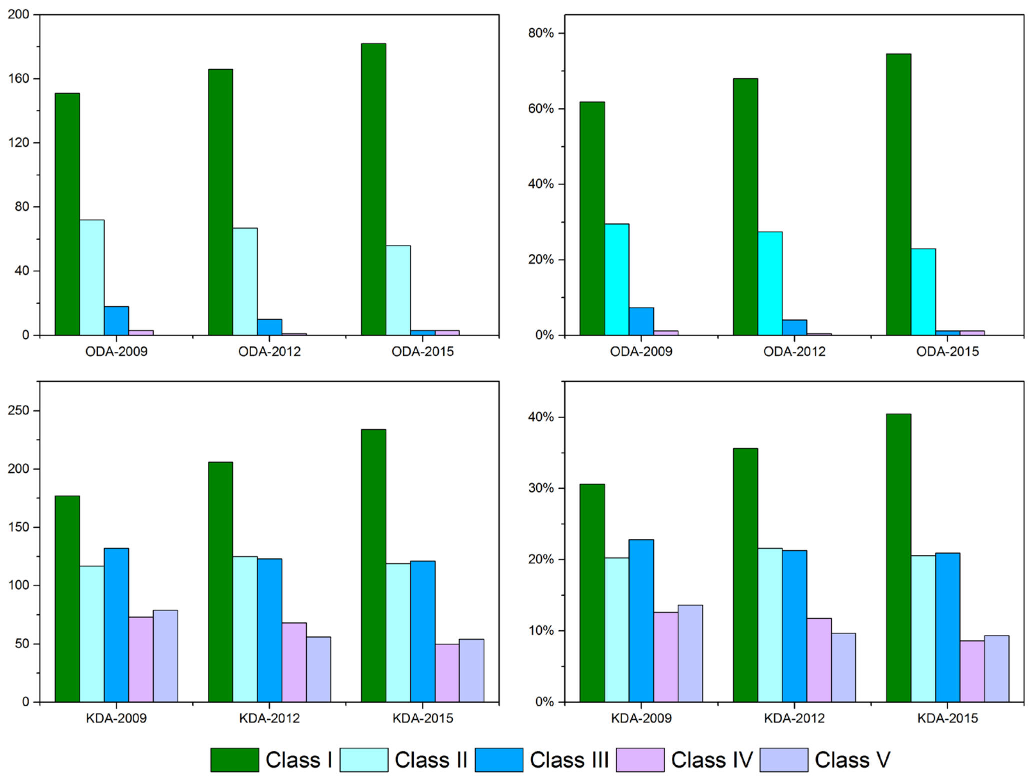

Fig. 7. Grade variations of UDLs in ODAs and KDAs. *(TIFF format, 140 mm * 105 mm, 600 dpi, 1.5 column fitting image)*

Table 1 UDLs assessment index system

First-level	Second-level	Third-level	Fourth-level
UDLs	Industrial products and services products	Land economic density	GDP (10,000 yuan) Areas of county level administrations (km^2)
	Population	Population agglomeration degree	Urban population (10,000 people) Areas of county level administrations (km^2)
	Urban space	Space development intensity	Construction land (km^2) areas of county level administrations (km^2)

Table 2 Weights of indicators

Third-level indicators	Effect direction	Weights
Land economic density	+	0.3696
Population agglomeration degree	+	0.3303
Space development intensity	+	0.3001

Note: "+" represents positive indicators. "-" represents negative indicators.

Table 3 Classification criteria for UDLs

Classification	Value of F_i	UDLs
Class I	$F_i \geq 70$	very high
Class II	$70 > F_i \geq 65$	high
Class III	$65 > F_i \geq 60$	medium
Class IV	$60 > F_i \geq 55$	low
Class V	$F_i < 55$	very low