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Bibliometric Analysis of the Utilization of Remote Sensing in Post-Disaster Environmental Recovery

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Abstract

Remote sensing is a strategic technology in spatial data collection that plays an important role in supporting post-disaster mitigation through the provision of fast, accurate, and wide-ranging information without direct interaction with affected areas. As the frequency and impact of natural disasters increase, a comprehensive study is needed to understand the development of research related to the use of remote sensing in environmental damage assessment and post-disaster recovery processes. This study uses bibliometric mapping methods to analyze international scientific publications that discuss the use of remote sensing in environmental damage assessment and post-disaster recovery over a period of 15 years. Data were obtained from reputable international journal databases Scopus and Google Scholar which were analyzed using VOSviewer software to identify patterns of author collaboration, major journals, and keyword co-occurrence. This analysis aims to map the knowledge structure, research trends, and dominant topics in the field. The results of the study show a significant increase in publications related to remote sensing, with a dominant focus on the use of satellite imagery for disaster impact identification, mapping environmental damage, and monitoring long-term environmental

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changes.

Keywords: Remote Sensing; Post-Disaster Recovery; Bibliometric Mapping; Research Trends.

INTRODUCTION

Remote sensing can be interpreted as measuring or collecting data or information from a certain object or area that is carried out remotely without having to make direct physical contact or be at that location. According to (Ghaffarian et al., 2021), remote sensing is the science of obtaining information about objects and features on the Earth's surface through the analysis of data obtained by sensors without making direct contact. Satellite remote sensing is one of the main supporting devices for disaster management (Kaku, 2018). The process of remote sensing images contains several procedures as well as related methods used (Ma et al., 2019). In today's modern era, remote sensing technology is also used in the medical world and the entertainment world, such as MRI, *X-ray* photos, Sonograms, and taking pictures of an object using a camera lens is also one of the sensing techniques. The development of remote sensing technology is widely found in other scientific fields, such as forestry, and the observation program also varies greatly based on the geography of the region (Fassnacht et al., 2023).

One of the basic principles of remote sensing is the utilization of electromagnetic radiation. Using electromagnetic waves, observed objects can be captured remotely for example, with satellites from space. Every object on earth reflects, absorbs or emits radiation, and in this context the radiation in question can be infrared, visible light or microwave that has specific characteristics and applications. The information that can be obtained from this radiation can be processed into various variables such as color, temperature, texture, or altitude. In addition to radiation, another principle of remote sensing is resolution, including spatial, spectral and temporal resolution. The resolution referred to here is a resolution that refers to the ability of sensors to identify the earth's surface, and the selection of the right type of resolution can be adjusted to the purpose of the research and the data needed. Basically, remote sensing technology sorts out objects by determining the difference from the electromagnetic waves that are transmitted, reflected, and received (Y. Huang et al., 2018).

With continuous advances in the manufacture of satellite remote sensing and chip process technology, the resolution of remote sensing satellite data is increasing in spatial, spectral, and time dimensions (Zhang et al., 2022). Spatial, spectral, and temporal resolution in remote sensing applications can be used to analyze a disaster such as earthquakes, *tsunamis*, floods, landslides,

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forest fires, and volcanic eruptions. Since 2000, remote sensing technology has played a crucial role in resource surveying, planning, agricultural development, national security, and other related fields (Zhang et al., 2022). Remote sensing technology can generally be applied to several activities, such as observing land cover changes, monitoring vegetation growth, forest fires, environmental pollution, and the impact of climate change on observing wildlife. The depiction classification of remote sensing images serves to mark sensing images by categorizing based on results and application in various fields (Cheng et al., 2020). Remote sensing can also be used to obtain data or information for the planning and development of an area, as well as infrastructure monitoring, and in the case of disaster management, can be applied to assess environmental damage caused by natural disasters such as earthquakes, floods, landslides, or volcanic eruptions. Indonesia is one of the countries that has many large and small islands and is located in the Pacific Rim or Ring Belt area, so it is very prone to disasters (Efendi et al., 2022). There are several areas that are prone to a disaster, for example, along the coast of Sumatra to the south of NTT has the potential for earthquake natural disasters. In addition, some areas in Indonesia have other potential disasters such as tsunamis, tidal waves, flash floods, landslides, volcanic eruptions, forest fires, and droughts. Natural disasters are always a major threat to human survival (J. Li et al., 2023) and environmental damage. In disaster-prone areas, disaster risk management and post-disaster recovery are very important, this requires an assessment of the damage that has occurred and how big the impact of the risk is (Ghaffarian et al., 2021). The development of accurate strategies to prevent impacts and minimize the occurrence of catastrophic events requires modeling and forecasting of severe conditions (Mohajane et al., 2021).

