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Analysis of Urban Marginal Expansion Based on Remote Sensing Means and Its Impacts on Landscape Pattern Changes

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Abstract. The rapid expansion and development of the city have introduced a large number of surrounding rural populations into the city, resulting in the continuous outward expansion of the city area. The expansion of the town leads to changes in the morphology and number of patches in the urban fringe area, and a larger degree of expansion leads to loosen urban morphology, landscape fragmentation, and a reduction in the efficiency of land use, resulting in a series of problems such as loss of arable land, waste of resources, and damage to the ecological environment. Landscape pattern is an expression of land use, and a series of problems brought about by urban expansion will directly cause the evolution of landscape patterns. This paper introduces the research methods and main techniques of urban edge expansion based on remote sensing techniques and analyses the impact of urban edge expansion on the evolution of landscape patterns. Results show that studying urban edge expansion based on remote sensing technology includes buffer analysis using remote sensing data, establishing landscape indicators, and then discussing their impacts on the evolution of landscape patterns. The buffer zone analysis can identify the buffer zones of different circles to determine the scope of urban expansion in various periods, while the landscape pattern index analysis can evaluate the evolution of landscape patterns after the calculation and statistics of data. Finally, the impact of urban expansion on landscape pattern changes is mainly reflected in the fragmentation, heterogeneity, and complexity of the landscape.

Keywords: Urban Expansion; Landscape Pattern; Buffer Analysis; Land Use.

1. Introduction

The urban fringe area is the geographical intersection between the city and the countryside and the most active area of urban spatial and functional outward expansion [1-4]. With the rapid development of all aspects of the city, the influence on the surrounding towns and villages is expanding, and the city boundary is also gradually expanding outward. Most of the urban fringe areas are rural areas, with landscape features such as unstable landscape structure, gradient landscape change, patch fragmentation and unremarkable matrix landscape [5]. At the same time, different forms of expansion make the urban structure show the development trend of diffusion or compactness, which has various impacts on the connectivity of landscape patches [6]. As for the cultivated land in rural areas, such as forest land, due to the disorderly expansion of the city, and encroachment of ecological and agricultural land around the city, so that the area of land other than construction land is reduced year by year. These have caused greater damage to the environment and resources and seriously violated the concept of sustainable development. Therefore, the change of landscape pattern in the urban fringe area is particularly important, and analyzing the law of urban expansion as well as the change of landscape pattern is of great significance to scientifically and reasonably guide urban planning and protect the limited arable land resources and ecological environment.

Many scholars in China have analysed and discussed the expansion of urban edge and the evolution of its landscape pattern, and the research direction is rough as follows: the calculation of the urban landscape expansion index, the impact of urban spatial expansion on landscape pattern, and the analysis of landscape fragmentation of urban expansion. The study of the expansion law and landscape change characteristics can directly reflect the impact of urban fringe expansion on the

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landscape pattern change, which can help the use of land resources in the urban-rural interface area, and has a guiding significance for the rational planning of land.

In this paper, the research progress on urban fringe expansion and its landscape pattern evolution is counted, the research method and main technology of urban fringe expansion based on remote sensing are discussed, and the impact of urban fringe expansion on landscape pattern evolution is analysed.

2. Research Progress

Most of the research areas of scholars at home and abroad are concentrated in economically developed regions with rapid urban development (Table 1). For example, Estoque and Murayama studied the relationship between urban expansion and the change of spatial pattern of land use based on remote sensing data through the change of urban land expansion in two cities, Bangkok and Manila, between 2 years. Ma Chaonan scholars used Arcgis and Fragstats 4.0 software to study the dynamic change of landscape pattern of land use and landscape expansion index. Scholar Chen Yonglin similarly combined buffer zone analysis and landscape pattern index calculation to study urban spatial expansion in Changsha and its impact on landscape pattern in marginal areas. Scholar Wang Jiahui calculated the landscape spatio-temporal characteristics of Zhengzhou City through land use data at different times of the landscape index. Many researchers also made detailed analyses of the spatial expansion patterns of individual cities, such as Beijing, Chengdu, and Guangzhou [6].

