

***Research on the Classification and Evaluation of Production-living-ecological Space in China Based on Land Use Functions***

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**Abstract**

Optimizing production-living-ecological space has become one of the cores of China's ecological civilization and sustainable development strategy, and it is also a crucial goal of land use and management in China. Constructing and identifying a land use evaluation index system based on production-living-ecological space is of great importance to sustainable land use in China. The concept of land use functions can be defined as goods and services provided by different land use types, including production, living, and ecological functions. These functions accord with the purpose of identifying production-living-ecological space. However, few studies have focused on the identification and evaluation of production-living-ecological space from the perspective of land use functions and multifunctionality. In this study, literature review methods, comparative analysis, and induction were performed to discuss the conceptual and logical connection between production-living-ecological space and land use functions, and a framework to identify and evaluate the production-living-ecological space was constructed based on the multifunctional land use framework. Taking Yubei District of Chongqing, China as a case study, this study will provide a reference for promoting the coordinated development among production-living-ecological functions and creating a reference for sustainable land use in China, especially in urban fringe areas facing rapid urbanization.

Keywords: Production-Living-Ecological Space, Land Use Functions, Evaluation, Yubei District

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## Introduction

Land use involves technological and biological activities by humans for social and economic purposes and is a long-term or cyclical operation of land (Liu, Fang and Li, 2014). As an indispensable part of sustainable development, sustainable land use has risen to a universal goal for planners across the globe (Foley et al., 2005; Lambin et al., 2001; Turner, Lambin, & Reenberg, 2007). Amid the economic boom that China experiences now, poorly organized land use activities resulted in a colossal waste of resources, excessive urbanization, ecological deterioration and a slew of environmental and social ills (H. Zhang et al., 2016), thereby holding off efforts towards sustainable development.

Land is a multi-functional comprehensive system. As a crucial carrier of human life, land provides a series of services and goods, which are referred to as land use functions (LUFs). LUFs summarize the most relevant economic, societal, and environmental aspects of a specific region, and is an important issue to realize the meaning of sustainable land development (Wiggering et al., 2006). A vital step to realize sustainable land use is to determine the multiple functions of land use and evaluate these functions according to the specific geographical environment (Wiggering, Müller, Werner, & Helming, 2003). In the evolution of the LUFs concept, research on LUFs mainly includes the definition, classification and evaluation, indicator systems of LUFs. The research on land use function mainly focuses on economic, social and environmental dimensions.

Multifunctionality is a concept which is regarded as an useful way to the sustainable land use (Hagedorn, 2007). The concept of LUFs originated from the agricultural system (Helming et al., 2008), and was proposed initially by (OECD, 2001) as a concept related to the jointness of agricultural production. Within the LUFs and multifunctionality concept, it is believed that LUFs can be attached to land use types, for instance: forest land may have ecological functions (supporting biodiversity, regulating air and water) as well as economic and social functions, such as providing wood, as a cultural landscape (Pérez-Soba et al., 2008). Therefore, land use typologies and LUFs are not one-to-one correspondence, but a complex many-to-many relationship (Figure 1).

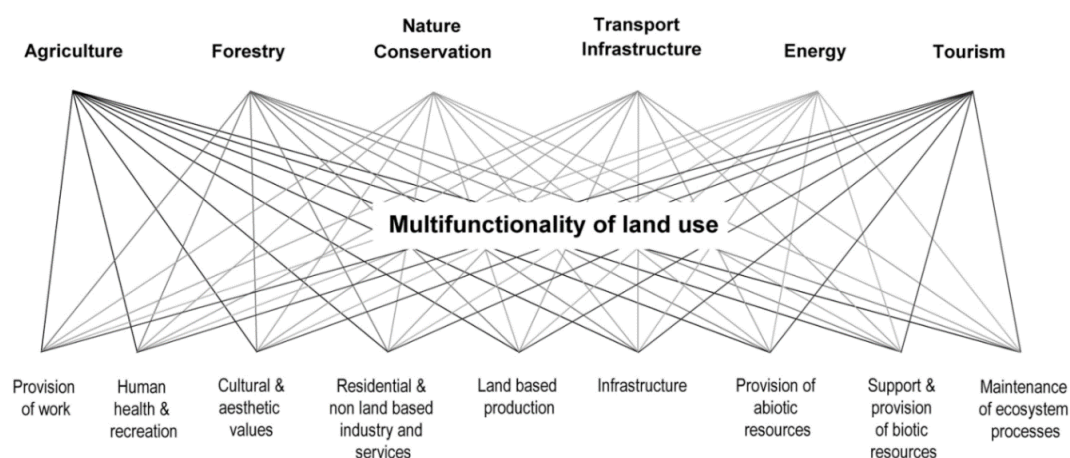


Figure 1: Many-to-many relationship between land use typology and land use functions (Adapted from Helming et al. 2008 & Schöber, Helming, and Wiggering, 2010)

Based on the idea of LUFs, the Chinese government has begun to generate a new notion aiming to classify production land, living land and ecological land in the process of land use management, and the concept of the “production-living-ecology space” (PLE space) is developed. PLE space has become one of the core discourses of land use in China, and is considered to be able to tackle sustainable land use issues. The report of the 18th National Congress of the Communist Party of China (2012) pointed out that China should ensure “the space for production is used intensively and efficiently, that the living space is livable and proper in size, and that the ecological space is unspoiled and beautiful”. Identifying, evaluating and optimizing the PLE space has become one of the important contents of sustainable land use in the context of ecological civilization.

