Research proposal
Spatial-temporal patterns study of Shenzhen

Multi-order Shape-weighted Landscape Evolution Index :

An improved approach for simultaneously analyzing urban land expansion and redevelopment

Keywords: Multi-order Shape-weighted Landscape Evolution Index (MSEI); Ecological land degradation;Ecological land restoratio; Patch shape

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Abstract

Ecological land supports regional biodiversity and ecosystem material-energy-information cycle, which is a strong guarantee for global ecological balance and sustainable development. Therefore, Ecological Land Degradation (ELD) and Ecological Land Restoration(ELR) have become one of the current priorities of urban ecological research, but the exploration of ELD and ELR is still limited.This study combines remote sensing techniques, as well as the landscape index, to characterize the spatiotemporal patterns of ELD and ELR (infilling, edge, adjacent, isolating, and spreading degradation / restoration) in Shenzhen from 1988 to 2015. This study proposes a Multi-order Shape-weighted Landscape Evolution Index (MSEI) for simultaneously analyzing the ELD and ELR types of patches in two or more periods. Compared with existing landscape expansion metrics, the MSEI can depict the spatial relationships between new and old patches from a more detailed perspective and is thus more comprehensive and meaningful in terms of geospatial recognition. The changed urban patches can reflect the spatial patterns and distribution of urban redevelopment, and indicate the characteristics of the spatial optimization of urban land uses and urban greening. Shenzhen's urban expansion is roughly divided into three stages : early urbanization phase (1988-1993), rapid urbanization phase (1993-2005), and intensive urbanization phase (2005-2015). The recognition can provides further understanding of rules behind development of the cities and provides more feasible plans for the subsequent landscape ecological protection.

1.Introduction

With the rapid urbanization process in China, the original ecological land decreases, the carrying capacity of resources and environment declines, and it is imperative for territorial restoration and management [1]. In the new era, the ecological restoration of territorial space has gradually changed from single point, single element and single process restoration to the whole region, whole factor and whole process such as mountain, water, forest, field, lake and grass restoration[2]. In the face of the current new demand of territorial space restoration, it is of great significance to understand the spatial-temporal changes pattern of urban ecological land, and the role of its internal driving factors for the establishment of a systematic and holistic ecological restoration framework.

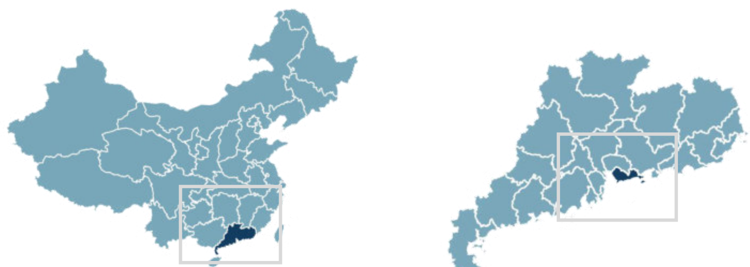
Ecological Land Degradation (ELD) is defined as the loss of important ecosystem functions in ecological land, such as soil and water conservation, resource and environmental carrying capacity, biodiversity, or other ecosystem service functions [3-4]. Ecological Land Restoration(ELR) is the process of ecological land restoring and degraded ecological land recycling and ecosystem functions. Typical ELD includes deforestation, desertification, grassland degradation, and wetland loss, and the continuous expansion of construction land is also the cause of ELD in cities.The process of urbanization is usually accompanied by the simultaneous occurrence of ELD with ELR. However, at present, some studies pay more attention to the quantitative change [5] in the process of ELD, and less [6] to pay attention to the spatial and temporal change of ELD and ELR..

