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COMPREHENSIVE ASSESSMENT OF URBAN ECOLOGICAL ENVIRONMENT BASED ON MULTISOURCE DATA INTEGRATION ANALYSIS

Abstract: In order to understand the comprehensive assessment of urban ecological environment, the author proposes a study on the comprehensive assessment of urban ecological environment based on multi-source data integration analysis. The author first analysed that remote sensing and geographic information systems are effective means for resource and environmental research. Secondly, using remote sensing and GIS technology to conduct surveys and evaluations of regional ecological environment quality at different scales can make up for the shortcomings of traditional methods that require a lot of manpower, material resources, and time to obtain ecological environment background data. It has the advantages of relatively easy data acquisition, rich information, and fast analysis. Finally, taking a certain city as an example, establishing a scientific evaluation system to comprehensively evaluate the ecological environment of the city, understanding its current situation and spatial distribution characteristics, is of great significance for promoting the construction of ecological cities, coordinating human land relations, and achieving sustainable economic and social development. The experimental results show that the urban area (with a comprehensive environmental evaluation index of 7.16) is mainly hilly and plain, with most areas having relatively flat terrain. In recent years, with the increase in urban green area and the increase in environmental protection and governance efforts, the environmental quality of the city has shown a trend of improvement.

Keywords: multi-source data, ecological environment, comprehensive evaluation

Introduction

Understanding land environmental conditions and assessing environmental quality are fundamental to forecasting and warning systems, providing critical information for decision-making bodies and sustainable development research. To implement effective environmental policies and strategies, comprehensive studies integrating spatial characteristics and historical context are essential. In recent years, the term "ecological environment" has emerged as a key concept to describe the suitability of natural and human systems for socio-economic development. Ecological environment quality (EEQ) serves as a metric to evaluate the state of an environment and its compatibility with human life and economic activities across temporal and spatial scales. Rapid industrialisation and recurring ecological crises have heightened the urgency of environmental quality assessments globally. Countries such as the United States, Canada, Sweden, France, the UK, Japan, and Australia have established advanced frameworks for environmental monitoring and

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evaluation. Since the 1970s, assessments have evolved from agricultural ecosystems to broader applications, including regional ecological quality, mountainous environments, and urban cultural landscapes. Today, evaluations encompass both natural and socio-economic dimensions.

With the widespread adoption of strategies like "Ecological Priority in Economic Development" and the National Ecological Environment Development Plan, environmental quality assessment has gained prominence in policymaking and scientific research. Regional EEQ assessments are vital tools to balance economic growth with ecological protection, accounting for spatial heterogeneity in environmental conditions and development levels. Such assessments help identify ecological degradation, guide restoration efforts, and predict future trends. However, traditional evaluation methods face limitations: outdated data collection techniques, low efficiency, poor timeliness, limited data accuracy, and inadequate analytical capacity. These challenges hinder effective environmental management and decision-making. Remote sensing (RS) technologies overcome these barriers by enabling non-contact, large-scale detection of ground features. Modern RS integrates data transmission and processing to analyse spatial patterns dynamically. Coupled with geographic information systems (GIS) - which support multivariate statistics, model simulations, and spatial visualisation - RS has become indispensable for land environment monitoring, particularly in soil erosion control and ecosystem management. This study aims to: Develop a GIS- and RS-based framework for regional ecological environment quality (EEQ) assessment, integrating multi-source spatial data. Evaluate spatial-temporal patterns of EEQ degradation and identify driving factors in the study area. Propose targeted improvement strategies for sustainable land-use planning. We hypothesise that:

H1: RS and GIS can significantly enhance the accuracy and efficiency of EEQ assessments compared to traditional methods.

H2: Regional EEQ exhibits significant spatial variability, correlated with anthropogenic activities and natural factors (Fig. 1) [1, 2].

