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Spatial-Temporal Evolution Characteristics of Vegetation Coverage and Urbanization Expansion in Dongguan Based on Remote Sensing

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***Abstract*— The purpose of this study is to use the Landsat satellite image of Dongguan from 2005 to 2021, combining the dimidiate pixel model and stochastic matrix method, to calculate the vegetation coverage grade and land use type area, express the urbanization process with construction land, and analyze the relationship between the temporal and spatial evolution characteristics of vegetation coverage and urbanization expansion. The results indicate that: (1) The overall distribution of vegetation coverage is consistent, showing a spatial distribution characteristic of "high in the east, low in the west, and lowest in the north". (2) During this period, the overall coverage area of medium low, medium, and medium high vegetation decreased, while both low and high vegetation coverage areas increased. (3) The area of construction land has increased significantly, with the increased built-up area coming from bare land, followed by vegetation and water bodies. (4) The spatio-temporal evolution characteristics of vegetation coverage are closely related to urbanization expansion. This study can provide reasonable scientific data support and an effective decision-making basis for evaluating the regional ecological environment, construction, and urban development of Dongguan City.*

Keywords*— Dimidiate Pixel Model (DPM); Support Vector Machine (SVM); Land Use Type; Urbanization; Stochastic Matrix; Remote Sensing

I. INTRODUCTION

With the continuous expansion of China's urbanization, many problems have arisen. The process has negative and positive externalities for vegetation coverage. Many regions are occupying a large amount of ecological land during the rapid urbanization process, with some of it being transformed into impermeable surfaces to support human habitation, roads, and other infrastructure. Meanwhile, during the process of urbanization, a large amount of rural labor is transferred to secondary and tertiary industries, resulting in idle rural land and the restoration of forests.

In addition, with economic growth and residents' awareness of environmental protection rising, cities can increase and restore vegetation resources through institutional and policy reform measures, making urbanization and vegetation coverage develop in harmony. Although urbanization brings burdens, it will also bring positive externality to vegetation coverage [1]

In this context, this paper takes Dongguan City, Guangdong Province, as a confirmatory research area, and uses the Landsat data from 2005 to 2021 to carry out research on the estimation of vegetation coverage in the city, to quantitatively analyze its spatial and temporal distribution and change characteristics, and then to explore the correlation between the change trend of vegetation coverage and the level of urbanization. So as to clarify the spatial and temporal change law of vegetation and the pattern of urbanization expansion, which is the regional ecological environment construction and urban development of Dongguan City, provide reasonable and scientific data support and an effective basis for decision-making.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

The total area of Dongguan City is about 2542.67 km^2, between 113° 31′ -114° 15′ E and 22° 39′ -23° 09′ N. Located in the south-central part of Guangdong Province, on the east bank of the Pearl River Estuary and the Pearl River Delta at the lower reaches of the Dongjiang River, it borders Huizhou City in the east, Zengcheng District of Guangzhou City in the north, Panyu District of Guangzhou City across the sea in the west, and Bao'an District of Shenzhen City in the south. It is an important waterway between Guangzhou and Hong Kong. It currently governs 32 townships (4 streets, 28 towns), 546 village committees, and 132 neighborhood committees..

Its climate conditions are a subtropical monsoon climate with a long summer without winter, an annual average temperature of 23.3 °C, abundant rainfall, and an annual precipitation of 2042.6 mm. Topographic conditions are mainly hilly tableland and Alluvial plains. The mountains in the southeast are large and concentrated, with an altitude of 200–600 meters, a gradient of about 30°, and large fluctuations. The central and southern regions are mainly composed of low mountains and hills. The northeast is dominated by Alluvial plains with an altitude of 30–80 meters. The slope is relatively small, and the terrain undulates gently (Figure 1). The Forest cover of the city reached 37.4%, and the greening coverage of the central urban area reached 47.51%.

Throughout the history of Dongguan's urban development, in the past 40 years, it has developed from an agricultural county with a gross regional product of only 600 million yuan to a global manufacturing base for multinational companies with a total economic volume of more than 700 billion yuan. It is the first of the "Four Tigers of Guangdong", known as the "World Factory", and an important transportation hub and foreign trade port in Guangdong. This process has made the process of urbanization and change dramatic. By the end of 2022, Dongguan will have a permanent resident population of 10.437 million, including 9.6281 million urban residents, with an urbanization rate of 92.25%. The constructed area will expand from less than 5 square kilometers to more than 900 square kilometers today, surpassing many provincial capitals and ranking on the new front line.

