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MORALITY BEFORE KNOWLEDGE

Study of the implementation of geoint and remote sensing in climate change

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ABSTRACT

Background: This research highlights the critical role of geospatial technologies, including remote sensing and Geospatial Intelligence (GEOINT), in addressing climate change and its impacts. These technologies extend beyond defense and security applications, proving valuable across sectors such as health, social, economic, and environmental fields. By providing real-time data, they enhance the understanding and mitigation of climate change-related issues. **Methods**: A systematic literature review was conducted by searching databases using relevant keywords. Peer-reviewed articles from the past 10 years were selected. Data were collected through a data extraction form, and the articles were categorized based on themes including geospatial technology applications, benefits, challenges, and recommendations. **Findings**: The study found that geospatial technologies significantly enhance the understanding of regional environmental conditions, aid in natural disaster mitigation, and support environmental conservation efforts through real-time monitoring of weather and climate change. Despite the high costs and data format challenges, these technologies offer indispensable tools for analyzing climate impacts and formulating effective mitigation strategies. **Conclusion**: The benefits of geospatial technologies in climate change mitigation are clear, though challenges such as implementation costs and data compatibility remain. These technologies provide policymakers with essential insights for crafting more informed and effective decisions in combating climate change. **Novelty/Originality of this article**: This study offers a comprehensive review of the diverse applications of geospatial technologies in the context of climate change. It uniquely integrates insights from multiple sectors, showcasing the broader potential of these technologies beyond traditional fields, and provides recommendations for improving data processing and analysis for climate-related decision-making.

KEYWORDS: climate change; geospatial intelligence; remote sensing.

1. Introduction

The role of weather and climate in human life is very important. However, weather can also cause disasters for humans, such as floods, strong winds and drought which can cause infrastructure damage, loss of property and even loss of life. Stable climate conditions will affect important sectors, including agriculture, fisheries and tourism. Understanding and correct predictions about weather and climate can be key in mitigating the environment to climate change. Advances in geospatial technology have developed in recent decades, opening up opportunities to improve understanding and prediction of weather and climate (Malhotra et al., 2018). The development of geospatial technology such as GEOINT (Geospatial Intelligence), remote sensing, and geographic information systems (GIS) has

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increased interest in research related to geographic information science (Randazzo et al., 2021).

GEOINT is widely used for intelligence purposes, but its wide use is not limited to the fields of defence and security. The application of GEOINT can be used in the health sector (Gehlen et al., 2019), politics, economics, social, culture, and even the environmental (Krassakis et al., 2022). The sources of geospatial data, among others, can come from several remote sensing equipment such as satellites, radar, meteorological stations and marine observation networks. In remote sensing, information about an object is obtained without having direct contact with the object. This technique uses electromagnetic waves to find out more data about the earth's surface and atmosphere. Integrating GEOINT and remote sensing allows meteorologists to obtain more comprehensive and accurate information about weather and climate. Geospatial data can be used to monitor weather patterns globally, analyze the impacts of climate change, and develop more precise weather prediction models.

2. Methods

The research method employed in this study is a systematic literature review aimed at collecting, analyzing, and synthesizing information on the utilization of geospatial technologies, such as remote sensing and Geospatial Intelligence (GEOINT), in understanding and mitigating climate change. Comprehensive literature searches were performed across several academic databases, utilizing relevant keywords tailored to the research focus. Only articles published within the last ten years that had undergone peer review and were deemed relevant to the research topic were included in the review. The literature selection process commenced with an initial screening based on titles and abstracts, followed by a thorough evaluation of the full text to ensure the quality and relevance of the included studies.

Once selected, data was collected using a standardized data extraction form, and categorized according to key themes such as the applications of geospatial technology, associated benefits and challenges, and actionable recommendations. Data analysis involved narrative synthesis coupled with a critical evaluation of the methodologies and conclusions of the selected studies. The results of this analysis were compiled into a comprehensive literature review that highlights the significant role of geospatial technology in climate change mitigation efforts. Additionally, the review provided recommendations for optimizing the use of these technologies in disaster management and climate adaptation strategies. This systematic approach not only clarifies the current state of knowledge in the field but also identifies areas for future research and application. The following brainstorming was used in designing this study (Fig. 1).

