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Study on the spatio-temporal characteristics and influencing factors of urbanization process based on satellite remote sensing data: A case study of Shenzhen

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Abstract. With the development of society and economy, China’s urbanization process has accelerated, affecting the way of land use in China. Traditional methods of analyzing urbanization characteristics and their influencing factors make it difficult to visualize the changes in land-use patterns during the urbanization process. Satellite remote sensing has a greater advantage in identifying concrete coverage and built-up areas. In this study, the visualization and analysis of remote sensing images are used to monitor the trend of urban expansion and changes in land-use patterns in Shenzhen during the period of 1987-2023. At the same time, this paper provides an in-depth analysis of the spatial and temporal characteristics of urbanization in Shenzhen and explores the role of policy as a major factor in promoting the process. It is found that the proportion of built-up land in Shenzhen increased significantly between 1987 and 2023, and most of the built-up land was transformed into vegetated areas and waters. During the study period, urbanization in Shenzhen was characterized by high-speed expansion in the early period and slow growth in the later period. Upon analysis, the promotion of China’s reform and opening-up policy is the main factor that makes Shenzhen’s urbanization show the above characteristics. The research in this paper helps show the importance of policies in China’s urbanization process, which can provide experience for China’s urbanization to transfer from the high-speed mode to the high-quality mode.

Keywords: Satellite Remote Sensing, urbanization, Factors, Shenzhen.

1. Introduction

The study of the urbanization process and the analysis of its influencing factors have always been a subject of great concern and great value in modern society. With the development of society and economy, urbanization gradually accelerates. The acceleration of urbanization leads to the transformation of a large number of rural populations into urban populations, which in turn leads to the rapid expansion of urban land.

In 1978, China began to implement the strategy of ‘reform and opening up’. From 1978 to 2023, China’s economy grew at a rapid pace. Urbanization rate increased from 17.9% to 56.1% between 1978 and 2015[1]. The area of towns and cities expanded dramatically, and the population concentrated from rural to urban areas. High-speed urbanization has brought about drastic changes in land use and changed people’s lifestyles in China, especially in the southeastern coastal areas of China. At the same time, high-speed urbanization has also brought about a series of problems such as urban

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land constraints, poor living environment, and ecological deterioration, which makes it more and more important to research high-quality urbanization development methods.

Current research is mainly based on statistical data to demonstrate the spatial and temporal characteristics of urbanization and summarize its influencing factors through theoretical analysis. However, because China's research on the influencing factors of urbanization started late, the statistical data of the 20th century are rather imperfect. Meanwhile, textual data have difficulty in visualizing the change of land use. The development of remote sensing technology has made up for this limitation. Compared with purely statistical data, satellite remote sensing data has the advantage of being able to identify concrete coverage and built-up areas, and thus monitor the trend of urban expansion over a large period. In addition, the intuitiveness of dynamic monitoring of urban expansion can be further improved through the analysis and visualization of remotely sensed images. Remote sensing methods have already been applied in related studies. Ye Zhou visualized the urbanization process of Zhejiang Province based on its satellite remote sensing data from 1994-2015 and analyzed the spatial and temporal evolution characteristics from a multivariate perspective[2]. Yayun Deng identified and analyzed the spatial and temporal evolution of green space landscape patterns based on satellite remote sensing data of Hefei City[3].

Shenzhen, China, was approved by the government to establish a special economic zone in 1980. It has experienced rapid urbanization and has risen to become one of the cities with the highest urbanization rate in China. The urbanization process of Shenzhen started early, and the transition from rural land to urban land is obvious, which makes it suitable for the study. Therefore, this paper takes Shenzhen as the study area and selects Landsat satellite remote sensing images from 1987 to 2023 to dynamically monitor its urbanization process. The long-time series of remote sensing images will show the expansion trend of urban area in Shenzhen during this period, and assist in studying the evolution of land use over time.

On this basis, this study will corroborate the remote sensing monitoring results with demographic and economic statistics, and explore the influencing factors of the urbanization process in China's southeastern coastal areas under the impetus of national policies. Through this research, the valuable experience of China's urbanization can be further summarized, and constructive advice can be provided for the high-quality development of China's urbanization in the future.

2. Method

2.1. Overview of the research area

Shenzhen is located in the south of Guangdong Province, China, between 113°43′ and 114°38′ east longitude and 22°24′ and 22°52′ north latitude. The topography of Shenzhen is high in the southeast and low in the northwest. Its main topography is low hills, interspersed with gentle terraces. There are coastal plains in the west, and low mountains in the southeast. Shenzhen has a subtropical monsoon climate, which is warm and pleasant with abundant precipitation.

