The research on dynamic changes of urban green spaces in Wuhan at a local scale

Yuwei Wang1,*, Xiaoliang Meng2, Kaicheng Wu1 and Wang Gao1

1 School of Artificial Intelligence, Jianghan University, Wuhan 430056, China
2 School of Remote Sensing and Information Engineering, Wuhan University, Wuhan 430079, China
*Corresponding author’s email: weberwang@jhun.edu.cn

Abstract. Urban green spaces play a vital role in urban ecological construction and sustainable development. The primary objective of this paper is to monitor the dynamic changes of urban green spaces in Wuhan city, China from a local perspective. Combined with ArcGIS and Fragstats software, we applied two landscape metrics to detect the change process and change type of urban green spaces during two consecutive periods, 2009–2014 and 2014–2019 at pixel level. The results showed that except for few edge regions, the coverage of urban green spaces declined during 2009-2019. The urban green patches tended to be more fragmented mainly in the central part of Wuhan in the past decade. At the same time, the research results could provide reasonable decision support for the protection of urban green spaces.

1. Introduction

Urban green spaces are integral part of urban green system, which have important ecological, social, psychological and economic functions [1]. With the continuous development of urbanization in the past few decades, human activities exert strong interference on nature progressively, leading to the degradation and fragmentation of urban green spaces [2,3]. Therefore, it is worth exploring the spatial pattern and dynamic change characteristics of urban green spaces in different periods of a region.

Relying on remote sensing and geographic information system technology, spatial analysis and landscape metrics have been widely used in the study of urban green space change [4,5]. By mapping the spatial distribution of urban green spaces and calculating the landscape metrics of urban greenness, researchers can not only monitor the dynamic changes of urban green spaces, but also can evaluate the changing trajectory of landscape patterns [6]. Nevertheless, most of the previous studies explore the dynamics of urban green spaces at a global scale, they have not fully included spatial heterogeneities for urban green spaces, making it hard to analyze the spatial distribution features of urban green spaces in detail. With support from landscape pattern analysis tools such as Fragstats, we can design and conduct the exploration of landscape changes at a local scale.

The main aim of this paper is to detect the changing patterns of urban green spaces in Wuhan from 2009 to 2019. Firstly, two representative landscape metrics were computed to measure the urban green spaces pattern at a global scale in the whole area. Then the two landscape metrics were calculated at a local scale with moving windows. Afterwards, the distributions and changes of the landscape metrics were displayed for two consecutive periods. The results can help to identify the changes of urban green spaces during 2009-2014 and 2014-2019, in order to provide the basis for the protection and rational use of urban green spaces.
2. Study area, data and methodology

2.1. Study Area
Wuhan (29°58′N-31°22′ N, 113°41′E-115°05′ E) is located in Jianghan Plain and the east of Hubei Province. It is the metropolis of the middle and lower reaches of the Yangtze River and the largest city in central China. The city consists of 13 districts (Figure 1). Wuhan features a subtropical monsoon humid climate, marked by cold winter and hot summer [7]. The city is also characterized by its water body areas, covering about one quarter of the city. With the rapid development of urbanization rate and resident population in recent years, great quantity of urban green spaces are occupied by urbanized or built-up areas.

2.2. Data
The land cover classification data used in this paper are archived from Europe space agency climate change initiative land cover (CCI-LC) products [8]. The CCI-LC products provide consistent global LC maps at 300m spatial resolution from 1992 to 2019. Accordingly, we acquired the land cover classification data for year 2009, 2014 and 2019 in this study. Based on land cover classification system (LCCS) developed by the United Nations food and agriculture organization (FAO), the data products were classified into 36 categories. Here we reclassified the LCCS into 7 categories, namely, cropland, forest, grassland, wetland, urban areas, bare areas and water bodies. According to the previous studies, the all forests, grasslands, wetlands and cultivated lands are defined as urban green spaces [9,10]. The 7 land cover classifications were further divided into 2, i.e., urban green spaces and non-urban green spaces for research purposes. The dichotomous urban green spaces distribution maps were then clipped by the Wuhan boundary.

