International Journal of Rural Development, Environment and Health Research
[Vol-7, Issue-4, Jul-Aug, 2023]
Issue DOI: https://dx.doi.org/10.22161/ijreh.7.4
Article DOI: https://dx.doi.org/10.22161/ijreh.7.4.4
ISSN: 2456-8678 ©2023 IJREH Journal

The Evaluation of Land Use Evolution and Ecological Sensitivity of Guangzhou Based on GIS and RS

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Received: 07 Jun 2023; Received in revised form: 14 Jul 2023; Accepted: 22 Jul 2023; Available online: 28 Jul 2023

Abstract— *The dynamic stability of the local ecological environment is related to changes in land use patterns and ecological sensitivity. The study aims to identify the land use characteristics and dynamic change features in Guangzhou City using RS and GIS technology. We choose six ecological sensitivity factors, such as land use type, elevation, watershed buffer, vegetation cover, slope, and slope direction, and use the analytical hierarchy process (AHP) to obtain the results of single-factor and comprehensive ecological sensitivity. The findings indicate that, in terms of land use, the area of four types—forest land, grassland, arable land, and unused land—decreased from 2000 to 2020, while the area of water bodies and construction land rose, with a minimal overall change. According to total ecological sensitivity, very sensitive areas make up the majority of the total area and are primarily found along the northern township boundary; very low-sensitive and mildly sensitive areas are mostly found in the south and center. In order to encourage the development of an ecological civilization in the city, Guangzhou City must establish the idea of harmony between people and the land and increase the ecological conservation function.*

Keyword— ***Land Use/Cover Change (LUCC), Ecological Sensitivity; Analytic, Hierarchy Process (AHP), Land Use Transfer Matrix, Land Use Dynamics Degreed***

I. INTRODUCTION

Land is a crucial component for the survival of organisms on earth, and ecological sensitivity evaluation can carry out ecological zoning for it in a scientifically sound manner (Yuan et al., 2021). This can help to protect biodiversity, the ecological environment, and ecosystems, as well as analyze potential issues with the current ecological environment and further the research through spatial analysis (Gan et al., 2018; Wu & Chen, 2021).

Scholars are paying more and more attention to the study of land use evolution and ecological sensitivity, and scholars in China have also conducted a significant amount of research on these topics. Some researchers choose nine categories of ecological sensitivity indicators, such as watershed buffer, soil, etc., to complete the ecological sensitivity analysis and evaluation of the river basin using GIS-based spatial analysis methods and the creation of the corresponding evaluation index system (Zhang et al., 2021). Cheng et al. (2018) report that ecological sensitivity evaluation is conducted at the county scale using five kinds of impact characteristics, including elevation, slope, road, etc., as indicators; To analyze the ecological sensitivity of suburban areas of cities and towns and to explore the restoration potential of hollow villages. Liu et al. (2019) chose four evaluation variables based on land use data. Liu (2022) examined how land use evolved, how the value of ecosystem services changed, how human activity affected ecosystem patterns, and how the value of ecosystems changed in the Erhai Basin between 2010 and 2015. In terms of changes in pattern and service value, the Analytic Hierarchy Process (AHP) method was utilized as one of the evaluation techniques to determine the ecological sensitivity of the area (Yang & Yang, 2022).

Based on RS and GIS technology and incorporating the land use transfer matrix and AHP method, this study investigates the land use evolution of Guangzhou and evaluates its ecological sensitivity through the comprehensive analysis of six ecological sensitivity factors, such as elevation, watershed buffer, vegetation cover, land use type, slope, and slope direction, so as to provide a reference for the delineation of the ecological environment functional zones and the ecological red line of protection in Guangzhou.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

Guangzhou City, the capital of Guangdong Province, is situated in the lower reaches of the Pearl River, bordering the South China Sea, between 112 and 115 degrees east longitude and 22 and 24 degrees north latitude. It is bordered by Huizhou in the east, Foshan in the west, Qingyuan in the north, and Zhongshan and Dongguan in the south. Additionally, it is located in China's terrain with three terraces, topographic diversity, the structure of the "five mountains, two fields, two cities, one water", for the hilly terrain, the northeast terrain is higher (Figure 1), the south for the alluvial plain, belonging to the oceanic subtropical monsoon climate, plenty of heat and light, the average temperature throughout the year in the 20–22 °C range, the average annual temperature difference is relatively small, abundant water, an annual rainfall of 1736 mm, and the territory is the largest city in Guangdong Province.

There are many rivers in the territory; in an area of 100 km2 of the river, there are 22. The territory is rich in plant resources; the northern terrain is complex, more alpine woodland, and is known as the "lungs of the city" of the Baiyun Mountain, containing numerous rare vegetation species. In addition to serving as the Belt and Road's and the Greater Bay Area's hub cities, Guangzhou is a significant hub for trade and commerce in China. There are 11 districts inside the city's boundaries, totaling around 7,400 km2. Urbanization is growing quickly, and the economy is strong. The evaluation of ecologically sensitive rows has an important guiding value for the development of ecological environmental protection in Guangzhou, as the construction of the Guangdong-Hong Kong-Macao Greater Bay Area has increased the amount of construction land and the impact on the ecological environment.