As one of the four central cities in the Guangdong-Hong Kong-Macao Greater Bay Area, Shenzhen has experienced rapid socio-economic development and urbanization. The resident population of Shenzhen has grown from 314,000 in 1979 to 17,661,800 in 2022. On the economic front, Shenzhen's GDP grew at an average annual rate of 23.0%, from 196 million yuan in 1979 to 1.67 billion yuan in 2016; by 2022, Shenzhen has realized a gross regional product (GRP) of 323,876.8 million yuan and a per capita GRP of 183,274 yuan[4]. After experiencing high-speed urban expansion and rough development in the early period, Shenzhen faces multiple challenges such as human-land conflicts and reduction of green space. As a result, it has been exploring a deep urbanization system since 2005, gradually moving into a high-quality economic development stage. By 2022, Shenzhen's urbanization rate has reached 99.79%, and it is making every effort to build itself into an international science and technology industry innovation center and a global ocean center city. The urbanization process of Shenzhen is highly representative in China, so the city is selected as the research area. During the past

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forty years, the administrative boundaries and zoning of Shenzhen have changed. To better study the urbanization process, this paper uses the administrative division of 2023.

2.2. Data sources

2.2.1. Data and information sources. The main data involved in this paper are shown in Table 1, including the following types: image data, vector data, statistical data, and planning data.

Table 1. Data Sources

Type	Data	Source	Purpose
Image data	1987, 1996, 2005, 2016, 2023 Shenzhen Landsat Series	EarthExplorer (usgs.gov)、Geospatial Data Cloud (GDC)	Extract land use distribution maps
Vector data	Shenzhen District Map 2023	http://datav.aliyun.com/tools/atlas GeoDa software	Get Shenzhen administrative division data
Statistical data	Shenzhen Population Census Data	Statistical Yearbook-Shenzhen Bureau of Statistics Website (sz.gov.cn)	Obtain demographic and economic data of Shenzhen for analysis
	Shenzhen's Gross Regional Product by Year		
Planning data	City Master Plan in Shenzhen from 1996 to 2010	http://pnr.sz.gov.cn/ztzl/csztgh/	Obtain the Shenzhen City Master Plan to assist in the analysis
	City Master Plan in Shenzhen from 2010 to 2020	http://pnr.sz.gov.cn/ztzl/csztgh/	

2.2.2. Landsat data sources. NASA's Landsat series of satellites has been launched sequentially since 1972. Currently Landsat 1-4 have been disabled one after another, and Landsat 5 was retired in June 2013, while Landsat 8 was launched on February 11, 2013. Landsat series have characteristics including a long time span and wide coverage, among which the equal spatial resolution (30m) sensors can meet the demand of land-use distribution map extraction and mapping. Therefore, Landsat series images (from EarthExplorer, the United States Geological Survey website, and the Geospatial Data Cloud Platform) are selected for extracting the land-use distribution data of Shenzhen in 1987, 1996, 2005, 2016, and 2023. Table 2 shows the Landsat series sensors and band parameters used in this research. Landsat 8 and Landsat 9 use different sensors, but have the same wavelength and resolution in bands 1-7, so they are listed together.

Table 2. Landsat series sensor and band parameters

Sensor	Band	Band length(μm)	resolution(m)
Landsat 4-5 TM	Band 1 Blue	0.45-0.52	30m
	Band 2 Green	0.52-0.60	30m
	Band 3 Red	0.63-0.69	30m
	Band 4 NIR	0.76-0.90	30m
	Band 5 SWIR 1	1.55-1.75	30m
	Band 6 Thermal	10.40-12.50	120(30)m
	Band 7 SWIR 2	2.08-2.35	30m

Table 2. (continued)

Landsat 8 OLI Operational Land Imager / Landsat 9 OLI-2 Operational Land Imager	Band 1 Coastal	0.43-0.45	30m
	Band 2 Blue	0.45-0.51	30m
	Band 3 Green	0.53-0.59	30m
	Band 4 Red	0.64-0.67	30m
	Band 5 NIR	0.85-0.88	30m
	Band 6 SWIR 1	1.57-1.65	30m
	Band 7 SWIR 2	2.11-2.29	30m

Encountering poor image quality of the study area in the target years (1986, 2006) due to excessive cloudiness or damaged image edges, high-quality images of the nearest years (1987, 2005) were selected for replacement and supplementation. The selected image data are shown in Table 3.

Table 3. Status of selected image data

Orbital No.	Status of data				
	1986 Landsat4-5 TM	1996 Landsat4-5 TM	2006 Landsat4-5 TM	2016 Landsat 8 OLI	2023 Landsat 9 OLI-2
121/044	1987-12-17	1996-11-23	2005-01-16	2016-12-16	2023-04-16
122/044	1987-12-08	1996-03-03	2005-11-23	2016-02-07	2023-03-06

2.3. Method

2.3.1. Data preprocessing. The image preprocessing process mainly includes radiometric correction, geometric correction, atmospheric correction, image mosaicking, and image cropping. The Landsat data downloaded from the EarthExplorer website are processed with a correction of L2SP, which means that the data have been radiometrically, geometrically, and atmospherically corrected, and can be cropped and mosaicked directly.