The PLE space proposed by the Chinese government refers to the production space, living space, and ecology space, respectively, and the name of each space is according to its primary function (Peng, Wang, & Chen, 2019). In recent years, with the popularity of the “three pillars” theory of sustainable development, many Chinese scholars have focused on bridging LUFs with the Chinese concept “PLE space” (Fan et al., 2018; Liao et al., 2019; Xi, Zhao, Ge, & Kong, 2014; Yang, Bao, & Liu, 2020; Yu, Xu, Zhang, & Shang, 2020; Zhou, Xu, & Lin, 2017; Zou et al., 2020). Combining these two concepts and in reference to the definition of LUFs, several studies on PLE space have launched and the concept of PLE space is defined from multiple perspectives.

G. Li and Fang (2016) believe that the PLE space covering biophysical process, direct and indirect production, as well as satisfactions of spiritual, cultural, leisure, and aesthetic needs, is the product of synergistically coupling natural systems and social economic systems. Fan et al. (2018) insist that the PLE space, as a comprehensive partitioned mode of land utilization, and is a core part of optimally allocating China's land spaces guided by the goal of sustainable development. A. Huang et al. (2020) conclude that the PLE space is a functional space that is partitioned in accordance with various products and services offered by the land for human beings. As for J. Huang, Lin, and Qi (2017), production space is an area with a dominant function of providing industrial products, agricultural products and servicing products; living space is an area that is dominated by providing human settlement, consumption, relaxation and entertainment; and ecological space is an area dominantly offering ecological products and ecological services, which plays a vital part in regulating, maintaining and safeguarding regional ecological security. Identifying the primary functions of different land use patterns is the key to the classification of PLE space (Liao et al., 2019). Based on the previous studies, this study listed the definition of production, living and ecological functions under the concept of PLE space (Table 1).

Table 1: Definition of production, living and ecological functions under the concept of PLE space

PLE criteria	space	Function criteria	Definition
Production space		Production function	Production space is an area with a dominant function of providing industrial products, agricultural products and servicing products. (Fan et al., 2018; Jin, He, Wang, & Gong, 2018).
Living space		Living function	Living space refers to an area that is

Ecological space	Ecological function	<p>dominated by providing human settlement, consumption, relaxation and entertainment. (De Groot, 2006; Geoghegan, 2002; Plantinga &amp; Miller, 2001).</p> <p>Ecological space is an area dominantly offering ecological products and ecological services, which plays a vital part in regulating, maintaining and safeguarding regional ecological security. (De Groot et al., 2012; MEA, 2005).</p>
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To sum up, land use spaces are partitioned according to the multifunctionality of land use in the PLE space. Since the PLE space is an important strategy for optimizing and managing national land space in China, the key to identifying the PLE space is to qualitatively or quantitatively identify primary and subfunctions of the space based on LUFs upon taking into account multi-functions of the land. Besides, primary functions of the land should be highlighted with the consideration of subfunctions while partitioning the PLE space as land use typologies may either have a single function, or any combination of production, living and ecological functions. Few previous studies have focused on the identification and evaluation of production-living-ecological space from the perspective of LUFs and multifunctionality.

Thus, the aim of this research is to discuss the conceptual and logical connection between the Chinese notion “PLE space” and international concept “LUFs” and identify and evaluate PLE space from the perspective of LUFs. Based on the latest Land-Use Classification guidance (GB/T21010-2017), this research provides a new reference for China’s PLE space identification and evaluation. And taking Yubei District of Chongqing as a case study, this research analyzes the spatial-temporal evolution of PLE space from 2009-2018.

## Methodology

### *- The framework of PLE space classification system*

Based on the definition of LUFs, multifunctionality, and PLE space, this paper defines a classification framework. In figure 2, different types of land use constitute different land use patterns. The goods and services provided by different land use structures are quite different, which forms the spatial differences of LUFs. Under the regional primary function, the spatial pattern of PLE space has been formed. Taking multifunctionality into consideration, the PLE space were first divided into 9 categories according to the ability of providing goods and services.