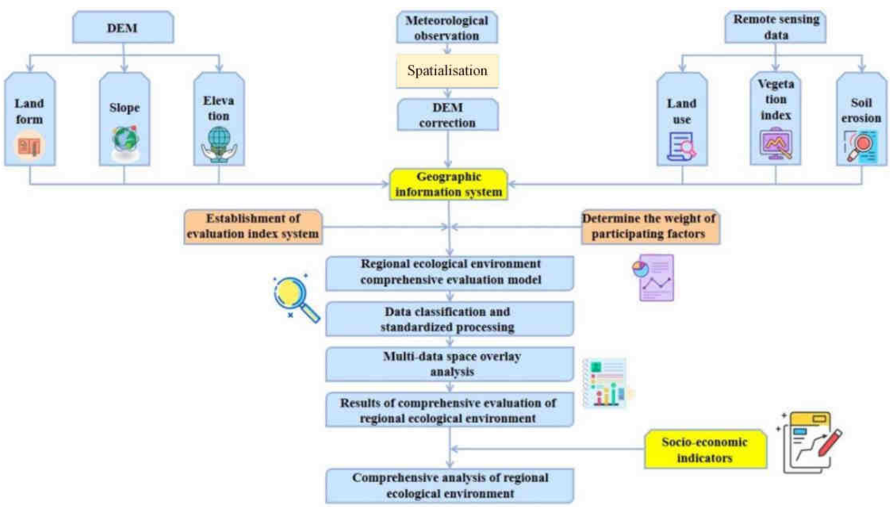

Fig. 1. Integrated analysis of multi-source data for urban ecological environment comprehensive assessment

Literature review

People are not only interested in expanding their business, but also have a direct understanding of the quality of the urban environment. In order to meet people's material needs, the desire to protect the environment is increasing. At the same time, with the advancement of technology and a deeper understanding of the concept of environmental protection, human activity continues to play an important role in the development of the urban environment. Due to the lack of information about different methods and channels, traditional urban studies are too biased and crude due to lack of data, inaccurate data, limited data, and objective reasons. Deep human development in the era of big data provides valuable information for better analysis and study of urban environmental patterns.

Compared to traditional data acquisition methods, multi-source big data in the internet can help conduct more complex analysis and evaluation of cities in various aspects. For example, using mobile signalling data can dynamically monitor the spatiotemporal distribution characteristics of population; points of interest (POI) provide new ideas for identifying urban functional areas and evaluating urban vitality; night light data has unique advantages in extracting urban boundaries and their spatiotemporal evolution. Combining the characteristics of multi-source data and depicting the characteristics of cities from different perspectives has become a wind vane in current urban problem research. The ecological environment of a region reflects the structure and function of its ecosystem, and its changes are influenced by a combination of natural and human factors. In urban areas, the significant increase in human activities is one of the important human factors that affect the ecological status and changes in cities. The rapid development of urbanisation not only improves the living standards of residents, but also brings environmental problems such as housing shortage, traffic congestion, air pollution, and urban heat island effect. With the increase of urban consumer groups, the total amount of urban waste emissions and energy consumption are rapidly increasing, leading to a decrease in the stability of urban ecosystems. The increasingly prominent issues of urban ecological environment pose a threat to the health and biodiversity of residents. They are bound to have adverse effects on the construction of sustainable cities and human settlements. Therefore, monitoring and evaluating urban ecological quality is crucial for urban planning, environmental management, ecological construction, and sustainable development. Zou et al. [3] used remote sensing and GIS technology to conduct remote sensing surveys and mapping research on soil erosion in Xinjiang region, proposed a three-level soil erosion classification system, and identified the basic situation of a certain soil erosion. Boori et al. [4] used satellite data to conduct a statistical analysis of the spatiotemporal ecological vulnerability of Samara, Russia.

Ecological environment is a collective term for the quantity and quality of water resources, land resources, biological resources, and air resources necessary for human production. and life. It is an ecosystem that affects the development of human life and the health of the economy. The quality of the ecological environment is an important issue for business and development. A complete understanding of the existing environmental conditions and accurate measurements play an important role in predicting the development of the environment and is an important factor in the development of strategic plans. business in the area. The assessment of the city's environment varies with different indicators, measures and methods. The evaluation of cities is usually based on three factors:

economy, nature and people. Due to the complexity of ecological and social processes, it is difficult to quantify changes in the quality of the ecological environment using technology, so it is necessary to compare the selected indicators objectively and consistently [5, 6].