Among the images used in this study, the data with orbit number 121/044 is in WGS84/UTM zone 50N coordinate reference system (No. EPSG: 32650), and the data with orbit number 122/044 is in WGS84/UTM zone 49N coordinate reference system (No. EPSG: 32649). To get the complete land-use distribution map of Shenzhen, it is firstly necessary to reproject the data of two neighboring orbits, 121 and 122, to the same coordinate system. In this study, the Warp tool of QGIS 3.32.1 software was used to reproject the data built on the WGS84/UTM zone 50N and WGS84/UTM zone 49N coordinate reference systems to the WGS84/UTM reference coordinate system (No. EPSG: 4326).

Image cropping and mosaicking were performed next. When processing the 2005 image data, it was found that the edge of the raster image was jagged, so this part of the raster image was appropriately cropped in order not to affect the accuracy of the subsequent identification and classification. Finally, the reprojected neighboring track data were subjected to an image mosaicking operation using the Merge tool, and cropped according to the vector range of the administrative divisions of Shenzhen (the procedure is shown in Figure 1).

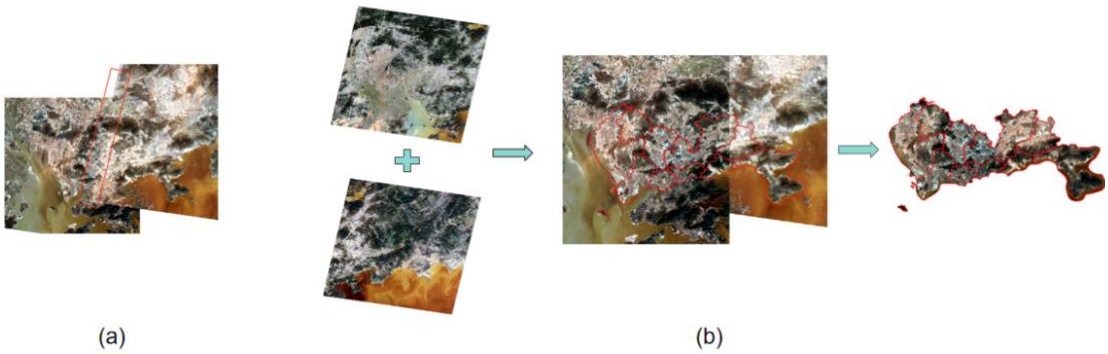

Figure 1. Image pre-processing procedure: (a)Cropping the jagged edge; (b)Merging and clipping procedure

After the above data preprocessing steps were completed, five complete areas of image data were obtained for the years 1987, 1996, 2005, 2016, and 2023 in Shenzhen. Results are shown in Figure 2 below.

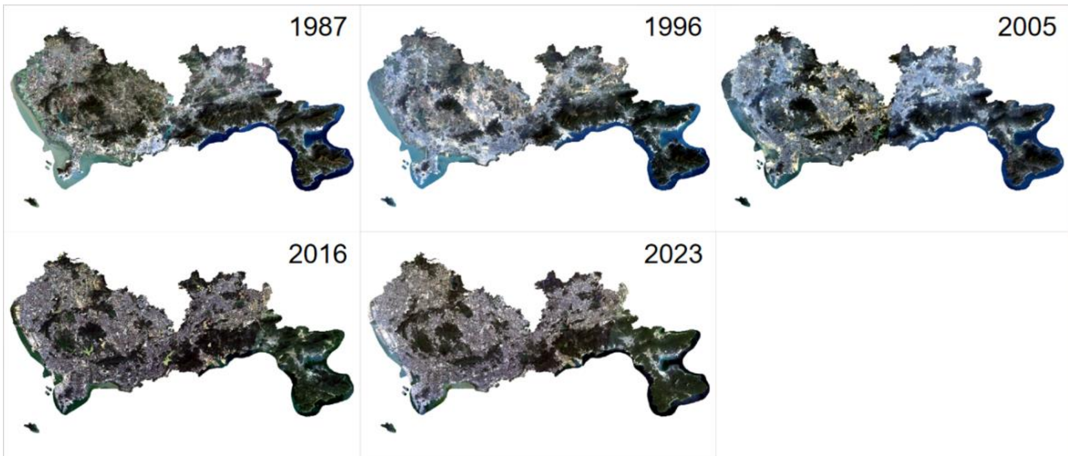

Figure 2. True color image of Shenzhen, 1987-2023

2.3.2. Band selection and calculations. Remote sensing indices that may be used in this study and how they are calculated:

(1) Normalized Building Index NDBI

Built-up areas have a stronger reflective intensity on the SWIR than the NIR. Around this property, the Normalized Building Index NDBI is created to help with classification.

$$\mathrm{NDBI} = \frac{\mathrm{SWIR} - \mathrm{NIR}}{\mathrm{SWIR} + \mathrm{NIR}} \tag{1}$$

Although NDBI can have an enhancement effect on building areas, due to the heterogeneity between different building areas, i.e., different building materials, etc., there is a difference in reflectivity, which results in the unsatisfactory extraction of some areas when the building is extracted using NDBI. At the same time, when using NDBI to enhance the building area, the bare soil area is also enhanced due to the similarity between the bare soil area and the building area in the reflectivity band[5].