Figure 1. The location of the study area.
2.3. Methodology

Quantitative analysis of landscape pattern can highly condense the information of landscape pattern and reflect the structure and spatial configuration of landscape [11]. This study employed two typical landscape metrics to measure the spatial pattern of urban green spaces, including number of patches (NP hereafter) and percentage of landscape (PLAND hereafter). NP counts the number of patches in the landscape and measures the extent of subdivision or fragmentation of urban green patches. The higher the NP value, the landscape fragmentation of the urban green area is greater. PLAND calculates the relative proportion of green patches in the whole landscape area, and is used to determine the dominant landscape elements in the landscape. The metric is calculated as follows:

\[ PLAND = \frac{\sum_{i=1}^{n} a_i}{A} \times 100\% \]  

Where A is the total landscape area, ai is the area of the urban green patch i, n is the total number of green patches. When its value approaches 0, it means that green patches become very rare in the landscape. The value 100 indicates that the whole landscape is composed of green patches. The landscape metrics were calculated using the FRAGSTATS (Version 4) program.

The dynamic moving window approach was applied to explore the local landscape pattern at pixel level. For a focal cell in the study area, a 5000m×5000m square moving window was defined as sub-landscape, NP and PLAND values were quantified in the sub-landscape respectively, representing landscape structure gradients at a local scale.

3. Result

3.1. Changes of urban green space pattern in the whole city

The NP and PLAND for urban green spaces in Wuhan were calculated for 2004, 2014 and 2019. Table 1 shows the results for the comparison between different years.

| Landscape metric | 2009  | 2014  | 2019  |
|------------------|-------|-------|-------|
| NP               | 144   | 162   | 212   |
| PLAND            | 80.94 | 79.56 | 77.25 |

The NP values of urban green spaces in Wuhan kept an increasing trend during 2009 to 2019. Of these two consecutive periods, namely, 2009–2014 and 2014–2019, the latter period showed the largest increment of NP values, which increased from 162 in 2014 to 212 in 2019. The result indicated that the patch distribution of urban green spaces tended to be dispersed, and the fragmentation degree was strengthened, most likely due to the invasion and division of intensified human activities. The PLAND values in Wuhan decreased from 80.94% (2009) to 77.25% (2019). The result revealed that the proportion of green patch areas decreased. In the urbanization process, more urban green spaces were converted to non-green spaces.

3.2. Changes of urban green space pattern at a local scale

Figure 2 and Figure 3 illustrate the changes of NP and PLAND values of urban green space during 2009–2014 and 2014-2019 respectively. In Figure 2, during the period 2009-2014, the regions with positive NP values were mainly concentrated in the central part of the city. These areas were dominated by urban areas, with urban construction and intensified human activities, the large green patches were divided into smaller ones and caused NP values to increase. During 2014-2019, the regions with positive NP values further concentrated in built-up areas, indicating the urban green spaces were fragmented even more obvious. Exceptionally, in the central part of Wuhan, the southwestern part of Hongshan District, the Wuchang District, Jiang'an District, Qingshan District and
Jianghan District occurred negative NP values for urban green spaces. It can be attributed to the green space recover policies proposed by the municipal government.

Figure 2. Changes in NP values of urban green spaces in Wuhan between 2009 and 2019.

Figure 3 depicts the changes in PLAND values between 2009 and 2019. During the study period, most of the areas in Wuhan have experienced negative PLAND values. This finding indicated that Wuhan suffered the loss of urban green spaces during 2009-2019, particularly in the central area in Wuhan during 2014-2019. The areas showing positive PLAND values were sporadic distributed around the non-urban edge areas. These areas are less affected by human activities so that the areas of green spaces increase.

Figure 3. Changes in PLAND values of urban green spaces in Wuhan between 2009 and 2019.
4. Discussion

With the rapid development of urbanization, great changes have taken place in the spatial structure and distribution of urban green spaces. It is meaningful to study the dynamic evolution of urban green spaces at a local scale to maintain the stability of urban green space system. The landscape metrics have been proved to be effective in revealing the urban green spaces coverage and fragmentation patterns.