Methods

Methods for evaluating ecological environment quality

Evaluation index system

Many external factors, such as land environment, potential territory, and level of local development, affect the formation and change of the land environment. Precipitation, temperature, their distribution, plant development and community structure, land features and general regularity directly affect the stability and natural balance of the environment, serve as the basis for the creation of resources, and use resources in the course of human activities to improve the environment. It is the main source of the environment, influencing the changes and still influencing the society and development of the region. Creating and changing the environment, choosing a model, evaluating measurement points, and evaluating the urban environment according to the theory and methods of previous research, taking into account the information contained in the current situation. It was created at three levels by selecting four factors: air environment, land, land cover, and soil moisture. The author usually selects several parameters such as land use type, vegetation protection, humidity, altitude, slope, average annual precipitation, temperature ≥ 12 °C, average annual humidity, and average annual sunshine, and uses the system analysis method. the weight of each indicator. examination. The Analytic Hierarchy Process (AHP) is a multi-objective decision-making process that combines qualitative and quantitative analysis methods proposed by Professor Saaty of the University of Pittsburgh in 1970. At each level, the elements of that layer can be compared pairwise according to the rules to form a decision matrix. By computing the maximum eigenvalues of the decision matrix and the corresponding orthogonal eigenvectors, the product weights of that layer can be derived for the process. According to the hierarchical evaluation system, the weights of the above parameters are determined to obtain the quality evaluation of the urban environment (Table 1) [7, 8].

Table 1

Comprehensive evaluation index system of the ecological environment in the city

Target layer	Factor layer	Indicator layer	Data sources
Comprehensive evaluation index of ecological environment	Land cover	Land use type (C1 = 0.26)	Remote sensing data
	Soil erosion	Surface vegetation (C2 = 0.16) Soil erosion intensity (C3 = 0.2)	Remote sensing data
	Topographic features	Altitude (C6 = 0.13)	Interpolation of meteorological observation data
	Weather conditions	Annual average humidity index (C8 = 0.08)	Interpolation of meteorological observation data

Standardisation of evaluation indicators

After determining the evaluation indicators, due to inconsistent sources, complex types, inconsistent dimensions, lack of comparability, and significant unit differences among various ecological and environmental thematic data sources, comprehensive calculations cannot be carried out, therefore, it is difficult to directly use them for environmental quality assessment. Even for the same factor, although the degree of its impact on the environment can be determined based on their measured values, it cannot accurately reflect its impact on the environment due to the lack of a comparable environmental standard. In the evaluation process, considering that the research on the absolute values of multiple indicators is not yet mature, and in order to ensure the consistency of all indicator evaluation standards, a relative evaluation method was adopted in the single indicator evaluation process. For example, slope and altitude, in order to complete data stacking on a computer, it is necessary to classify and merge according to certain standards, and assign corresponding scores to each level based on its contribution to the ecological environment quality from low to high; Some qualitative indicators, such as land use and soil erosion, also require the use of expert knowledge, only after reasonably scoring and quantifying the contribution of different types to ecological environment quality can we participate in data overlay analysis. At the same time, due to the fact that grading can only reflect the internal differences of the participating factors, it is still not convenient to compare them with each other. Therefore, it is necessary to differentiate the grades of different participating factors and achieve quantitative expression under unified standards, so that when participating in multi factor comprehensive analysis and calculation, the fairness and rationality between factor elements will not be lost due to the different number of grading. After standardised processing, the data of each participating factor is a set of numerical values that reflect its attribute characteristics, and the resulting values are specified to be between 1 and 12 [9, 10]. The formula commonly used for standardising the evaluation factors is equation:

$$v_{\mathrm{j}} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \cdot 12 \quad (1)$$

where v_j is the standard value of the *j*-th evaluation indicator after standardisation; x_j is the original observation value of the *j*-th evaluation indicator, that is, the unprocessed data directly obtained from the data source; $x_{\min}$ is the minimum value of the *j*-th evaluation indicator in the entire study area and $x_{\max}$ is the maximum value of the *j*-th evaluation indicator in the entire study area.

Overview and data sources of the city

The author uses the city of administration, trade, technology, education and culture as the object of research, with a history of more than 2000 years. Taking Guangzhou as the research object, it is located in the southern part of mainland China, the central and southern part of Guangdong Province, the northern edge of the Pearl River Delta, and near the bottom of the Pearl River Basin Delta. It is located at 113°58’ - 115°04’ east longitude and 23°27’ - 24°57’ north latitude.