(2) Normalized difference between bare ground and building land index NDBBI

The reflectance of bare land and building area shows an overall increasing trend from Green to the SWIR band, followed by a slight decreasing trend to MIR; the spectral separation between bare land and building and vegetation and waters in the MIR band is very obvious, the reflectance of bare land

and building is usually higher, and there is a sudden decrease in reflectance of waters and vegetation in MIR band. Combining the reflectance peaks in the vegetation Green band and the NIR band, a new normalized difference between bare ground and building land use index, NDBBI can be constructed.

$$\mathrm{NDBBI} = \frac{1.5\mathrm{MIR} - \frac{\mathrm{NIR} + \mathrm{Green}}{2}}{1.5\mathrm{MIR} + \frac{\mathrm{NIR} + \mathrm{Green}}{2}} \tag{2}$$

In Landsat, MIR can be replaced by SWIR. Compared to NDBI, NDBBI is less affected by vegetation and water, while is more complete for extraction of urban areas. However, its drawback is that it can not subdivide buildings and bare soil[6].

(3) Normalized impervious surface index NDISI

NDISI proposed by Hanqiu Xu is used to extract impervious surface information. The index is composed by the method of the composite band, which can effectively distinguish impervious surfaces and soil and can suppress the influence of sand and water body information. So it does not need to be rejected in advance, and it improves the purity of information. The formula of NDISI is as follows:

$$\mathrm{NDISI} = \frac{\mathrm{TIR} - \left[\frac{\mathrm{VIS} + \mathrm{NIR} + \mathrm{MIR}}{3}\right]}{\mathrm{TIR} + \left[\frac{\mathrm{VIS} + \mathrm{NIR} + \mathrm{MIR}}{3}\right]} \tag{3}$$

Among them, NIR, MIR, and TIR represent the near, middle, and thermal infrared bands, respectively. MIR can be replaced by SWIR1(B5) in Landsat; VIS represents any of the 3 visible bands, red, green, and blue, which are selected according to the actual effect. To a certain extent, NDISI can somewhat help to distinguish the building from the bare soil [7].

(4) Normalized vegetation index NDVI

Vegetation has strong reflection in the NIR band, and at the same time, it has strong absorption in the Red band, which is manifested in the spectra as the appearance of peaks and valleys of reflectance. This is the feature of vegetation distinguishing from other features, and it is highly separable so that the Normalized Vegetation Index NDVI established by these two bands can extract the characteristics of the vegetation[8] . The NDVI formula is as follows:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} - \mathrm{Red}} \tag{4}$$

The image data obtained in this study fuses seven bands, and the band combination selected for the classification view is RGB=753 (Landsat 4-5 TM) or RGB=764 (Landsat 8/Landsat 9), which can more clearly label the built-up land (purple, brown, white), vegetation (green), and water bodies (dark blue, black). After processing, the pseudo-color images of Shenzhen City from 1987 to 2023 are shown in Figure 3 below.

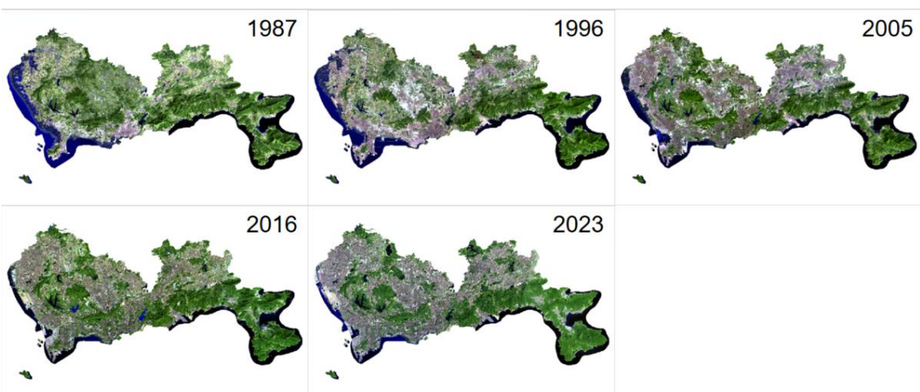

Figure 3. False color image of Shenzhen, 1987-2023

3. Result

3.1. Classification of land use types

In this study, this kind of pseudo-color band combination image is used as the classification base map, together with the normalized building index NDBI and the composite index NDISI to extract the building land and bare soil, and the normalized vegetation index NDVI is used to discriminate the vegetated land.