Most of the study areas are concentrated in relatively developed areas mainly because of the rapid development of transport arteries in large cities, which provides the basic conditions for urban expansion. At the same time, in response to the national policy guidance, large cities are mostly concentrated in the area for regional development, showing a circle expansion from the centre outward or the development of groups or belts oriented to the traffic arteries. In contrast, there is a lack of attention to the Yellow River basin, especially the middle and upper reaches of the Yellow River, where the ecological environment is more fragile and the level of economic development is relatively lagging [7]. The main reason for this is that China has built a tower-like hierarchical administrative system with an irrational distribution of resources, and it is difficult to compare the level of expansion of small cities with that of large cities. On the other hand, small cities lack the intrinsic development power of big cities, which limits the potential and research value of small city expansion.

Table 1. Main research methods and results of urban sprawl as well as landscape patterns based on remote sensing image data [6]

Research Area	Methodologies	Pros and Cons	Results-based
Zhengzhou Construction Land	arcgis analyses the process of building land expansion and performs landscape pattern index calculations.	Multiple landscape indices were calculated to obtain trends in landscape patterns; however, the relationship between urban sprawl and landscape patterns was not strongly enough linked.	The change of urban landscape pattern of construction land expansion in Zhengzhou City was studied through the calculation of landscape index, which resulted in the trend of change of construction land patches, as well as the problems brought by urban expansion in Zhengzhou.
Changsha Built-up area	Using the buffer zone analysis method and the landscape index method, the urban expansion of	The thesis identified several spatial thresholds of landscape pattern changes. Using the spatial	Studies have shown that the characteristics of changes in various landscape indices vary for the same land type;

	Changsha City and its impact on the landscape pattern of the fringe area were explored.	relationship between the area ratio of arable land to built-up land and the urban boundary, as well as the spatial relationship between the landscape indices of different land-use types and the urban boundary, it is possible to obtain the impact of urban spatial expansion and landscape pattern.	the characteristics of changes in landscape indices also vary for different land types.
Six Districts of Harbin	Random forest algorithm is used to process the remote sensing data, and the data is converted by arcgis software to count the land use types. Finally, the urban expansion law is derived through the urban centre of gravity transfer.	Combined with machine learning, a large amount of more accurate data is obtained; at the same time, the centre migration model, combined with changes in land type, not only analyses the urban periphery, but also reacts to the expansion trend of the urban centre.	The area of built-up land in the study area has seen rapid urban expansion over a 20-year period, with the most pronounced trend of growth and expansion in the first 10 years. In the latter 10 years, the urban centre is clustered and the rest of the area has an even distribution of building land pattern.
Wuhan	Calculate the dynamic change model of landscape types and calculate the landscape expansion index to get the urban expansion trend of Wuhan.	Utilising a dynamic data model is more realistic and accurate.	Arable land retains its landscape dominance and is more cohesive, with a trend towards fragmentation and a more cohesive character for built-up land; marginal and infill expansion can improve land use efficiency as well as reduce damage to the landscape environment.

3. Remote Sensing Research Methods of Urban Marginal Expansion

3.1. Data Sources

Most scholars combine remote sensing data, land use data and landscape index methods to discuss the expansion of urban edges. The combination of remote sensing technology and ArcGIS, as well as the use of landscape ecology principles to jointly study the spatial pattern of large-scale ecosystems, have become important methods for research in this field. Quantitative analysis of spatial patterns through landscape indices is the core of this research approach [7]. Remote sensing technology is used to obtain accurate large-scale spatial data, while ArcGIS software is responsible for processing and analysing these data. This approach provides an effective tool for landscape-scale monitoring and assessment.