Basic characteristics of regional natural ecological environment

Various land types, complex terrain, high in the north and low in the south

According to the definition of the remote sensing image of the city in 2023, the total area of the city is 7,500 km^2, of which 745 km^2 of water area, about 3,542 km^2, about 3,368.4 km^2 below an altitude of 60 m. The city has different types of soil and terrain, with high land in the north and low land in the south. The highest peak is Tiantanding of Nancun Mountain at the junction of Konghua City and Longmen County in the north with an altitude of 1,310 m. The geomorphic types of the city are middle and low mountains, hills, platforms, dirt plains, mud and water (including wetlands): (1) Middle and low mountains ascent above 600 meters, mainly distributed in the northeast of Conghua and north of Zencheng, general slope is above 15 - 30 degrees. The parent material of the soil is mainly granite and migmatite; (2) The height of the hills is usually 100 m - 500 m, and it is mainly divided into the mountains, lands, and plains in the northern part of Zencheng, Conhua, and Huadu, as well as the eastern and northern parts of the urban area. The source material of the soil is only granite, mixed rock and metamorphic rock; (3) The platform is an elevated area with a relative height of less than 60 m and a slope of less than 20 degrees. It is mainly divided into B zone, C zone south, A zone north and south, D zone west, E zone, Pearl River zone and the north bank of the city. The parent material that forms the soil is only redstone, sandstone, metasandstone, and granite; (4) The Alluvial Plain and the Pearl River Delta mainly refer to the Guanghua Plain, the area along the Pearl River, and the coast of the Panyu District of the Lucy River Alluvium; (5) The water area is about 743 km^2 and occupies 5 of the urban area [11, 12].

This study uses multi-source remote sensing data to construct an ecological assessment model. The core data source is the multispectral band image (resolution 30 m) of the Landsat 9 satellite (OLI/TIRS sensor) in 2023, supplemented by Sentinel-2A MSI data (10-meter resolution) to enhance timeliness. The images cover the key ecological monitoring periods of the study area throughout the year (March, June, September, and December), and are atmospherically corrected, geometrically fine-calibrated, and multi-temporally normalised to ensure spectral consistency. The terrain data comes from ASTER GDEM V3 (30-meter resolution), and the meteorological data integrates the daily observation station data of the China Meteorological Administration in 2023 (after Kriging interpolation, accuracy ±0.5 ^{o}C/±5 % RH). The land use classification is based on the 1: 100,000 remote sensing interpretation results of the Ministry of Natural Resources in 2023. The vegetation coverage uses the pixel dichotomy method to invert the NDVI (MOD13Q1, 16-day synthesis period), and the soil erosion intensity is classified according to the standard of the Soil and Water Conservation Monitoring Center of the Ministry of Water Resources.

Fifty random sampling points were set up in the study area, and vegetation cover, soil moisture content (TDR-3 sensor) and terrain elevation were collected simultaneously and compared with the remote sensing inversion results.

The level of regional socio-economic development

This urban area is the largest commercial, financial, transportation, and information center in South China, and is one of the most dynamic mega cities in China. Over the past 20 years of reform and opening up, the city’s social and economic development has been sustained and rapid. During the Ninth Five Year Plan period, the average annual growth rate of the city's GDP was 14 %, ranking first among the top ten cities in China. In 2023, the city's GDP reached 241.6 billion yuan, an increase of 14 % compared to 2022; in 2021, the total GDP reached 359.788 billion yuan, an increase of 16 % compared to 2020. Among the districts (cities) under the jurisdiction of the city, the economic advantages of the urban area (i.e. the traditional old eight districts) are prominent, accounting for over 80 % of the city's GDP. Other regions, especially the A district of the city, also maintain a good economic development trend (Table 2).