Remote sensing technology can be used for various sectors and needs, one of which is related to disasters. Natural disaster vulnerability in an area is an area that has spatial conditions that have certain characteristics both in land and water areas, which often experience landslides, tidal waves or tsunamis, volcanic eruptions, floods, and earthquakes (Kuswandi et al., 2020). With remote sensing technology, we can analyze the vulnerability level of an area by mapping areas that have a high level of vulnerability and risk to the threat of natural disasters. Floods are the most common natural disasters around the world (Kulk et al., 2023). The existence of climate change globally has resulted in the number of weather-related disasters increasing more than twice worldwide (J. Li et al., 2023) so the analysis of the impact on the level of vulnerability of an area and post-disaster environmental damage is needed. The process that can be carried out is by collecting data on physical damage to buildings and infrastructure, the distribution of affected land areas, environmental damage, ecosystems and habitats, and socio-economic losses that

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occur to the community. Impact evaluation on disasters must be a priority program for the government in order to plan an appropriate and effective post-disaster recovery strategy. For example, in the event of an earthquake, remote sensing has been applied for damage response and assessment, as well as to monitor recovery dynamics in spatially and temporally explicit dimensions (Derakhshan et al., 2020)

Disaster mitigation is also an important part of disaster management. As part of efforts to preserve nature and protect the source of human welfare, it is necessary to implement disaster mitigation strategies, such as protecting forests to prevent landslides (Mihardja et al., 2023).. Community participation is increasingly important in disaster mitigation globally (Ali & George, 2022). In general, disaster mitigation is an important step to take to reduce the impact of disasters in the future. In addition to disaster mitigation, well-structured disaster risk management is also needed. Remote sensing technology with Geostationer satellites has the ability to observe atmospheric conditions and monitor environmental phenomena, so that it can provide important information in disaster risk management (Higuchi, 2021). Disaster response involves actions that must be taken immediately after a disaster occurs, such as evacuation, rescue, search, and provision of humanitarian assistance, whether health assistance, logistics, or other needs. Providing infrastructure services to communities during and immediately after a disaster is critical (Chester et al., 2021) such as providing logistical needs, water resources, temporary housing, health facilities, energy needs, communication access, and ensuring that other supporting infrastructure facilities are available and adequate for use by the community.

Hydrological disasters are inevitable but can be anticipated with the development of science and technology supported by accurate data (Helmi et al., 2019). The damage caused by floods is very diverse and includes loss of life, urban buildings, industries, and the food sector affected by disease (De Petris et al., 2020). The use of remote sensing in the monitoring and management of environmental damage due to disasters is very important to be carried out. One example of a remote sensing application is to be able to monitor in *real-time* environmental conditions before, during and after a disaster event such as bad weather, heavy rain, strong winds, forest fires, earthquakes, floods, droughts. In addition to monitoring environmental damage, this remote sensing technology can also be used to analyze damage to infrastructure, vegetation, ecosystems and habitats due to disasters. As a technology with fast, continuous, extensive and repetitive observations, satellite remote sensing is essential for environmental protection (Zhao et al., 2017). An effective damage control strategy can be carried out with several steps, including conducting a comprehensive risk assessment, identifying disaster-prone areas and understanding

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their ecological characteristics. The primary goal of disaster response and relief services is to quickly map disaster-stricken areas to identify affected buildings or infrastructure (Munawar et al., 2022). The use of remote sensing in disaster management can increase public awareness of environmental risks. Remote sensing-based damage mapping techniques are indispensable in rapid disaster response practices (Bai et al., 2018).