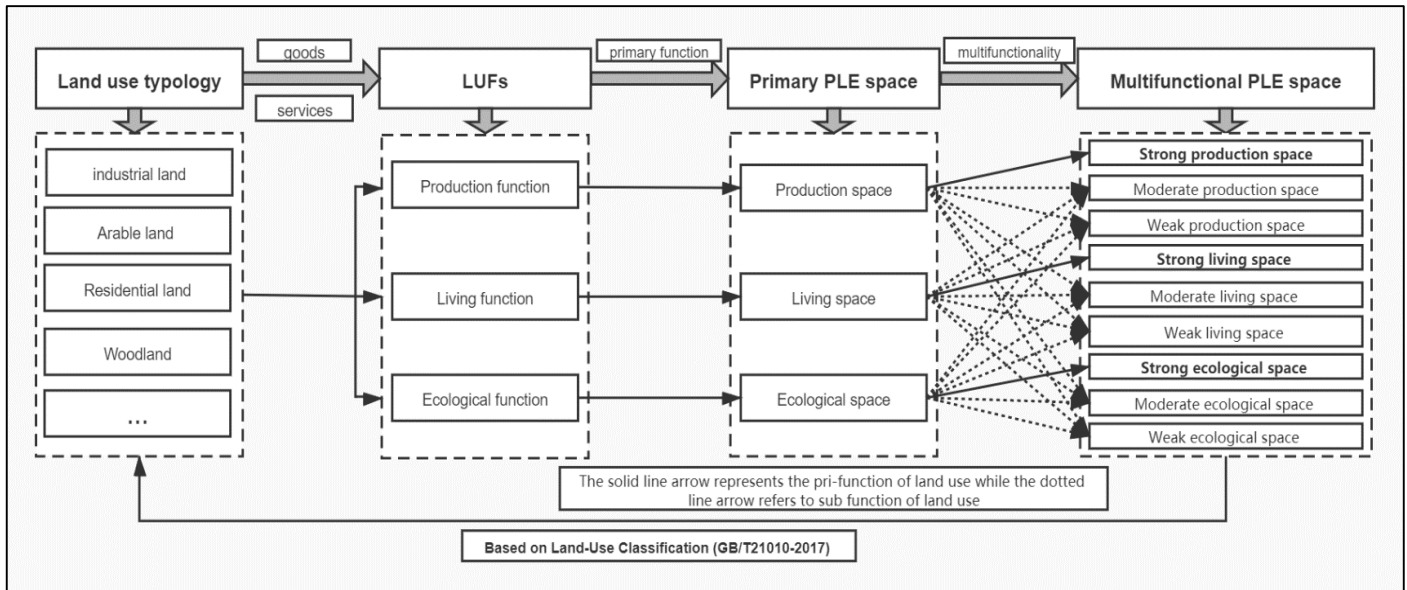


Figure 2: The framework of PLE space classification system

According to the Current Land-Use Classification (GB/T21010-2017) proposed by the Ministry of Natural Resources of the People's Republic of China, the detailed PLE space based on land use typologies is shown below (Table 2). The 1st class land use type and 2nd class land use type are consistent with the land use type in GB/T21010-2017.

Table 2: Classification system of PLE space based on Current Land-Use Classification (GB/T21010-2017)

PLE space	1st class land use type	2nd class land use type
strong production space	commercial services	retail commercial land wholesale market land catering land lodgings commercial and financial land recreational land other commercial services
	industrial and mining warehouse	industrial land mining lease salt fields warehousing land
	transportation	land for railway land for rail transit land for highways land for roads in urban villages land for transportation service station rural roads land for the airport harbor land pipe land

	land for water area and water conservancy facilities	land for hydraulic construction
moderate production space	arable land	paddy field
		irrigated land
	garden	the dry land
		the orchard
		tea garden
		rubber plantation
		other garden
	public management and public service land	public management and public service land
		land for press and publication
		land for education
		land for science
		medical and health land
		social welfare land
		cultural facilities land
		sports land
		public facilities land
		ditch
	land for water area and water conservancy facilities	scenic facilities
	special land	facility farmland
	other land	ridge of field
weak production space	the grass	natural grassland
		artificial grassland
	land for water area and water conservancy facilities	the reservoir of the water
strong living space	residential land	pond water surface
		town house
	special land	house-site at countryside
		military facilities
		embassies and consulates land
		the sites of superintendent's premises
		religious land
		land for the funeral
moderate living space	public management and public service land	scenic facilities
		public management and public service land
		land for press and publication
		land for education
		land for science
		medical and health land
		social welfare land
		cultural facilities land
		sports land
		public facilities land
		parks and green space
weak living space	commercial services	retail commercial land
		wholesale market land

strong ecological space	woodland	catering land
		lodgings
		commercial and financial land
	the grass	recreational land
		arbor forest
		bamboo forest
	land for water area and water conservancy facilities	mangrove forest
		forest swamp
		shrub land
	other land	shrub swamp
		other woodland
		natural grassland
	land for water area and water conservancy facilities	swamp grassland
		artificial grassland
		the river of the water
other land	the lake water	
	coastal beach	
	inland tidal flat	
moderate ecological space	arable land	marshland
		glaciers and permanent snow cover
		idle land
	garden	saline alkali land
		sand
		bare land
	other land	bare rock gravel land
		paddy field
		irrigated land
	public management and public service land	the dry land
		the orchard
		tea garden
	land for water area and water conservancy facilities	rubber plantation
		other garden
		ridge of field
weak ecological space	the grass	parks and green space
		the reservoir of the water
		pond water surface
	public management and public service land	ditch
		facility farmland
		artificial grassland
	land for water area and water conservancy facilities	parks and green space
		the reservoir of the water
		pond water surface
	other land	ditch
		facility farmland

*- The evaluation principle*

Based on previous studies conduction research on PLE space or LUFs evaluation, this research defined an evaluation principle. 5, 3, 1 and 0 points to a strong, moderate, weak

and non-existent function (Dong, Zhang, Si, Tong, & Na, 2020; Liu, Liu, & Li, 2017; X. Zhang, Zhu, & Xu, 2014). For instance, for paddy field (1st land use type is arable land), which has moderate production function, non-living function, and moderate ecological function, will be given the evaluation points 3, 0, 3, respectively.