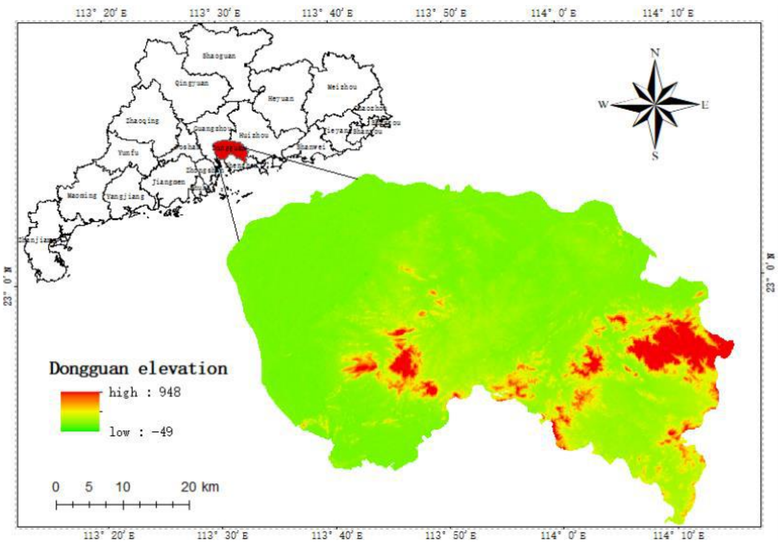

Fig.1 Location Map of Dongguan City

2.2 Data Sources

In this study, remote sensing images, including Landsat 5 TM remote sensing imagery from 2005 and 2009 and Landsat 8 OLI from 2015 and 2021, with a spatial resolution of 30 m, come from the Chinese Academy of Sciences geospatial data cloud (http://www.gscloud.cn/search), and the research data interval is 5 years, as shown in Table 1.

Table 1 Landsat TM/OLI Satellite Imagery Information List

Landsat images	Data Number	Acquire date	Resolution	Cloud cover/%
Landsat5 TM	LT51220442005327BJC02	2005-11-23	30m	0.22
Landsat5 TM	LT51220442009034BKT01	2009-02-03	30m	0.17
Landsat8 OLI	LC81220442015291LGN01	2015-10-18	30m	0.58
Landsat8 OLI	LC81220442021003LGN00	2021-01-03	30m	2.88

2.3 Data Preprocessing

For the remote sensing image data of the Dongguan area, ENVI 5.6 software was used for pre-processing, including band superposition, radiometric calibration, atmospheric correction, image mosaic, and mask, to obtain the remote sensing image of the study area that meets the requirements. Based on this, Normalized Difference Vegetation Index (NDVI), vegetation coverage, and supervision classification were extracted.

In atmospheric correction, the FLAASH processing function was used to perform radiometric calibration on the four remote sensing images from 2005 to 2021, converting the brightness gray value of the images into absolute radiation brightness. Then the vector boundary of the study area was used to crop out the study area in the image.

III. METHODOLOGY

3.1 Method

This study is based on Landsat-5 and Landsat-8 remote sensing images of Dongguan city, and its main analysis steps (Figure 2) are as follows:

1. First, the images were classified into four categories: vegetation, construction land, bare land, and water bodies by Support Vector Machine (SVM) classification. Then calculate the areas of these four categories and their transfer matrix, which analyzes the spatio-temporal evolution characteristics of land use types.
2. Then, the image NDVI data was extracted, and the Dimidiate Pixel Model (DPM) was used to calculate the vegetation coverage, dividing their standard into five levels in this study area and calculating the transfer matrix of the five levels, which analyzed the spatio-temporal evolution characteristics of vegetation coverage.
3. Finally, the urbanization process of Dongguan city is represented by the change in construction land area, and the spatio-temporal evolution characteristics of vegetation coverage and urbanization expansion are analyzed by combining the urbanization process and the spatio-temporal evolution characteristics of vegetation coverage.

3.2 Support Vector Machine (SVM)

SVM classification is a kind of binary classification model that has many unique advantages in solving small sample, nonlinear, and high-dimensional pattern recognition problems. To date, SVM have been widely used to solve the problem of supervised classification of high-dimensional data, especially for high-dimensional feature space and large data volume problems such as hyper-spectral data.

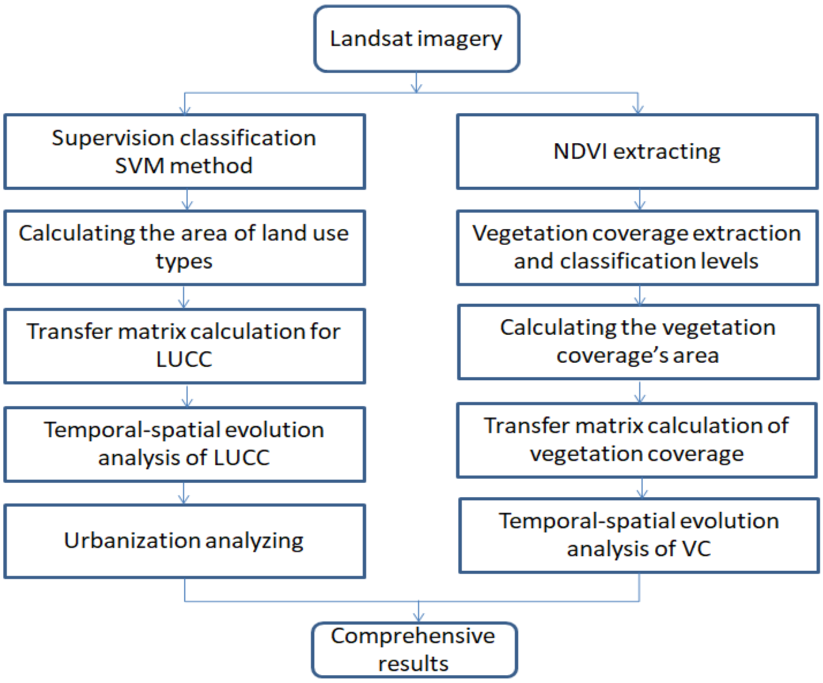

Fig.2 The Schema of This Study

The core idea of the SVM is based on the idea of structural risk minimization as the induction principle. By nonlinear mapping, the sample is projected to the high-dimensional feature space, constructing the optimal classification surface with the lowest VC (Vapnik Chervonenkis) dimension as possible in the high-dimensional space, which minimizes the upper bound of classification risk so that the classifier has the optimal generalization ability for unknown samples. Due to the fact that statistical learning theory has a complete theoretical system and solid mathematical foundation, and the vector holding machine generated by it has strong generalization ability, the theory and SVM have become a new research hotspot in the field of machine learning around the world. The main principles are as follows [2]:

If the vector x is linearly divisible in M-dimensional space, there is at least one hyperplane, dividing x into two types: -1 and 1, and then the hyperplane can be represented as shown in (1):

$$f(x) = w \cdot x + b \qquad (1)$$

Let the mark of xi be yi, if the classification is correct, as shown i n (2):

$$y_i(w \cdot x_i + b) \geq 1; i = 1,2,3 \cdots, N \qquad (2)$$

The minimum distance between the point closest to the hyperplane and the hyperplane is called the interval, which can be expressed as: 1/‖w‖, and the point is called the support vector. The sum of the minimum distance between two support vectors of different types and the hyperplane is 2/‖w‖, so finding the optimal hyperplane is to maximize the interval, which is minimized in the form, as shown in (3):

$$min \frac{1}{2}\|w\|^2 \qquad (3)$$

Through the constraints of equation (2), the expression of the optimization problem is obtained, as shown in (4):

$$minL(w, b, \alpha) = \frac{1}{2}\|w\|^2 - \sum_{i=1}^{N} \alpha_i[y_i(w \cdot x_i + b) - 1] \qquad (4)$$

After taking the partial derivative and setting it to 0, the constraint condition is obtained, as shown in (5):

$$\sum_{i=1}^{N} \alpha_i y_i = 0 \qquad (5)$$

Obtaining, as shown in (6):

$$w = \sum_{i=1}^{N} \alpha_i y_i x_i \qquad (6)$$

After equation s (5) and (6) are substituted into equations (4), the dual optimization problem is obtained, as shown in (7):

$$Q(\alpha)=\sum_{i=1}^{N}\alpha_i+\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\alpha_i\alpha_j y_i y_j\left(x_i\cdot x_j\right) \quad (7)$$

Equation (7) can be solved by convex quadratic programming method, and the category decision function is finally obtained, as shown in (8):

$$f(x)=\sum_{i=1}^{N}\alpha_i y_i K(x_i\cdot x)+b \quad (8)$$

The above is a linear and nonlinear hard classification problem, and the position of the hyperplane is strictly fixed. Considering that a few points cannot be classified by hyperplane, by adding the relaxation variable ξ and the penalty factor C, equation (2) becomes:

$$y_i(wx_i+b)\geq 1-\xi_i;\ i=1,2,\cdots,N \quad (9)$$

Equation (3) becomes, as shown in (10):

$$min\frac{1}{2}\|w\|^2+C\sum_{i=1}^{N}\xi_i \quad (10)$$

3.3 Normalized Difference Vegetation Index (NDVI)

Based on the NDVI calculation tool in ENVI 5.6 software, the NDVI was extracted from the pre-processed Landsat images covering the study area in four phases in 2005, 2009, 2015, and 2021. The calculation equation is as follows:

$$NDVI=\frac{(NIR-\ RED)}{(NIR+\ RED)} \quad (11)$$

In equation (11), NIR is the reflectivity of the near infrared band (%), and RED is the reflectivity of the red band (%).

Statistical analysis indicates that the calculated NDVI value is not within the range [-1, 1], which is because remote sensing images are affected by aerosol, shadow, and other factors, and excessive atmospheric correction leads to overflow phenomena. It is therefore necessary to normalize the NDVI value, that is to say, remove outliers. The calculation equation is as follows:

$$(b1\ lt\ -1)*(-1)+(b1\ gt\ 1)*1 + (b1\ ge\ -1\ and\ b1\ le\ 1)*b1 \quad (12)$$

In equation (12), "b1" is the NDVI value of the remote sensing image, "lt" is "less than", "ge" is "greater than or equal to", "le" is "less than or equal to", and "gt" is "greater than". After outlier processing, the gray scale images of the NDVI in each year of Dongguan City are finally obtained.

Some studies indicate that the NDVI value of the vegetated area is greater than zero, and the higher the vegetation coverage, the greater the NDVI value. On rocks, bare soil, and other surfaces, the reflectivity of visible light and near infrared is similar, and the NDVI value is about zero. On water vapor, clouds, snow, and other surface objects, the reflectivity of the visible light band is higher, and the NDVI value is usually less than zero. Therefore, NDVI is suitable for large-scale vegetation monitoring and has a good indicator [3].