The results of accurate remote sensing mapping of environmental damage can be leveraged to design effective recovery strategies. Disasters are a unique opportunity to better rebuild, reducing the negative impact of future disasters (Chester et al., 2021). Recovery is the main focus, with the aim of helping people return to normal conditions, both physically and emotionally. Post-disaster recovery is known as the process of rebuilding society to its normal condition, which is the same as the condition before the disaster occurred (Ghaffarian et al., 2021). Although the post-disaster recovery process is the result of a strategy based on risk perception and a vision of the future, it is heavily influenced by the experience and memory of the disaster (Monteil et al., 2020). The data obtained from remote sensing can be helpful in identifying disaster-affected areas to get a value of the severity and damage that occurred. A timely and accurate assessment of a disaster and economic resilience are essential for post-disaster reconstruction and recovery (F. Li et al., 2022). Another recovery action is by rehabilitating land and natural resources. For example, remote sensing-based forest damage assessments provide important information about which locations are most affected and where restoration efforts are taking place for forest and ecosystem health (Marlier et al., 2022)

Although the use of remote sensing in post-disaster environmental damage assessment has been extensively studied, much of the previous research has focused on technical and applicative aspects. Studies that examine the development of research as a whole, including publication trends, knowledge structures, and patterns of scientific collaboration in this field, are still relatively limited. In fact, understanding the dynamics and direction of research development is very important to identify dominant topics, research gaps, and opportunities for future research development. Based on the literature review, there are several significant research gaps. First, although the number of publications on the use of remote sensing in post-disaster environmental damage assessments continues to increase, there has not been much research that systematically maps the development, patterns of collaboration, and global research direction in this area. Second, previous studies generally focused on image analysis and technical results, but have not examined the structure of scientific knowledge, dominant topic clusters, and the evolution of research themes over time. Third, there is still limited research that integrates bibliometric

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analysis with a special focus on post-disaster recovery and environmental damage, especially using visualization tools such as VOSviewer, especially for long and comprehensive time spans. The bibliometric approach utilizes statistical techniques as a means of quantitative analysis to analyze, assess, and project current trends (L. Huang et al., 2020). (Iqbal et al., 2023) said that the process consists of three stages, namely determining keywords, searching for data from databases, and bibliometric analysis to identify research patterns and trends. Bibliometric analysis is a widely used quantitative method to evaluate patterns of scientific publications based on metadata such as authors, keywords, and citations. Through this analysis, the direction of research development can be identified, as well as the collaborative relationship between researchers in certain studies. In this study, bibliometric mapping was carried out using VOSviewer software which allows systematic visualization of scientific networks through keyword *co-occurrence* analysis, *co-authorship,* and *co-citation* (Martín-Del-río et al., 2021). This approach is used to analyze the collection of international journal publications for 15 years from 2010 to 2025, thus providing a comprehensive picture of the evolution of researchers, key topic clusters, and research *gaps that are* still open. By combining the conceptual study of remote sensing and bibliometric analysis, this research is expected to be able to make a scientific contribution in understanding the strategic role of remote sensing in post-disaster recovery as well as being the basis for the development of data-driven research and policies in the future

METHODOLOGY

This study uses a quantitative approach with a bibliometric analysis method. Bibliometrics is a scientific approach used for statistical analysis in determining the volume and mapping of patterns, as well as trends in academic development that develop in certain fields (Shuangyun & Hongxia, 2020; Toker & Emir, 2023). This approach was chosen to obtain a comprehensive overview of research developments, knowledge structures, and research directions related to the use of remote sensing for post-disaster environmental damage recovery. Research data is obtained from reputable international journals indexed in international scientific databases. In bibliometric research, digital databases such as Web of Science (WoS), Scopus, and Google Scholar are often the main choice in searching and retrieving data for analysis purposes (Karakose et al., 2022). The data collection process was carried out using *Harzing's Publish or Perish* by tracing publications published over a period of 15 years during the period 2010-2025. The search strategy is conducted using a combination of keywords relevant to the research topic, as well as being limited to the relevant document type, journal articles, and conference proceedings to ensure the

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quality and consistency of the data. The stages of data filtering are carried out through several steps, including:

a) Early identification of all publications that match search keywords
b) Document filtering based on topic relevance, document type, and publication time range
c) Data cleansing by substantially eliminating duplication and irrelevant publications

The data that has been obtained is then mapped using VOSviewer to display a map of scientific networks based on the relationships between bibliometric elements. The mapping results are presented in the form of network *visualization*, *density visualization*, and thematic clusters.