### - Study area and materials

Chongqing, an economic hub along the Yangtze River in China, has witnessed rapid economic and social development since being approved as a municipality directly under the central government in 1997. Compared with the metropolis in Eastern China, Chongqing's economic development potential is greater, the demand for construction land is higher, and the degree of land use change is expected to be more intense in the next few years. Thus, the sustainable development of land use is essential for the development of the region.

Yubei District (106°27'30"–106°57'58"E, 29°34'45"–30°07'22"N) is located in the northeast of the urban area of Chongqing City (Figure 3). As one of the nine main city districts of Chongqing, it is a transitional zone between downtown and suburbs of Chongqing. Yubei District has a total area of 1457.07 km<sup>2</sup>. The south-west of its jurisdiction is located in the downtown area of Chongqing, which is defined as the core industrial area of Liangjiang New Area (LJNA), a national new district, by the government. The northeast consists of about 1000 km<sup>2</sup> of rural areas. This region is adjacent to Chongqing's core metropolitan area (downtown) and extended metropolitan function area (mainly rural areas at present) and is a typical urban fringe area (Yilong Li et al., 2018).

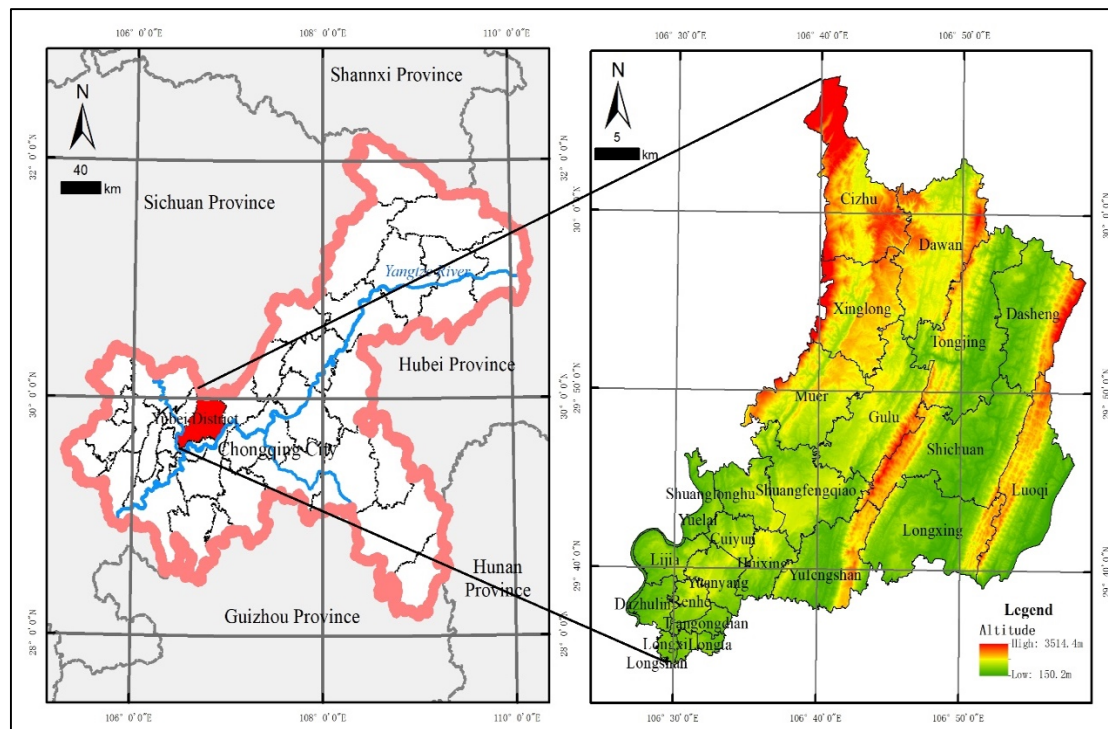


Figure 3: Location of Chongqing and Yubei District

Although there are several areas in Chongqing that can be identified as a urban fringe region, for this study, we selected the most populated and fastest growing part of



Chongqing city. In 2018, both the number of permanent residents and the GDP of Yubei District ranked first among all Districts/Counties of Chongqing (Chongqing Statistics Bureau, 2019). In recent years, due to the government's northward development strategy and the development of LJNA, the social and economic development of Yubei District speeds up and urban construction land has expanded rapidly to meet the needs of industrial economic development.

In terms of data and sources, the spatial data and statistical data of land use in Yubei District (the year of 2009, 2018), documents and maps of land use planning in Yubei District, and urban planning map are derived from the Bureau of Natural Resources of Yubei District. Digital elevation map of Yubei District is got from Geographic Information Centre of Chongqing. The satellite image (for reclassification) is downloaded via Google map.

