Analysis on the characteristics of urban expansion in Urumqi

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Abstract. The urban spatial structure change caused by urban expansion is the most intuitive manifestation of urbanization in space. In this study, Landsat TM remote sensing image maps from 2000, 2010, and 2017 were used as the main data sources. A combination of supervised classification and manual visual interpretation was used to extract the current distribution maps of the three impermeable surfaces in Urumqi. Based on the dynamic changes from 2000 to 2010 and 2000 to 2017, the changes in Urumqi's built-up areas from 2000 to 2017 were analyzed, and the characteristics and causes of urban expansion in Urumqi were analyzed. The results show that the interior of Urumqi city tends to be saturated. Due to the limitation of topographical factors outside the urban area, the overall urban form is axially distributed in a diagonal “T” shape. From 2000 to 2010, the area increased from 163.31 km² to 332.66 km², with a net increase of 169.35 km². The average annual growth rate was 10.37%, and from 2010 to 2017, the area increased to 434.02 km², a net increase of 101.36 km², the average annual growth rate was 3.05%. The average annual growth rate from 2000 to 2010 was greater than 2010 to 2017; Comparing the area and changes of various jurisdictions, the development advantages of the new urban area are obvious. From 2000 to 2010, the development advantages of the new urban area were obvious. Midong District and Toutunhe District developed rapidly, while Shaibak District had the fastest growth.

1. Introduction
City is a typical dynamic spatial complex system, and its spatial evolution is highly complex. Urban expansion is mainly the growth or decline of urban areas. The urban spatial structure change caused by urban expansion is the most intuitive manifestation of urbanization in space. Urbanization is a process in which a region's population is relatively concentrated in towns and cities [1-3]. With the introduction of the reform and opening-up policy in 1980, China’s economy and society are undergoing a qualitative leap, and the process of urbanization is increasing at an alarming rate [4,5]. Throughout the world, urbanization is a necessary stage for a country or region to modernize, and it is also an important indicator of the country's economic and cultural levels [6-8]. The impervious surface is a typical urban landscape generated with the development of urbanization, which can reflect the development of the city and affect the ecological environment of the city, etc [9,10]. The expansion of built-up areas is a spatial expression of urbanization, and the important basis for measuring the level of urbanization in a region is the area of built-up areas. The impervious surface in the city is an important symbol of urban built-up areas. The study of impervious surfaces can indirectly reflect the development and changes of urban built-up areas [11,12].
As the geographic center of Asia, Urumqi is one of the important cities on the New Silk Road Economic Belt. However, Urumqi is deeply inland. As an oasis city in a typical arid region, the natural environment is fragile and high-intensity human activities have seriously threatened the oasis natural ecological environment system. In the process of Urumqi urbanization's impact on the ecological environment, the role of spatial urbanization relative to social urbanization and economic urbanization is more obvious [13-15]. Therefore, studying the laws of urban expansion and summing up the driving factors of urban expansion can carry out reasonable urban planning for Urumqi, solve the problem of rational land use, and promote sustainable urban development.

2. Research area
Urumqi is the capital of the Xinjiang Uygur Autonomous Region, China. It is located in the northern foot of the middle part of the Tianshan Mountains and the southern edge of the Junggar Basin. The city is surrounded by mountains on the east, south, and west. Only the northern part is the low mountain river valley and the floodplain fan plain. With a total area of 14216.3km², it has jurisdiction over 7 districts and 1 county. At the end of 2017, the registered population was 2.22 million[16-18]. The selection of this research area is the center of Urumqi, including Shayibak District, Tianshan District, Shuimogou District, Xinshi District, Midong District, Toutunhe District, Urumqi County, and Daban District. Among them, due to the terrain of Urumqi, Daban District and Urumqi County involve fewer research elements and have no research value. Therefore, only six districts in the city center are used as the research object in the analysis.

3. Data source and processing
The main data sources used in this paper include remote sensing and non-remote sensing data. For the remote sensing data, Landsat TM image data of the United States Land Satellite in 2000, 2010, and 2017 were selected with a resolution of 30m and orbit number of 143/29. The collection time is concentrated in the summer period from August to September. The surface information is obvious, and cloudless images are selected, and the quality is good. The non-remote sensing data are the statistical years of Urumqi from 2000 to 2017.