To provide a systematic overview of the stages of research conducted, the figure below presents the flow of the bibliometric research methodology used in this study, the following flow of the research methodology can be seen in the following Figure 1:

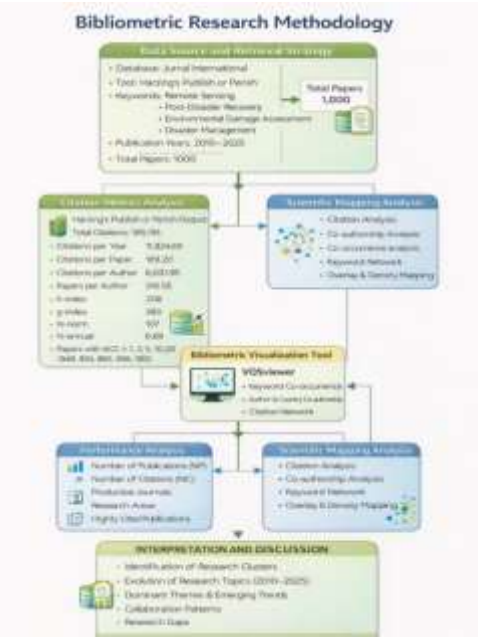


Fig. 1. Bibliometric analysis methodology flowchart
Author's Analysis, 2026

The flowchart describes the research process in stages, starting from the collection and tracing of scientific publication data, citation metric analysis, scientific mapping and bibliometric visualization, to the stage of interpretation of results. Each stage is integrated with each other to ensure a comprehensive analysis of the developments, structures, and trends of research in the field under review.

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1. Data Source

The initial stage of the research began with the collection of publication data obtained from international journals using the Harzing's Publish or Perish device. This search was carried out with the keywords Remote Sensing, Disaster, and Recovery, with a publication year range of 15 years for the period 2010-2025. From this process, 1,000 journal articles were obtained which became a database in bibliometric analysis.

2. Citation Metric analysis

Citation Metrics	Value
Publication years	2010 - 2025
Citation years	15
Papers	1.000
Citation	189.195
Cites/year	11.824,69
Cites/paper	189,20
Cites/author	60.316,95
Papers/author	318,55
Author/paper	3,96
h-index	208
g-index	383
hI,norm	107
hI,annual	6,69
hA-index	68

Table 1. Citation Metric of Publish or Perish (PoP) for Remote Sensing, Disaster, and Recovery (2010 - 2025)

In the analysis of citation metrics obtained from Harzing's Publish or Perish, the parameters analyzed include total citations, citations per year, citations per article, citations per author, number of articles per author, as well as scientific impact indicators, such as h-index, g-index, hI-norm, hI-annual. This analysis aims to assess the performance and scientific influence of publications in the field studied.

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The citation metrics in Table 1 show a quantitative picture of the productivity and scientific impact of the published works being analyzed. A total of 1,000 articles reviewed have received a total of 189,195 citations for 15 years of the 2010-2025 period, with an average of 11,824.69 citations per year. Each article obtained an average of 189.20 citations, and the average number of authors per article was 3.96, indicating a high level of scholarly influence and that research is generally conducted collaboratively. Meanwhile, the average article value per author is 318.55, and citations per author are 6,031.95, which indicates that the existence of researchers is very productive and influential. As for the indicators of scientific impact, such as the h-index of 208, the g-index of 383 indicates that there are a large number of publications with a high and consistent citation rate. The citation of these metrics confirms that the research areas analyzed have a strong level of productivity, collaboration, and scientific impact, and are growing consistently in the international scientific literature.

3. Scientific Mapping Analysis - VOSviewer

The next stage is scientific mapping using VOSviewer software to identify the structure of knowledge. This analysis includes citation analysis mapping, co-authorship analysis, and co-occurrence analysis. This visualization makes it easy to graphically identify research clusters and thematic relationships. In this scientific mapping analysis, a more in-depth analysis was also carried out to strengthen the results, especially on collaboration patterns, keyword networks, and visualizations on overlays and density mapping. This stage aims to see the dynamics and intensity of the development of research topics over time.

4. Performance Analysis

The performance analysis stage includes the number of publications (NP), the number of citations (NC), the most productive journals, the dominant research fields, and the publications with the highest citations. This stage highlights the main contributors and the most influential scholarly sources.