### *- Methods*

In this study, literature review methods, comparative analysis, and induction were performed to discuss the conceptual and logical connection between PLE space and LUFs, and a framework to identify and evaluate the production-living-ecological space was constructed based on the multifunctional land use framework.

To better understand the spatial and temporal evolution of PLE space in Yubei District, the study mapped the spatial distribution of PLE space via the software ArcGIS 10.3. Since the existing land use data classification method has not been unified with GB/T21010-2017, the land use data in 2009 and 2018 were reclassified based on the historical remote sensing images in google map, planning documents and field investigation of Yubei District.

In addition, the dynamic index of PLE space and the transformation of weighted center of gravity are used to track the changing trend and compare the distributions of PLE space from 2009-2018. The dynamic index of PLE space can be conducted to describe the change speed of regional PLE space in a quantitative way (Yafei Li, Liu, & Huang, 2017). The formula of the dynamic index of PLE space is given as:

$$K = \frac{S_b - S_a}{S_a} \times \frac{1}{T} \times 100\% \quad (1)$$

In this equation,  $S_b$ ,  $S_a$  are the area of a certain PLE space category at the end and beginning year of the research, respectively, and T refers to the length of the research period.

The concept of gravity center originated from physics (Z. Li, Jiang, Wang, Lei, & Deng, 2019). In this paper, the theory of gravity center was used to analyze the spatial development and gravity center of PLE space and determined the changing track of PLE space in the research period. The formula of weighted center of gravity is:

$$\begin{aligned} X_w &= \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i} \\ Y_w &= \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i} \end{aligned} \quad (2)$$

Where  $x_i$  and  $y_i$  are the longitude and latitude coordinates of the center,  $X_w$  and  $Y_w$  represent the longitude and latitude coordinates of the gravity center of PLE space.

## Results and Discussion

### - The Spatial Distribution of PLE space in Yubei District

Strong production spaces of Yubei District expanded from the southwest to the northeast between 2009 and 2018 (Figure 4). The original moderate production spaces were replaced by strong production spaces while the locations and areas of non-production and weak production spaces barely changed.

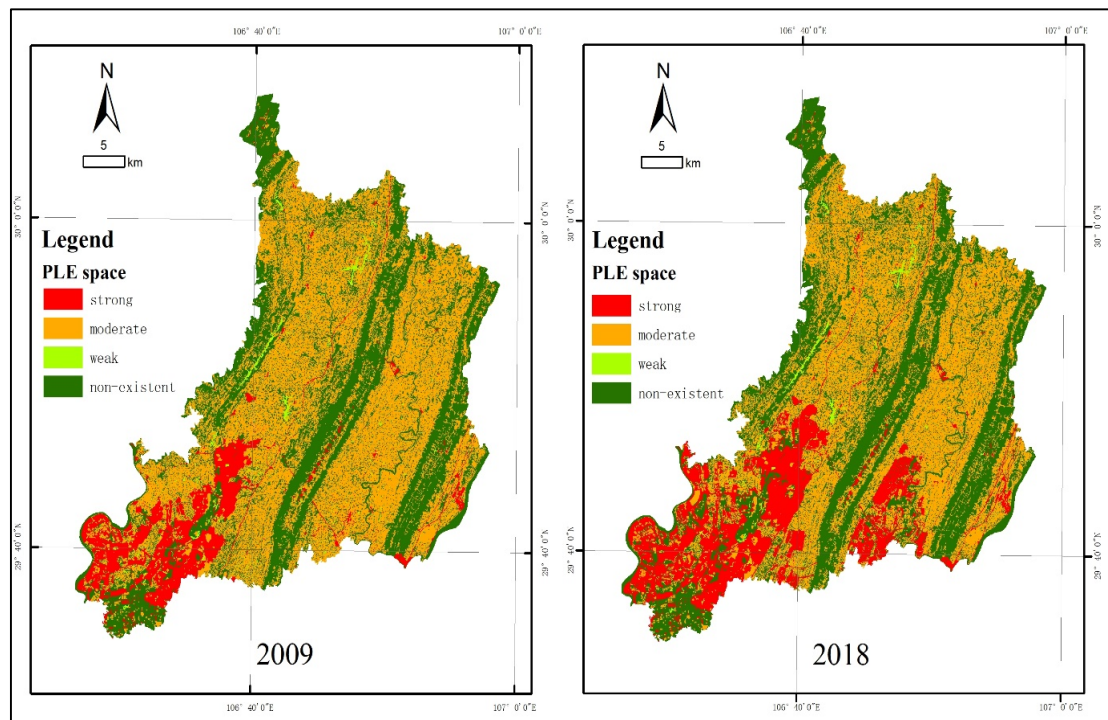


Figure 4: Spatial distribution of production space of Yubei (the year 2009 and 2018)

Living spaces of Yubei District during the research period saw significant changes (Figure 5). Strong, moderate, and weak living spaces all increased. Newly increased strong and moderate living spaces were mainly concentrated in the urbanized area of Yubei District and distributed around the strong production space. Whereas the increased moderate and weak living spaces were mainly distributed in LJNA where is undergoing rapid urbanization in Yubei District. A large number of public service facility land, mixed commercial and residential land, and commercial finance land have increased in these areas in the past decade.