The TM remote sensing data of the three phases are processed by geometric correction, registration, data fusion, image enhancement, etc., and then ENVI software is used to perform band synthesis, supervised classification, and correction by visual interpretation. The modified image was imported into ArcMap, and the raster to vector was used to statistically analyze and calculate the vector data to obtain the feature change data of Urumqi built area. To extract the built-up area in the supervised classification, the impervious surface area, non-impervious surface area, unrecognizable area, and mixed pixel area are selected as the classification system, and the training area selects typical features.

4. Results and discussing

4.1. Analysis of the status of built-up areas
The supervised and classified remote sensing image maps are processed by ArcMap, as shown in Figure 1, Figure 2, and Figure 3. Then use the vector cropping tool to crop the impervious surface in this vector area. Open the attribute table after cropping each vector data, add the area field, and use the geometric calculation method to calculate the area of the impervious surface in the area, as shown in Table 1.

According to Figure 1, Figure 2 and Figure 3, it can be seen that the interior of the city is constantly being filled, and the obvious filling areas are the new urban area, Shuimogou District, Shayibake District, and Tianshan District. From 2000 to 2017, the scope of the built-up area is also expanding. From the morphological point of view, it is found that the entire city has a diagonal T-shaped distribution with a wide width in the north and a narrow width in the south, and the expansion range is obvious. The main expansion directions of the built-up area are one in the direction of the new urban area in the northwest, the other in the direction of the northern edge of the western mountain, namely
Shayibak District and Toutunhe District; Expansion. From the perspective of terrain, Urumqi is surrounded by mountains on the east, west, and south, and there are Boda Mountain, Karatag Mountain, and Dongshan Mountain in the east; Karazha Mountain and Xishan Mountain in the west; (George Mountain), Tugda Bantag, etc. Only the valley between the northern impact plain and the east and west mountains is a relatively flat area. Therefore, the Tianshan District and the Shuimogou area cannot be significantly expanded outward due to the influence of the mountainous terrain, while most of the northern areas are agricultural areas. There is less resistance to urban expansion and the trend of expansion is obvious. In general, the development of Urumqi’s built-up area is constrained by topographic conditions and presents an expansion pattern diverging along with the old city to the north.

Data analysis revealed that the area of built-up areas changed significantly from 2000 to 2017. From 163.31km² in 2000 to 332.66km² in 2010, a net increase of 169.35km², and the area of the built-up area in 2017 became 434.02km², a net increase of 101.36km².

The four jurisdictions with large areas built-in 2000 were the new urban area, the Shayibak District, the Tianshan District, and the Shuimogou District, respectively 49.83km², 33.10km², 31.79km², and 21.04km², while Midong District and Toutunhe Areas are only 14.36km² and 19.88km². It is roughly judged that the main urban areas are located in Tianshan District, Xincheng District, Shuimogou District, and Shayibake District. The area distribution of built-up areas in 2010 changed from the original four jurisdictions to the new urban area, Midong area, Toutunhe area and Shuimogou area, which are 105.78km², 67.12km², 47.95km², and 42.05km² respectively. The built-up areas of Tianshan District and Shayibake District no longer have the advantages of development in 2000 but have been replaced by Midong District and Toutunhe District. In 2017, the main area of the built-up area continued to change, becoming the new urban area, Midong District, Shayibak District, and Toutunhe District, respectively 115.65km², 85.83km², 85.14km², and 70.63km², of which the Shayibak District changed. Significantly.
Regarding Figure 4, analyze the trend of the proportion of built-up areas in each jurisdiction for each year. From 2000 to 2017, the area of built-up areas in each jurisdiction expanded to varying degrees. Among them, the proportion of new urban areas in built-up areas has remained high, and the largest proportion was in 2010. The proportion of Tianshan District and Shuimogou District has been decreasing year by year, while Midong District and Toutunhe District have both increased.

