Monitoring Land Use/Land Cover Change (LULCC) Using Remote Sensing

Yi Chen[1, *]

[1]School of Remote Sensing and Information Engineering, Wuhan University, Wuhan, 430000, China

Abstract. Land use/land cover change (LULCC) is crucial for social and economic systems. For detecting LULCC, remote sensing technology has become crucial. This paper illustrated the use of remote sensing to monitor LULCC, with particular emphasis on urban planning and the ecological environment which is currently in the news, and the limitations of remote sensing. Remote sensing performs well in urban land cover change, urban growth analysis and urban heat island monitoring, giving these areas a effective way to solve problems. In ecological environment monitoring, it develops some new methods combined with computer science in vegetation monitoring. Meanwhile, more and more researchers focus on the wetland monitoring and ecosystem service evaluation. Remote sensing is anticipated to support the monitoring and study of LULCC in the future. This paper provides an overview of current study and developments in the application of remote sensing to track LULCC.

1 Introduction

For social and economic processes, LULCC is essential. According to research, it is closely linked to a decline in biodiversity, pollution of the soil and water from the abuse of pesticides and fertilizers, soil sealing and compaction, and other factors [1]. It provides critical information for environmental management, including monitoring changes in habitats, vegetation cover, and water resources. Understanding LULCC is helpful to identify potential environmental risks and develop strategies to mitigate them. Additionally, monitoring LULCC is vital for assessing the influences of human activities on the environment and for making policies and regulations to manage and mitigate those impacts. Moreover, it can provide valuable data for research purposes, such as understanding trends in urbanization or agriculture expansion, which can inform a range of disciplines from ecology to economics. Overall, monitoring LULCC plays an important role in ensuring healthy land use and environmental management.

Remote sensing technology makes contributions to tracking LULCC. The ability to obtain high-quality images of the Earth's surface at various times has been made feasible by advances in remote sensing technology, making it simpler to monitor LULCC. For instance, a major advantage of using remote sensing to watch LULCC is that it offers high-quality images of the Earth's surface that make it simpler to spot and monitor land cover changes. This technology is not only time-saving, but it is also cost-effective. Remote sensing technology can provide high-resolution images of the Earth's topography, which can be interpreted to detect changes in land coverage patterns, including deforestation, urbanization and other land use changes. Another benefit of monitoring land use\land cover change by remote sensing is that it provides valuable information to decision-makers.

* Corresponding author: 2020302131050@whu.edu.cn

Governments and other organizations can use this information to create better land use plans and policies, manage natural resources effectively, and address environmental concerns. Remote sensing data can provide detailed information about LULCC, which can be used to identify areas that are at risk and need immediate attention.

This paper briefly introduces application of detecting LULCC by remote sensing, focusing on its application in urban planning and ecological environment monitoring, and points out the limitations for monitoring LULCC by remote sensing.

2 Application of monitoring LULCC by remote sensing

Remote sensing is a technology that involves analyzing and processing remote sensing data to obtain information about the Earth's surface. In land cover change monitoring, remote sensing technology can provide high-quality remote sensing images and data for detecting and tracking land cover changes. It is primarily used for categorization of land use and cover, monitoring and analyzing their changes, and evaluating land resources. In order to categorize remote sensing images into various surface cover categories, such as forests, grasslands, farmlands, urban areas, water bodies, etc., land use/land cover classification employs image classification algorithms. Changes in different surface cover types can be monitored through remote sensing images taken at different times. Remote sensing technology can detect information about the location, type, and timing of surface cover changes. For example, it can detect changes such as forest development, grassland degradation, farmland expansion, and urban expansion. Remote sensing images can provide a large amount of time-series data for analyzing trends and patterns in land use changes. For example, it can analyze the speed and direction of urban expansion, the reasons and degree of forest degradation, and so on. Remote sensing technology can provide high-resolution surface images and data for evaluating the quality and quantity of land resources. For example, it can evaluate crop yields and water use efficiency in farmlands, the ecological environment and biodiversity in forests, and so on. In addition, a variety of disciplines, including urban planning and environmental monitoring, have extensively used remote sensing technology. This research primarily uses ecological environment monitoring and urban planning to illustrate the use of remote sensing technology.