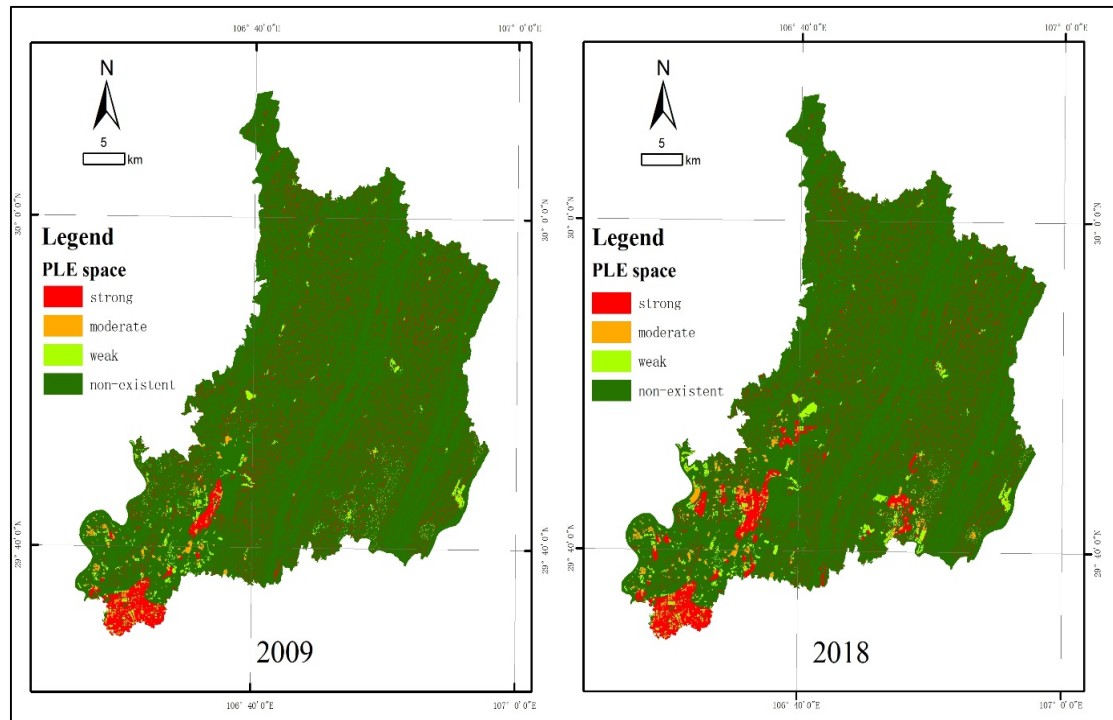


Figure 5: Spatial distribution of living space of Yubei (the year 2009 and 2018)

From 2009 to 2018, the area of ecological spaces in Yubei District has been significantly reduced and non-ecological spaces expanded significantly and demonstrated similar spatial change directions as strong production and living spaces (Figure 6). Strong ecological spaces mainly concentrated in the three mountainous regions where forests are the major land use type. These regions are not over developed as they have already become important natural reserves of Yubei District and are restricted by topographical factors. Therefore, the spatial distribution and scale of strong ecological spaces were relatively stable during the research period.

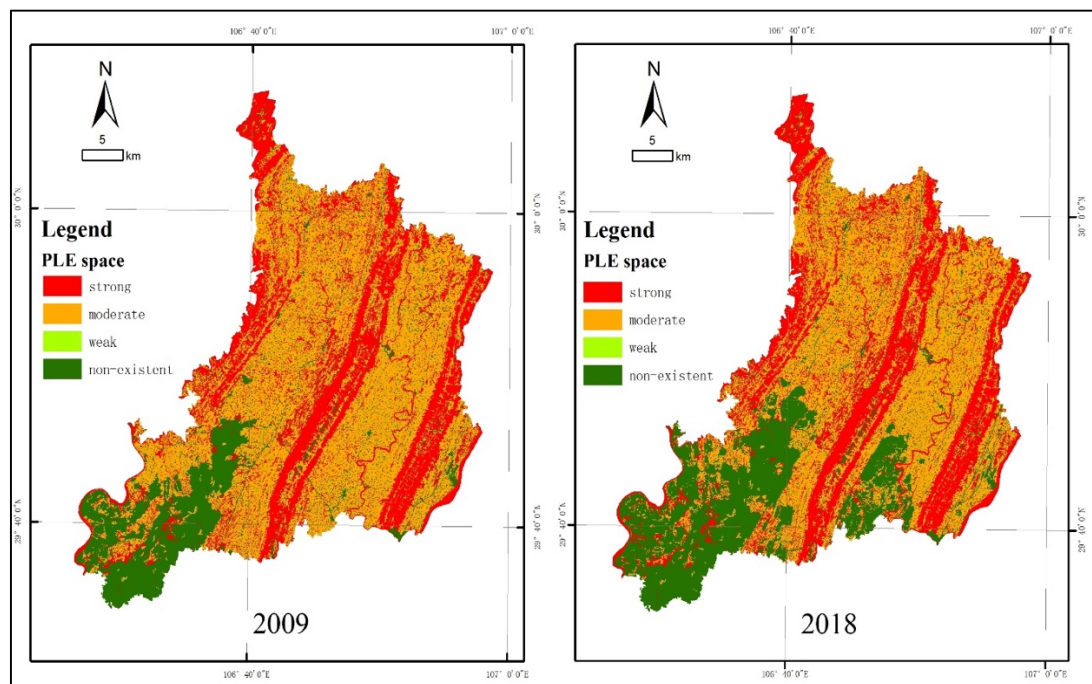


Figure 6: Spatial distribution of ecological space of Yubei (the year 2009 and 2018)