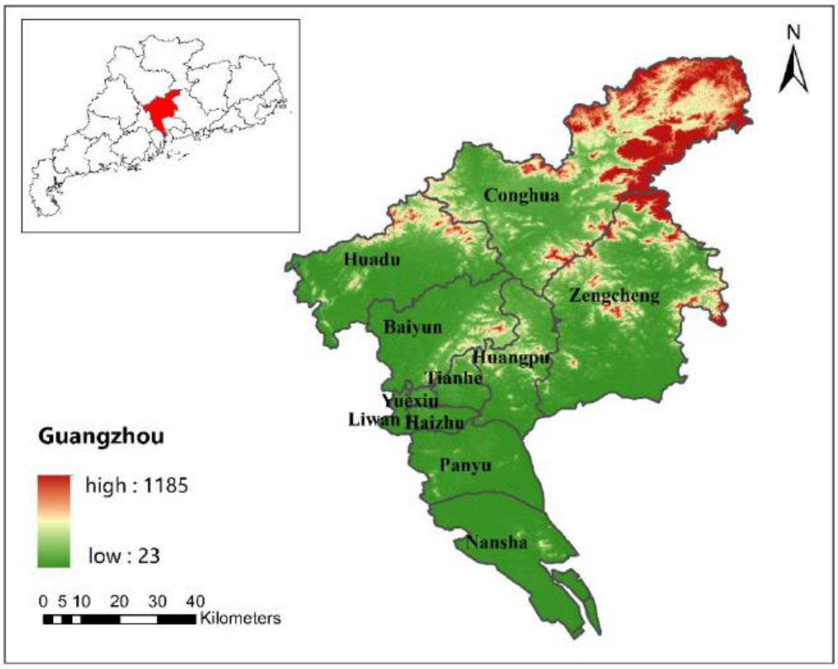


Fig.1 Location and topographic map of Guangzhou City

2 Data Collection

The data used in the study of land use and ecological sensitivity mainly include (Table 1):

1. The raster data with 10 m×10 m resolution and the WGS_1984_UTM_Zone_49N projected coordinate system were uniformly used for cartography. Among them, the administrative division layer of Guangzhou City was obtained from the administrative division data downloaded from the National Center for Basic Geographic Information (http://www.ngcc.cn/ngcc/) and extracted by mask.
2. The land use/cover change (LUCC) layer and ecologically sensitive land use layer were obtained from the data of 2000 and 2020 at 30 m resolution for land cover (LUCC) downloaded from the Chinese Academy of Sciences (https://www.syjshare.com/res/57L812SN) and obtained by reclassification.
3. The elevation, slope, slope direction, and watershed buffer factor layers were obtained from 30 m DEM data downloaded from Geospatial Data Cloud (https://www.gscloud.cn/home#page1/1) and extracted through reclassification, slope analysis, slope direction analysis, and hydrological analysis tools of ArcGIS.
4. FVC (Fractional Vegetation Cover) factor layers, obtained from Geospatial Data Cloud (https://www.gscloud.cn/home#page1/1) downloaded remote sensing satellite images, were obtained through the vegetation cover extraction process.

Table 1 Collection of data source

Data requirements	***Source of data***	***Application***
Administrative boundary vector data	*Data from the National Centre for Basic Geographic Information (http://www.ngcc.cn/ngcc/)*	*Generate administrative map*
2000 and 2020 Land cover map (LUCC)	*Sourced from the Chinese Academy of Sciences (https://www.syjshare.com/res/57L812SN)*	*Generation of land use layers, ecologically sensitive land use factor layers*
30m DEM	*Geospatial data cloud (https://www.gscloud.cn/home#page1/1)*	*Gen Generate factor layers for elevation, slope, slope direction, watershed buffer, etc.*
Satellite imagery	*Geospatial data cloud (https://www.gscloud.cn/home#page1/1)*	*Generate FVC factor layers*

III. METHODOLOGY

3.1 Method

This study is based on the vector data of the administrative boundary of Guangzhou city, 30 m DEM, remote sensing satellite images, and 2000 and 2020 LUCC data. The main analysis steps (Figure 2), respectively, are as follows:

1. Prepare the vector map of the administrative area of Guangzhou: try the quick map tool to extract the vector map of the administrative area of Guangzhou in 30 m DEM.
2. After extracting the 30 m DEM data by mask, use the reclassification tool to get the elevation factor; use the slope analysis and slope direction analysis tools to get the slope and slope direction factors; and then use the hydrological analysis tool of ArcGIS and the raster calculator to get the watershed buffer factor.
3. After reclassifying the 30 m resolution LUCC data according to the specification of "Current land use classification (GB/T21010-2017)", the land use factor was obtained.

4. When the remote sensing image is extracted by mask, the normalized difference vegetation index (NDVI) is extracted using a band calculator, and then the FVC data is obtained by performing it and assigning values to it.
5. The above data are weighted and superimposed according to the weighting values to get the comprehensive ecological sensitivity value of Guangzhou.