2.1 Urban planning

Urbanization is a global phenomenon, and it has brought significant challenges to urban planners and policymakers. Monitoring land cover change is a critical task in urban planning, which can provide valuable information for decision-making. Remote sensing technology has the advantages of wide coverage, high resolution, and multi-temporal observations. It can provide valuable information on land cover changes, urban growth, and urban heat island effects. We review the application of remote sensing technology in monitoring land cover change in urban planning.

2.1.1 Urban land cover change detection

Accurate and comprehensive data on urban land cover types and their spatial distribution are important for a variety of physical and social science research and local government planning. Since the inception of the Landsat program in 1972, the visible-to-short-wave infrared (VSWIR) bands of Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data have been widely applied to the analysis of land cover in forestry and agriculture [2]. Different land cover types such as vegetation, buildings, water and bare ground can be effectively distinguished using remotely sensed land cover classification. Pixel-based and object-based techniques are the two main types of change detection techniques based on remotely sensed imagery. The statistical study of the pixel values in the remote sensing images serves as the foundation for pixel-based methods. The segmentation of the remote sensing images into various items forms the foundation of the object-based methods. These days, this discipline incorporates computer science to build models for better analysis and prediction. For example, a 2005 study used aerial photographs acquired in 1975 and 2000 to examine changes in land use and cover in 11 communities in Merseyside, UK. To model the impact of these changes on three key environmental parameters (rainfall run-off, surface temperature, and green space diversity), the study took into account both these changes and socio-economic status of the local areas. Through comparisons, it was discovered that each of the 11 case study sites experienced a loss of green area. Moreover, the regions that were wealthier and lower in density lost more green space, particularly in terms of tree cover. The negative environmental effects on all areas were predicted by the models used in this study, highlighting the demand for critically reviewing concepts like urban densification and preserving and managing urban greenspaces [3].

2.1.2 Urban growth analysis

Urban growth analysis helps to understand the changes in the physical and social characteristics of urban areas over time. This information is critical for land-use planning, policy-making, and decision-making related to urban development. Useful information on urban growth can be collected by remote sensing technology. The urban growth analysis based on remote sensing images can effectively monitor the urban sprawl. The remote sensing images can be processed to obtain various indicators of urban growth, such as urban area, urban density, and urban form. Spatial-temporal characteristics of urban development can also be discovered by analysing urban growth based on remote sensing imagery. The Mexico-Lerma-Cutzamala Hydrological Region's (MLCHR) land-cover changes and urban expansion between 1993 and 2018 are examined. The study analyses LULCC and urbanization utilizing remote sensing data. Results showed significant increases in urbanization and decreases in natural land cover, with the greatest changes in areas of high population growth. Fig. 1 displays the land cover groups that supported urban growth between 1993 and 2018. To reduce the negative effects of urbanization and ensure the ecosystem's long-term health, it is crucial to respond to the region's desire for sustainable land management practices [4].

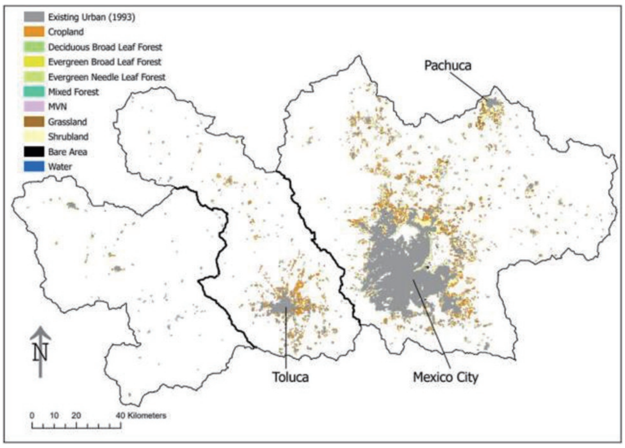

Fig. 1. MLCHR Areas that underwent urbanization between 1993 and 2018 [4]. https://ars.els-cdn.com/content/image/1-s2.0-S0143622822001564-gr4.jpg

2.1.3 Urban heat island monitoring

Urban growth can cause urban heat islands and local microclimate changes, which has negative effects on human health and comfort. Studies have shown that intense urbanization can also impact local weather and climate, highlighting the need for further research to understand the relationship between urban growth and environmental changes. Local land use/land cover conditions are usually related to these changes and should be carefully evaluated in such studies [5]. The spatial distribution of urban heat island impacts can be accurately detected by urban heat island monitoring using remote sensing images. The remote sensing images can be processed to obtain various characteristics of urban heat island effects, such as land surface temperature, emissivity as well as albedo. The urban heat island monitoring based on remote sensing images can also reveal the factors that affect the urban heat island effects, such as land cover, urban form, and atmospheric conditions.