*- PLE space structure and dynamic index*

The dynamic index can quantitatively describe the rate of change of PLE spaces and plays an important role in comparing the changes in different types of PLE spaces and analyzing the variation trend of PLE spaces (Table 3). During the research period, the highest positive dynamic indexes were shown for strong production spaces, weak living spaces, and moderate living spaces. The highest negative dynamic indexes were shown for moderate ecological spaces, moderate production spaces, and weak production spaces.

Table 3: The quantity structure and dynamic index of PLE space in Yubei District

PLE space category		2009	2018	The dynamic index
Strong production space	Area (hm <sup>2</sup> )	13817.25	23809.50	7.23%
	Proportion (%)	9.48%	16.33%	
Moderate production space	Area (hm <sup>2</sup> )	73998.00	63594.00	-1.41%
	Proportion (%)	50.76%	43.63%	
Weak production space	Area (hm <sup>2</sup> )	1845.00	1656.00	-1.02%
	Proportion (%)	1.27%	1.14%	
Strong living space	Area (hm <sup>2</sup> )	12064.50	13531.50	1.22%
	Proportion (%)	8.28%	9.28%	
Moderate living space	Area (hm <sup>2</sup> )	1451.25	2097.00	4.45%
	Proportion (%)	1.00%	1.44%	
Weak living space	Area (hm <sup>2</sup> )	2085.75	3141.00	5.06%
	Proportion (%)	1.43%	2.15%	
Strong ecological space	Area (hm <sup>2</sup> )	44145.00	43701.75	-0.10%
	Proportion (%)	30.28%	29.98%	
Moderate ecological space	Area (hm <sup>2</sup> )	74000.25	62736.75	-1.52%
	Proportion (%)	50.76%	43.04%	
Weak ecological space	Area (hm <sup>2</sup> )	0.00	0.00	0.00%
	Proportion (%)	0.00%	0.00%	

Such phenomena suggested that a regional development model based on the production functions of the secondary, tertiary industry is being established in Yubei District. The newly increased strong production spaces replaced part of moderate and weak production and ecological spaces. In this process, the changes in land utilization type were mainly reflected in the transformation from cultivated land to construction land. The increase of moderate and weak living spaces represented the increase of public service facility land, commercial land, and mixed commercial and residential land in Yubei District during the research period. The increase in such land utilization types might enrich the residents' lives, improve the overall level of the commercial service industry in Yubei District, and improve the living qualities of local residents.

*- The weighted center of gravity of PLE space*

Figure 7 illustrated the transition of weighted gravity center of PLE space from 2009 to 2018. The red Pentagon represents the geometric center of Yubei district for reference only. Past decade has witnessed the changes of PLE space center in Yubei District in different directions and degrees while taking the land use function evaluation into account. Specifically, the production space center shifted southwest from 106.7212°E, 29.7934°N to 106.7192°E, 29.7890°N, the living space center shifts southwest from

106.6924°E, 29.7655°N to 106.6884°E, 29.7602°N and the ecological space center shifted northeast from 106.7653°E, 29.8337°N to 106.7725°E, 29.8434°N, respectively.