5. Discussion

The results of the analysis are then interpreted and discussed comprehensively. The focus includes the identification of research clusters, dominant themes, emerging research trends, patterns of scientific collaboration, and research gaps.

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RESULTS

Analysis Temporal Trends of Scientific Publications in Remote Sensing and Disaster Research

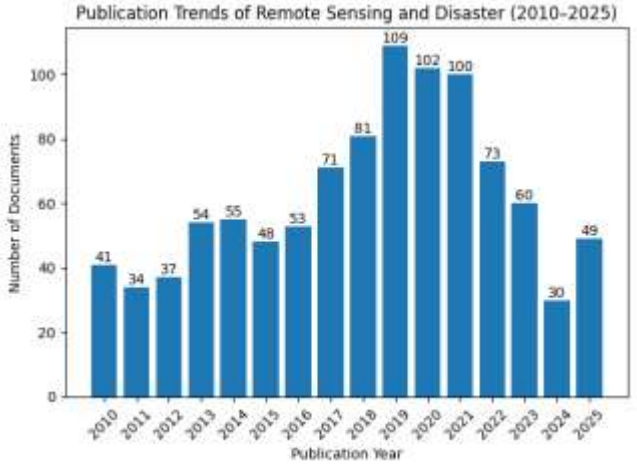


Fig. 2. Publication Trends of Remote Sensing and Disaster (2010 - 2025)
Author's Analysis, 2026

Based on the publication trend chart for the period 2010-2025, it can be seen that the number of publications related to remote sensing and disasters has experienced a dynamic development with a tendency to increase until the end of 2010, especially in 2019-2021. This increase reflects the growing academic attention to the use of remote sensing in disaster analysis and management. In 2024, the number of publications will decline significantly, likely influenced by publication pauses and data limitations in recent years. However, by 2025, there will be a resurgence, indicating that the field of research remains relevant and has the potential for further development in the future.

Analysis of Co-Authorship

No	Author	Document	Total Link Strength
1	Li, x	19	8
2	Liu, y	14	7
3	Wang, c	12	7
4	Chen, j	13	6
5	Li, z	15	5

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6	Zhang, y	18	5
7	Zhang, x	13	4
8	Li, w	12	3
9	Wang, q	9	3
10	Wang, x	12	2

Table 2. List of the Top 10 Authors with the Highest Publication Documents

Table 2 above illustrates an uneven authorship structure, where research productivity and collaboration are concentrated in a certain number of authors. Some authors are dominant with a higher number of publications and the strength of collaborative relationships, such as Li, x., and Liu, y. Meanwhile, other authors have limited contributions both in terms of the number of publications and the connectivity of collaborations, such as the author Wang, q. This pattern shows that the collaboration structure is centralized in several key actors that are the main drivers of the productivity and integration of research from the field studied.

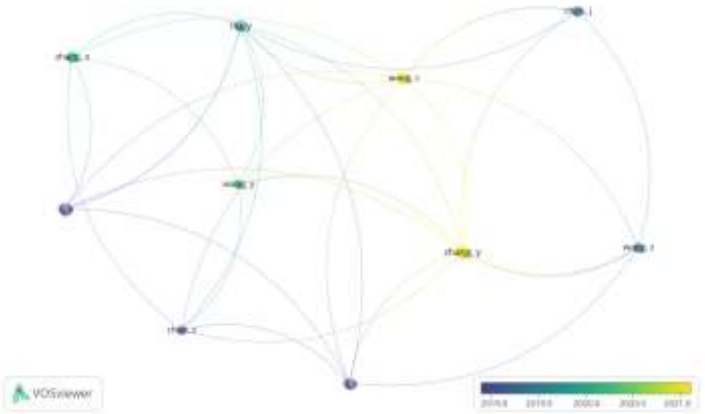


Fig. 3. Network Visualization "Overlay Visualization of Co-Authorship"

Analysis of the visualization overlay in Figure 3 above shows that the authors' collaborative network is sustainable and temporally evolved, with an average publication year of around 2019-2021. The interconnectedness between the nodes suggests that some authors acted as links across time, notably Wang, c., and Zhang, y., who associated early writers with more active writers in the later phases. This pattern confirms the continuity of collaboration and the shift in the role of research leadership over time without the disconnection of the main collaboration network.