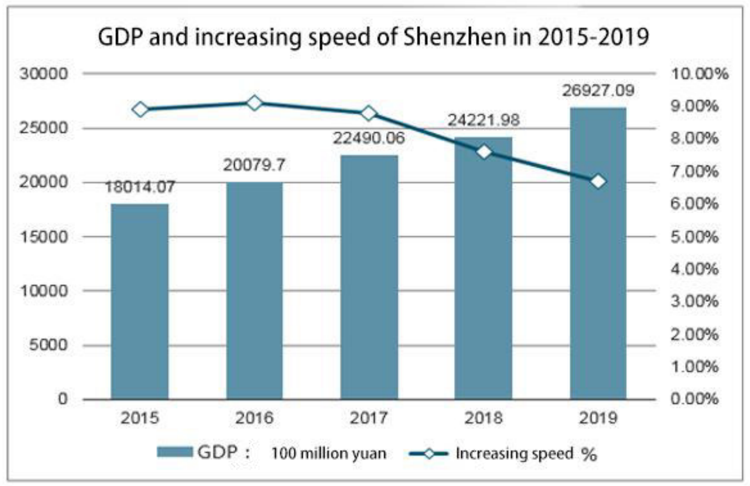
1.1 Core questions

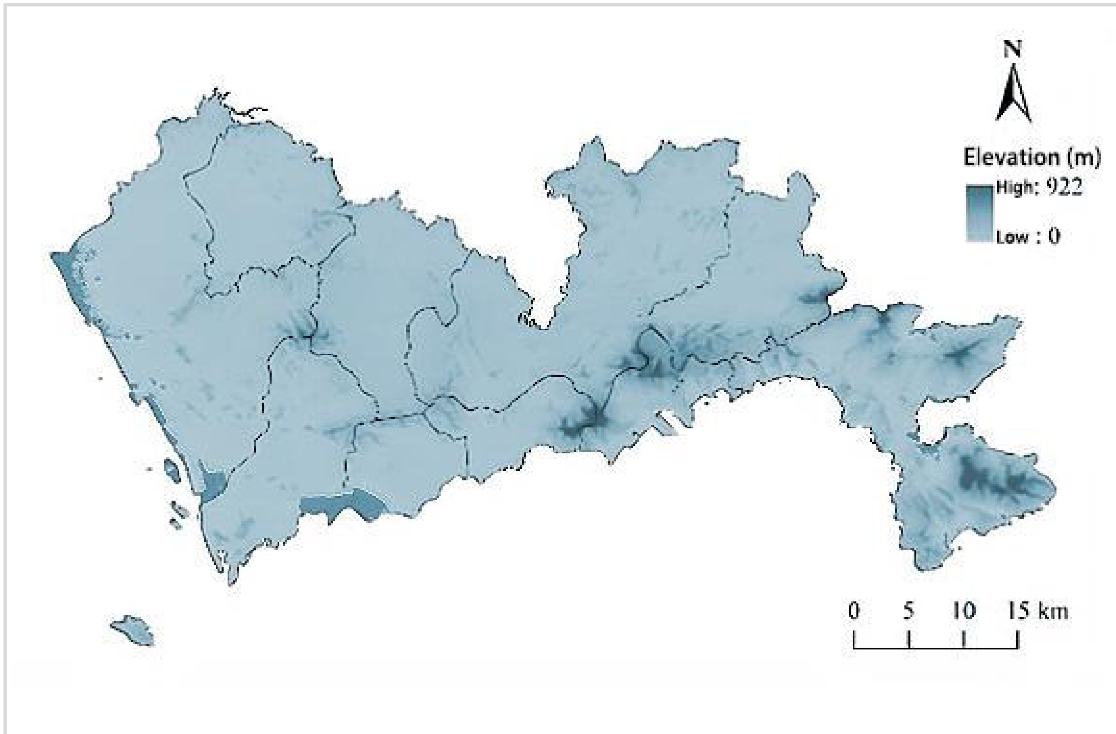
City system is complex giant system, many factors can affect the change of ecological landscape pattern, thus it is difficult to quantitatively indicate the interaction among various influencing factors. As the urbanization process is inevitably accompanied with the expansion of urban land, the extensive urban construction in the early stage is often accompanied by the unreasonable spread of the urban landscape (urban sprawl) [7]. The use of the landscape index to reflect the urban land change process in the urbanization process is of great significance for the deep understanding of the urbanization mechanism [8]. I present a new index, multi-order shape-weighted evolution index (MSEI) to identify it, MSEI has more diversified division of urban renewal evolution in big cities, and has more accurate identification of small urban renewal. For cities and urban agglomerations with fast urbanization process, it can help to understand the trend of land evolution, capture the characteristics of urban changes, and identify the reasoning behind it, and provide a forerunner for future urban planning. The research can be further broken down into next aspects: How's the urban evolution pattern of Shenzhen city? What are the driving factors behind the change and their influencing factors?

1.2 Study area

Shenzhen is one of the most developed cities in China, due to rapid population growth and high-intensity integrated development, the territorial space of Shenzhen is facing serious regional ecological degradation and pollution problems.