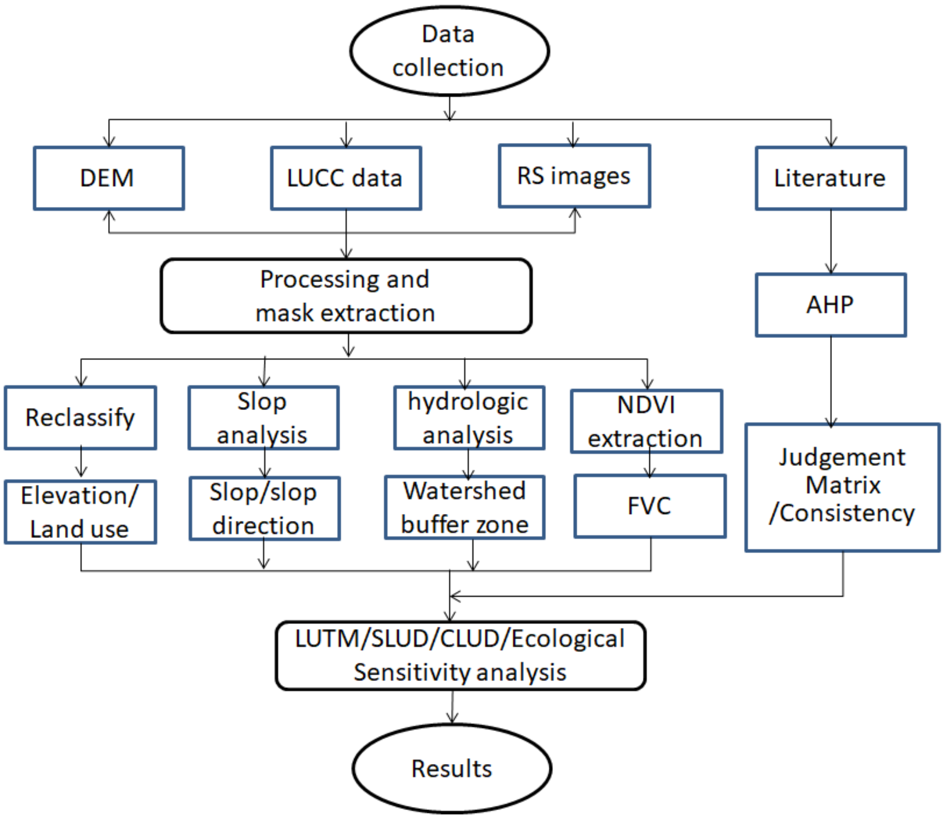


Fig.2 The schema of the study

3.2 Land Use Transfer Matrix (LUTM)

The land use transfer matrix is an application of the Markov model to land use change that quantifies the transitions between different land use types. The expression for the land transfer matrix is:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ \vdots & \vdots & & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \quad (1)$$

where Sij denotes the area of the land type, i.e., the area of the ith land type transferred to the jth land type, and n denotes the number of land use types.

3.3 Single Land-Use Dynamics (SLUD)

The single land-use dynamics degree is the study of changes in the quantity of a land-use type in a region over a certain time interval. The single land-use momentum equation:

$$K_T = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (2)$$

Where K_T is the ratio of change (Dynamic Degree) of a land use type over the study time period T, Ua and Ub are the areas of the land use type at the beginning and end of the study, respectively, and T is the time period of the study.

3.4 Comprehensive Land Use Dynamics (CLUD)

The Comprehensive Land Use Dynamics Degrees reflect the overall change in the amount of land use in the study area over a given time interval, as calculated by the formula (Liu, 1996)::

$$LC = \frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2 \cdot \sum_{i=1}^{n} LU_i} \times \frac{1}{T} \times 100\% \quad (3)$$

In the formula, Lc is the comprehensive dynamic degree of land use in the study area, LUi is the area of the i-th type of land use at the starting time of the study, △LUi-j is the absolute value of the area of the i-th type of land converted into the jth type of land use during the study period, and T is the study time.

3.5 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a decision-making method for quantitative and qualitative analysis. Its principle is to first build a hierarchical structure, similar to a tree diagram, to build the object of the parent-child hierarchy, to build a multi-layer target layer and indicator layer, to build a judgment matrix for each layer, and to find the weight of a factor on each layer, layer by layer. Finally, determine the weight of the total target, but also check the consistency of the results of the weight test. According to the weight and size of each indicator, the evaluation can be made more accurately. The hierarchical structure of this paper is the target layer, i.e., the ecological sensitivity of Guangzhou, with six indicator factors, namely: elevation, slope, slope direction, land use, FVC, and watershed buffer zone.

(1) Judgment Matrix Construct

Comparison between two evaluation indicators, given their quantitative values of 1 (equally important), 3 (more important), 5 (slightly strong important), 7 (strongly important), and 9 (very important), according to the importance of the rating, and the results of the two comparisons to form a judgement matrix, which has the following condition:

$$a_{ij} = \frac{1}{a_{ji}} \quad (4)$$

where i and j denote evaluation indicators.