After processing with the Semi-Automatic Classification Plugin of QGIS software, the land use distribution map of Shenzhen can be obtained each year. The colors used for each land-use type are as follows. The results of land use type classification are shown in the following figure:

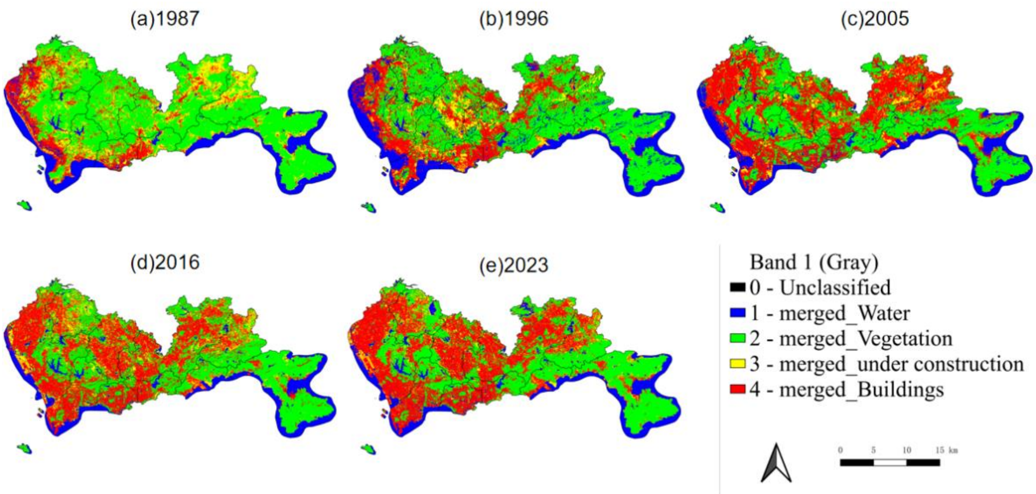

Figure 4. Classification results of land use types in Shenzhen, 1987-2023.

3.2. Analysis of changes in land use types

Based on the results of the 1987-2023 Shenzhen land use classification obtained in the previous chapter, the proportion of land use types in each year is analyzed as follows in Table 4. The compositional structure of land-use types in Shenzhen from 1987 to 2023 mainly presents the following characteristics.

(1) The proportion of waters and areas covered by vegetation together exceeds 50% each year, which is an important component of land use in Shenzhen. The sum of the proportions of the two declined continuously from 1987 to 2023.

(2) Vegetation-covered areas showed an overall decreasing trend between 1987 and 2023, with their proportion decreasing from 56.123% to 39.632%.

The area occupied by built-up land increased significantly from 1987 to 2023, and its proportion expanded from 14.990% in 1987 to 39.868% in 2023. In 2023, this land-use type has also become an important component of land-use in Shenzhen.

Table 4. Area share of each land use type in Shenzhen, 1987-2023

Land-use type	1987(%)	1996(%)	2005(%)	2016(%)	2023(%)
Waters	12.559423	17.929621	14.305205	11.737768	12.259449
Vegetation	56.123352	49.931116	40.643297	40.526315	39.631583
Unutilized land /under-construction area	16.327207	7.460718	6.08157	10.676473	8.240478
Built-up	14.990018	24.678546	38.969928	37.059443	39.86849

Then, further analyze the changes in the percentage of each land use type in four time periods: 1987-1996, 1996-2005, 2005-2016, and 2016-2023.

(1) The percentage of water fluctuates up and down throughout the study period, showing an upward trend between 1987 and 1996, and a continuous decline between 1996 and 2016. A slight increase was shown after 2016, with the final percentage close to that of 1987.

(2) The vegetation area decreased significantly during the 36 years, and its declining process was mainly concentrated from 1987 to 2005, from 56.123% to 40.643%. The decline from 2005 to 2023 is small, with a decrease of about 1% in percentage.

(3) The proportion of built-up land, i.e., urban land area, increased significantly from 1987 to 2023, and the increase mainly centered on the period from 1987 to 2005. Among them, 1996-2005 has the largest increase, with a 9-year increase of about 14%; the 1987-2005 time period is the second largest, with an increase of about 10% in 9 years. After 2005, the growth rate of the share of built-up land area in Shenzhen slowed down and even showed some fluctuations (the share was about 37.06% in 2016). By 2023, the share stabilizes to 39.868%, which is the same as the share of area covered by vegetation.