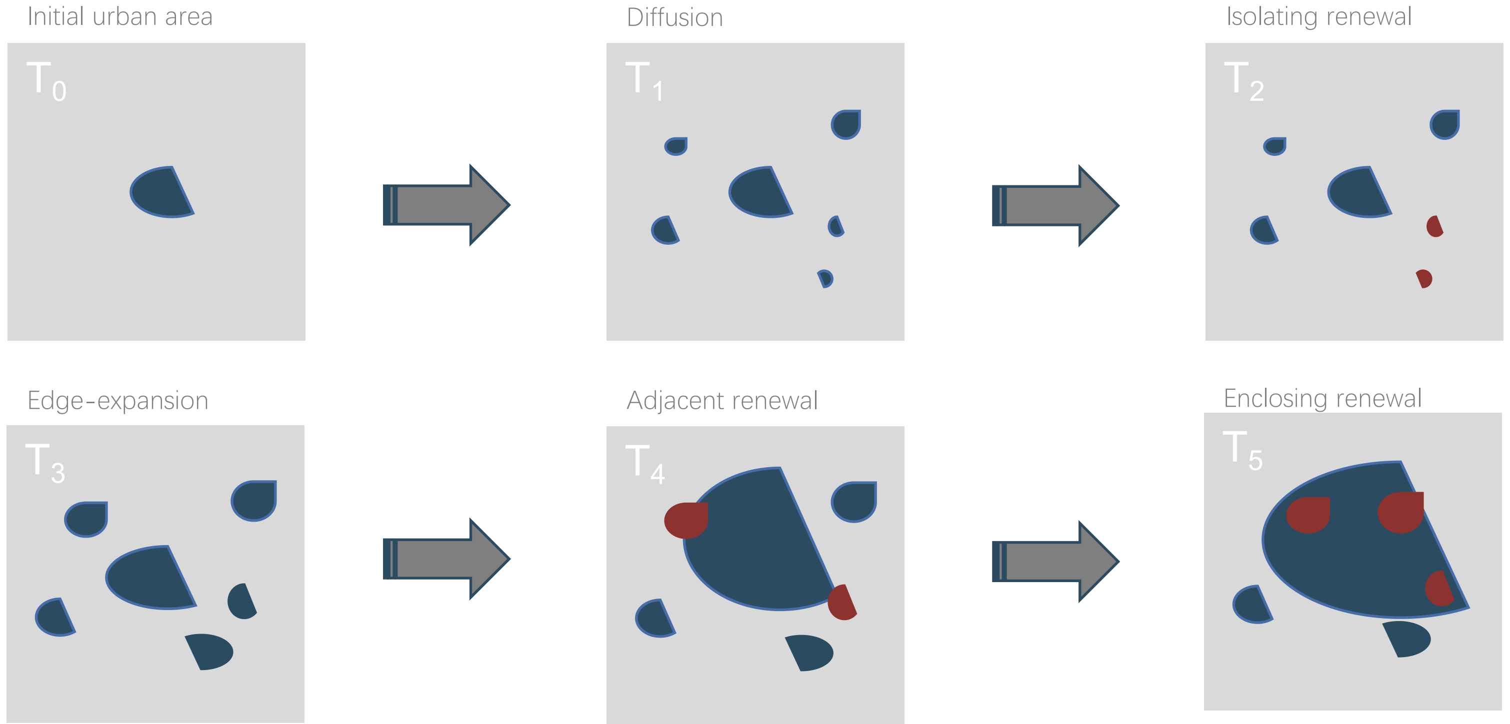




2 Literature Review

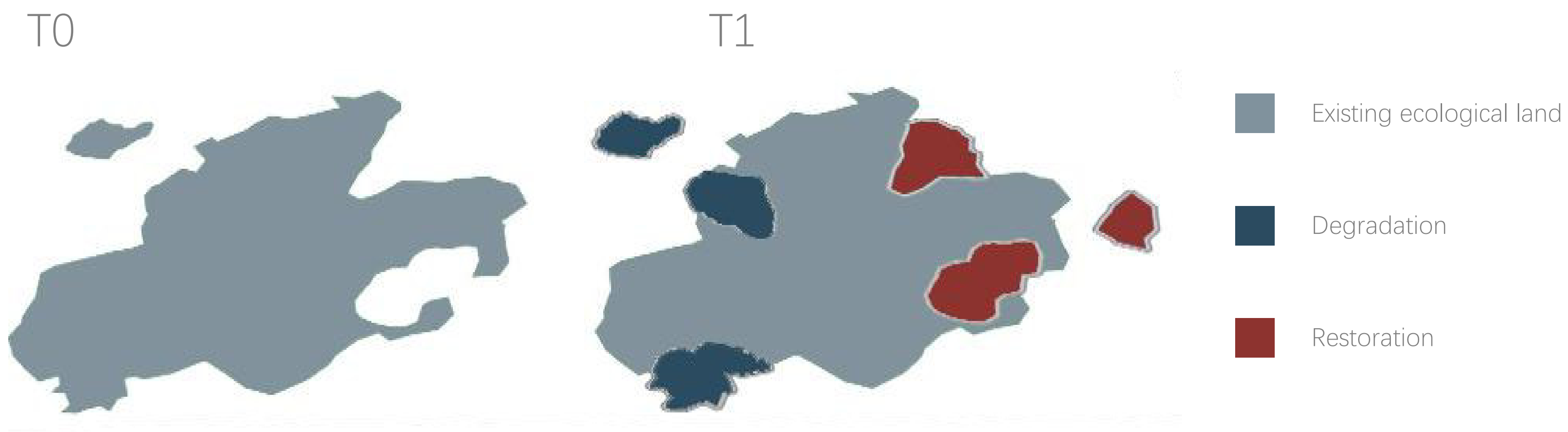
2.1 Urban evolution theory

Urban evolution, which involves urban expansion (ELD) and redevelopment (sometimes can be recognized as ELR) , has attracted considerable attention in the field of landscape ecological analysis. The spatial evolution of urban areas can be characterized as the processes of diffusion and coalescence of individual urban areas [10][11]. At the early stages of cities, evolution starts with the growth of an urban seed or core area. As the seed spreads, it diffuses to new city development centers or cores, and this process is comparable to the pattern of outlying growth [12]. Then, urban centers or cores spread unidirectionally from an edge, and this process is comparable to the edge expansion pattern. As the diffusion process continues, organic growth leads to the infilling of gaps amongst existing urban areas, which is called the process of coalescence. Urban areas substantially change during these processes,where growth and redevelopment occur simultaneously.