(2) Consistency Test

According to the judgment matrix that can be calculated for each evaluation factor weight value, in order to test whether the weight value is scientific but also to judge the consistency of the matrix test, the formula is

$$\lambda_{max} = \sum_{i=1}^{n} \frac{[A\omega]_i}{n\omega_i} \quad (5)$$

$$CI = \frac{\lambda - n}{n-1} \quad (6)$$

$$CR = \frac{CI}{RI} \quad (7)$$

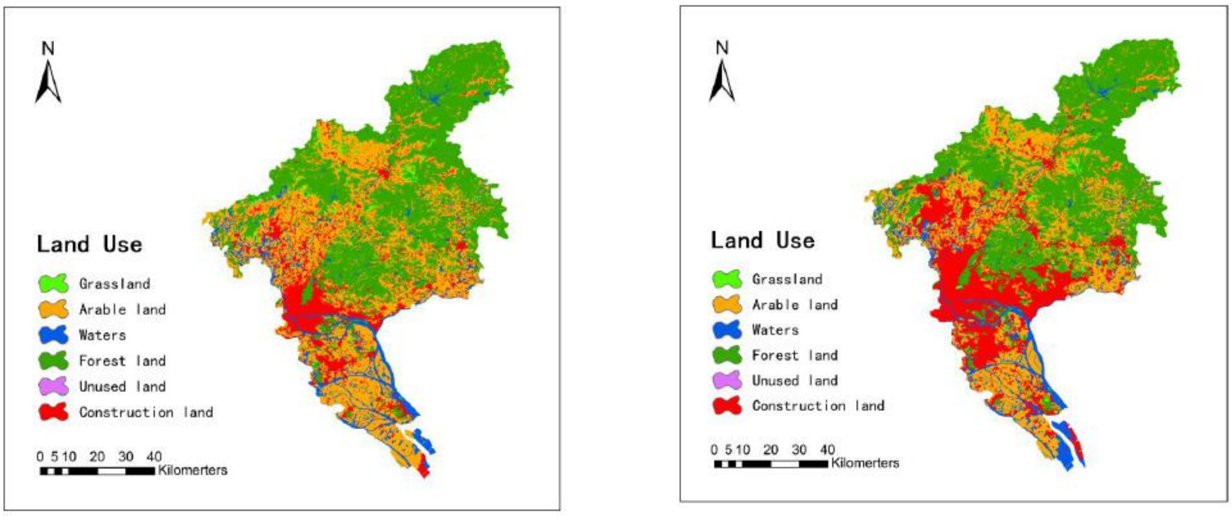
Where λmax is the maximum eigenvalue; A is the judgment matrix; ω is the eigenvector; n is the matrix order; CI is the consistency index; CR is the test coefficient. RI is the average stochastic consistency index (obtained by looking up the table). Normally, if CR <0.1, the judgment matrix is considered to pass the consistency test, and the closer CR is to 0, the higher the quality of the judgment matrix; on the contrary, it means that the matrix does not pass the consistency test.

IV. ANALYSIS AND RESULTS

4.1 Characteristics of LUCC in Guangzhou

4.1.1 Changes Analysis of Landforms

The land use types were divided into six major categories, including construction land, unused land, arable land, forest land, grassland, and water bodies (Figure 3). After being classified, the land use data from 2000 and 2020 were statistically obtained, as were the area and proportion of each category in Guangzhou. The total land area of Guangzhou City is approximately 7,190.13 km² (Table 2).



(a)2000 *(b)2020*

Fig.3 Distribution of land use types in Guangzhou in 2000 and 2020

Table 2 Distribution of area and percentage of different land use types

Use type	2000		2020	
	Area/km²	Percentage/%	Area/km²	Percentage/%
Arable land	2582.92	35.92 %	1997.42	27.71 %
Forest land	3149.73	43.48 %	3017.98	41.87 %
Grassland	107.34	1.49 %	103.87	1.45 %
Waters	523.23	7.29 %	538.33	7.58 %
Construction land	821.97	11.43 %	1530.46	21.36 %
Unused land	4.95	0.07 %	2.08	0.03 %

Table 2 shows the size and percentage of the total area occupied by various land use categories in 2000 and 2020. It is clear that the proportion of land use types has changed significantly since 2000. The two land uses that have changed the most are construction land and arable land. Construction land increased from 11.43% to 21.36% in 2000, indicating that one of the main characteristics of the change in Guangzhou's land use pattern is the substantial expansion of construction land; arable land decreased from 35.92% to 27.71% in 2000, indicating that a sizable portion of arable land has been occupied by the development of the city. Although the overall area of forest land has decreased from 43.48% in 2000 to 41.71% in 2020, forest land still represents the land type in the region with the highest proportion of area; the proportion of unused land area decreases in 2020, indicating that a part of the land has been effectively utilized. The water area is expected to raise with time, reaching 538.33 km² in 2020, an increase of 0.29 percent from 2000. The percentage of grassland area in 2020 has decreased by 0.04 percent compared to 2000, without much change.

4.1.2 Inter-Conversion Analyses of Land Types

The mutual conversion between land use types should also be taken into account because the analysis of the area change of land use categories cannot accurately reflect the conversion between various kinds. In this study, the land use change process in Guangzhou is statistically analyzed using ArcGIS software to produce the land use transfer matrix for Guangzhou from 2000 to 2020 (Table 3).