3.3. Analysis of land use type transfer

Using the SCP Plugin /Land Cover Change tool of QGIS software, the distribution of land-use types transfer between years was obtained. The transfer of land-use types in Shenzhen in 2023 compared to 1987 is shown in Figure 5 below:

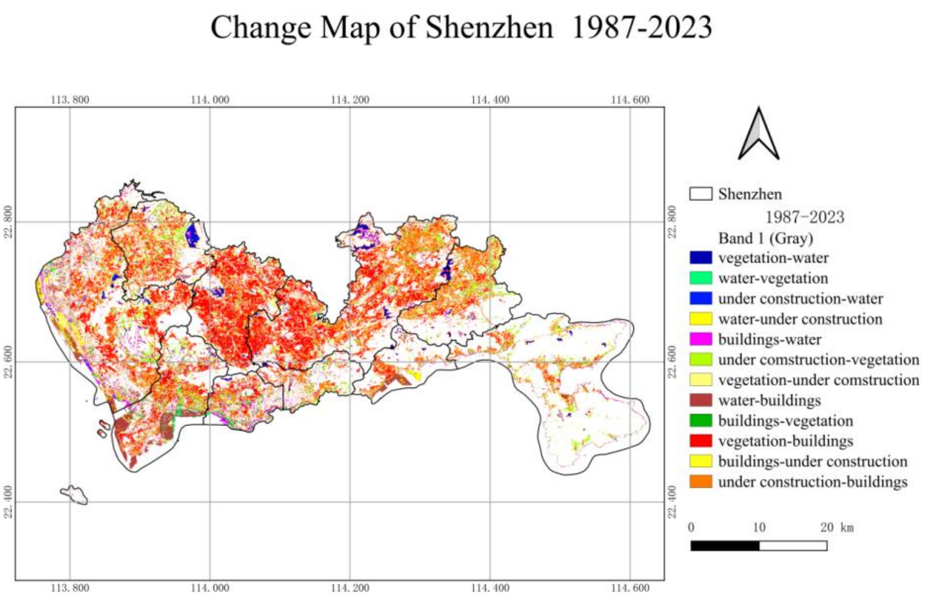

Figure 5. Shift in land use types in Shenzhen, 1987-2023

It can be seen that the area of built-up land expanded significantly during the period 1987-2023, with the portion of the flow from other land-use types to built-up land accounting for two-thirds of all transfers. Among the types of land converted to built-up land, the largest share is vegetated land converting to built-up land, which reaches about 37% of all flows, followed by unutilized land/land under construction, which reaches about 25%; the remaining 5% represents the conversion of watersheds to built-up areas.

Figures 6 and 7 below show the changes in land-use types over the four time periods.

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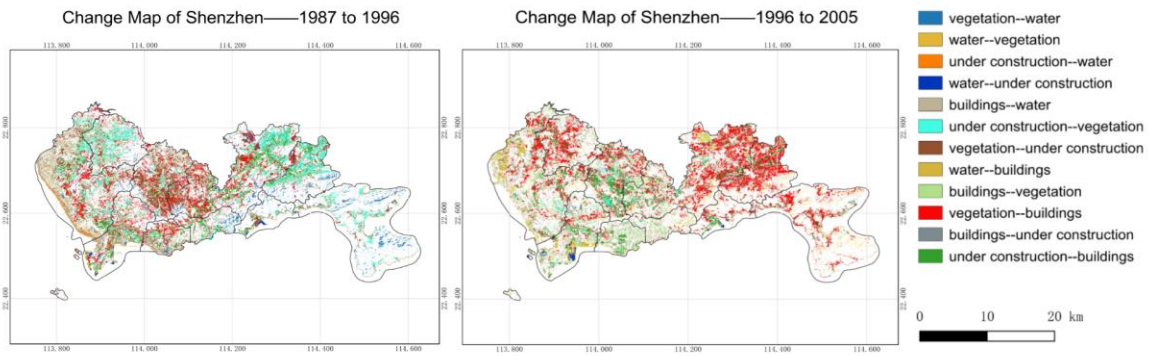