Urban evolution according to the theory of urban growth phases

2.2 Definition of ELD and ELR

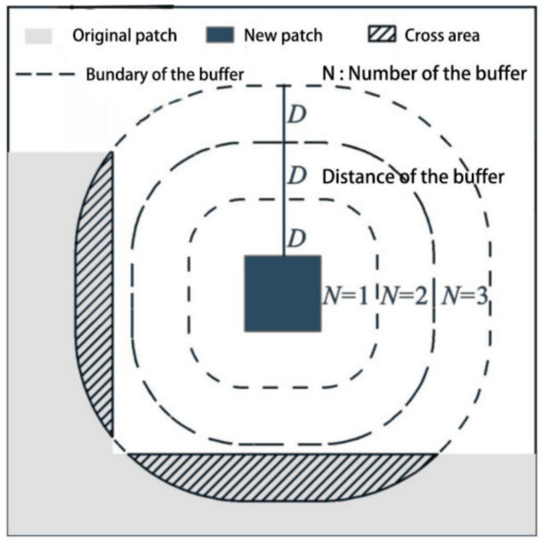


Ecological land degradation and ecological land restoration

2.3 Current landscape evolution indexes

2.3.1 Multi-order adjacency index (MAI)

$$MAI = N - A_i / A_0$$

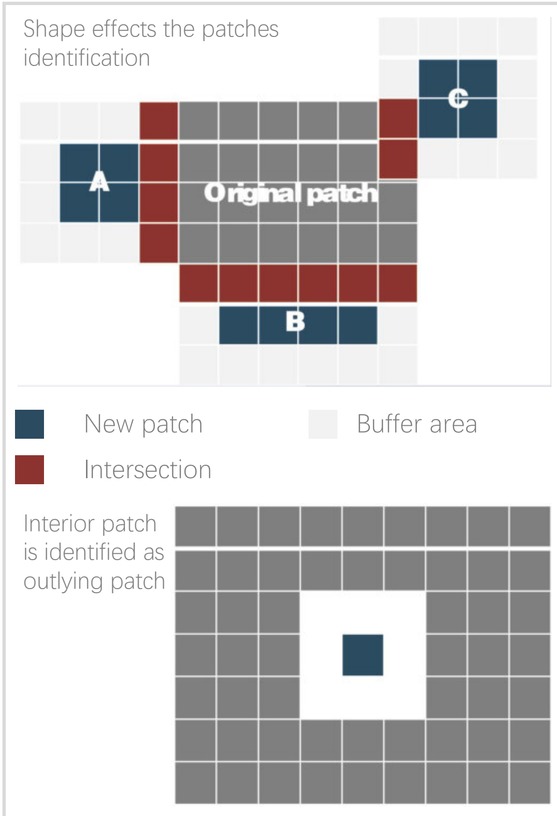


In the formula, MAI is the multi-order adjacency index for new patches; N is the number of buffers for new patches; A_0 is the area of the N buffer (outermost buffer); A_i is the area where the N buffer intersects the original patch. The smaller the MAI value is, the closer the new patches and their adjacent original patches are, and it indicates smaller level of urban expansion. Due to the consideration of efficiency, in the calculation of the MAI, the buffer distance D should be set to be equal to the resolution of the data source remote sensing image.

Advantages : It separates the urban expansions into more levels than other indexes, thus the result is very detailed and can reflect the expansion mode in an explicit way.

Disadvantages : 1. It cannot reflect the restoration and degradation simultaneously. 2. The buffer does not match the image pixels. 3. Irregular patches will affect the analysis result.

2.3.2 Shape-weighted evolution index (SWLEI)



$$SWLEI_i = (-1)^{\lambda} \times \frac{N_i}{N_i} \times 100 \quad (1)$$

$$N_i = D_i \times P_i + 4 \times D_i^2 \quad (2)$$

$$D_i = \left\lceil \frac{S_i}{P_i} \right\rceil \quad (3)$$

Where λ is a binary variable representing the status of the targeted patch (new or extinct patches) during the study period (t0, t). If it is a newly developed patch at time t, then λ=0 , otherwise λ=1. N_i is the number of pixels in the neighborhood of the targeted patch at time t, and N^{*}_i is the number of pixels in the intersection area of the targeted patch's neighborhood with existing patches. D_i is the neighborhood radius, S_i is the number of pixels in the targeted patch, and P_i is the ratio of the targeted patch's perimeter to the spatial resolution.

Advantages : It reflects the restoration and degradation simultaneously and eliminates the effects of shape.

Disadvantages : 1.There will be a large number of new patches wrongly defined as outlying as the picture. 2. The division of evolution modes is not as detailed as MAI.