From the analysis of Google Earth image maps, Urumqi's urban expansion is mainly two modes of axial development and scattered distribution. The axial development mainly extends outward along with the old city and highways, mainly distributed inside and around the city. The sporadic shape is mainly distributed independently and distributed in the suburbs. The features of the expanded features in and around the city are mainly red or gray commercial houses, and the buildings are taller. Such as the sunny north bank of Shuimogou District, Wantai Sunshine City in the Xinshi area. There are two types of suburbs. The first is the expansion of villages on the original foundation, with lower buildings and surrounding green farmland areas, such as the northern part of the new urban area and the northwestern part of Toutunhe District. The second is the factory buildings with blue or gray roof features, such as the northeast of the Midong District and the southwest of Toutunhe District.

### Table 1. Area of impervious surface in each jurisdiction in 2000, 2010 and 2017 (km²).

| District       | Tianshan | Xinshi | Shuimogou | Shayibak | Midong | Toutunhe | Total   |
|----------------|----------|--------|-----------|----------|--------|----------|---------|
| 2000           | 31.79    | 49.83  | 21.04     | 33.10    | 14.36  | 19.88    | 163.31  |
| 2010           | 33.85    | 105.78 | 35.91     | 42.05    | 67.12  | 47.95    | 332.66  |
| 2017           | 40.31    | 115.65 | 36.46     | 85.14    | 85.83  | 70.63    | 434.02  |

4.2. Analysis of dynamic changes in built-up areas

In order to more clearly see the changes in these three years, the maps of impervious surfaces from 2000 to 2010, and 2010 to 2017 are superimposed to obtain the spatial characteristics changes of Urumqi from 2000 to 2017 (Figure 5 and Figure 6). The red area is the area that changed.

From 2000 to 2010, the changes in built-up areas mainly spread outward along the main urban area, such as the eastern part of the new urban area, the Xishan area of Toutunhe District, and the Midong District. From 2010 to 2017, the built-up area mainly exhibited sporadic distribution, with a relatively regular shape, distributed in pieces, and far from the city, such as the northeast of Midong District and the southwest of Shayibak District.

![Figure 5. Impervious surface changes from 2000 to 2010.](image)

![Figure 6. Impervious surface changes from 2010 to 2017.](image)

4.2.1. Area change rate. Calculate the area change of the built-up area in these two time periods according to Table 1. The reuse dynamic degree (K) reflects the rate of change of the built-up area in the three years. Dynamic degree (K) is the degree and rate of change in the area of a certain element within a certain time range of the area. The calculation formula is:
\[ K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \]

In the formula \( K \) is the dynamic change rate of an element during the study period; \( U_a \) and \( U_b \) are the areas of the element at the beginning and end of the study period, respectively; \( T \) is the study duration.

From 2000 to 2017, the average annual growth rate of the built-up area of Urumqi from 2000 to 2010 was 10.37%, while the average annual growth rate from 2010 to 2017 was 3.05%. The average annual rate of change from 2000 to 2010 was greater than that from 2010 to 2017 (Table 2).

Judging from the average annual growth rate, the jurisdictions with larger average annual growth rates from 2000 to 2010 are Xinshi District, Midong District and Toutunhe District, which are 5.59km², 5.28km², and 3.48km². However, the jurisdictions with a large area increase from 2010 to 2017 became Shayibak District, Toutunhe District, and Midong District, which were 6.16km², 3.24km² and 2.67km², respectively. It shows that from 2000 to 2010, the development advantages of the new urban area, Midong District and Toutunhe District were obvious, and from 2010 to 2017, the Shayibak District developed rapidly, surpassing the new urban area.