2.2 Ecological environment monitoring

Monitoring the ecological environment is an essential task for protecting the environment and making informed decisions. It provides critical information for decision-making related to environmental protection. It allows us to identify changes in the environment, understand the causes of these changes, and predict their potential impacts. Remote sensing technology, which is often used in ecological environment monitoring, provides valuable information on land cover changes, forest cover change, wetland monitoring, and ecosystem services evaluation. The artical outlines the use of remote sensing to monitor LULCC.

2.2.1 Vegetation change detection

Vegetation change detection is important for understanding the health and productivity of ecosystems. Monitoring changes in vegetation cover and structure over time can provide valuable information on land-use changes, climate change impacts, natural disasters, and ecological disturbances. This information can be used to inform land management practices, conservation efforts, and policy decisions related to biodiversity, carbon sequestration, and ecosystem services. Research shows that deforestation of rainforests has negative impacts on agricultural productivity and can affect the climate at local, regional and global scales. Deforestation and vegetation degradation contribute significantly to anthropogenic CO_2 emissions, with tropical vegetation being the primary contributor to global warming [6]. Additionally, vegetation change detection is important for assessing the effectiveness of restoration and rehabilitation projects and for identifying areas that may require additional monitoring or intervention to prevent further degradation. Forest cover changes, such as deforestation, reforestation, and forest fragmentation, can be tracked using change recognition techniques based on remote sensing images. The forest biophysical factors, such as biomass, leaf area index, and productivity, can be tracked using the remote sensing images. It has been successfully and reliably used to predict vegetation properties using remote sensing technology. To forecast vegetation coverage information from multi-spectral remote sensing images, several techniques have been developed, including vegetation indices, multiple regression, classification decision tree, and spectral mixture analysis [7]. Analyzing remote sensing imagery for vegetation properties by using Convolutional Neural Networks (CNN) has been shown to be highly effective in recent studies. CNN is a deep learning technique that can accurately represent spatial patterns.It can be used to derive a broad range of plant characteristics from remote sensing data [8].

2.2.2 Wetland monitoring

Wetlands are areas of land where there is constant accumulation of water and high levels of humidity in the underlying surface. These areas are highly productive and are known as the “kidneys of the Earth”. The forest biophysical factors, such as biomass, leaf area index, and productivity, can be tracked using the remote sensing images.

In recent years, due to the rapid increase in population and continuous economic development, uncontrolled exploitation and utilization of water resources by humans have resulted in many wetlands facing the threat of drying up, and problems such as water scarcity and deteriorating water environment have become increasingly prominent. To achieve sustainable development, it has become crucial to determine the ecological water demand of wetlands rationally, for optimizing water resources allocation and protecting the ecological environment. Therefore, accurately and efficiently estimating the evapotranspiration and ecological water demand of wetlands provides an important scientific basis for the protection of wetland biodiversity, as well as for effective management and rational utilization of regional water resources [9].

Wetlands provide essential ecosystem services but are at risk due to pollution and development. Over recent decades, using remote sensing to assess the health and sustainability of wetlands has grown considerably. Research presents a comprehensive review and meta-analysis of over thirty years of research on the role of remote sensing and machine learning in wetland monitoring. The study reveals that remote sensing is now a crucial tool for managing and monitoring wetlands. It also highlights the potential of machine learning techniques for improving the accuracy of wetland mapping and monitoring. The paper concludes by identifying future research directions and the need for standardized data collection and processing protocols to support wetland monitoring at a larger scale [10]. This technology has allowed for more scientific monitoring of wetlands and has contributed to efforts to protect and conserve them. Remote sensing technology can also provide valuable data for wetland surveillance. Different wetland types, such as freshwater wetlands, saltwater

https://doi.org/10.1051/e3sconf/202342403002

wetlands, and mangrove wetlands, can be successfully distinguished using the land cover classification based on remote sensing images. Wetland changes, such as wetland loss, wetland degradation, and wetland restoration, can be tracked using change detection techniques based on remote sensing pictures. The wetland biophysical factors, such as water level, water quality, and plant cover, can also be observed using the remote sensing images.