3.Methodology

3.1 Multi-order shape-weighted evolution index (MSEI)

$$\mathbf{MSEI} = (-1)^{\lambda} \times \left(N - \frac{A_i}{A_0}\right) \quad (1)$$

$$D_i = \left[\frac{S_i}{P_i}\right] \times R \quad (2)$$

Where λ is a binary variable representing the status of the targeted patch (new or extinct patches) during the study period (t0, t). If it is a newly developed patch at time t, then λ=0, otherwise λ=1. N is the number of the buffer, and A_i is the area of intersection area of the targeted patch's neighborhood with existing patches, A_0 is the area of the outermost buffer. D_i is the neighborhood radius, S_i is the number of pixels in the targeted patch, R is the spatial resolution, and P_i is the ratio of the targeted patch's perimeter to the spatial resolution.

Evolution pattern division

Generizing the spatial distribution difference of the landscape into the different types of spatial expansion can provide a basis for the characterization of the landscape expansion mode.Gottmann et al. believe that the spatial expansion of cities can be divided into sprawl type, continuous piece type, fragmentation type, and diffusion type axial type, enclave type. Liu mainly divides the types of landscape expansion modes into infilling type, edge-expansion type and outlying type according to LEI. However, the outlying type can be divided more detailedly, further subdivision of it helps to understand the gradient of spatial relationships between old and new patches. Based on MSEI, the evolution types will be divided into infilling restoration/degradation, edge restoration/degradation, adjacent restoration/degradation, separating restoration/degradation and outlying restoration/degradation,

When |MSEI|∈[0,0.5), it's infilling restoration/degradation, when |MSEI|∈[0.5,1], it's edge restoration/degradation, when |MSEI|∈(1,3], it's adjacent restoration/degradation, when |MSEI|∈(3,4] , it's separating restoration/degradation and when |MSEI|∈(4,+∞), it's outlying restoration/degradation.

Tablet 1 Attribution of evolution type based on MSEI

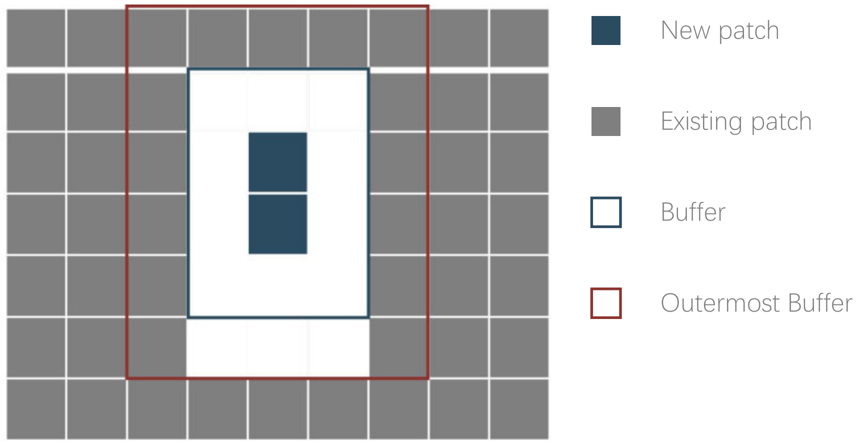
Evolution type	Infilling	Edge	Adjacent	Separating	Outlying
Buffer amount	1	1	(1,3]	4	(4,+∞)
Distance	[0,0.5D)	[0.5D,D]	(D,3D]	(3D,4D]	(4D,+∞)
MSEI	[0,0.5)	[0.5,1]	(1,3]	(3,4]	(4,+∞)

3.2 Landscape evolution patterns

Evolution type classification based on MSEI

The MSEI discrimination of the 5 evolution types is shown (10 types if considering restoration and degradation) , with a buffer distance of D. Patch A and B connect with the original patch, but A embedded in the original patch represents the infilling evolution; B is only half embedded in the original patch, representing edge evolution; C~E patches need to do multiple buffers to intersect the original patch.

Inner renwal



Considering the inner renewal of urban evolution, which could be mistaken as edge or adjacent restoration / degradation, we proposed a way to identify the inner renewal. That is, take the ratio of the outermost buffer area and the intersection area into consideration.

When |MSEI|∈（0.5，4], and

$$\frac{A_i}{A_0} \geq 0.5$$

The patch is identified as inner rewal.