Figure 6. Change map of Shenzhen, 1987-1996 /1996-2005

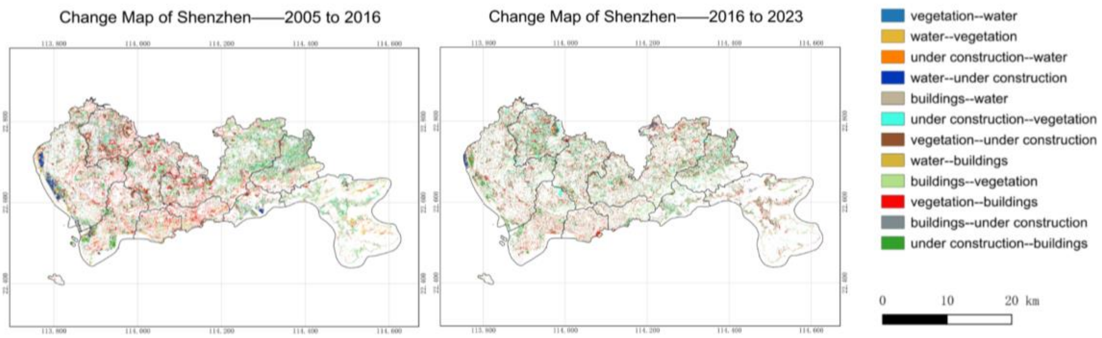

Figure 7. Change map of Shenzhen, 2005-2016 /2016-2023

Building land expanded rapidly from 1987 to 1996, with all three other categories having portions that flowed into building land. Of these, the largest proportion of vegetated areas was converted to building land and building land, which together accounted for about 35 percent. The conversion of unutilized land/built-up land to built-up land was similarly large, at about 16%. The other transformation of this period is the ‘conversion of unutilized land to vegetated land’, with a share of nearly 20%. The inter-conversion of water and built-up land is also evident in this period, with both accounting for 7-8% of the total.

The transformation of vegetated land to built-up land was the most pronounced and the largest of all the periods from 1996 to 2005, with a share of 37%. The percentage of all shifts from other types to built-up land was also the highest in this period, totaling nearly 60%. This data is the main feature of the change of land-use types in this period, showing that the urbanization of Shenzhen from 1996 to 2005 covered a wide range of areas and had a huge amplitude. The share of all other types of transformation is more even, with a similar share to that of the 1987-1996 time period.

The transformation of each land use type during the period of 2005-2016 is scattered as a whole, and the transformation modes that account for a larger proportion of the total include the transformation of built-up land into land covered by vegetation, the transformation of unutilized/under-construction land into built-up land, the transformation of land covered by vegetation into built-up land, and the transformation of built-up land into under-construction land. Relative to the other periods, the shift from built-up land to vegetated land was more pronounced in the 2005-2016 time period and even became the dominant form of change in land-use types during that period.

The overall shift of each land use type during 2016-2023 is also characterized by dispersion. The main land use type change in this period is back to the category of “unutilized/under-construction land to built-up land”, followed by a larger share of the conversion of vegetation to built-up land. At the same time, the conversion of built-up land to vegetated land is roughly equal to its reverse. There is

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also a portion of conversion from built-up land to water in this period, and such areas are located in the northern part of the city.

3.4. Example analysis of the spatial distribution of land use type changes in Shenzhen City

The change of land use type in Shenzhen from 1987 to 2023 is mainly the conversion of vegetation into building land. The spatial distribution of this change in the two time periods 1987-1996 and 1996-2005 is labeled in Figure 8.

The rapid urbanization of Shenzhen in 1987-1996 mainly occurred in Longhua District and the western part of Longgang District in the central north. In contrast, from 1996-2005, urban land in Shenzhen expanded mainly to Longgang District and Pingshan New District in the northeast, while the urbanization process in the northwest also advanced.

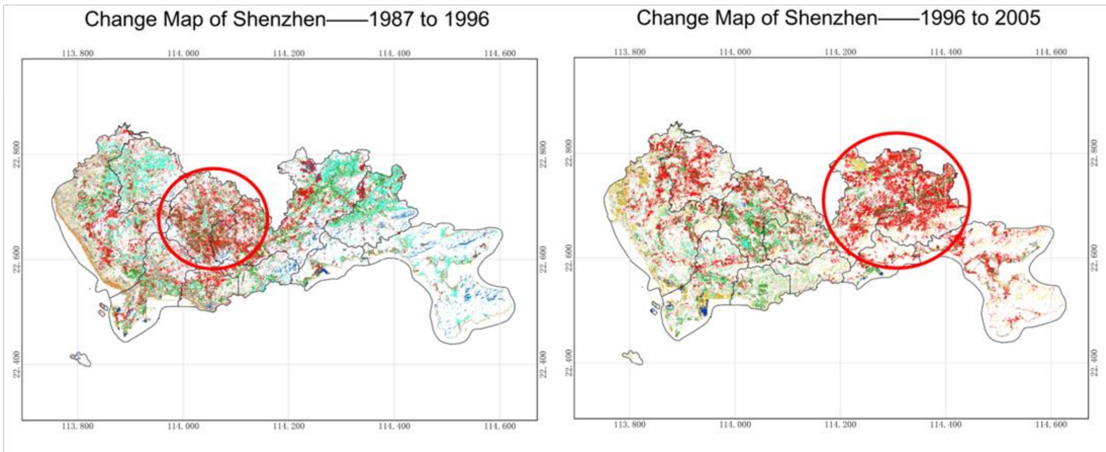

Figure 8. Spatial distribution of changes in land-use types in Shenzhen City

4. Discussion

4.1. Analysis of the causes of urbanization in Shenzhen

Compared to spontaneous urbanization caused by other factors, Shenzhen's urbanization is different in that it has been greatly driven by national policies; in 1980, the Chinese government approved the establishment of a special economic zone in Shenzhen. With the support of national policies, Shenzhen absorbed a large number of foreigners and entered into a high-speed urbanization process driven by the combined forces of industrialization and marketization. From 196 million yuan in 1979 to 1.67 billion yuan in 2016, Shenzhen's GDP grew at an average annual rate of 23.0%[4]. In 2013 it was 1,450,023 million yuan , 8055 times what it was before 1980[9]. Shenzhen's resident population grew from 314,000 in 1979 to 11.91 million in 2016; and by 2022, the urbanization rate had reached 99.79%.