3.4 Dimidiate Pixel Model (DPM)

Dimidiate Pixel Model (DPM) is a commonly used method to calculate the fraction of vegetation cover (FVC), which is one of the more widely used remote sensing estimation models. The model assumes that the ground area represented by each pixel is composed of two parts covered by vegetation and no vegetation, and the reflection spectrum information of ground objects received by the sensor is also formed by the superposition and combination of different reflection spectrum information from these two parts. The weight of reflected spectral information of objects in different places represents the proportion of objects in this pixel, so vegetation coverage can be used to represent the proportion of vegetation [4-6].

NDVI data were used to calculate the vegetation coverage, and NDVI values with cumulative frequencies of 95% and 5% were used as the two extreme values of NDVI to represent the $NDVI_{veg}$ value and $NDVI_{soil}$ value. When NDVI is less than $NDVI_{soil}$, the value of VFC is 0. When NDVI is greater than $NDVI_{veg}$, the value of VFC is 1. When the value of NDVI is greater than or equal to $NDVI_{soil}$ and less than or equal to $NDVI_{veg}$, that is to say, when it is between the $NDVI_{veg}$ value and $NDVI_{soil}$ value, calculate equation (13). Using DPM to estimate the vegetation coverage equation, the calculation equation is as follows:

$$(b1\ lt\ NDVI_{soil})*0+\left(b1\ gtNDVI_{veg}\right)*1+ \left(b1\ ge\ NDVI_{soil}\ and\ b1\ le\ NDVI_{veg}\right)*(b1-\ NDVI_{soil})/\left(\ NDVI_{veg}-\ NDVI_{soil}\right) \quad (13)$$

In equation (13), $NDVI_{soil}$ is the NDVI value of bare land or non-vegetated area. $NDVI_{veg}$ is the NDVI value of the pixel in the area completely covered by vegetation.

3.5 Vegetation Coverage Classification

In order to better quantify the characteristics of vegetation coverage evolution, this paper divides the vegetation coverage in this study area into 5 grades according to 《the Classification and Grading Standard of Soil Erosion》 promulgated by the Ministry of Water Resources of the People's Republic of China in 2008. The criteria are as follows: <30% (low coverage), 30%-45% (medium to low coverage), 45%-60% (medium coverage), 60%-75% (medium to high coverage) and > 75% (high coverage).

3.6 Land Use Transfer Matrix

The main purpose of this paper is to study the relationship between vegetation coverage and urbanization expansion. Thus, according to the image of Dongguan, land use types are defined as vegetation, construction land, bare land, and water substances. Vegetation includes forestland, arable land, and grassland; construction land includes buildings, transportation facilities, and roads; bare land includes bare soil surface with less vegetation coverage, such as wasteland, abandoned arable, and quarry; and water substance includes lakes, reservoirs, sea areas, and wetlands. The change in construction land area indicates the urbanization process in Dongguan.

In this study, the land use transfer matrix is used for dynamic monitoring and analysis of land use, which can not only quantitatively and accurately indicate the transformation and change of different types of land use [7-9], but also quantitatively reveal the change rate of land transfer among different types of comprehensive land use transfer types. In other words, a two-dimensional matrix is obtained according to the change in land cover status at different times and phases in the same area, and the state and status of the system are described quantitatively [10-15]. The specific calculation equation is as follows:

$$P_{ij} = \frac{S_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} S_{ij}} \quad (13)$$

In equation (13), P_{ij} is the conversion probability of land use type i to land use type j; S_{ij} is the area of land use type i transformed into land use type j (km^2).

The land use transfer matrix model [11] is:

$$\begin{bmatrix} P_{11} & \cdots & P_{1j} \\ \vdots & \ddots & \vdots \\ P_{i1} & \cdots & P_{ij} \end{bmatrix} \quad (14)$$

IV. ANALYSES AND RESULT

4.1 Spatiotemporal Evolution of Vegetation Coverage

The analysis data indicate that the overall distribution of vegetation coverage in Dongguan is basically the same, showing the spatial distribution characteristics of "high in the east-low in the west -the lowest in the north" (Figure 3). The eastern part of the mountain is huge, concentrated into pieces with relatively large ups and downs, forming a very obvious high vegetation belt, including Xiegang town, Qingxi town, Huangjiang Town and other areas. Among them, Guanyin Mountain, Yinping Mountain, Dawang Mountain, Baoshan, Nanmen Mountain and other areas of the original forest are the main reasons for the formation of high vegetation areas. The distribution of middle, high and medium vegetation areas is relatively dispersed, mainly in the west and south, and the proportion of low vegetation areas is relatively large.