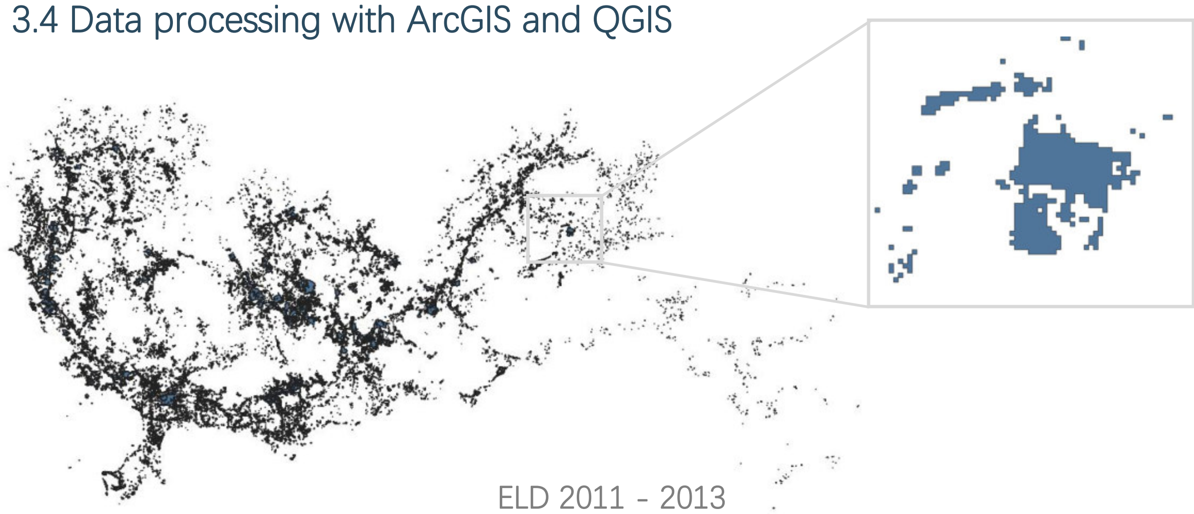
3.3 Application and practical significance of MSEI

Realistic meaning : The urbanization process is inevitably accompanied by the expansion of cities in space, and it is of great significance to depict and understand the evolution of the landscape pattern caused by urban expansion. Especially in large cities, urban growth and recession processes occur simultaneously.MSEI has a more accurate division of urban renewal and evolution in big cities, and compared with the previous index, it has a more accurate identification of a small scale of urban renewal. For cities like Shenzhen, Guangdong, Hong Kong and Macao, it is more meaningful to identify the growth model. ,

Application senarios : Identifying the trends in landscape restoration / degradation, capturing the characteristics of urban changes, and identifying the inferences behind them. And providing a guide for future urban planning.

1. Evolution of urban landscape pattern (Ecological restoration)
2. Small-scale renewal of urban villages (Urban renewal)
3. Improve the land use efficiency in underutilized areas or inactive urban areas
4. Change the cognition of the irreversible urban construction

3.4 Data processing with ArcGIS and QGIS

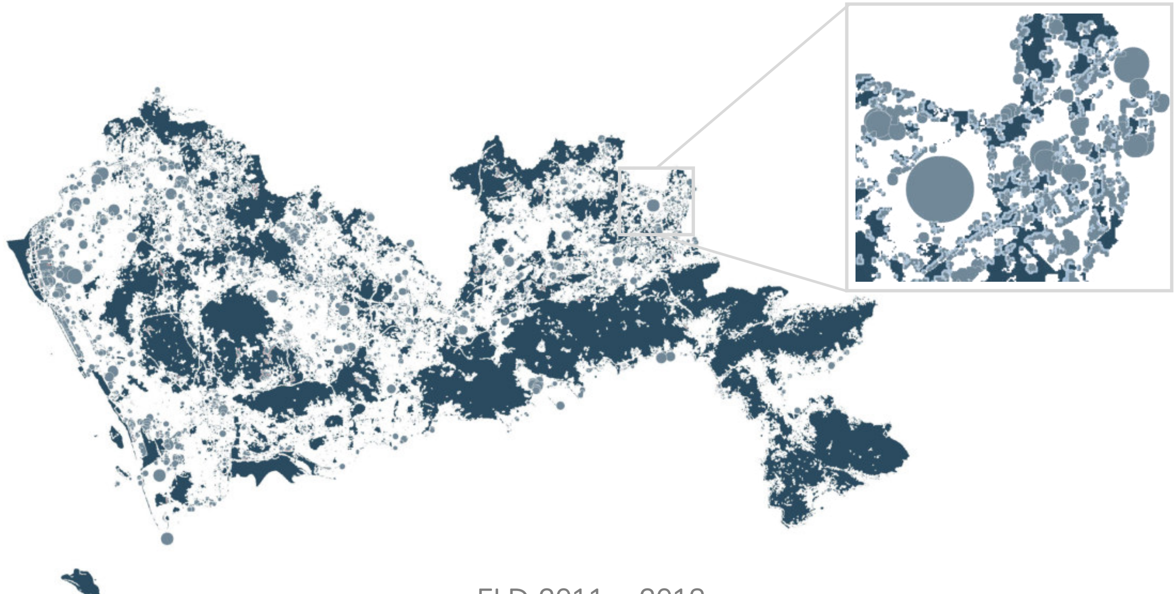


ELD 2011 - 2013

Use Vectorization of Raster Data to change the raster patch into vector patch.

(Need to use 8- connectedness).

The decrease patch is cut based on the original patch. If the decrease pattern, say patch of 1988-1991 and 1988 is used directly, all patches will be identified as infilling degradation (distance from the closest patch is 0), so the base map needs to be obtained from the original patches to minus the decrease patches.



ELD 2011 - 2013

Base patch   Intersection between patch buffer and original patch   Outermost buffer

1.Use Create a new table to calculate the distance between the new patch and the closest patch (Dist).