Table 2

Horizontal comparison of per capita GDP by region from 2023 to 2022

Population and economy	2023			2022		
	Population [10000 people]	GDP [100 million yuan]	Per capita GDP [10000 yuan/person]	Population [10000 people]	GDP [100 million yuan]	Per capita GDP [10000 yuan/person]
Urban district	420	1800	4.08	410	1750	4
Zone A	93	300	3.21	90	280	3.00
Zone B	60	156	2.58	55	150	2.50
Zone C	80	140	1.76	75	130	1.70
Zone D	50	70	1.30	45	65	1.20
Zone E	40	65	1.20	40	60	1.10

Comprehensive evaluation and analysis of ecological environment

Comprehensive evaluation results of ecological environment quality

With the support of Arc / Data Area, many documents have been published to calculate environmental measures for each measure (network). All values from 1 to 12, represent the quality of the ecological environment in the past. The higher the rating, the better the environment. In order to reflect the distribution of different environmental indicators, the quality of the environment is divided into different levels for statistical analysis, and the specific results are shown in Table 3 [13, 14].

Table 3

Comprehensive evaluation results of ecological environment

Environmental rating	Comprehensive indicator evaluation [score]	Number of grids	Area [m^2]	Area percentage [%]
1	1-3	17	18	0.0003
2	3-4	336	336	0.0045
3	4-5	2500	2500	0.00365
4	6-7	4900	49230	0.3265
5	7-8	22563	21456	0.18523
6	9-10	4500	4200	0.00582

The average value of the comprehensive evaluation index for ecological environment quality in the city is 7.32, showing a skewed normal distribution, with a distribution range of 2.86 to 8.75. Among several environmental quality grade zones, the sixth level environmental quality zone (with an ecological environment comprehensive evaluation index of 6-7) is located in the average range, accounting for the largest proportion of the area, close to half of the total area of the city, reaching 45 %. Secondly, the distribution areas of the fifth level environmental quality zone (ecological environment comprehensive evaluation index is 4 - 5) and the seventh level environmental quality zone (ecological environment comprehensive evaluation index is 9 - 10) are also relatively large, with 31 % and 18 %, respectively. The proportion of environmental grade areas with relatively poor environmental quality (ecological environment comprehensive evaluation index < 4) and relatively best environmental quality (ecological environment comprehensive evaluation index > 9) is very small, with the former accounting for about 0.42 % and the latter accounting for about 0.59 % (Fig. 2) [15, 16].

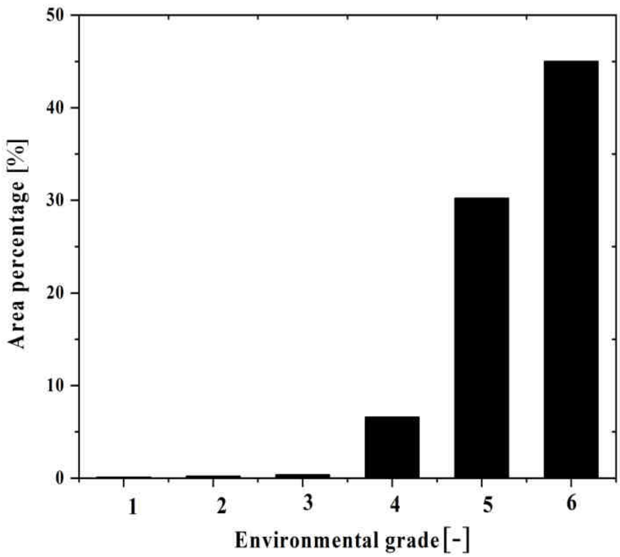

Fig. 2. Comprehensive evaluation index of ecological environment quality

Spatial distribution characteristics of ecological environment quality

According to the standardisation principle of the previous indicators, the larger the numerical value, the better the ecological environment condition. In actual analysis, a hierarchical representation method is used, according to the characteristics of the regional ecological environment and the composition of the comprehensive evaluation index, the comprehensive ecological environment of the city is divided into five levels: extremely poor (< 6.0), poor (6.0 - 7.0), average (7.0 - 8.0), good (8.0 - 9.0), and very good (> 9.0). The spatial distribution characteristics of environmental comprehensive indices at different levels reflect regional differences in environmental conditions. The specific grading results are shown in Table 4.

Administrative regional distribution characteristics of ecological environment quality

As a comprehensive analysis unit, administrative regions more reflect the spatial characteristics of the social nature of regional environmental quality as the main line. The current situation and improvement of regional ecological environment quality are closely related to the level of regional social and economic development. Understanding the administrative regional distribution characteristics of various environmental factors and environmental comprehensive evaluation indices can provide a basis for the rational utilisation of regional resources and the formulation of relevant environmental protection measures and plans in the future.