Table 3 Land use transfer matrix of Guangzhou, 2000-2020 (Unit: km2)

2000/2020	Grassland	Arable land	Construction	Forest land	Water bodies	Unused land	Total
Grassland	86.81	2.25	10.85	6.32	1.06	0.05	107.34
Arable land	4.58	1852.76	594.63	57.47	73.44	0.05	2582.92
Construction	4.19	62.02	702.57	22.64	30.54	0.00	821.97
Forest land	7.45	48.86	158.80	2922.25	12.23	0.14	3149.73
Water bodies	0.77	31.25	61.88	8.51	420.78	0.03	523.23
Unused land	0.07	0.27	1.74	0.78	0.27	1.82	4.95
Total	103.87	1997.42	1530.46	3017.98	538.33	2.08	7190.13

From Table 3, the growth of construction land is much greater than the decrease, and the primary sources of growth are arable land, forest land, water bodies, grassland and unused land in descending order of area. Meanwhile, the transfer of existing construction land to other land types is arable land, water bodies, forest land, grassland, and unused land in descending order of area, with the net growth amounting to 708.49 km2. This indicates that the period 2000–2020 is a period of urbanization and development.

Because it might be challenging to tell the difference between forest and arable land in remote sensing images, the rise in both types of land is much lower than the reduction, and the phenomenon of inter-transfer between forest and arable land is more pronounced. Additionally, it demonstrates that the total amount of arable and forest land in the entire city exhibits a diminishing tendency, which requires the relevant authorities to pay adequate attention. The overall area of unused land is shrinking by 2.87km^2, and is primarily being used as development land, showing that the city's unused land has been heavily utilized.

4.2 Analysis of Land Use Dynamics

4.2.1 Single Land Use Dynamics

According to the dynamic degree formula (2), the results of the dynamic degree of single land use in Guangzhou were calculated, as shown in Table 4. According to the findings, only Guangzhou City's dynamic degree toward water bodies and construction land use had favorable changes, whereas arable land, forest land, grassland, and unused land all experienced negative changes. The largest change among them is in construction land, with a dynamic degree of 4.31%, showing that the area of construction land, compared to other land use types, shows a substantial growth trend. The water area has a dynamic degree of 0.14%, reflecting that the overall area of the water area does not change much, but there is a steadily increasing trend of development; and the dynamic degrees of forestland and grassland are -0.21% and -0.16%, respectively, showing that the forestland and grasslands are declining but that these changes are not substantial. Arable land dynamic degree is -1.13%, with significant fluctuation; the change in unused land has decreased the most, with a motivation of -2.90%, indicating that unused land is being used effectively.

Table 4 Single land-use dynamics degree in Guangzhou, 2000-2020

Type	Dynamic degree /%
Arable land	-1.13 %
Forest land	-0.21 %
Grassland	-0.16 %
Water bodies	0.14 %
truction land	;
ed land	%

4.2.2 Comprehensive Land Use Dynamic

According to the comprehensive dynamic degree formula (3), Guangzhou City's comprehensive land use dynamic degree was calculated at 0.50%, which shows that there has been some change in the city's land use between 2000 and 2020, albeit a very slight one. In general, however, the intensity of the state has not been particularly high and has been relatively stable.

4.3 Ecological Sensitivity of Guangzhou City

4.3.1 Determining and Grading Evaluation Factors

The elements impacting ecological sensitivity are screened, and an indicator system is constructed based on the geographic features of Guangzhou and integrated with prior relevant study instances. Firstly, Guangzhou City's ecological sensitivity is broken down into five levels. Secondly, the three aspects of land use type, anthropogenic factors, and natural environment that have a greater impact on regional ecological sensitivity are reasonably selected as the main sources of the factors, which are further subdivided, and the six most significant ecological sensitivity factors of Guangzhou are finally screened out. These factors are derived from the regional characteristics and specific ecological processes of Guangzhou, combined with the availability of data. Table 5 displays each factor's index criteria.