2. Calculate the radius of the buffer (R) , formula as followed :

math.ceil(!area!/!Perimeter!/30)*30 (area,perimeter is the new patch's area and perimeter)

3. Calculate the number of the buffer,formula as followed :

Int (Dist / R) +1

4. Generate the buffer and calculate the area of the new patch's outermost buffer and and the intersection area between the closest original patch.

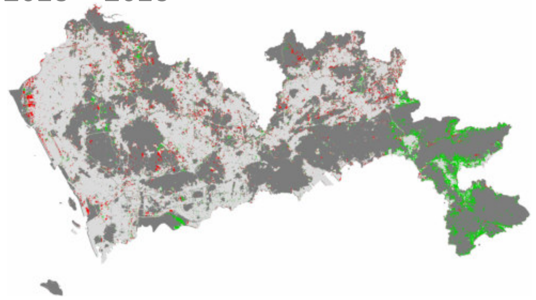
3.5 Drving factors determined by Geographical detector

The use of Geographical detector

Geographical detector will be used to determine the driving factors of urban evolution. The results can be used for better understanding of the spatial-temporal coupling of urbanization and ecosystem changes in urban agglomerations.

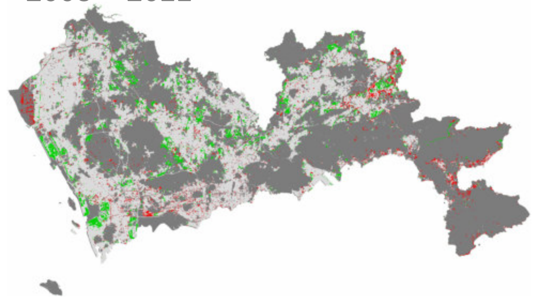
4. Preliminary Data Processing

2013 - 2015

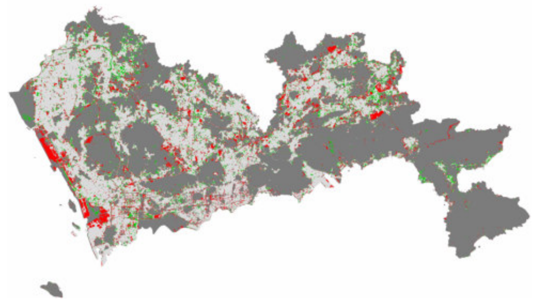


2011 - 2013

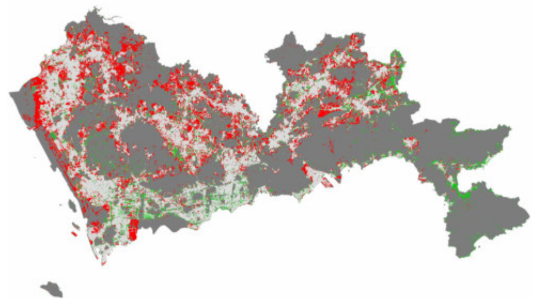
2008 - 2011



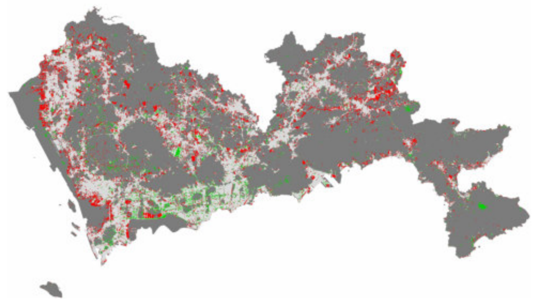
2005 - 2008



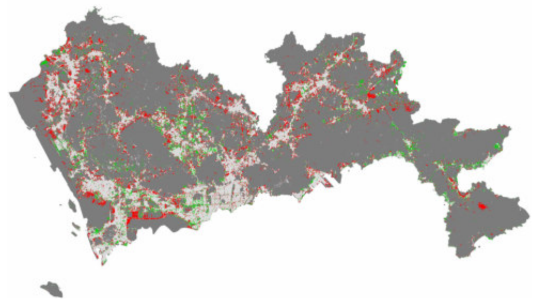
2001 - 2005



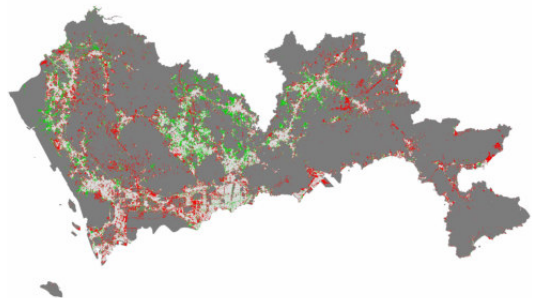
1999 - 2001



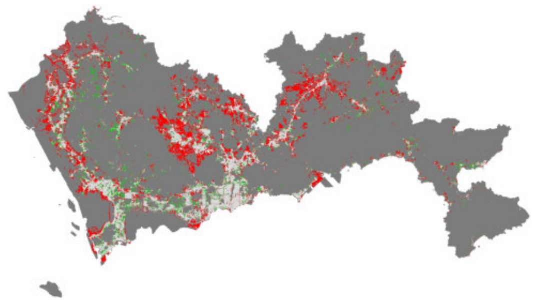
1996 - 1999



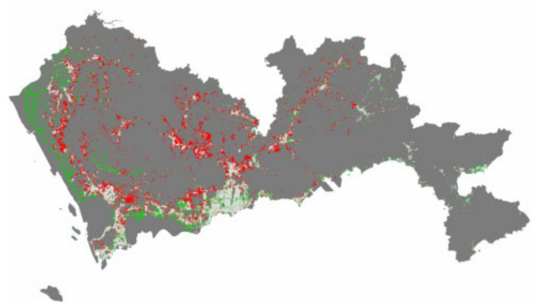
1993 - 1996



1991 - 1993



1988 - 1991



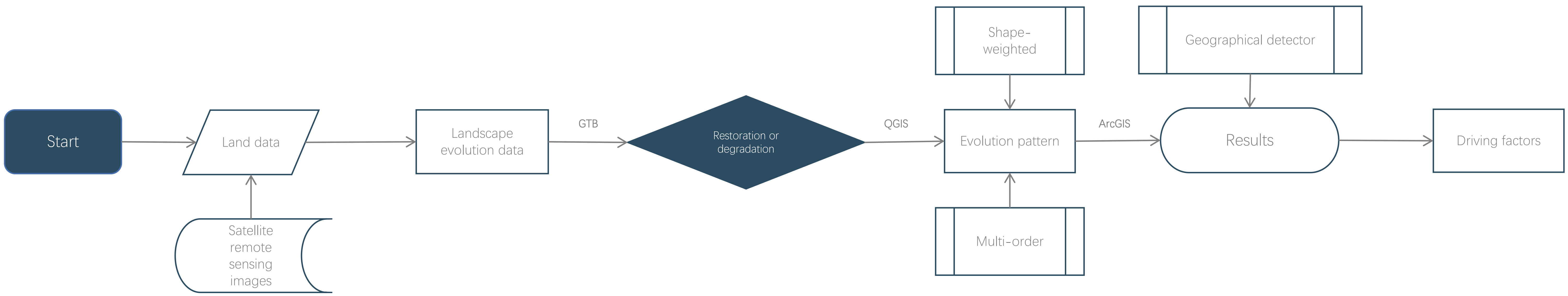
Green patches : increase, red patches : decrease

Preliminary data preparation: Recode the land use data. The needed is recoded as 2, the other is 1, no data is 0.

Calculation: Reclassify the land data, use Simple Change Statistics to calculate the change of the land data. The increase patch is coded as 12, the decrease is 21.

Extract by attributes: Extract the increase and decrease patches.

5.Detailed Framework



I propose the research framework as follows:

Firstly, the remote sensing images of cities in different time scales will be recognized and divided into urban zones and landscape zones.

Then the changes of landscape/urban patches will be calculated and compared to the former land use.

After that, the landscape evolution index will be used to recognize the evolution pattern of each patch that changed, charting them into infilling, edge, adjacent, separating, or outlying.

Finally, I'm prepared to use the geographical detector to determine the driving factors of urban evolution.