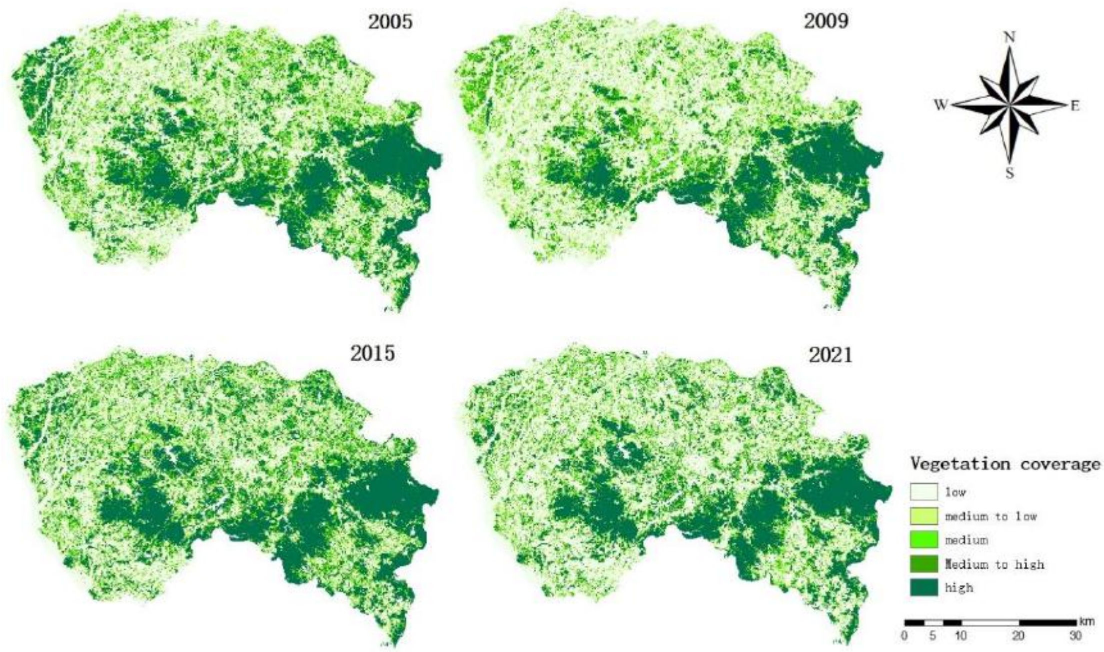

Fig.3 Vegetation Coverage Grade Map of Dongguan from 2005 to 2021

From 2005 to 2021, the area of low-vegetation area in Dongguan increased significantly, with an increase of about 92.14 km^2, and the area of high-vegetation area also increased, but the increase was relatively small, with an increase of about 13.36 km^2. Compared with 2005, the increased areas of high vegetation are mainly located in Huangjiang Town and Tangxia Town in the south in 2021, while the increased areas of low vegetation are located in the west and central north, as shown in Table 2.

Table 2 Grade of Vegetation Coverage in Dongguan from 2005 to 2021 (Unit: km^2)

Year	Low	Rate /%	Medium -low	Rate /%	Medium	Rate %	Medium -high	Rate /%	High	Rate /%
2005	993.98	40.53	311.28	12.69	261.20	10.65	249.60	10.13	637.70	26.00
2009	1152.70	47.00	352.58	14.35	249.62	10.13	210.31	8.58	489.60	19.94
2015	880.18	35.82	327.56	13.35	253.08	10.30	225.63	9.20	768.40	31.33
2021	1086.12	44.28	292.78	11.94	226.41	9.23	196.50	8.01	651.06	26.54

According to the distribution results of vegetation coverage in 2005 and 2021, the transfer matrix can be calculated, and the mutual transformation of vegetation coverage at all levels can be obtained by analyzing the transfer matrix.

In Dongguan, the area of medium and low vegetation transferred out was 247.35 km^2 in 2005, mainly to low and medium vegetation; in 2021, the area of low vegetation transferred in was 140.87 km^2, and the area of medium vegetation transferred in was 46.63 km^2. In 2005, the area of medium vegetation conversion was 218.03 km^2, which was converted to low and high vegetation in 2021. The area of low vegetation conversion was 83.88 km^2, and the area of high vegetation conversion was 51.51 km^2. In 2005, the area of mid-high vegetation transferred out was 209.54 km^2, and in 2021, the area of low and high vegetation transferred in was 56.95 km^2, while the area of high vegetation transferred in was 88.05 km^2. In 2005, the area of low vegetation conversion was 250.11 km^2. The area of high vegetation transfer was 179.39 km^2. In 2021, the area transferred from low to medium vegetation is 228.86 km^2, The transfer area of moderate vegetation is 218.03 km^2, The transfer area of medium to high vegetation is 156.44 km2, The area of low vegetation transfer in 2021 is 342.17 km^2, and the area transferred from high vegetation in 2021 is 193.70 km^2, as shown in Table 3.

The analysis shows that more vegetation has deteriorated from low-middle, middle, and middle-high vegetation to low vegetation, while less vegetation has improved from low-middle, middle, and middle-high vegetation to high vegetation since 2005. During the period from 2005 to 2021, the area of middle-low, middle, and middle-high vegetation decreased generally, while the area of low vegetation continued to increase with a relatively large increase and the area of high vegetation increased generally with a relatively small increase.

In general, the vegetation cover from 2005 to 2021 is decreasing, and the proportion of low vegetation cover areas is increasing, which may be related to human activities. For example, with the increase in population and the needs for economic and social development, cities continue to expand, arable land is converted into construction land, and arable land and forest land are reclaimed and developed, which results in the destruction and degradation of the original vegetation. On the other hand, climate change may lead to changes in precipitation and temperature, affecting vegetation growth. Drought, reduced water resources, and high temperatures may lead to the apoptosis and degradation of vegetation.