4.3.2 Distribution of single-factor ecological sensitivity

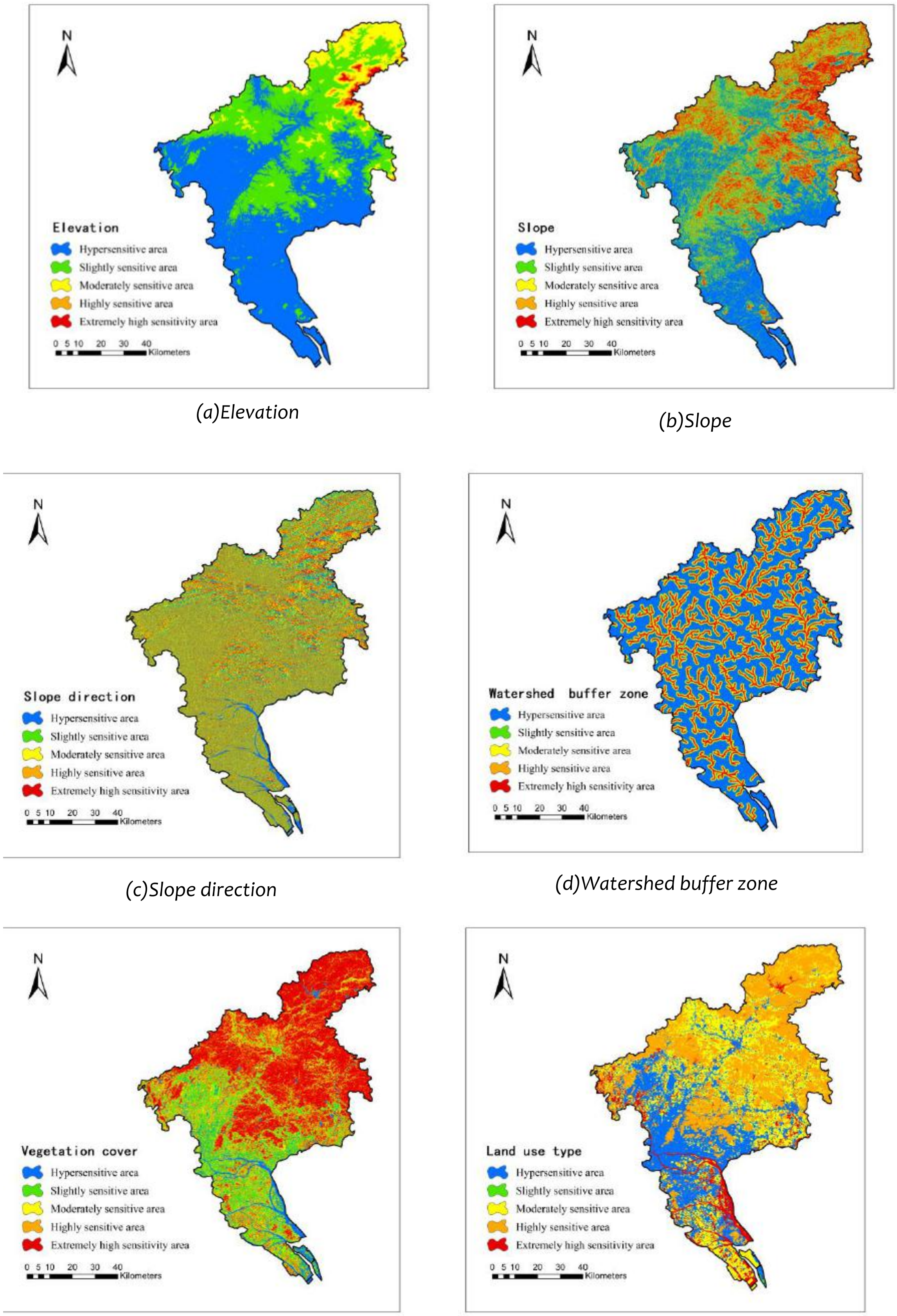
The results of the Guangzhou single-factor ecological sensitivity analysis in 2020 primarily fall into six categories, including elevation, slope, slope direction, watershed buffer, FVC, and land use (Figure 4). Table 6 displays the findings of the evaluation of each single factor. It shows that the area share of the moderately sensitive area, which accounts for 15.28% of the total land area of Guangzhou, is the smallest of all the sensitive areas. The areas of extremely low-sensitive and moderately sensitive areas, on the other hand, account for 21.09% and 21.13% of the total land area of Guangzhou, respectively. Highly sensitive areas and Extremely high-sensitive areas account for 42.51% of the total land area of Guangzhou, and these two types of sensitive areas are mainly distributed in areas with large slopes, high altitudes, and much vegetation cover, such as the edges of the boundary lines of townships and districts in the northern part of Guangzhou, which are mostly high mountainous peaks. Highly sensitive areas are typically centered on extremely sensitive areas that spread out in all directions. These two types of areas exhibit strong ecological environment interference and weak ecological environment self-recovery ability, and Guangzhou City's highly sensitive area is ranked first among all the sub-districts, indicating that its overall ecological sensitivity is slightly below high and that its tolerance for human activity interference is low. All districts have some areas that are considered moderately sensitive, and these areas tend to be low-sloped with a mix of low-hill plains, alluvial plains along rivers, hilly valleys, etc., as well as some vegetation cover. The two main land-use types are forested and arable land

Table 5 The evaluation indicators of single factor' ecological sensitive

Evaluation factor	Extremely low sensitive(1)	Slightly sensitive (2)	Moderately sensitive (3)	Highly sensitive (4)	Extremely high sensitive (5)	Weights
Elevation	<40m	40~300m	300~600m	600~800m	>800m	0.16
Slope	<5°	5~10°	10~15°	15~20°	20~25°	0.11
Slope direction	Flatlands, south slopes	South-east slope, south-west slope	East Slope, West Slope	North-east slope, north-west slope	North slope	0.07
Land use	Construction land	Unused land	Arable land, grassland	Forest land	Water bodies	0.33
FVC	<0.1	0.1~0.3	0.3~0.5	0.5~0.7	>0.7	0.24
Watershed buffer zone	>800m	600~800m	400~600m	200~400m	>200m	0.08

Table 6 the results of the ecological sensitivity evaluation in Guangzhou, 2020

Affect factor	Percentage of sensitive area/%				
	Extremely low	Mildly	Moderately	High degree	Extremely high
Elevation	52.63%	35.67%	9.42%	1.46%	0.82%
Slope	39.34%	23.12%	13.48%	9.48%	14.58%
Slope direction	20.41%	22.52%	20.71%	21.22%	15.14%
Watershed buffer	52.65%t	10.52%	11.29%	12.18%	13.37%
FVC	8.07%	18.58%	14.21%	15.52%	43.61%
Land use type	26.08%	0.09%	29.72%	35.83%	8.29%
Ecological sensitivity	21.09%	15.28%	21.13%	21.83%	20.68%