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Analysis of Verified Selected Terms and Keyword Relevance

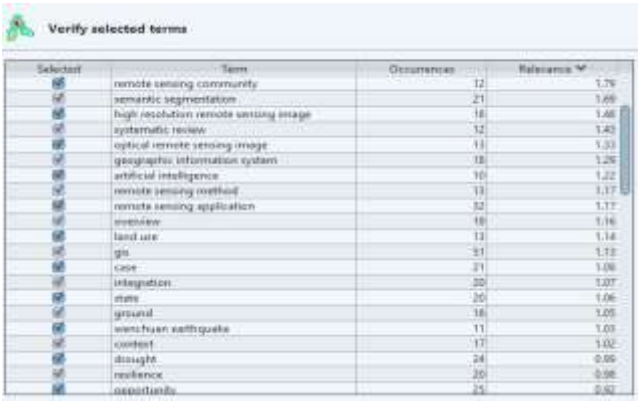


Fig. 4. Verified of Selected Terms with the of Remote Sensing dan Disaster Recovery Research

The results of verified selected terms from VOSviewer show that remote sensing research in the context of disasters is dominated by interintegrated applicative and methodological themes. The high emergence of the terms GIS, remote sensing application, and resilience indicates the focus of research on the application of remote sensing for risk analysis, disaster impact, and environmental vulnerability. Meanwhile, the presence of terms with high relevance values such as semantic segmentation, high-resolution remote sensing images, and artificial intelligence reflects a shift towards the use of high-resolution data based on artificial intelligence. These findings indicate that remote sensing and disaster research is evolving towards an increasingly integrated approach.

Clustering Analysis

Bibliometric analysis using VOSviewer resulted in keyword clustering that summarized the mapping of the thematic structure of research in the fields of Remote Sensing, Disaster, and Environmental Recovery. The *co-occurrence* relationship in scientific publications forms each cluster as a representation of an interrelated thematic group, as presented in Table 3, below:

Cluster	Items	Keyword
Cluster 1	20	Advance, article, challenge, context, future direction, opportunity, order, overview, platform, potential, progress, remote sensing application, remote

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		sensing communications, section, state, survey, systematic review, UAV, UAVs, unmanned aerial vehicle
Cluster 2	16	Artificial intelligence, case, case study, change, China, earthquake, effect, environment, Google Earth Engine, ground, integration, land use, Landsat, recovery, Wenchuan earthquake, work
Cluster 3	14	Advantage, drought, flood, geographic information, GIS, India, mitigation, optical remote sensing, remote sensor, remotely, response, SAR, Sentinel
Cluster 4	14	Building, change detection, dataset, deep learning, field, high resolution remote sensing, image, landslide, network, optical remote sensing image, remote sensing image, remote sensing imagery, semantic segmentation
Cluster 5	7	Author, big data, damage, framework, post-disaster recovery, resilience, risk

Table 3. Keyword Clustering from Bibliometric Analysis in the field of Remote Sensing, Disaster, and Environmental Recovery

Based on the keyword clustering table above, it can be seen that the structure of remote sensing and disaster research is divided into five main thematic clusters. Cluster 1 represents common conceptual and methodological themes, such as systematic review, research development, and remote sensing applications, reflecting the theoretical foundations and future direction of research. Cluster 2 focuses on the application of artificial intelligence and disaster case studies, especially earthquakes and post-disaster recovery. Cluster 3 highlights the application of remote sensing for different types of hydrometeorological disasters, such as droughts and floods, with the support of GIS and satellite data, indicating an orientation on mitigation and spatial monitoring. Cluster 4 reflects advances in high-resolution image analysis technology, which indicates a shift towards an artificial intelligence-based approach. Cluster 5 describes a focus on disaster management, with attention to the framework, risk assessment, and impact of damage. This clustering shows that research is evolving from conceptual and methodological approaches towards advanced technology-based applications that support disaster mitigation, response, and recovery

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Keyword Co-occurrence Network Analysis