2.2.3 Ecosystem services evaluation

The evaluation of ecosystem services is a crucial step in ecological environment tracking, which can provide insightful data on the advantages that people derive from ecosystems. Utilizing remote sensing technology, it is possible to gather important data for the assessment of ecosystem functions. Multiple markers of ecosystem services, including carbon sequestration, water regulation, and biodiversity preservation, can be obtained by processing the remote sensing images. In order to manage ecosystems sustainably, remote sensing images can also be used to evaluate how ecosystem services have changed over time and place. Using remote sensing data, GIS analysis, and the InVEST model, a study compares the effects of land use change on ecological services. Data on land use and land cover were gathered by researchers and divided into six categories using remote sensing imagery. They used the InVEST model to quantify the ecosystem services offered by each type of land use, including carbon sequestration, soil conservation, water retention and agricultural production. To better understand how land use change affects ecosystem services, we compared ecosystem service valuation results from 1995 and 2015. To determine the economic value of the ecosystem functions offered by various land use types, they also performed a cost-benefit analysis [11].

3 Limitations of monitoring LULCC by remote sensing

One of the limitations of monitoring LULCC by remote sensing is that it relies on external factors such as weather conditions, cloud cover, and sensor performance. These factors can affect the quality of remote sensing images, making it difficult to obtain accurate information about land cover changes. Also, the cost of acquiring remote sensing data can be high, making it challenging for organizations with limited resources to utilize this technology.

Another limitation of monitoring land cover change by remote sensing is that it requires specialized knowledge and expertise to interpret remote sensing data accurately. For example, effective identification of land cover change requires an appreciation of the different types of remote sensing data, including radar, infrared and optical imagery. Also, the analysis of remote sensing data requires specialized software, which may not be available to everyone.

4 Conclusion

Remote sensing has been widely applied to monitor LULCC which is closely related to humanity in different aspects like social and ecology systems. This article reviews how remote sensing can be applied to monitor LULCC for urban planning and environmental assessment. Its main contributions in urban planning are urban land cover change, urban growth analysis and urban heat island monitoring. In ecological environment monitoring, it is mainly applied to the vegetation change monitoring, wetland monitoring and ecosystem service evaluation. After separately introducing their research significance and how to monitor, the paper proposes three limitations for remote sensing in monitoring LULCC. One is that there exists certain external factors that affect the quality of remote sensing data besides the possible expense of the technique. Another is that interpreting remote sensing data accurately is not an easy job. However, remote sensing is a useful and vital method of monitoring LULCC. In the future, researchers should focus on how to overcome the limitation like updating the hardware to reduce the cost and improving the accuracy. The use of remote sensing for the detection of LULCC is outlined.

References

1. Van A., Sanneke, Peter H.V., Global Change Biology, Global Change Biology 19(12): **3648-667** (2013).
2. Stefanov, William L., Michael S.R., Philip R.C., Remote Sensing of Environment 77(2): **173-85** (2001).

3. Pauleit, Stephan, Roland E., Yvonne G., Landscape and Urban Planning **71.2** (2005): 295-310.
4. Manley, Ethan, Yelena O.H., Morgan R., Ravi H., Marisa M.H., Timothy J.D., Applied Geography (Sevenoaks) 147: **102785** (2022).
5. Silva, Janilci Serra, Richarde Marques Da Silva, and Celso Augusto Guimarães Santos., Building and Environment 136: **279-92** (2018).
6. Rêgo, Joherbeth C.L., Abílio S.G., Fabrício S.D.S., Land Use Policy **71: 593-601** (2018).
7. Liu, L., Xia J., Wang J., Zhao C., Environmental Monitoring and Assessment 153(14): **339-49** (2009).
8. Kattenborn, T., Jens L., Felix S., Stefan H.,ISPRS Journal of Photogrammetry and Remote Sensing 173: **24-49** (2021).
9. Gong, Z., Li L., Jin D., Qiu H., Zhang Q., Guan H., Shengtai Xuebao, Shengtai Xuebao = Acta Ecologica Sinica, 9: **3572**(2021).
10. Jafarzadeh, Hamid, Masoud M., Eric W.G., Brian B., Fariba M. Remote Sensing (Basel, Switzerland), 14(23): **6104** (2022).
11. Liu, Y., Li J., Zhang H., Ecological Modelling 225(24): **127-32** (2012).