After experiencing high-speed expansion and crude development in the early period, Shenzhen has gradually stepped into the stage of high-quality economic development since 2005, exploring a system of deep urbanization. In 2005, the government designated the Basic Ecological Line to strictly control human land use[10]. This change is reflected in the land use situation as a slowdown in the growth rate of the proportion of built-up land and a slow decrease and stabilization of the proportion of vegetation and water area. The reason can be traced back to the national policy of high-speed development to high-quality development mode change, as well as the encouragement of the construction of ecological civilization. Over the past 10 years Shenzhen has made substantial efforts to build an ecological city as a response to the call for a Green Living Circle in the Greater Pearl River Delta[11]. Another example is that the land-use type changes from 1987 to 1996 were mainly concentrated in Longhua District in the north of Shenzhen, while from 1996 to 2005 they were mainly concentrated in Longgang District and Pingshan District in the northeast. These areas are mainly characterized by the conversion of vegetated land into built-up land in terms of land-use type changes. Combined with the Urban Master Plan document of Shenzhen, these areas have been successively established by the government as new technological zones, and the rapid advancement of their urbanization cannot be separated from the guiding role of the state policy on high-tech industries.

4.2. Limitations of this study

The analysis of the spatial and temporal characteristics and dynamic changes of the urbanization process in Shenzhen in this study still has certain limitations.

Firstly, due to the early selection, the number of Landsat satellite remote sensing data covering the Shenzhen area is relatively small, and this study only adopts data from a single source of Landsat, which is not representative and reliable enough.

Secondly, this study focuses on the analysis of land-use classification results to study the characteristics of urbanization in Shenzhen, the classification is based on various remote sensing indices that are commonly used, so the accuracy of the identification of each land-use type needs to be improved. It can be improved through the development of new algorithms.

5. Conclusion

This paper finds that the proportion of built-up land in Shenzhen increased significantly between 1987 and 2023, and most of the built-up land was transformed into vegetated areas and waters. Among them, from 1987 to 2005, the area of vegetation was greatly reduced and transformed to other land-use types, and the proportion of built-up land increased dramatically; from 2005 to 2016, the expansion of the city slowed down, and the trend of the reduction of the vegetated land also slowed down. From 2016 to 2023, the proportion of each land-use type tends to be stabilized, and the urban area grows slightly. In terms of spatial change, from 1987-2005, built-up land in Shenzhen mainly expanded from the southern coastal area to the west, north, and northeast, while the vegetated areas and non-urban areas in these areas were transformed into towns. In 2005-2023, the changes in land-use types and their mutual transformation in Shenzhen were more spatially dispersed. Most of them were localized and small-scaled, with inconspicuous features. Distinguished from the influencing factors of spontaneous urbanization, the factors that make Shenzhen's urbanization process show the above characteristics are mainly the guidance from national policies. How policies have effects on urbanization in Shenzhen are as follows: from 1987 to 2005, driven by the policy of 'reform and opening up', Longhua District and Longgang District were established in the northern part of Shenzhen, and the central and northern parts of the city became the center of development, with the process of urbanization in the stage of high-speed expansion. In 2005, in response to the government's call for "high-quality development", Longgang District, Pingshan District and Dapeng District were set up in Shenzhen. Since 2005, Shenzhen has responded to the government's initiation for "high-quality development" by establishing new high-tech districts such as Longgang, Pingshan and Dapeng, as well as improving district cooperation and division.

This study visualizes the urbanization process of Shenzhen from 1987 to 2023 based on Landsat satellite remote sensing images, which enriches the study of the characteristics of the early stage of urbanization in Shenzhen. The selected period is larger than that of other studies in the same field, so it shows the spatial and temporal characteristics of urbanization in Shenzhen more completely. In addition, this study also analyzes the influencing factors of urbanization in China's southeastern coastal areas from a more novel perspective of national policy support. Future studies will use remote sensing indices or algorithms with higher accuracy to identify land-use types and classify them, to reveal the spatial and temporal characteristics of urbanization in Shenzhen City from 1987 to 2023 in a more effective visualization method, which will provide valuable experience for the development patterns of other cities in China.

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