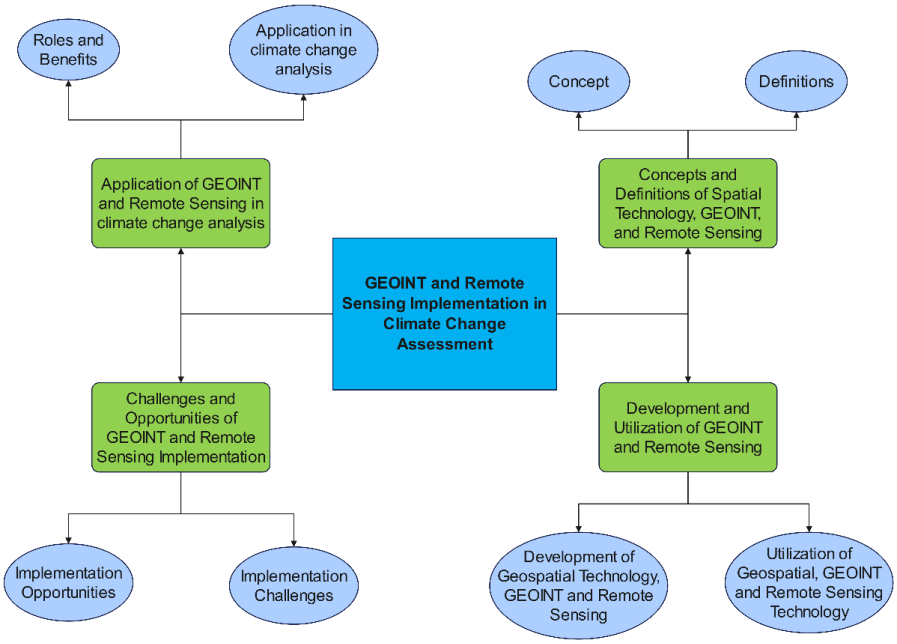

Fig. 1 Brainstroming

3. Results and Discussion

3.1 Concepts and definitions of spatial, geoint and remote sensing technologies

Geospatial technology has developed rapidly and has had a significant impact in various fields. Some examples of geospatial technology such as GIS (Geographic Information System), GPS (Global Positioning System), aerial photography, remote sensing (satellite, radar, LiDar) (Hatta Antah et al., 2022), including GEOINT (Geospatial Intelligence). Sometimes people assume that GIS and geospatial are the same. This is not completely wrong because both describe technology with geography as its main component. The term GEOINT refers to the technique of collecting, analyzing, and disseminating geospatial information suitable for intelligence purposes (Slesinski et al., 2023). Initially, the term GEOINT was synonymous with the field of defence and security, but in its development, GEOINT can be implemented in various other fields such as health, environment, social (Inwood & Alderman, 2020), politics (Sufi & Alsulami, 2022), economics, and culture. GEOINT is widely used to solve problems related to spatial relationships using spatial analysis techniques. In GEOINT, the geospatial information obtained will be analyzed using various techniques to be interpreted into useful spatial data for intelligence purposes. One of the uses of GEOINT can be used by decision-makers to take immediate action in preparation for strategic plans (Islam & Azizul, 2020). How GEOINT works is by synergizing images, imagery intelligence (IMINT), and geospatial data, to perform the task of continuously monitoring an area to observe changes that occur (Slesinski et al., 2023). GEOINT will provide information regarding the location, shape, size, and characteristics or attributes of an object or phenomenon on the earth's surface. One source of GEOINT data is obtained from remote sensing devices, such as satellites and radars. SAR (satellite aperture radar) is one example of remote sensing that can produce geospatial data. The use of SAR allows monitoring of various areas on the earth's surface at any time, unlimited time even in dark conditions at night (Meester & Baslamisli, 2022).

Remote sensing is a technique for collecting information about an object, environment or phenomenon without having direct contact with the object (Ullo & Sinha, 2021). Remote sensing techniques are carried out by utilizing electromagnetic waves to determine the condition of structures on the earth's surface (Cheng et al., 2020) and atmosphere. Remote sensing images are very important to be applied for various purposes such as monitoring, analysis and identification (Wang et al., 2023). Remote sensing makes it possible to collect

spatial data widely and in detail but without the need to visit an observed location directly. Research by B. Zhang et al. (2022), the use of remote sensing, especially satellite-based, can be used to obtain data and images of the earth's surface, to find out information about environmental conditions, various resources and targets on earth through sensors on the satellite. Remote sensing data, among other things, can be used to create maps and spatial models, analyze spatial changes in an area over time (multitemporal analysis) (Tsiakos & Chalkias, 2023); monitoring natural phenomena such as climate change and disaster monitoring; as well as determining the location and characteristics of objects on the earth's surface such as land use classification and changes detection (X. Zhang et al., 2022). The scope of geospatial technology is very broad including devices, software and equipment that produce geospatial data so that it becomes something useful. Integration of geospatial data with other technologies can open up new opportunities for geospatial applications and services.

