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# Exploring the Current Status of the Development of Desert Change Monitoring Methods

**Yucong Hong**

Kharkiv Institute, Hangzhou Normal University, Hangzhou, China
hongyucong@stu.hznu.edu.cn

**Abstract:**

The increasingly serious desertification phenomenon poses a severe challenge to the ecological environment, and it is urgent to strengthen the monitoring of its dynamic changes. This paper aims to summarize the current status of several desert change monitoring methods and compare and analyze the advantages and disadvantages of several monitoring methods. This paper concludes that traditional digital mapping has high accuracy, but there are still limitations in terms of safety, scale, and other related issues. The coherence analysis technology like SAR is susceptible to subtle changes in the desert and is often used as an important means for qualitative analysis of desert changes, but there are technical bottlenecks in terms of quantitative parameters. In addition, due to the limitations in monitoring range and accuracy, traditional methods are currently mainly used as basic and auxiliary means. The current remote sensing monitoring methods have made progress in accuracy and scope, but still need to be combined with multiple monitoring methods to complete a complete qualitative and quantitative analysis.

**Keywords:** Desert; change; monitoring; desertification

## 1. Introduction

Deserts have characteristics such as dry and little rain, strong solar radiation, intense wind action, and sparse vegetation, and are fragile ecosystems[1]. Desertification refers to the process of land degradation in arid, semi-arid, and sub-humid arid areas, under the combined effects of natural factors and human activities, eventually evolving into a desert-like landscape. Desertification will lead to various changes in vegetation, soil, and even climate in the area, severely disrupting the ecological balance, threatening agricultural production, and at the same time leading to a reduction in biodiversity, water scarcity, and a series of problems such as the induction of natural disasters. Desertification accelerates the degradation of the ecosystem, posing a severe challenge to the survival of humans and other organisms. And for a long time, desertification has been a major ecological environmental problem in China. In recent years, global warming has worsened the ecological environment, coupled with the strengthening of natural wind erosion and the combined effects of human over-ex-

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ploitation, overgrazing, and other factors, which have made land desertification increasingly severe. Although countries around the world are fighting against desertification, desertification is still dynamically expanding at an extremely rapid rate. Therefore, in this process, the monitoring of desert changes has become one of the urgent problems to be solved.

Desert change monitoring methods can provide a reference for identifying effective desertification control measures. The development prospects of remote sensing science and technology are becoming wider[2], which plays a vital role in the field of desertification prevention and control. Through remote sensing technology, large-scale, high-resolution desertification information can be obtained, providing effective data support and technical means for desertification monitoring, assessment, and early warning[3]. For example, Zhu et al. monitored the surface coverage changes of the Kumtag Desert and its surrounding areas, providing a reference for the monitoring and management of the Kumtag Desert [4]. Zhou Jianxiu et al. monitored the ecological environment status and dynamic changes of the Ulan Buh Desert comprehensive management area on the west bank of the Yellow River through remote sensing methods [5]. Rajendran Sankaran and others monitored some areas of the Arabian Desert through desertification remote sensing, hoping to serve the sustainable development of arid environments [6]. In addition, remote sensing technology can also be combined with related technologies like geographic information systems to achieve dynamic monitoring and analysis of the desertification process, providing a scientific basis for desertification prevention and control[7].

This paper first briefly explains the principles of several desert change monitoring methods. Then, it systematically summarizes the research progress related to desert change monitoring at home and abroad. Furthermore, it explores the advantages and disadvantages of current research in this field. Finally, it looks forward to the development of future monitoring technologies with current technology. This paper aims to provide useful references for desert change monitoring in China.

## 2. Overview of Commonly Used Methods for Desert Change Monitoring

The main methods for desert change monitoring can be divided into three categories: the first is traditional methods, such as manual sample data collection and digital mapping; the second is methods based on remote sensing images, including visual interpretation of optical images, optical image matching technology, vegetation cover monitoring, RGB spectral detection, and time-series monitoring using digital surface elevation models (DEM); the third relies on radar technology, such as the coherence analysis technology of Synthetic Aperture Radar (SAR).