From the rate of change, the expansion rates of the new urban areas, Shuimogou District, Midong District, and Toutunhe District from 2000 to 2010 were greater than the expansion rates from 2010 to 2017, especially in Midong District and Toutunhe District Large, the difference between the changes reached 32.77% and 26.35%. However, the expansion rates of the Tianshan District and Shayibak District were less than the expansion rates from 2010 to 2017. Among them, the Shayibak District had a significant change with a difference of 11.94%. In the case where the average annual change rate from 2010 to 2017 is relatively small, the change in the Shayibak area is relatively obvious.

| District          | Tianshan | Xinshi | Shuimogou | Shayibak | Midong | Toutunhe | Total |
|-------------------|----------|--------|-----------|----------|--------|----------|-------|
| Average annual growth rate (km²/a) |          |        |           |          |        |          |       |
| 2000–2010         | 0.21     | 5.59   | 1.49      | 0.89     | 5.28   | 3.48     | 16.93 |
| 2010–2017         | 0.92     | 1.41   | 0.08      | 6.16     | 2.67   | 3.24     | 14.48 |
| Annual average rate of change (%) |          |        |           |          |        |          |       |
| 2000–2010         | 0.6      | 11.23% | 7.06      | 2.70     | 36.75  | 26.35    | 10.37 |
| 2010–2017         | 2.73     | 1.33%  | 0.22      | 14.64    | 3.98   | 6.76     | 4.35  |

4.2.2. Change driver analysis. From a population perspective, changes in urban population directly affect urbanization and changes in urban land use, and population demand for housing, transportation, and public facilities is the original driving force for urban expansion. According to the statistical yearbooks of Urumqi in 2000, 2010 and 2015, Table 3 is obtained.

In 2000, the districts with higher urban population density in each jurisdiction were Tianshan District, Xinshi District, Shuimogou District, and Shayibak District. After 2010, the new urban district became the district with the highest population density, and the rest were Tianshan District and Shuimogou District and Scheibak District. From Figure 7, it can be seen that, except for the Toutunhe District, the average annual urban population density from 2000 to 2010 in the other jurisdictions was greater than that from 2010 to 2010. Among them, the average annual population density in the new urban areas remained the largest, which can be verified Since 2000, with the continuous increase in population, the built-up area has also been changing. The Tianshan District, Shuimogou District, and Shayibak belong to the old city. Although the development of the built-up area has not changed much in the horizontal angle, it is more obvious in the vertical direction. The most typical manifestation is
the increase in high-rise buildings. Because Midong District and Toutunhe District are industrial areas, although the built-up area has developed rapidly, the population growth has less obvious advantages than the city center.

Table 3. Urban population density in each jurisdiction in 2000, 2010 and 2017 (People / km²).

| Year | Tianshan District | Shayibak District | Xinshi District | Shuimogou District | Toutunhe District | Midong District |
|------|------------------|------------------|----------------|-------------------|------------------|---------------|
|      | 2000             | 2010             | 2017           |                   |                  |               |
| Tianshan District | 2471             | 3233             | 3348           |                   |                  |               |
| Shayibak District  | 923              | 1238             | 1307           |                   |                  |               |
| Xinshi District    | 2213             | 3738             | 4484           |                   |                  |               |
| Shuimogou District | 1420             | 2893             | 3176           |                   |                  |               |
| Toutunhe District  | 428              | 503              | 795            |                   |                  |               |
| Midong District    | 27               | 81               | 84             |                   |                  |               |

Figure 7. Average annual urban population density by jurisdiction.

From the analysis of location factors, the new urban area is a rapidly rising new area since the reform and opening up. There are many research institutes and universities. It is a high-tech concentrated area in Urumqi and even Xinjiang. Economic and technological development zones and high-tech industrial development zones have gathered. Here, attract a large number of talents. The new urban area also has superior transportation advantages. It has one of the five major national gateways for civil aviation—Urumqi International Airport and the largest material distribution center in Xinjiang—Urumqi North Railway Station Freight Yard. It is a transportation hub in the autonomous region and communicates with Asia, Europe, and the Middle East. Important international channel. Therefore, the new urban area has maintained a steady growth from 2000 to 2017.