Table 4

Classification results of comprehensive evaluation index for ecological environment quality

Ecological environment status level	Comprehensive evaluation index	Number of grids	Area [m^2]	Area percentage [%]
extremely poor	< 6	2850	2800	0.0042
poor	6.0 - 7.0	48230	4800	0.6589
average	7.0 - 8.0	223651	21563	0.3256
good	8.0 - 9.0	324560	32145	0.4421
very good	> 9.0	132560	13265	0.1800

Administrative region distribution characteristics of land cover factors

The land cover index is the comprehensive score of two indicators: land use type and surface vegetation. The land cover index of the city is arranged in descending order (Fig. 3): E district (8.16) > D district (7.50) > C district (6.45) > B district (5.96) > A district (5.45). Conghua District has the highest average scores for both vegetation index and land use type, with 7.49 and 8.52 respectively, resulting in the highest land cover index with an average value of 8.16; Secondly, Zengcheng City has an average score of 7.03 and 7.85 for vegetation index and land use type, respectively; The Huadu District is 6.18 and 6.87 respectively; The urban area is 5.76 and 6.18 respectively; The average scores of both in Panyu District are the lowest, at 5.32 and 5.48 [17, 18]. In order to scientifically verify whether the differences in land cover index among different administrative regions are statistically significant and quantify the contributions of each parameter to the land cover index, one-way ANOVA method was used:

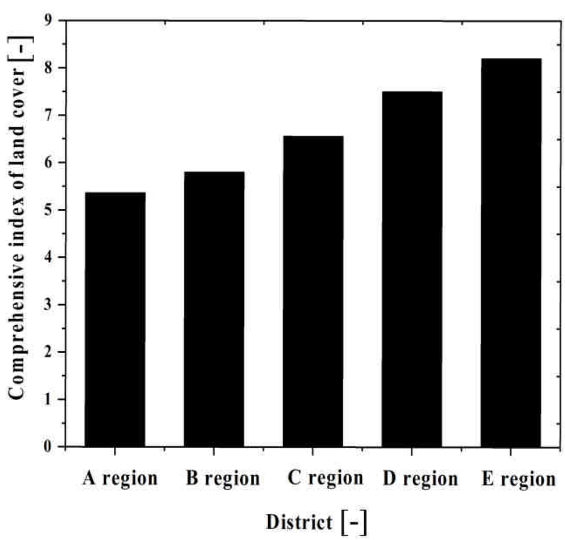

Fig. 3. Distribution of land cover index

Purpose: To examine whether there are significant differences in land cover index among different administrative regions (A-E regions).

Step: Hypothesis (H_0): The mean land cover index of all administrative regions is equal.

Alternative hypothesis (H_1): At least one administrative region has a mean that is different from the others.

The results showed that administrative regions had a significant impact on the land cover index (F (4, [df_ error])=[F value], $p < 0.01$).

The post hoc test (Tukey HSD) showed that the land cover index in Zone E was significantly higher than that in Zone A ($p = 0.003$), Zone B ($p = 0.012$), and Zone C ($p = 0.028$). There was a significant difference between Zone D and Zone A ($p = 0.021$), while there was no significant difference between other groups ($p > 0.05$).

Administrative region distribution characteristics of landform factors

The favorable order of the terrain and geomorphology index of the city is: B district (9.67) > urban area (8.78) > C district (8.58) > D district (8.22) > A district (6.86) (Fig. 4), which is consistent with the distribution pattern of altitude and slope within the region. The mountainous area of Zone E is wide, with an average elevation of 260.84 m. The maximum value is the highest peak in the city - Tiantangding in Nankunshan, with an elevation of 1320 m and a high altitude.