Thus, I plan to finish processing the remote sensing images and recognition in one week.

And the literature review will be enriched in two weeks. The content of geographical detector will be added.

Then the caculation and recognition of landscape pathes will be finshed in one weeks.

And driving factors will be determined by geographical detector, the determination of driving factors framework will be settled in one week, and the result of the evalutation of driving mechanism will finish in two weeks.

6. Hypothesis and Research Impact

Hypothesis

In Shenzhen's early stage of urbanization (1988-1990s), the urbanization shouldn't be quite rapid. ELD and ELR will probabaly be all in a relatively slow speed and reach the balance, the landscape will be in a healthy status.

After that, the urbanization slowly speeds up and ELD would become severe. However, ELR at that stage is likely to also developing quickly. This finding may be attributed to the fact that the inner rewal and reconstruction of the infrastructure are necessary and beneficial for new development during the rapid urbanization process. Enclosing and adjacent renewal during this period may account for most of the changed urban patches in area.

From 2001 to 2005, Shenzhen reached the stage of extensive development, large amount of landscape degrades and few ELR could keep landscape quality for it's mainly adjacent restoration that could change into area for the next development.

Around 2005, Shenzhen released the basic ecological control lines. This will lead to the ELR's increasement. Large patches could appear far away from the construction area and the proportion of outlying restoration add up.

Research impact

This research will investigate the driving mechanisms of land coverage modification. During the urbanization process, urban areas and landscape space are in a conflict transformation status; however, few studies focus on their simultaneous conversion.

The results can be used for better understanding of the spatial-temporal coupling of urbanization and ecosystem changes in urban agglomerations. Subsequently, decision-makers could respond to the spatial distributions of the land changes and evolution trends. They can formulate effective countermeasures that promote healthy development in key areas.

7. References

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