3.2. Research Methods

3.2.1. Buffer analysis.

The buffer zone analysis method is mainly used to determine the influence range around a specific geographic object or area. Based on remote sensing data, urban expansion is divided into circles using GIS, and the speed, direction and intensity of urban expansion can be monitored through buffer zone analysis of the current map of urban land use in different periods. Based on this, the dynamic changes of urban development can be better understood. As Martino pointed out buffer zones and their effective use are one of the agendas and top priorities of natural resource conservationists and wildlife organisers [8]. By establishing buffer zones for key geographic elements, the boundaries of sensitive areas are defined, and buffer zones of a certain width are created around these areas to reduce human activities' disturbance of the natural environment. This is important for maintaining ecological balance and protecting biodiversity. It also allows for effective planning and management of urban space, and better protection and detection of resources and the environment.

A tool in ArcGIS software, buffer analysis can quantify the physical features around the feature related to spatial distance and so on within a certain range (the shape of the range can be chosen according to different situations). Based on the natural discontinuity method, urban expansion in different periods is analysed by clustering, and the spatial differentiation map of urban land expansion in different periods is obtained. The category of 'natural breaks' is based on the natural groupings inherent in the data. Similar values can be most appropriately grouped by identifying classification intervals, and differences between classes can be maximized. For these groupings, boundaries are set at thresholds where the difference in values is relatively large so that urban sprawl is spatially differentiated across buffer zones.

3.2.2. Calculation of landscape pattern index.

Landscape pattern indices are mathematical indices that quantitatively describe the characteristics of landscape composition and spatial structure. These indices reveal the complexity and heterogeneity of the landscape by analysing the spatial distribution, morphology, quantity and interrelationships of various elements in the landscape (e.g., patches, corridors, substrates). Landscape pattern indices commonly include patch density, spreading degree, aggregation degree, Shannon diversity, etc. Indicators are established from different perspectives and levels to respond to the evolution of the landscape and to explore the impact of urban spatial expansion on the landscape pattern (Table 2). In actual research, scholars usually combine the background of the study area, select typical indicators with good response effects, and apply them comprehensively to assess landscape evolution. For example, based on Fragstats 4.0 software, Chen Yonglin et al. calculated the landscape pattern indices of raster maps processed using ArcGIS software and selected the patch density, Shannon diversity index, spreading index, and cohesion index from the type level and the landscape level to comprehensively study the urban expansion and landscape pattern evolution. Subsequently, Ma Cheonan, to get the dynamic change of the landscape, used the landscape type change magnitude model to reflect the evolutionary process of the change of different landscape types, while the study used the land use transfer matrix to reflect the dynamic process information of the mutual transformation between the area of each landscape type at the beginning and the end of a certain time in a certain region [9]. Compared with the two, the latter uses a mathematical model to bring in mathematical formulas for calculation, and the model is the final mathematical conclusion derived from multiple sets of actual calculations, which have good generality and universality. Professional mathematical software is more reliable and can accurately reflect the process of landscape pattern change.

Table 2. Landscape pattern index system for site expansion [9]

	Landscape Index	Description of indicators
Type Level	PD Patch Density	Reflects the degree of spatial coherence of the landscape
	ED Edge Density	Reflects the degree of landscape fragmentation and the degree of boundary of patch types
	COHESION	Reflects the degree of aggregation and dispersion of patches in the landscape.
	LSI Landscape Shape Index	Reflects the complexity of landscape shape
Landscape Level	CONTAG	Reflects the degree of clustering of different patch types in the landscape space
	SHDI Shannon Diversity Index	Reflects the degree of landscape diversity
	SHEI Shannon Homogeneity Inde	Reflects the degree of heterogeneity of the landscape

4. Impacts of Urban Fringe Expansion on Landscape Pattern

According to existing studies, the impact of urban fringe expansion on landscape patterns is mainly reflected in the land use layout, landscape physical characteristics and ecological functions.