Table 3 Analysis of Transfer Matrix of Vegetation Coverage in Dongguan (Unit: km^2)

Year	Index	2021 year				
		Low	High	Medium	Medium-low	Medium-high
2005 year	Low	743.60	25.85	64.67	123.95	35.64
	High	60.47	457.18	37.53	31.64	49.76
	Medium	83.88	51.51	43.12	43.16	39.49
	Medium-low	140.87	28.29	46.63	63.88	31.56
	Medium-high	56.95	88.05	34.43	30.11	40.01

4.2 Spatiotemporal Evolution of Land Use Types

In terms of the overall distribution of land use types in Dongguan, vegetation dominates the south and east of the city (Figure 4), and water substance is divided into rivers, lakes, reservoirs, and some sea areas. Rivers are distributed in the northwest, including the Shima River and Dongjiang River, and lakes and reservoirs are scattered and distributed in areas with high terrain and vegetation coverage. The sea areas are mainly in the Lion Ocean and distributed in the west.

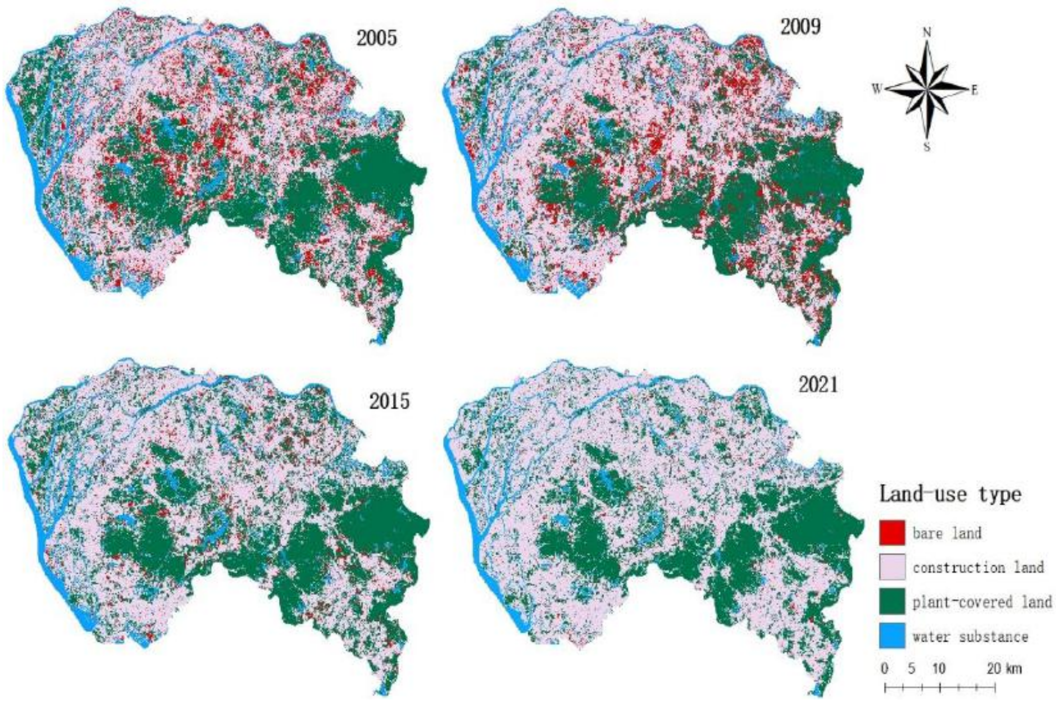

Fig.4 Distributions of Land Use Types in Dongguan from 2005 to 2021

According to the area changes of various types of land use (Figure 5), from 2005 to 2021, it can be seen that the area of construction land in Dongguan increased from 1092.43 km^2 to 1453.04 km^2, with a steady and large increase in area. And the increased built-up area is mainly bare land; the second is vegetation, which is mainly from arable land and forest land; and the last is water, which is mainly from wetlands.

During the period from 2005 to 2009, the vegetation area decreased significantly, and the built-up area and bare soil area continued to increase, indicating that sustained and intense urban construction activities were carried out during this period.

During 2009-2015, the vegetation area recovered somewhat, the increase rate of urban construction area slowed down, and the bare land area decreased, indicating that the urban construction activities in this period mainly used the original bare land, and the vegetation covered area recovered somewhat.

During the period from 2015 to 2021, the built-up area increased rapidly again, the bare land area continued to decrease, and the area covered by medium and low vegetation decreased, indicating that the urban expansion phenomenon of occupying arable and grassland appeared again.