(a)Elevation *(b)Slope*

(c)Slope direction *(d)Watershed buffer zone*

(e)Vegetation cover *(f)Land use type*

Fig.4 Distribution of single-factor ecological sensitivity of Guangzhou in 2020

(1) Elevation Sensitive Analysis

The topography of the study area, which slopes from north-east to south-west with highs in the north and lows in the south, plays a significant role in defining its level of ecological sensitivity. The study area's extremely high, highly, and moderately sensitive areas make up 0.82%, 1.46%, and 9.42% of the total land area, respectively. These areas are primarily found in the northeastern region of Guangzhou, in the Conghua District, Huadu District, Zengcheng District, and the surrounding areas. For instance, among the Tiantang Peak, the Jizhen Mountain, the Tiger Hilltop, and the Guifeng Mountain, the first and second-highest peaks in Guangzhou are Tiantang Peak (1,210 m above sea level) and Jizhen Mountain (1,146.7 m above sea level), respectively. A few are distributed in the central area of Guangzhou, such as Prince Mountain (580 m above sea level) and Yaying Mountain (570 m above sea level) in Huadu District.

Most parts of Guangzhou are extremely low-sensitive and slightly sensitive areas in terms of elevation, of which the largest is the extremely low-sensitive area, accounting for 52.63% of the total area, which is mainly distributed in the southwestern part of Guangzhou in Tianhe, Liwan, Yuexiu, Haizhu, Panyu, and Baiyun districts, as well as part of the southeastern part of Huangpu District, and most of which are arable land, forestland, and construction land, and most of them are concentrated in the region's low-hill plains, alluvial plains on the banks of rivers, hilly valleys, and gently sloping lands. With elevations ranging from 40 to 300 meters, slightly sensitive areas make up 35.67% of the total area, mostly located in central and northeastern Guangzhou.

(2)Slope Sensitive Analysis

Slope is directly related to the size of the land's carrying capacity; according to the slope, the degree of steepness of an area is determined. The steeper the slope, the more fragile the ecological environment is and the more prone it is to natural disasters. The landform type of Guangzhou is mainly hilly with a gentle slope, so this study divided the slope into five classes: $< 5°$, 5°～10°, 10°～15°, 15°～20°, and 20°～25°.

Through the analysis, it can be obtained that: the area of extremely low sensitivity is the largest, accounting for 39.34% of the total area, distributed in the south and central parts of the area; the area of slightly sensitive area is also slightly higher, accounting for 21.32% of the total area, second to the extremely low sensitivity area, distributed in the central part of Guangzhou; and the slope sensitivity is not high in the place of the topography of the more flat, which is conducive to the social activities of the people.

The moderately sensitive area accounts for 13.48% of the total area, the highly sensitive area accounts for 9.48% of the total area, and the extremely highly sensitive area is slightly larger, accounting for 14.58% of the total area. It is located in Huadu, Conghua, and Zengcheng districts, where the higher mountain ranges within the town include Tiantiantian Ding (Top of Paradise), Jizhen Mountain, Tiger's Head, Guifen Mountain, and so on.

(3) Slope Direction Sensitive Analysis

In this study, a five-direction classification method was used, and the analysis shows that the moderately sensitive area is the largest, accounting for 22.52% of the total area; the extremely highly sensitive area is the smallest, accounting for 15.14% of the total area; and the highly sensitive area, the moderately sensitive area, and the extremely low-sensitive area account for 21.22%, 20.71%, and 20.41%, respectively, of the total area.

(4) Watershed Buffer Zone Sensitive Analysis

Water is crucial for human activity, plant growth, and animal survival, and the more ecologically sensitive a place is, the more important water is to human activity, plant growth, and animal survival. The buffer zone of water bodies in Guangzhou has the largest area of extremely low sensitivity, accounting for 52.65% of the total area; the area of slightly sensitive area is the smallest, accounting for 10.52% of the total area; the extremely highly sensitive area is widely dispersed in the central region of Guangzhou, around the rivers; and the moderately sensitive area, the highly sensitive area, and the extremely highly sensitive area account for 11.29%, 12.18%, and 13.37% of the total area, respectively. Compared to extremely high sensitive and highly sensitive zones, extremely low-sensitive areas are significantly larger. In Guangzhou, the distribution of waterways is comparatively even. To lessen the harm brought on by human activity, we should increase the management and protection of water bodies.

(5) FVC Sensitive Analysis

FVC is an important factor reflecting the capacity of ecosystems, and this study uses a NDVI for characterization. The areas with vegetation coverage less than 30% are slightly sensitive areas and extremely low sensitive areas, accounting for a total of 26.65% of the city's area, mainly distributed in and along water areas. The moderately sensitive area and highly sensitive area, respectively, account for 7.52% of the land area of Panyu District in the south of Guangzhou, part of Haizhu District, Liwan District, Yuexiu District, Tianhe District, and Baiyun District in the central and western regions, and part of Huangpu District in the east. Moderately sensitive areas and highly sensitive areas, respectively, account for 14.21% and 15.52% of the land area in Guangzhou. Areas with vegetation coverage of over 70% are extremely sensitive. Due to the mountainous and hilly terrain in the northern part of Guangzhou, highly sensitive areas with vegetation coverage are widely distributed in the northern part of Guangzhou, accounting for 43.61% of the total area of Guangzhou and nearly half of the total land area. They are the areas with the highest proportion of ecological sensitivity in vegetation coverage.

