

Remote Sensing Data Analysis for Urban Planning and Land Use Change

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Abstract. With the acceleration of urbanization, rational use of land resources and effective town planning and layout have become particularly important. Through its advantages of high temporal and spatial resolution, remote sensing technology provides strong data support for dynamic monitoring, precise planning and management of land use. This study thoroughly analyzed urban planning and land use changes over the past decades using remote sensing technology, revealing the advantages of remote sensing application in land resource management. The study shows that remote sensing technology can provide continuous and multi-period land use images, effectively monitor land use changes, and provide scientific basis for land use planning and dynamic adjustment. In addition, remote sensing data's high resolution and automated processing capability significantly improves the accuracy of land use type classification, providing strong support for urban planning and land management decision-making. Integrating remote sensing data with GIS, deep learning and other technologies, this paper hopes further to promote the intelligence and refinement of land use planning, and make significant contributions to achieving the goal of sustainable development.

Keywords: Remote sensing data; urban planning; land use change; urban heat island effect; data interpretation methods.

1. Introduction

Accelerated urbanization is an important phenomenon facing the world today, which has significantly impacted the original ecological environment while promoting economic growth and population concentration. Urbanization has not only changed the physical structure of cities, but also triggered a series of ecological and environmental problems, such as environmental degradation, resource crises and the so-called "urban diseases" [1]. These problems seriously affect the daily life of residents and the sustainable development of cities [2, 3]. Rational utilization of land resources and effective town planning is the most important basic tasks in urban construction, and the development of remote sensing technology provides a new solution to this demand.

As an important tool for urban planning and land use analysis, remote sensing technology has made remarkable progress at the technical level in recent years. The spatial resolution has been improved from tens of metres in the early days to several metres, sub-metre level, and even centimetre level at present, which greatly enhances the ability of remote sensing data to capture the details of the ground surface [4]. Improvements in data processing techniques such as image fusion, texture analysis, and multi-source data fusion have made the information extracted from remote sensing data richer and more precise. The introduction of artificial intelligence and machine learning techniques has significantly improved remote sensing data processing intelligence in terms of automated feature extraction, image classification and change detection. The development of cloud computing and big data technologies has also made the storage, processing and analysis of remote sensing data more efficient, providing the possibility of processing and analyzing large-scale remote sensing data sets. The current remote sensing technology is able to provide continuous, multi-period land use images, effectively monitor land use changes, and provide a scientific basis for land use planning and dynamic

adjustment. Its high-resolution and automated processing capability significantly improves the accuracy of land use type classification, providing strong support for urban planning and land management decision-making. In addition, remote sensing technology also plays a key role in environmental monitoring, capable of monitoring environmental elements such as air quality, water resources and green vegetation, and visually displaying the spatial distribution of cities through DEM models. In traffic problem solving, remote sensing technology combined with modern information technology can effectively control traffic flow and improve the traffic environment. Analysis of urban heat island effect is also an important application of remote sensing technology, which can reveal the formation mechanism and spatial pattern of urban heat island effect. Land use type classification, change monitoring and precise boundary extraction are also important applications of remote sensing technology. Nevertheless, the existing studies are deficient in the comprehensive analysis of urban remote sensing. There are relatively few comprehensive studies on many elements of urban remote sensing. The inherent problems of the timeliness of data acquisition, image processing accuracy on the analysis of the difference patches still exist, and further studies are needed to solve these problems [1].

This paper focuses on analyzing urban planning and land use changes over the past decades based on remote sensing data. This paper aims to improve planning accuracy, monitor and evaluate urban expansion, and optimize land resource management. Remote sensing technology plays a key role in urban planning and land use analysis. This paper first reviews the development background and application techniques of remote sensing technology. Then, it points out the shortcomings of existing studies and specifies the objectives of this study. This study aims to explore in depth the complex issues in the urbanization process and seek more comprehensive theories and methodologies to guide the research. Finally, a comprehensive analysis of issues in the field of urban remote sensing is presented. Then, the application methods of remote sensing data in urban planning are discussed in detail, including surface cover classification, land use and change monitoring, and urban thermal environment analysis. Finally, the results of the application of remote sensing data in urban planning and land use are summarized, and the future development trend is looked forward to.

2. Remote Sensing Data and Platforms

Satellite data, with their macro-coverage and high temporal resolution, are suitable for large-scale and continuous surface monitoring and for long-term environmental monitoring and analyses of land-use change trends.