In terms of land use layout, the land use layout will be more reasonable in cities with outward expansion, and the peripheral fringe areas can better relieve the pressure for the urban centre area. For example, Peng Wenfu established an equidistant buffer zone with a spacing of 4km to get the state of urban expansion in Chengdu in different periods. In the opinion of Wang Hu and Liu Yu, urban expansion is divided into two different directions: axial expansion and outward expansion. From Peng Wenfu's study, the urban spatial expansion of Chengdu is based on the centre of the city forming outward expansion. In addition, axial expansion of cities is relatively rare in practice, such as Wuhan City in China and Ho Chi Minh City in Vietnam. Both of these cities use highways as the dominant urban development, with high-density new urban construction along the routes.

In terms of the physical characteristics of the landscape, the process of urbanisation is associated with the shape and size of the landscape as well as the types and patterns of land use that undergo significant changes [10,11]. As the city undergoes continuous outward expansion, among the greenfield land use types, the density of patches and the number of patches of agricultural land and forest land, etc. have increased significantly, indicating that a large amount of agricultural land and forest land, etc. have been largely encroached upon and dispersed by the urban expansion, and converted into construction land [12]. In addition, the degree of fragmentation at the edge of the city is obvious, in the city centre, the construction land is more complete and the cultivated land is less fragmented. This is mainly due to the large amount of construction land in the city centre, which cuts the original landscape pattern and creates a fragmented landscape status quo. At the same time, a large number of construction sites in the city replaced the complex landscape pattern, and these contiguous development of construction sites led to a great reduction in the heterogeneity of the landscape. After comparing different cities, it is found that compared with large cities, the urban expansion process of small and medium-sized cities is slower, and tends to be disorganized and scattered. On the other hand, large cities have more centralized development, resulting in a higher degree of fragmentation and complexity of the landscape in the peripheral areas of large cities.

In terms of ecological functions, the following two aspects are mainly reflected:

(1) Reduction of biodiversity: During urban expansion, natural habitats are destroyed on a large scale, and many wildlife habitats are lost. The fragmentation of the landscape divides the biological habitat

into multiple small fragments, further reducing biodiversity and affecting the migration of species and gene flow.

(2) Decline of ecological service system: Green space has been continuously compressed, which has led to the loss of biodiversity and decline of ecological services in urban ecosystems, such as the decline of air quality and the intensification of the urban heat island effect. At the same time, a large amount of sewage discharge and chemical substances enter the water body, destroying the water quality and the healthy state of the water ecosystem, posing a serious threat to the protection of water resources and the ecological environment in the city.

5. Conclusion

This paper discusses the research method of urban expansion based on remote sensing technology, and its impact on landscape evolution. The research on urban expansion is mainly based on remote sensing technology combined with ArcGIS software for image processing, buffer analysis, etc., and then with the help of Fragstats 4.0 software for calculating landscape pattern index, to explore the impact of urban expansion on landscape pattern. In addition, some scholars adopt more accurate methods, using mathematical models, matrices, and machine learning to get more accurate data.

In terms of research methodology, most scholars use buffer zone analysis and landscape pattern index analysis together. Regarding buffer zone analysis, most of the existing studies are based on natural fractures, and the use of circular circle buffer zone analysis can reflect the state of urban expansion and analyse the pattern of urban expansion according to different periods. In terms of landscape pattern index analysis, the researchers selected patch density, Shannon diversity index, spreading index and cohesion index, which are calculated directly or more accurately using mathematical models.

The urban fringe expansion has profoundly impacted the landscape physical characteristics and ecological functions of the landscape pattern. In urban expansion, the natural landscape is constantly cut and subdivided, resulting in increased landscape fragmentation and changing the layout of land use. At the same time, the loss and fragmentation of natural landscapes have led to a decrease in biodiversity and a decline in ecosystem services. These impacts have regional differences, with the expansion of construction land in small and medium-sized cities having the strongest impact on landscape complexity, followed by medium-sized cities and the weakest in large cities. However, in terms of indices such as landscape aggregation, the impact of construction land expansion in medium-sized cities may be more significant.

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