### 2.1 Traditional Methods

Traditional desert change monitoring is heavily based on field investigations, which were carried out earlier. Field observations are often conducted in areas that are accessible, safe, and not too large-scale deserts or desertified areas, and the number of observations is limited. Traditional digital mapping can obtain high-precision dune migration rates, but it cannot continuously obtain large-scale dune migration results. For uninhabited areas and desert areas with frequent sandstorms, the basic safety of the surveyors is hard to guarantee[8]. Therefore, relying on only a few field investigation data, it is difficult to reflect the spatial characteristics of desert changes on a global or regional scale, and the obtained desert change trends and their response to climate change are also inevitably limited. Now, traditional manual sample data collection and traditional digital mapping have also gradually been transformed into auxiliary means, while modern technologies represented by remote sensing, drones, the Internet of Things, and big data analysis have become mainstream.

### 2.2 Remote Sensing Image Methods

#### 2.2.1 Visual Interpretation of Optical Images

Visual interpretation is a type of remote-sensing image interpretation, also known as visual reading or visual translation. It refers to the process by which professionals obtain specific target feature information on remote sensing images through direct observation or with the aid of auxiliary interpretation instruments[9]. Visual interpretation of optical images refers to the process by which professionals analyze optical remote-sensing images through direct observation or with the aid of simple tools to identify and extract useful information.

Visual interpretation of optical images has unique advantages in desert change monitoring, such as intuitiveness, flexibility, low cost, and experience. It is especially suitable for qualitative analysis, complex scene processing, and field verification. Although its degree of automation is lower than that of machine learning algorithms, its irreplaceability in macro-trend grasping, detailed feature recognition, and human-computer interaction make it an indispensable and fundamental method in desertification dynamic monitoring. For example, Jiang Zhiwei et al. used visual interpretation of optical images as a basic method to assist in the quantitative analysis of Landsat optical image EVI (Enhanced Vegetation Index) in the dynamic change analysis of Kubuqi Desert from 2000 to 2023 based on Landsat-8[10]. Now, visual interpretation of dune migration changes through high-spatial-resolution historical optical images has become a high-precision classic measurement method in the field of desert monitoring, but the internal tasks are heavy, and the cost of high-resolution optical images is high, which is not conducive to the monitoring of wide-area deserts. Moreover, as a relatively traditional monitoring method involving personnel, visual interpretation of optical images also has certain errors. However, these errors can be reduced through auxiliary analysis with some modern methods. Like Zhang Xingyu, he explored the causes of errors in visual interpretation by superimposing GPS positioning sampling and remote sensing image visual interpretation feature classification analysis and improved the accuracy of remote sensing image visual interpretation[11], which also proves from another aspect that visual interpretation of optical images still has a certain research prospect at present, and can still be used as a basic method and auxiliary method in desert change monitoring.

#### 2.2.2 Optical Image Matching Technology

Image matching is also commonly referred to as image cross-correlation, and the core of optical image matching technology is to find the differences between homologous points in two optical images with the help of the cross-correlation function, and then determine the surface displacement. In actual operation, usually among them.

An image used as a benchmark is called the master image, and another image used to retrieve differences is called the slave image. The advantage of this technology lies in its ability to use freely available medium-resolution optical image datasets to monitor long-term surface displacement in a wide area of desert regions. For example, Li Na used the matching technology of optical images in her paper “Research on Airborne Laser Point and Optical Image Registration and Accuracy in Desert Areas” to provide a reference for the application of optical image registration in desert areas in the future[12]. However, the accuracy of its monitoring results is largely limited by the image quality and the scientific nature of the data processing flow.

#### 2.2.3 Vegetation Cover Monitoring

Vegetation coverage is an important indicator of whether land is desertified. For example, a decrease in vegetation coverage (such as from 30% to 10%) indicates an increase in surface exposure and an increase in the risk of wind erosion and salinization (bare ground is easily transported by wind, forming mobile dunes). The United Nations Convention to Combat Desertification (UNCCD) defines vegetation coverage <15% as one of the typical characteristics of “severe desertification”. The Normalized Difference Vegetation Index (NDVI) is a staple and indispensable tool in desertification monitoring, which converts complex ecological processes into quantifiable values through the spectral response of vegetation.

By monitoring NDVI, changes in vegetation coverage can be indirectly observed, and then desertification can be judged according to international standards, to monitor the changes in the desert. For example, in 2023, Wang Zhijun and others used Arc GIS and ENVI software to analyze NDVI and other values in the Ulan Buh Desert from 1991 to 2021, to calculate the change of FVC (vegetation coverage), and to obtain the changing trend of the Ulan Buh Desert[13]. Wang Tingting and others, when analyzing the area changes of the Kumtag Desert, used the calculation of NDVI and FVC to judge the changes in the desert area[14]. Although the changes in NDVI calculated from remote sensing data can reflect changes in vegetation coverage on the surface of sand dunes, the vegetation changes in different seasons are huge, making it difficult to effectively quantify the migration rate and direction of sand dunes[15].