In terms of data types, multispectral data, which contain multiple bands, are commonly used for vegetation analysis and land-use classification, while hyperspectral data provide continuous spectral information, which is useful for identifying and classifying surface materials, such as minerals and vegetation types, more precisely. Radar data have the ability to penetrate clouds. They are suitable for terrain mapping and surface deformation monitoring. In contrast, infrared data are able to measure surface temperature, which is useful for analyzing the urban heat island effect and assessing vegetation and soil moisture status [5]. Commonly used monitoring bands include visible and near-infrared (NIR) bands, which are sensitive to vegetation cover and growth conditions; short-wave infrared (SWIR) bands, which help to identify rocks and minerals; thermal infrared (TIR) bands, which are used for surface temperature measurements; and radar bands, such as C- and L-bands, which are suitable for terrain mapping and flood monitoring in cloudy weather. Combining these features, remote sensing technology provides strong data support for urban planning, land use management, environmental monitoring, etc., and helps researchers and decision makers to more accurately grasp surface characteristics and change trends.

Remote sensing technology provides diversified means of monitoring and analyzing through different platforms, of which the three most widely used are satellites, aircraft and drones. With their macro-coverage capability and high temporal resolution advantages, satellite platforms are ideal for long-term environmental monitoring and analysis of land-use change trends. For example, the Landsat

satellite series has been widely used for land-use classification, urban expansion monitoring and vegetation cover change analysis through more than 40 years of continuous data collection. On the other hand, MODIS satellites utilise their daily global coverage capability to provide key data for vegetation indices, land surface temperature and fire monitoring, among others. The aircraft platforms' flexibility and rapid response characteristics make them ideal tools for region-specific or contingency monitoring. With its high-precision 3D data acquisition capability, the airborne LiDAR system is used for terrain mapping, urban 3D modelling and flood simulation applications.

Meanwhile, airborne hyperspectral imagers provide important support for vegetation classification, soil property analysis and mineral exploration by capturing continuous spectral information. Unmanned Aerial Vehicle (UAV) platforms are particularly suitable for small-area or target-specific monitoring due to their ease of operation, low cost and rapid deployment. UAV-mounted cameras or multispectral sensors are important in land use surveys, farmland management and infrastructure planning. In addition, UAV-mounted thermal infrared cameras are able to acquire surface temperature distributions, providing new perspectives for analyzing the urban heat island effect. Drone and aerial photography data combine the advantages of flexibility and high resolution to enable the rapid acquisition of detailed surface imagery for specific areas or events. Drones are particularly suitable for small-area or target-specific monitoring because of their ease of operation and low cost, while aerial photography provides fast-response and high-resolution surface imagery suitable for detailed surface characterization.

3. Remote Sensing Data Interpretation Methods in Urban Planning

With the acceleration of urbanization, urban planning is faced with many challenges, such as environmental pollution, reduction of green space, and urban heat island effect. Remote sensing data interpretation methods can help solve various challenges in urban development by providing accurate and real-time large-scale data. With the continuous development of remote sensing technology, its application methods in urban planning are changing and improving. The high-resolution remote sensing image can provide abundant spatial information, and the remote sensing technology can monitor the urban dynamic change in real time, including urban expansion, traffic congestion, environmental quality and so on. Manual intervention and error can be reduced by automatic data processing and information extraction. Multi-source data fusion technology provides multi-level and multi-angle integrated data support, provide scientific and accurate decision-making basis for urban planning [1, 6].

In the early days, remote sensing data was mainly extracted through visual and human-computer interactive interpretation [7]. Visual interpretation refers to the observation of different colors, brightness, tones and other image features and spatial features such as shape, size, shadow, texture, pattern, and position on remote sensing images through the naked eye, magnifying glass or stereoscope observation, combined with a variety of non-remote sensing information, comprehensive use of geological laws, combined with the interpreter's experience and domain knowledge. The method of classifying and interpreting the ground objects in the images can identify various types of land cover in the city, such as buildings, water bodies, green Spaces, etc. In the 1970s, the landsat satellite was launched successfully, and the development of computer software and hardware technology prompted people to start using computers to interpret remote sensing digital images. At first, geometric correction, relative registration, and image enhancement are carried out using image processing software. On this basis, relevant geoinformation is obtained from remote sensing images by human-computer interactive interpretation. Human-computer interactive interpretation, also known as "human-computer interactive interpretation". It takes remote sensing digital image as the basic information source, and it is a method to extract and edit remote sensing data and interpret remote sensing images by using the fast-processing power of computer and professional image software under the corresponding software and hardware conditions. This kind of method is greatly affected by human factors and requires the interpreter to have rich geological knowledge and experience and have a deep understanding of the interpretation region. The work efficiency is low

and subjective, difficult to quantify and systematize, and cannot be integrated with GIS in real time. Human-computer interaction involves many data and privacy security issues [8].