Although Toutunhe District and Midong District are the suburbs of Urumqi, they are the main force of Urumqi's main industrial areas. With the development of the economy, land demand in cities is getting larger and larger, and environmental requirements are getting higher and higher. Most of the factories originally concentrated in the city center moved to the city center. In the 1980s, Urumqi's industrial categories increased, of which the number of large and medium-sized enterprises in Tianshan District accounted for 23.8% of the city, and Shayibak District accounted for 30.16%. Since 2000, most of the industrial land in the old city has been replaced, and it is located in the lower land areas in the south and north suburbs, such as Toutunhe, Midong District and Shayibak District. Polluting enterprises like Tianshan District have all moved into Toutunhe and Midong Industrial Parks. Therefore, after 2000, Midong District and Toutunhe District developed rapidly.

In 2000, Urumqi's industry accounted for 26.79% of the total output value and rose to 38.46% in 2010. However, in 2015, it showed a downward trend to 25.51%. The secondary industry experienced a decline and was replaced by the tertiary industry. It confirms that the development rate of built-up areas from 2010 to 2017 is lower than that from 2000 to 2010.
5. Conclusion
1. Urumqi's new urban area, Shuimogou District, Shayibake District, and Tianshan District tend to be saturated in the interior, while Urumqi is surrounded by mountains on three sides, limiting urban development, and the overall urban form is distributed in a diagonal “T” shape axially.

2. From 2000 to 2010, the area increased from 163.31km$^2$ to 332.66km$^2$, with a net increase of 169.35km$^2$, with an average annual growth rate of 10.37%; and from 2010 to 2017, the area increased to 434.02km$^2$, with a net increase of 101.36km$^2$. The average annual growth rate is 3.05%. The change from 2000 to 2010 is greater than the change from 2010 to 2017.

3. Comparing the area changes of various jurisdictions, it has been found that the changes in the built-up areas of the new urban area have always had significant advantages. From 2000 to 2010, the development process of the Midong District and Toutunhe District was obvious, but from 2010 to 2017, compared with Construction is faster in other jurisdictions.

4. Through demographic factors and location factors, it is found that most of the population is concentrated in cities. The new urban area, as a new area just beginning to develop, has advantages in development space. Midong District and Toutunhe District have also developed rapidly due to the rise of industry, and the speed of development has decreased during the transformation of the industry from the secondary industry to the tertiary industry, which has made the relative development of Shayibak District obvious.

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Reference
[1] Fang C L and LI GD Z Q. 2017 J. Journal of Natural Resources 32(3) 363-376
[2] Cai Q, Wang Z and Xiao L 2018 J. Journal of Systems Science and Information 6(3) 237-248
[3] Bonifazi A, Balena P and Rega C. Springer, Cham 118-133
[4] Wang X, Shi R and Zhou Y 2019 J. Socio-Economic Planning Sciences 100736
[5] Wanfu J, Chunshan Z, Tao L and Guojun Z 2019 J. Cities 91 193-201
[6] Yan Y, Liu X, Wang F, et al 2018 J. Science of the Total Environment 613 1417-1429
[7] Shihong G 2017 J. Economic Geography 37(1) 170-175
[8] Qiao W, Gao J, Guo et al 2019 J. Journal of Geographical Sciences 29(5) 749-761
[9] Liang Z F, Chen W B and Zheng J 2018 J. the journal of applied ecology 29(5) 1705-1714
[10] Li Y, Miao S, Chen et al 2017 J. International Journal of Climatology 37(7) 3111-3122
[11] Zhou Y, Xing B and Ju W 2015 J. Journal of Selected Topics in Applied Earth Observations and Remote Sensing 8(5) 2318-2331
[12] Gao J, Chen W and Yuan F 2017 J. Land Use Policy 68 604-613
[13] Li Z, Zhong J and Sun Z 2017 J. Sustainability 9(11) 1951
[14] Wang Y, Bi G H, Yang et al. 2016 J. Journal of Mountain Science 13(10) 1855-1866
[15] Liu Y S, Yan B and Wang Y F 2016 J. Econ. Geogr 36 1-8
[16] Tian L, Ge B and Li Y 2017 J. Cities 60 476-486
[17] Yan Y, Zhang C, Hu Y, et al. 2016 Remote Sensing 8(1) 6
[18] He C, Li J, Zhang X, et al. 2017 J. Journal of Cleaner Production 165 57-69