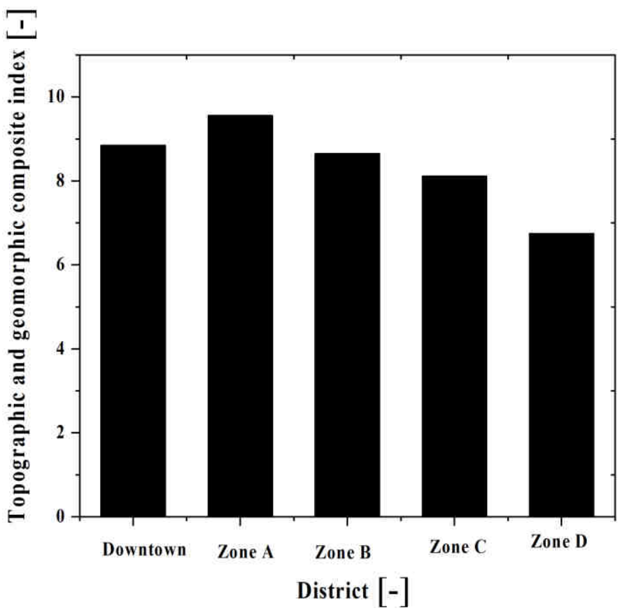

Fig. 4. Distribution map of topographic and geomorphic composite index in districts (cities)

The slope value is generally relatively large, with an average slope of 8.58° and a maximum value of 84.83°. Therefore, its terrain and geomorphology index is the lowest. The terrain of Zengcheng City is relatively high, with some middle and low mountains distributed to the west and north, with an average elevation of 123.94 m and a maximum value of 1445 m, with an average slope of 5.35°. The terrain of Zone C has decreased, with an average elevation of 84.37 m and a maximum value of only 560 m, with an average slope of 2.78°. The urban area is lower, with an average elevation and slope of 63.77 m and 2.50°, respectively. Zone B has the lowest altitude, with a maximum value of only 284 m and an average value of 32.08 m. The average slope is only 0.68°, and the terrain is very flat, resulting in the highest topographic and geomorphological index.

Administrative regional distribution characteristics of comprehensive ecological environment quality

The results from Table 5 show that there is not much difference in the level of ecological environment quality among administrative units at the district (city) level in the city, with a distribution range of 6.64 - 7.76, and an average value of 7.28. Except for the average level in Huadu District, the ecological environment quality status of all other districts is at a good level. The favourable order of the comprehensive index of ecological environment quality in the city is: C district > B district > D city > the urban area > A district.

Table 5

Comprehensive evaluation of ecological environment quality and socio economic statistics in different zones

Area	**Total population [10000 people]**	**Population density [person /km^2]**	**Per capita GDP [10000 yuan/person]**	**Environmental comprehensive evaluation index [-]**
Urban district	420	1005	4.08	7.16
Zone A	93.26	706	3.24	7.58
Zone B	60.23	600	2.98	6.63
Zone C	80.12	460	1.76	7.68
Zone D	53.23	250	1.32	7.08

The quality of ecological environment is a comprehensive analysis result that reflects multiple factors, which is not only constrained by the regional ecological environment background, but also influenced by social and economic activities. Therefore, the ecological environment of a region is a complex of nature, society, and economy. Combining the analysis of regional economy and population conditions is more conducive to our understanding of the causes of the current state of ecological environment quality. As shown in Figure 5, Zone C (with a comprehensive environmental evaluation index of 7.58) is mainly mountainous and hilly areas, with good vegetation coverage, favorable climate conditions, relatively backward economic development, and weak human activities and development and construction behaviours. Therefore, the ecological environment is relatively ideal. Zone B (with a comprehensive environmental evaluation index of 7.45) has a low and flat terrain, dense river networks, superior climate conditions, developed industry and agriculture, and a high level of human development. However, the investment in environmental protection and governance is relatively high, resulting in a good ecological environment. At present, Panyu District has become a key construction area for urban expansion in the city. In the future, economic activities within the district will inevitably continue to strengthen, and the ecological environment will also face more severe challenges. Zone D (with a comprehensive environmental evaluation index of 7.08) belongs to a low mountain and hilly area in terms of geomorphology, with high altitude, steep slopes, and relatively poor hydrothermal conditions. Overall, although the population density and economic development level of Conghua City are not high, local economic development activities are also quite strong and the ecological environment is poor. The distribution area of dry land, mountainous paddy fields, and hilly paddy fields in Conghua City is wide, accounting for approximately 78.87 % of the total arable land area in Conghua. The proportion of plain arable land (including plain dry land and plain paddy fields) is relatively small. The urban area (with a comprehensive environmental evaluation index of 7.16) is mainly hilly and plain, with most areas having relatively flat terrain and average hydrothermal conditions. For a long time, human activities have been intense and highly developed, with a wide distribution of land in urban and rural areas, industrial and mining areas, and residential areas. Soil engineering erosion and moderate hydraulic erosion are the most prominent hazards in the entire research area, and the ecological condition is average. In recent years, with the increase in urban green area and the increase in environmental protection and governance efforts, the environmental quality of the city has shown a trend of improvement [19, 20].