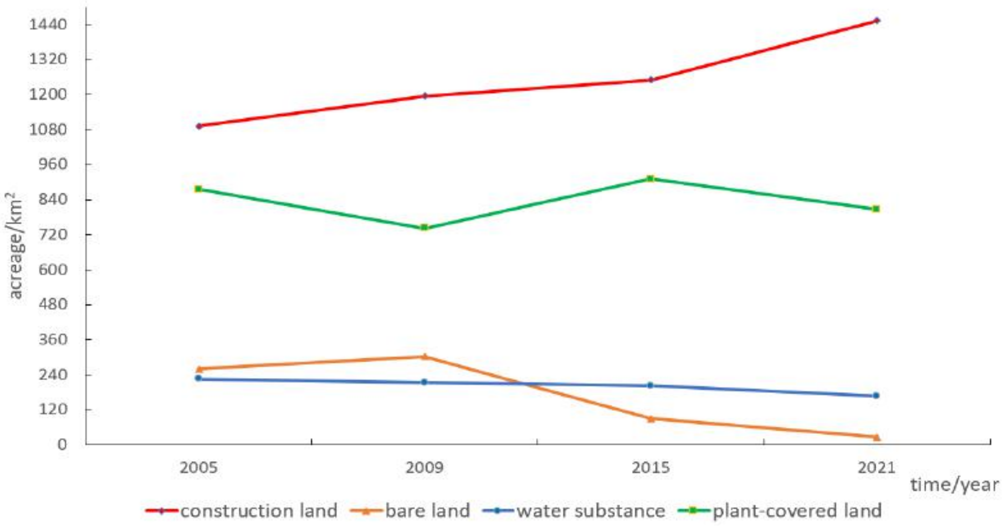

Fig.5 Area Changes of Land Use Types in Dongguan in Different Years

The land use status of Dongguan from 2005 to 2021 includes the area of bare land transferred out, which is 256.29 km^2, and the area converted into construction land, which is 222.87 km^2. The area of vegetation transferred out is 249.49 km^2, and the area converted to construction land is 233.63 km^2. Simultaneously, the area of water substance transferred out is 78.74 km^2, and the area converted into construction land is 62.71 km^2. The area of construction land transferred out is 159.64 km^2.

In addition, in 2021, the bare land transfer area was 21.94 km^2, the vegetation transfer area was 183.18 km^2, the water transfer area was 18.84 km^2, and the construction land transfer area was 519.21 km^2, as shown in Table 4. Among them, bare land has the largest net change, followed by vegetation and water bodies. The shift from bare land to construction land is the most obvious feature of the urbanization process. The shift of vegetation towards construction land reflects the process of urban construction at the cost of occupying agricultural land and logging forest land. The diversion of water bodies towards construction land mainly extends to wetlands, lakes, and other water bodies through land reclamation.

Table 4 Transfer Matrix of Land Use Types in Dongguan (Unit: km^2)

Year	Index	2021 year			
		Construction land	Bare land	Water substance	Vegetation
2005 year	Construction land	933.68	8.13	12.85	137.66
	Bare land	222.87	4.12	1.07	32.35
	Water substance	62.71	2.7	147.42	13.17
	Vegetation	233.63	10.93	4.93	623.79

4.3 Correlation Analysis of Vegetation Coverage and Urbanization

Objectively, there is a close relationship between urbanization and the ecological environment. Due to the transfer of rural populations to cities and the continuous expansion of urban areas, land resources in natural ecological space must be occupied, resulting in changes in vegetation and the ecological environment, which puts forward higher requirements for urban environmental protection. Simultaneously, the increase in economic aggregate makes cities more capable of environmental protection investment and protects vegetation resources to a certain extent. Therefore, urbanization has a dual effect on vegetation resources.

According to the vegetation coverage transfer matrix analysis, during the period from 2005 to 2009, the area of low vegetation and middle and low vegetation continued to increase, mainly from medium vegetation to low vegetation and high vegetation. The area transferred by low vegetation was 65.85 km^2, and the area transferred by high vegetation was 75.70 km^2. In this stage, the area of construction land and bare land continued to increase, and the area covered by vegetation continued to decrease, indicating that human beings carried out continuous and intense urban construction activities at the cost of destroying vegetation during this period, and the urbanization process increased significantly, resulting in an increase in the area of low-vegetation areas, that is to say, construction land and bare land.

During the period from 2009 to 2015, the area of high vegetation and middle and high vegetation continued to increase, from low vegetation and middle and low vegetation to middle and high vegetation, and the total area of middle and high vegetation transferred was 119.55 km^2, and the total area of high vegetation transferred was 112.67 km^2. At this stage, with the destruction of the ecological environment and the deterioration of the city's internal environment, Dongguan's economic development was affected. In the meantime, human beings realized the impact of the environmental destruction and began to restore the ecological environment, so that the vegetation area recovered somewhat, the increase rate of urban construction area slowed down, and the urbanization process slowed down. In this period, urban construction activities mainly used the original bare land; the bare land area was greatly reduced, and the vegetation coverage area was restored.

During the period from 2015 to 2021, the area of low vegetation and high vegetation continued to increase, due to the transformation of middle and low vegetation into low vegetation and the area of low vegetation into 162.48 km^2. During this period, the built-up area increased rapidly again, the bare land area continued to decrease, the middle and low vegetation areas decreased, but the high vegetation areas increased, indicating that population growth required greater space and resources, and the urban expansion phenomenon of occupying arable and grassland again appeared. However, during this period, Dongguan implemented many policies, such as returning arable to forest, protecting natural forests, adjusting industrial structure, and developing tourism such as ecological parks, which should also pay attention to the protection of the ecological environment and reduce the destruction of forest land in some natural ecological areas.

In summary, the urbanization level of Dongguan can be used as one of the reference factors for the change of vegetation coverage, but the level of urbanization cannot be used as an absolute influencing factor to measure the change of urban vegetation coverage, and comprehensive analysis should be carried out in combination with other influencing factors.