With the development of computer technology, remote sensing images began to be interpreted by automatic classification methods, and image processing and analysis gradually realized automation and intelligence [6, 9]. By setting classification algorithms and parameters, the computer can automatically identify different types of ground objects in remote sensing images and automatically classify land cover types into farmland, forest land, water area, and city, which greatly improves the efficiency and accuracy of data processing and land use classification. After that, the multi-temporal composite classification method is added: this method combines the remote sensing data of two or more phases. It extracts the change information through the remote sensing classification method. This method can monitor the dynamic change of urban land use and provide scientific basis for urban planning [1, 6, 8].

With the development of big data and cloud computing technology, the processing and analysis ability of remote sensing data has been greatly improved, and it can be integrated with other data sources, such as demographic data, meteorological data, etc., to provide diversified information support for urban planning [1, 6, 8]. It can process larger data sets, realize more complex analysis tasks, and provide more comprehensive and accurate data support for urban planning. A variety of remote sensing data processing methods and technologies can now be integrated to form comprehensive solutions. For example, combined with deep learning, GIS (geographic information system) and other technologies, intelligent and fine management of urban planning can be realized [1, 6].

4. Remote sensing applications

4.1. Remote sensing applications in urban planning

Remote sensing data are widely used in urban master planning, especially in spatial data acquisition, environmental monitoring and traffic problem solving. It can not only analyze geo-spatial information accurately and support urban spatial planning and development decision-making, but also monitor air quality, water resources, green vegetation and other environmental factors, DEM model can visualize the spatial distribution of the city. In traffic problems, remote sensing technology combined with modern information technology, improve the service level of traffic facilities, effectively control traffic flow, improve the traffic environment, improve service efficiency, become an important means to ease urban congestion.

Urban Heat Island (UHI) effect is an important issue to consider in urban planning, which refers to the phenomenon that the temperature in the city center is higher than that in the surrounding suburbs due to man-made surfaces such as buildings and roads. This effect can lead to local climate change in cities, affect residents' quality of life, increase energy consumption, and may negatively impact the environment and human health. Remote sensing technology can obtain the spatial information of urban surface temperature distribution, and reveal the formation mechanism and spatial pattern of urban heat island effect through the analysis of urban thermal environment to provide a reference basis for urban planners to regulate urban thermal environment. Using multi-source remote sensing data, this study examines the spatio-temporal evolution characteristics of the heat island effect in the Pearl River Delta urban agglomeration. Researchers primarily used Landsat5 TM and Landsat8 OLI-TIRS for land surface temperature inversion, supplemented by Landsat7 ETM+ and MODIS data. The findings indicate that the strong heat island effect is mainly concentrated in the central areas of both old and new urban regions, with a trend of further expansion and contiguous development. New heat island centers may be formed in the areas at the junction of various cities, such as Shunde on the border of Guangzhou and Foshan, Nanhai, Zengcheng on the border of Guangzhou and Dongguan. Combined with the data of land use type, vegetation cover, and urban luminescence, it is found that the main factors affecting the evolution of the Heat Island effect in the Pearl River Delta Economic Zone are the area and distribution of the urban built-up areas, the coverage rate of urban greening and

human activities. To prevent and control the urban heat island effect of the Pearl River Delta Economic Zone, we need to improve the green coverage, reduce the artificial heat source, adjust the urban planning layout and so on [9].

4.2. Remote Sensing Applications in Land Use

The application of remote sensing data in land use is mainly reflected in land use type division, land use change monitoring and accurate boundary extraction. The advantages of RS in land use are mainly reflected in its efficiency and reliability, comprehensiveness of data acquisition, high resolution and accuracy. The massive data generated by RS technology can evaluate land quality and water status, etc., provide scientific basis for land protection and sustainable use, and have a wide range of applications and can reduce the cost of data acquisition [10].

Using the research methods of remote sensing and GIS data statistics, Wang Baiyong and Zhang Yanhua conducted image fusion of remote sensing data and remote sensing interpretation by ENVI software to obtain land use classification results in different periods of the study area. Spatial and attribute analysis was made on the statistical results of the map data of the two periods to obtain the changes of land use area and proportion [8].

In order to study the dynamic monitoring and forecasting of land use change in Xi'an and its surrounding areas, Wang et al used Landsat TM images in 2000 and 2011 as the core data source, with the help of the powerful functions of remote sensing and geographic information system (GIS) processing software, the geometric correction of the image is carried out to ensure the accuracy of its spatial position. They conducted visual interpretation of the two remote sensing images and successfully obtained land use classification data of Xi'an City and its surrounding areas in two different phases, in order to ensure the accuracy of the data, they also evaluated the accuracy of the classification. In order to reveal the law of land use change, the paper makes an in-depth quantitative and spatial statistical analysis of the classification results by using GIS software. On this basis, the visual interpretation results are further calculated, and the land use type transfer matrix is obtained, which provides strong support for dynamic monitoring of land use change [10].