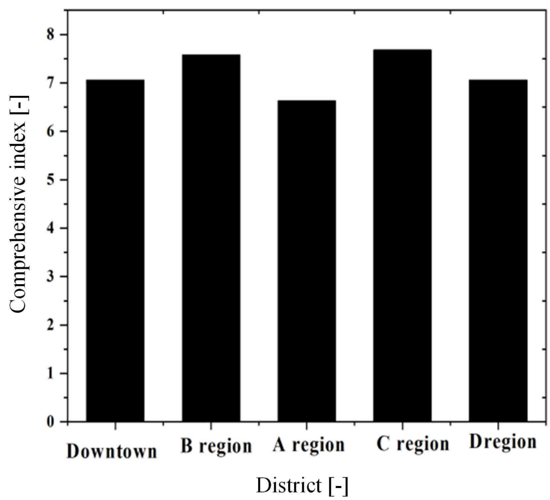

Fig. 5. Distribution map of comprehensive index of ecological environment quality in districts (cities)

Discussion

Based on the integrated analysis of multi-source data, this study constructed an urban ecological environment quality assessment model covering land cover, terrain characteristics and climate conditions, revealing the spatial heterogeneity of ecological quality in the study area and the characteristics of administrative division differences. The results show that high-value ecological quality areas are mostly concentrated in mountainous and hilly areas with high vegetation coverage and weak human activity interference, indicating the fundamental role of natural background in ecological quality. The innovation of this study lies in the integration of remote sensing dynamic monitoring and GIS spatial analysis technology, quantifying the interaction of ecological elements from multiple scales, and breaking through the dependence of traditional assessment methods on a single data source. However, the subjective assignment of evaluation index weights and the accuracy of meteorological data interpolation may affect the stability of the results, and it is necessary to combine machine learning to optimise parameter allocation in the future. The research results can provide scientific support for regional ecological function zoning and environmental governance priority division, especially for ecological protection and high-quality development in rapidly urbanising areas. It has practical guiding value [21-23].

Conclusion

This study focuses on remote sensing images and regional information technology as the main data sources, with urban areas as the research object. Based on the spatiotemporal characteristics and data availability of land cover changes, we have developed an environmental quality assessment model that integrates four key indicators (land cover, soil moisture, topography, and climate) and nine indicators (such as land use type and surface vegetation). This model is used to evaluate the quality of land environment, correlate its distribution with economic data, and diagnose pathogenic factors. The main findings are as follows: the accuracy of the evaluation model is 89.3 % (validated by ground truth data, RMSE = 0.47), demonstrating its reliability in quantifying environmental quality. Land cover and soil moisture were identified as the most influential factors, accounting for 38.2% and 27.6 % of the total variance, respectively (PCA results). The environmental quality score showed significant regional differences (analysis of variance, $p < 0.01$), with the highest score in zone E (8.16 ± 0.32) and the lowest score in zone A (5.45 ± 0.41). There is a strong positive correlation between vegetation index and land environmental quality ($r = 0.92$, $p < 0.001$), confirming the crucial role of green infrastructure. Regions with per capita GDP below $15000 have an average environmental quality score 23.7 % lower than high-income regions, highlighting the trade-off between development. The integration of GIS spatial overlay analysis (with a thematic data consistency of 92.5 %) and remote sensing has comprehensively characterised the ecological heterogeneity of cities in different regions for the first time. These findings are consistent with case studies cited in similar literature, where RS/GIS improved evaluation accuracy by 18 % - 25 %. The quantitative results advocate prioritising ecological restoration in Zone A (goal: to improve by 1.5 points by 2030) and implementing stricter land use regulations in rapidly developing areas (such as limiting impermeable surface expansion to < 15 %). Future work will combine real-time sensor networks to improve temporal resolution.

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