V. CONCLUSION

In this study, the DPM and transfer matrix were used to estimate the vegetation coverage of Dongguan, analyzing the area proportion and change of vegetation coverage area at all levels. Meanwhile, the transfer matrix method of vegetation coverage can effectively analyze the mutual transformation of vegetation coverage area in each year. Moreover, by analyzing the change trend of land type area and the transfer matrix of each land type, the change index of construction land area was compared with the change degree of vegetation coverage, analyzing correlation between the change degree of vegetation coverage and urbanization expansion.

This study provides a new way of thinking about the spatio-temporal evolution characteristics of vegetation coverage in the past 15 years and the interannual variation law of vegetation coverage, which can also provide a decision-making basis for ecological environment construction in Dongguan. The main conclusions are as follows:

(1) The overall distribution of vegetation coverage in Dongguan is basically the same, showing the spatial distribution characteristics of "high in the east-low in the west-the lowest in the north".

(2) During the period from 2005 to 2021, the coverage area of middle-low, middle and middle-high vegetation will decrease overall, while the coverage area of low vegetation will continue to increase with a relatively large increase, and the coverage area of high vegetation will increase with a relatively small increase.

(3) During the period from 2005 to 2021, the area of construction land in Dongguan will increase steadily and greatly, and the increased built-up area is mainly bare land, followed by vegetation and water area.

(4) Through the combined analysis of the change trend of vegetation coverage and land type area at all levels from 2005 to 2021, which indicates that the spatial-temporal evolution characteristics of vegetation coverage in Dongguan are closely related to urbanization expansion. On the one hand, urbanization will destroy vegetation in various ways. For example, urbanization increases the area of construction land, leading to the loss of arable land and forest land. On the other hand, with the acceleration of urbanization, the state will also implement various measures to protect the ecological environment, such as returning arable to forest, adjusting industrial structure, and developing some tourism to protect forest land.

Finally, this study only selected urbanization and vegetation coverage at all levels for comparative analysis, and did not consider other natural and social factors, such as natural disasters, population density, urban economic development and other factors, which would also have an impact on vegetation coverage. Therefore, the subsequent research will also incorporate these factors affecting the vegetation coverage into the decision-making of the analysis.

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REFERENCES

[1] Shi, Y. Temporal and Spatial Evolution and Influence of Vegetation Cover in the Process of Urbanization in China, Northeast Forestry University, 2022.

[2] Sun, L. Research on Classification of Hyperspectral Images Based on Support Vector Machine, Harbin Engineering University, 2011.

[3] Liu, H. The Research on the Vegetation Coverage Dynamic Change of Guangdong Province Based on RS and GIS, South China Agricultural University, 2015.

[4] Jiang, Q. Analysis of vegetation coverage change in Shanbei area of Huainan City based on RS. Agriculture and technology, 2021, 41(14):130-134.

[5] Wu, J., Li, H., and Lei, J. Remote sensing monitoring of spatiotemporal variation of vegetation cover in Dongjiang

source area, Journal of Jiangxi University of Science and Technology, 2017, 38(01):29-36.

[6] Chen, F., and Wu, F. Analysis of temporal and spatial evolution of vegetation coverage in Nanchang based on NDVI, Changjiang Information & Communications, 2022,35(11):120-122.

[7] Liang, B., Lu, R., Li, G., and Li, Q. The Effects of Land Use Carbon Emission Based on the Carbon Transfer Matrix —A Case of Guangxi Beibu Gulf Economic Zone, Hubei Agricultural Sciences, 2016,55(11):2779-2784.

[8] Zhang, Y., Zeng, J., Hu, X., Sun, D., and Song, Z. Study on land－use change in midstream of Shule River based on land use transfer matrix, Yangtze River, 2017,48(21):34-39.

[9] Qiao, W., Sheng, Y., Fang, B., and Wang, Y. Land use change information mining in highly urbanized area based on transfer matrix: A case study of Suzhou, Jiangsu Province, GEOGRAPHICAL RESEARCH, 2013,(08):1497-1507.

[10] Chang, D., Cheng, A., Bai, T., and Jiao, Y. Characteristics analysis of land use change in Tangjiahui Coal mine based on transfer matrix. Journal of Green Science and Technology, 2021, 23(22):222-224.

[11] Zhu, H., and Li, X. Discussion on the Index Method of Regional Land Use Change, ACTA EOPGRAPHIC SINICA, 2003,(05):643-650.

[12] Zhong, J., Huang, Y. and Guo, M. Spatio-temporal Change Characteristics Analysis of Vegetation Coverage in Western Hubei Province in Recent 20 Years. GEOSPATIAL INFORMATION, 2023,21(02):50-55. doi:10.3969/j.issn. 1672-4623.2023.02.010

[13] Xiao, X., Li, J., Han, B., Lu, C., and Xue, B. Spatial-temporal characteristics of vegetation coverage and its correlation with urbanization in traditional industrial area of Northeastern China, Ecological Science, 2017, 36(6): 71-77.

[14] Wang, Y., Zhang, X., and Shang, G. Analysis of Spatial and Temporal Changes of Vegetation Fraction Coverage in Beijing from 2013 to 2020, Journal of Hebei GEO University,2022,(01):99-105.

[15] Li, Y., Lin, F., and Yan, Z. Analysis of Urbanization Evolution Based on Landsat Remote Sensing Image, Urbanism and Architecture,2019,16(25):138-142. DOI： 10.19892/j.cnki.csjz.2019.25.030