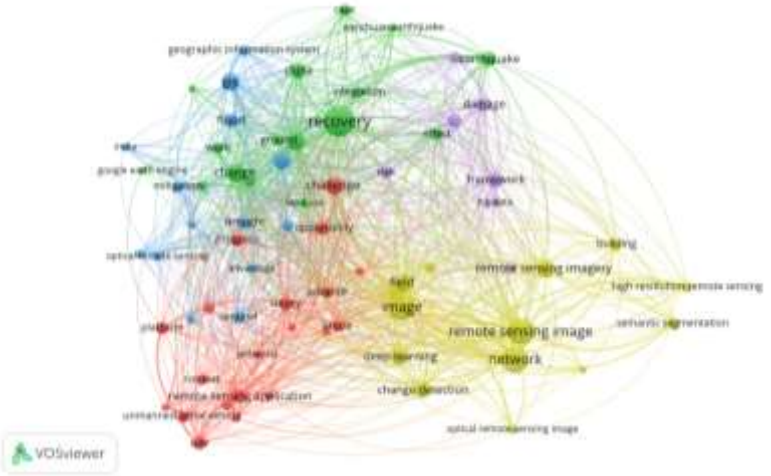


Fig. 5. Network Visualization of Remote Sensing, Disaster, and Environmental Recovery

Based on the keyword co-occurrence map generated by VOSviewer, it can be seen that the structure of remote sensing and disaster research forms a thematic network that is closely interconnected. Key keywords such as recovery, remote sensing image, image, and challenge indicate the main focus of research on the use of remote sensing imagery to support post-disaster recovery and the development of analysis methods. The clusters formed represent the integration of remote sensing with GIS and environmental change analysis, disaster risk and impact assessment, as well as the development of cutting-edge technologies. Overall, the network confirms that research is evolving towards an integrated and applicative approach to supporting disaster management. The intercluster interconnectedness pattern also indicates further research opportunities on multi-source data integration and the development of analytical methods that support sustainable disaster mitigation, response, and recovery.

Overlay Visualization Analysis of Keyword Evolution

Overlay visualization is a bibliometric mapping technique used to display the temporal dimension of keywords in a co-occurrence network. Overlay visualization helps to understand the evolution of research themes over time and uncover the direction of development and potential future research trends.

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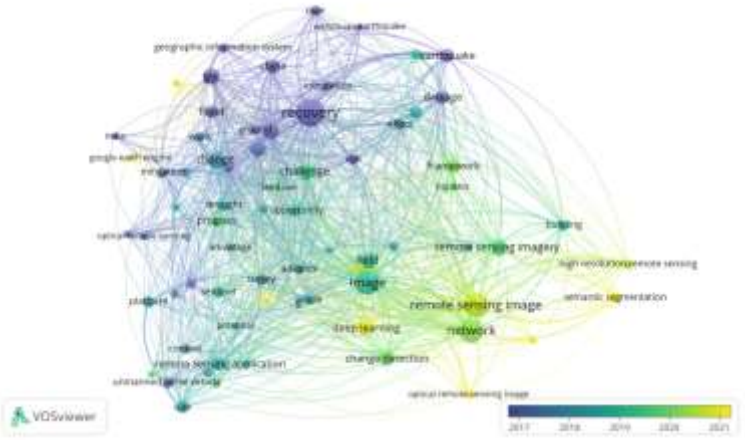


Fig. 6. Overlay Visualization of Remote Sensing, Disaster, and Environmental Recovery

In Figure 6. The above shows the network visualization Overlay Visualization output from VOSviewer, which shows the temporal shift in the focus of remote sensing and disaster research in the period of 2017-2021. Darker (blue-purple) keywords such as recovery, GIS, flood, earthquake represent earlier topics and focus on disaster impact analysis, post-disaster recovery, and integration of remote sensing with geographic information systems. Keywords with lighter colors (green-yellow), such as remote sensing image, deep learning, semantic segmentation, change detection, and high-resolution remote sensing show more up-to-date and rapidly growing themes. This visualization shows the evolution of research from a conventional applicative approach to a more automated, sophisticated, and big data-based approach without abandoning the primary focus on disaster management and recovery.

Density Visualization Analysis of Research Keywords

Density visualization from VOSviewer shows the level of density and intensity of keyword occurrence in remote sensing and disaster research. Figure 7 below, shows what topics are researched and how they relate to other keywords.