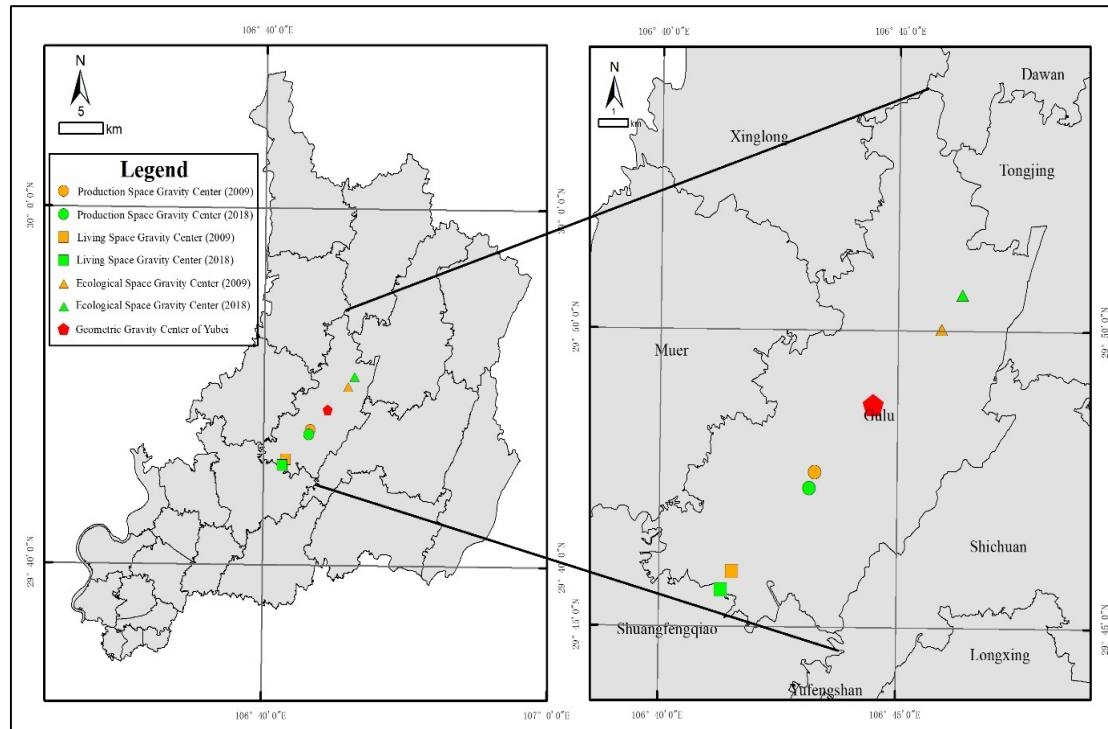


Figure 7: The weighted gravity center of PLE space from 2009 to 2018

It is worth noting that both the production space gravity center and living space gravity center in Yubei District has shifted towards southwest, which seems to be contrary to the construction land expansion in Yubei District. Therefore, this result further reflects the advantages of PLE space research in terms of studying the versatility of different land use types while comparing with traditional land use transformation research. Specifically, although the production space in Yubei District shows an expanding trend towards northeast as a whole, actually the production space center shifted southwest since the agricultural production function (moderate production function) of large rural areas in the northeast is gradually being replaced by the rapid expansion of the second and tertiary industry production function (strong production function) in the southwest urban areas. As for the living space, although there are a large number of scattered rural residential areas in the rural areas of Yubei District, the newly added production function land in the past ten years focuses on the core area of LJNA, which is mainly distributed in the southwest of the center in 2009. Therefore, the improvement of urban residence and living functions in Yubei District has become the driving force for the transfer of living space. From 2009 to 2018, the shift of ecological space center in Yubei District towards northeast reflects the fact that Yubei District occupies a large amount of ecological land in the process of urbanization from southwest to northeast and faces the mounting pressure on regional ecological protection.

## Conclusion

As one of the most essential concepts in China's land use development, the PLE space has been playing an important role in improving the sustainability of land use. This

study sorted out the theoretical connections and logical relationships between land utilization functions and PLE spaces, proposed a classification and evaluation method of PLE spaces in China based on LUFs, and took the Yubei district, which is located on urban fringe area of Chongqing and undergoing rapid urbanization, as an example to conduct empirical research on this methodology framework. The main conclusions are as follows:

During the research period and the process of urbanization, agricultural land close to the urban area in Yubei District was occupied and turned into construction land. The land production function changed from mainly agricultural production to mainly non-agricultural production. Moderate production spaces were replaced by strong production spaces in the urban fringe and inside the urban area, resulting in the center of production spaces being pulled towards the city. Urbanization and the development of the secondary and tertiary industry became the driving force for the significant increase of strong production spaces in Yubei District.

The weight gravity center of living space of Yubei District moved towards the southwest, which reflected the scattered and small-scaled rural living functions of Yubei District is much lower than urban living functions within the research period. A large amount of newly increased residential land emerged inside the city and in several regions in the south of the original center, especially in LJNA. In addition, moderate and weak living spaces in Yubei District increased significantly. Regarding land utilization types, it was reflected through significant increases in commercial service land and public service facility land, which contributed to improving the living qualities of local residents and the commercial development of Yubei District. The changes of PLE space center in Yubei District implies that the importance of rural areas has been weakened in terms of production and living functions during the process of urbanization. This will affect the overall development of urban and rural areas, and even aggravate the unfairness of regional development, which has a negative impact on the land sustainable use. Therefore, we should pay attention to land use changes in rural areas, strengthen infrastructure construction in rural areas during the process of urbanization, improve the quality of life of rural residents, and appropriately develop industrial land and protect ecological land.

Ecological functions of Yubei District declined in the past decade, mainly due to a large amount of agricultural and ecological land being developed into construction land. Areas with reduced ecological spaces mainly concentrated in non-mountainous flat regions and were mostly transformed into strong production and living spaces. In the context of ecological civilization, how to balance the trade-off between conservation and development in the process of rapid urbanization is an important issue for the future sustainable development of Yubei District.

The PLE space classification and evaluation system proposed in this paper contributes to the identification of PLE spaces based on land use types and functions. The empirical study of Yubei District tested the methodology framework and provided a reference for the identification and evaluation of PLE spaces in regions where facing rapid urbanization process in China. The results in this paper further reflects the advantages of PLE space research in terms of studying the change trend of different land use types while comparing with traditional land use transformation research. Future research will discuss the leading factors that cause the spatial and temporal evolutions of PLE spaces

in Yubei District and conduct further empirical analyses on the classification and evaluation methods of PLE spaces in China.



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