(6) Land Use Types Sensitive Analysis

The ecologically extremely sensitive and highly sensitive land use areas make up 44.12% of Guangzhou's total area, or nearly half of the city's total land area. They are concentrated primarily in the northern and central parts of the city, where Guangzhou has the highest proportion of forested land. This high proportion of forested land accounts for the ecologically extremely sensitive and highly sensitive land use areas' widest distribution and largest distribution areas. Although there is a lot of forested land, it is mostly found in high-altitude regions, and once damaged, it has a poor ability to self-regulate, necessitating expensive restoration. Vegetated forest resources can regulate the regional climate and have the function of maintaining the entire ecosystem of the region.

Land use ecologically extremely low sensitivity areas make up 26.08% of Guangzhou's total area, ranking third among land use types in terms of ecological sensitivity. These areas are primarily concentrated in the south and south-west of the city, mostly in the Panyu, Liwan, Tianhe, Yuexiu, and Haizhu districts, as well as in the southern part of Huangpu District and a slice of the north-central region. The major categories of land use include environments created by humans, such as those for transportation and water use, urban and rural construction, etc. The economy is more advanced, and land usage is more advanced.

4.3.3 Ecological Sensitivity Distribution of Guangzhou

When the weights of each factor are obtained through the AHP method using the weighted superposition tool within the spatial analysis module of ArcGIS, the sensitivity layers of the six single factors, namely, elevation, slope, slope direction, land use type, FVC, and water buffer, are respectively operated in accordance with the computed weights of 0.16, 0.11, 0.07, 0.33, 0.24, and 0.08 for the map algebra operation. The calculation results are shown in Figure 5.

Slightly and moderately sensitive areas of comprehensive ecological sensitivity account for 36.41% of the total land area of Guangzhou, while very low sensitive areas account for 21.09% of the total land area. These three types of sensitive areas are distributed in the plains where the carrying capacity of the resources and environment is strong and the conditions for economic and population agglomeration are good, such as the western part of Guangzhou and a few central areas, and there are also some scattered distributions in the eastern part of Guangzhou. The main characteristics are simple and stable ecosystems, poor biodiversity, and weak interference and destruction by human activities. The primary traits are weak biodiversity, simple and stable ecosystems, and minimal human meddling and devastation.

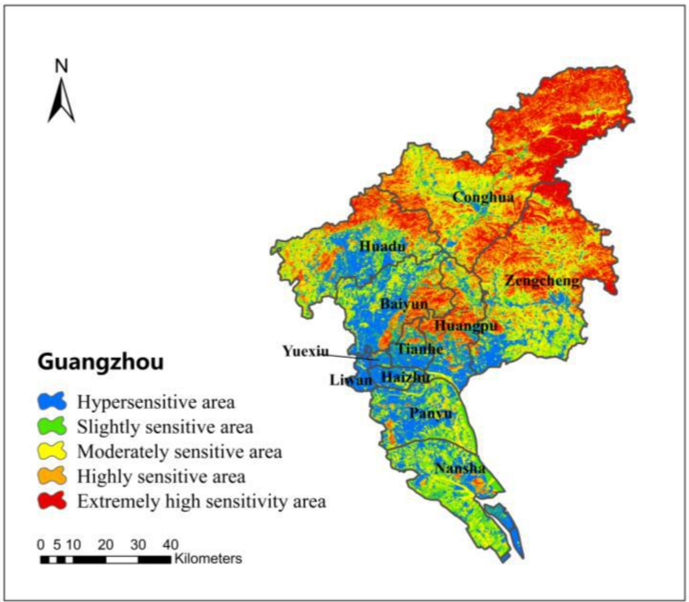


Fig.5 Comprehensive ecological sensitivity map of Guangzhou

V. CONCLUSION

The changes in land use types in Guangzhou from 2000 to 2020 varied, with a decrease in the area of unused land, cultivated land, forest land, and grassland and an increase in the area of construction land and water bodies. The dynamic degree of comprehensive land use in Guangzhou from 2000 to 2020 was 0.5%, indicating that there was a certain degree of change in land use in Guangzhou from 2000 to 2020, but overall, the intensity was not high and the state was relatively stable.

Through the six single-factor ecological sensitivity distribution results, according to their respective weight values for the map algebra operation, the results of the operation can be seen: high vegetation cover, high elevation, and steep slope areas are often extremely highly sensitive areas. The highly sensitive areas, most of which are located in the northern part of the Guangzhou District boundary line, are not easily affected by human activities, and if once affected, the recovery cycle is longer. There is a need to focus on the protection of mountains and forests as a whole and to strictly limit the interference of human activities. Extremely low-sensitive and slightly sensitive areas, such as low-hill plains with flat topography, alluvial plains on both sides of rivers, hilly valleys, etc., are primarily distributed in the south and a few central and eastern parts of Guangzhou, and it is necessary to establish the concept of harmony between people and land and prevent the over-expansion of the built-up areas. The majority of the area is made up of highly sensitive areas, which are widely dispersed, with the greatest concentration in the northern part of Guangzhou. As a result, Guangzhou needs to strengthen its role in ecological conservation while minimizing anthropogenic interference and fostering the development of an ecological land plan and an ecological civilization.

ACKNOWLEDGEMENTS

The author is grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment (No.2019rc098), Peoples R China under Grant No.702-519208, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

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