In this research, we calculated the landscape metrics at both global and local scales, and then the spatial distribution characteristics of green spaces were assessed for two consecutive periods in Wuhan. From a global perspective, the coverage of the urban green spaces in Wuhan city decreased, and the urban green spaces were more fragmented from 2009 to 2019. This discovery was consistent with some previous studies [12,13]. At a local scale, the new green small patches were mostly distributed in the central built-up areas in Wuhan. The expansion in these areas is often behaved as continuous areas in space, which will split the green spaces into small pieces. Moreover, the majority areas had experienced a decline in urban green spaces coverage, especially in the central area. Nevertheless, vegetation restorations were observed in some districts during the period. This reflects the implementation of the greening policies, but it seems that continuous efforts are needed to protect green spaces.

This work tested the moving window method for measuring the local landscapes. In the future work, more detail work should be input to measure the urban green spaces at a local scale.

5. Conclusion

This study adopted spatial analysis method and landscape metrics to grasp the change process and spatial distribution of urban green spaces in Wuhan. Through the comparison of landscape metrics at a local scale for different time series, the reduction of urban green spaces coverage and the increment of urban green spaces fragmentation were confirmed in this paper. Special attention should be paid to the central areas of Wuhan to protect existing urban green spaces. Continuous and effective land use policies are needed for the optimization of urban green spaces, especially in the built-up areas.

Acknowledgments

This research was funded by the National Natural Science Foundation of China (NSFC): 41971352.

References

[1] Stessens P, Canters F, Huysmans M and Khan A Z 2020 Urban green space qualities: An integrated approach towards GIS-based assessment reflecting user perception Land use policy 91 104319
[2] Hunter R F, Cleland C, Cleary A, Droomers M, Wheeler B W, Sinnett D, Nieuwenhuijsen M J and Braubach M 2019 Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis Environ. Int. 130 104923
[3] Colding J, Gren Å and Barthel S 2020 The Incremental Demise of Urban Green Spaces Land 9 162
[4] Dinda S, Das Chatterjee N and Ghosh S 2021 An integrated simulation approach to the assessment of urban growth pattern and loss in urban green space in Kolkata, India: A GIS-based analysis Ecol. Indic. 121 107178
[5] Li F, Zheng W, Wang Y, Liang J, Xie S, Guo S, Li X and Yu C 2019 Urban Green Space Fragmentation and urbanization: A spatiotemporal perspective Forests 10 333
[6] Nor A N M, Corstanje R, Harris J A and Brewer T 2017 Impact of rapid urban expansion on green space structure Ecol. Indic. 81 274–84
[7] Li X, Wang Y, Li J and Lei B 2016 Physical and socioeconomic driving forces of land-use and land-cover changes: A Case Study of Wuhan City, China Discret. Dyn. Nat. Soc. 2016
[8] Lamarche C, Santoro M, Bontemps S, D’Andrimont R, Radoux J, Giustarini L, Brockmann C, Wevers J, Defourny P and Arino O 2017 Compilation and validation of sar and optical data
products for a complete and global map of inland/ocean water tailored to the climate modeling community Remote Sens. 9 36

[9] Wu Z, Chen R, Meadows M E, Sengupta D and Xu D 2019 Changing urban green spaces in Shanghai: trends, drivers and policy implications Land use policy 87 104080

[10] Yang C, Li R and Sha Z 2020 Exploring the dynamics of urban greenness space and their driving factors using geographically weighted regression: A case study in Wuhan Metropolis, China Land 9 500

[11] Shen S, Yue P and Fan C 2019 Quantitative assessment of land use dynamic variation using remote sensing data and landscape pattern in the Yangtze River Delta, China Sustain. Comput. Informatics Syst. 23 111–9

[12] Wu J, Yang S and Zhang X 2020 Interaction analysis of urban blue-green space and built-up area based on coupling model-A case study of Wuhan Central City Water (Switzerland) 12 2185

[13] Lv J, Ma T, Dong Z, Yao Y and Yuan Z 2018 Temporal and spatial analyses of the landscape pattern of Wuhan city based on remote sensing images ISPRS Int. J. Geo-Information 7 340