### 2.3 Techniques for SAR

Coherence refers to the phase correlation between two views of SAR images at the same location, reflecting the stability of the surface scattering characteristics. High coherence indicates that the surface scatterers, such as fixed rocks and stable dunes change little; low coherence indicates that the scatterer’s location or characteristics change, such as dune movement, vegetation cover changes, surface erosion or accumulation, etc. The coherence analysis technique of SAR is to calculate the coherence coefficient by interfering with multi-temporal phase SAR data, such as Sentinel-1, ALOS-2, and other satellites, and combining it with the phase information to extract surface change features.

SAR is a wise choice for studying desert changes because its imaging structure is sensitive to small changes in dune surfaces and desert features. As for the monitoring and identification of dune migration, scholars have developed a series of methods and techniques based on SAR images[16]. For example, in 2018, Havivi and other scholars took the Ashdod-Nitzanim coastal dune belt in the coastal plain of southern Israel as a research object and realized the discrimination and assessment of the stability of individual dunes through the de-correlation analysis technique of TerraSAR satellite data[17]. 2021, Manzoni and other scholars, based on the multi-temporal coherence of Sentinel-1 satellite data, the mean short-term coherence (MSTC) and temporal stability index (TSI) were proposed

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to characterize the short-term dynamic features and long-term stability state of sand dunes, respectively. Through empirical studies in the desert regions of the United Arab Emirates and Egypt, the team verified the value of the SAR coherence analysis technique in sand control[18]. However, the method still has technical limitations - its monitoring results can only achieve a qualitative description of dune migration changes, which makes it difficult to meet the practical needs of quantitative analysis.

In terms of technical nature, the existing SAR coherence time series monitoring method can only realize qualitative analysis in dune migration monitoring, and there is a significant technical bottleneck in accurately obtaining key quantitative parameters such as dune displacement rate and deformation amplitude. This technical limitation needs to be broken through the fusion of remote sensing data from multiple sources (e.g., combining optical images and LiDAR point clouds) or the development of improved interferometry algorithms (e.g., introducing machine learning to optimize phase disentanglement), to enhance the quantitative monitoring accuracy of desert dynamics.

## 3. Recommendations and Prospects

Traditional methods have gradually become auxiliary with the development of time. Various methods based on remote sensing images also have their own advantages and disadvantages. Therefore, the superposition of multiple methods and the fusion of multi-source data have become the needs of the times. For example, SAR and optical remote sensing can be used to complement each other, utilizing the advantages of SAR satellites in precise dune change and displacement monitoring, combined with the ability of NDVI of optical images to analyze the change of vegetation cover, so as to accurately monitor the change of the desert. In fact, this method has already developed in other fields. Although the application of this integrated method in desert change monitoring is not popular at present, some researchers have explored a similar path in the identification of geological types in semi-arid areas, and its technical route is of some reference value for the analysis of desert dynamics. However, it is seldom used in the analysis of desert change monitoring, so there is more room for the development of this method.

Integrating the deep learning mode of artificial intelligence into monitoring is also an important development direction for desert change monitoring. The use of AI-driven monitoring greatly liberates manpower and improves monitoring accuracy. It can better realize the integrated path from monitoring at the beginning to analyzing in the middle and proposing treatment methods at the end. With the development of science and technology, the monitoring of desert change should be continuously developed and integrated with new technologies and means. In the future, the monitoring of desert change should pay more attention to the in-depth integration of remote sensing and intelligent algorithms, and gradually build a comprehensive monitoring system that integrates automatic sensing, intelligent analysis, and assisted decision-making.

## 4. Conclusion

In this paper, several methods of desert change monitoring are briefly defined, and the recent status of these monitoring methods is discussed. It demonstrates the application of various methods of desert change monitoring through relevant research on monitoring of desert change at home and abroad. The advantages and disadvantages of each method are briefly analyzed, and an outlook is given on the development of monitoring technology by current technology. It is found that although the traditional field monitoring methods have high accuracy and reliability. However, with the development of satellite remote sensing technology, the increasingly abundant high-resolution radar and optical image data are gradually becoming the core means of desert change monitoring, and its technical advantages of rapid response, dynamic tracking, and wide coverage can be fully utilized. The integration of multiple methods and the fusion of multi-source data has become a general trend. It is hoped that the summary of this paper can be a reference for future multi-method fusion.

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