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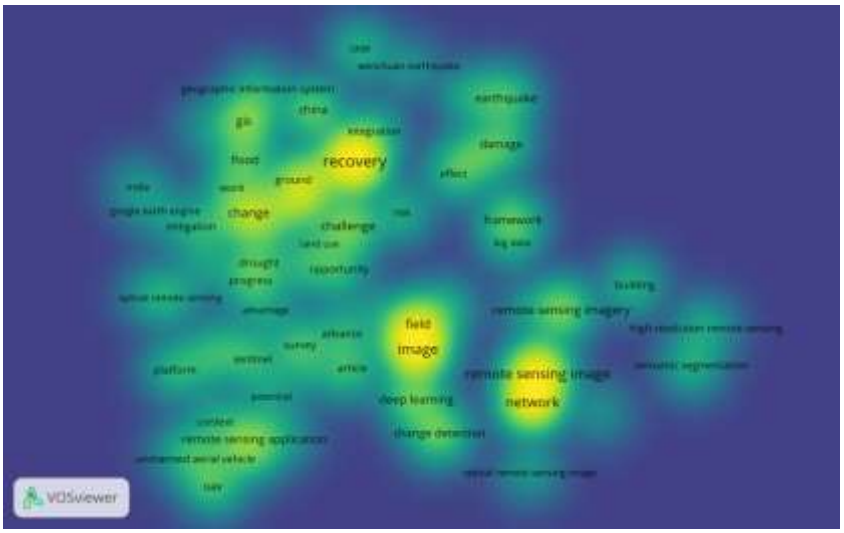


Fig. 7. Density Visualization of Remote Sensing, Disaster, and Environmental Recovery

The area with the lightest color (yellow) indicates the most frequently researched topic and has a strong association with other keywords. In the density visualization map above, keywords such as recovery, remote sensing image, image, and network emerged as the highest density centers, indicating that the main focus of the research was on the use of remote sensing imagery and network analysis to support the post-disaster recovery process. High density is also seen in the keyword groups of modern analysis methods, such as deep learning, change detection, network, and semantic segmentation, which indicates the increasing use of artificial intelligence-based approaches and high-resolution images. This density visualization confirms that remote sensing and disaster research is dominated by the theme of image processing with the tendency of methods with modern analysis, namely the integration of advanced technology and data-based methods.

CONCLUSIONS

This study presents a comprehensive bibliometric analysis of the development of international research on the use of remote sensing in post-disaster environmental recovery during the period 2010-2025. The results of the analysis show that the number of publications increased significantly until the end of the decade of the 2010, reflecting increasing academic attention to the strategic role of remote sensing in disaster management and recovery. Analysis of citation metrics indicates that this field has high levels of productivity, collaboration, and

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scientific impact, with a number of authors and publications acting as key actors in scientific development.

Mapping using VOSviewer reveals the knowledge structure and thematic evolution of the research. The co-authorship analysis revealed that the structure of research collaboration is centralized in a few key authors, who act as the main link in the scientific network. The dominant authors not only show high productivity, but also have great collaborative strength, thus contributing to the continuity and integration of research over time. The co-occurrence analysis of keywords and thematic clusters shows that research is evolving from conceptual and methodological approaches towards the application of advanced technologies. Overall, the results of this study show that remote sensing has become an important and sustainable component in supporting mitigation, response, and post-disaster recovery. The visualizations provided a comprehensive overview of global research trends and structures, and the study also highlighted the role of scientific collaboration as a key factor in strengthening knowledge development and innovation in the field of remote sensing and disaster management.

FUTURE DIRECTIONS

Based on the results of the bibliometric analysis and scientific mapping, several future research directions can strengthen the role of remote sensing in post-disaster environmental recovery. Future studies should prioritize the integration of multi-source and multi-resolution data, such as optical imagery, SAR, UAV, LiDAR, and in-situ data, to improve the accuracy of damage assessment and better capture spatial and temporal recovery dynamics. In addition, although the use of artificial intelligence and deep learning is increasing, their application remains largely focused on initial damage detection. Therefore, future research should develop models that support long-term monitoring of environmental recovery. Moreover, scientific collaboration is still dominated by a limited number of key authors, indicating the need for broader cross-national and cross-disciplinary collaboration involving researchers, practitioners, and policymakers. Finally, future studies may benefit from combining bibliometric analysis with qualitative approaches, such as systematic literature reviews, to provide deeper insights into research trends and gaps. Overall, future research should not only advance remote sensing technologies but also enhance their practical and policy relevance in supporting sustainable post-disaster environmental recovery.

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