The data used by Wang Yan of Jilin University in the field boundary extraction algorithm of remote sensing image is derived from GF-2 remote sensing satellite, which is the first civil optical remote sensing satellite with sub-meter spatial resolution developed by China. The ground object's spatial structure and surface texture will be clearer with high resolution and high positioning precision remote sensing data. The farmland boundary extraction system based on remote sensing image, using high-resolution remote sensing data as data source, realizes the functions of farmland boundary segmentation, farmland boundary extraction and farmland boundary centerline extraction, etc., it has a strong practical significance [11-13].

5. Conclusion

Based on remote sensing data, this paper studies and analyzes the changes of urban planning and land use in recent decades, mainly examining the role of remote sensing data and platforms, the change and development of the interpretation methods of remote sensing data in urban planning, and the remarkable achievements of the application of remote sensing data in urban planning and land use. With the support of remote sensing data, urban planners can more accurately understand the urban spatial pattern and land use status, and provide scientific basis for urban planning. At the same time, remote sensing data can also help urban planners understand environmental issues such as urban heat island effect, and provide strong support for the sustainable development of urban planning. Through the support of remote sensing data, land administration departments can more accurately understand the land use status, provide a scientific basis for land use planning, and help monitor land use change and provide data support for the dynamic adjustment of land use planning.

In order to overcome the limitations of remote sensing technology and promote the development of urban planning and land use, new technologies and methods need to be continuously developed. By

improving the performance and resolution of remote sensing sensors, the quality and detail of remote sensing images can be improved. In addition, combined with technologies such as machine learning and artificial intelligence, automated ground object extraction and classification can be achieved, improving the accuracy and efficiency of interpretation. Secondly, integrating remote sensing technology and other data sources should be strengthened. Combined with GIS, GNSS and other technologies, multi-source data can be integrated and analyzed, and more comprehensive and accurate urban spatial information can be obtained. There is also a need to focus on socio-economic factors and sustainable development considerations in urban planning and land use. Urban planning and land use research based on remote sensing technology should pay attention to the social impact and environmental benefits of urban development to promote cities' sustainable development.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

- [1] Zhang, F., Shao, Y., Huang, H., & Jupal Bahtibai. Status and development trend of urban remote sensing research in recent 20 years. *Acta Ecologica Sinica*, 2021, 41 (8), 3255 - 3276.
- [2] Bi, B. D., Chai, Q., Li, L., et al. *Land Economics* (6th Ed.). Beijing: China Renmin University Press, 2022.
- [3] Yao, S., Chen, W., Chen, Z., et al. Some problems of China's new-type urbanization under the new normal. *Regional Research and Development*, 2016, 35 (1), 4.
- [4] Feng, Y. Discussion on land use change detection under remote sensing images. *Housing and Real Estate*, 2018, 25, 173.
- [5] Zhu, L. D. Development and status quo of remote sensing of urban environment. *Environmental Science Dynamic*, 1983, 14, 8 - 10.
- [6] Zhang, X. Research on urban planning and survey based on remote sensing technology. *Urban Construction Theory Research (Electronic Version)*, 2024, 13, 174 - 176.
- [7] Deng, W. S. *The Information Mechanism of the Evolution of Urban Group Spatial Structure* [Doctoral dissertation, Wuhan University]. 2005.
- [8] Wang, B. Y., & Zhang, Y. H. Land use change monitoring based on remote sensing images. *Natural Resources of North China* 2020,, 02, 64 - 67.
- [9] Huang, T. L., Luo, J., Ke, J. C., & Wang, X. Spatio-temporal evolution of heat island effect in Pearl River Delta urban agglomeration based on multi-source remote sensing data. *Beijing Surveying and Mapping*, 2019, 10, 1165 - 1177.
- [10] Wang, L. M. *Study on the Dynamic Changes of Land Use in the Main Urban Area of Xi'an City Based on RS and GIS*, 2013.
- [11] Wang, Y. *Research on the Deep Learning and Morphological Extraction Algorithm of Farmland Boundary Based on Remote Sensing Image*, Master's thesis, Jilin University, 2023.
- [12] Han, P. P. Application analysis of remote sensing information technology in urban planning. *Urban Construction Theory Research (Electronic Version)*, 2018, 17, 77.
- [13] Hui. Study on the regionalization of landslide disaster based on remote sensing technology. Doctoral dissertation, Chang'an University, 2013.