3.2 Development and utilization of geoint and remote sensing

The rapid emergence and development of technology in the era of revolution 4.0 in the last few decades has greatly helped human activities in facing future challenges. Characterized by technological developments such as geospatial technology, big data analysis, artificial intelligence techniques, and the Internet of Things which are needed in making decisions about something. For example, in the field of agricultural, it can be used to increase agricultural production (Sishodia et al., 2020). Another example of the use of geospatial technology is in the socio-cultural field, such as monitoring illegal drug trafficking crimes (Jesús Pinto Hidalgo & Antonio Silva Centeno, 2023). In the health sector, geospatial technology can be used to monitor the spread of disease viruses and help plan strategic steps to control them (Gehlen et al., 2019; Scholze et al., 2022). By combining several technologies, it will be easier to obtain the information needed to solve a problem. For example, during the Covid-19 pandemic, the use of GEOINT and modelling techniques can provide an overview of the level of virus spread that is useful for health authorities in dealing with the pandemic effectively (Alrige et al., 2022). GEOINT can involve the analysis of remote sensing and geospatial data to describe and evaluate physical conditions and activities on earth (Pinto Hidalgo & Silva Centeno, 2023). Combining the use of several geospatial technology applications will provide benefits to help and simplify human activities. The widespread use of GEOINT data and the development of artificial intelligence (AI) algorithms can improve results analysis (Jones, Koehler, et al., 2023).

GEOINT and remote sensing are two fields that are closely related and have an important role in various fields, including meteorology, climatology and earth sciences. Combining these two technologies can be used to determine changes in the earth's surface, for example, due to climate change which can be seen from changes in the shape of the earth's surface contours over time. Therefore, understanding the concepts and definitions of both is very important to know the advantages of each field so that they can be utilized in analyzing and predicting weather and climate change. Concerning the two, remote sensing data can be an important data source for GEOINT. By combining with other technologies such as artificial intelligence (AI), the use of GEOINT and remote sensing can be used to determine the threat of climate change by measuring the impacts and risks, as well as the dangers it causes (Jones, Kuehnert, et al., 2023). Climate change can cause an increase or decrease in environmental temperature that affects ecosystems, resulting in changes in biodiversity. For this reason, research by Velasquez-Camacho et al. (2024) combines the use of remote sensing and AI to monitor the occurrence of climate change that causes changes in biodiversity. Another research was conducted by Yang et al. (2022) by combining the use of machine learning (ML) and remote sensing-SAR to monitor floods during heavy rain by monitoring river flow levels. These examples provide an illustration of the role and benefits of using geospatial technology such as GEOINT, remote sensing, and AI which are not only used for monitoring an area but are also used in risk management and determining mitigation strategies.(Gevaert et al., 2021). Extensively, analysis of the results of the

utilization of geospatial technology can be used as a basis for decision-making based on risk assessments, for example, to reduce vulnerability due to natural disasters, plan for ecosystem resilience, control the spread of disease, and take other strategic steps.

3.3 Challenges and opportunities for implementing geoint and remote sensing

The development of geospatial technology such as GEOINT and remote sensing provides many benefits and plays an important role in increasing understanding in dealing with various global problems such as global pandemics, climate change.(Al-Yadumi et al., 2021), as well as security due to war. However, this technology has several challenges in its implementation. According to Cui et al. (2022) implementation challenges often faced by users include large-scale data collection such as sensing satellites which are difficult to use. For this reason, it is very important that the data obtained is more easily accessible to a wider range of users to increase its usefulness. In addition, it is very important to determine the right scale of analysis to produce accurate observational data in research (Senf, 2022). Quality geospatial technology data has a high resolution such as that produced by sensing satellites, but it requires large acquisition costs and a long process. According to Shafapourtehrany et al., (2023) is also a challenge for the application of geospatial technology. Geospatial data can come from various data sources so they have different data formats. This difference in data format is another challenge when integrating various data to produce accurate data (Yu et al., 2019). Combining several geospatial technologies has its challenges in interpreting the resulting data because there are differences in the results of data visualization produced between one technology and another. As in the example of research Safari Bazargani et al. (2022) who compared GIS with Augmented Reality (AR) technology in the sharpness of data visualization. Another challenge is the limited availability of remote sensing datasets for developing countries that will be used in analysis using GIS (Kaur & Gupta, 2022).

Apart from the challenges that must be faced, of course, geospatial technology also has a lot of potential that is useful for the development of other technologies. Various applications of geospatial technology by combining one technology with another technology are increasingly opening up opportunities for its utilization. The opportunities of geospatial technology include its ability to provide spatial and temporal data information regarding the spread of a disease, to improve the monitoring of its transmission. This is an opportunity for geospatial technology to contribute to the health sector by providing geospatial model data to develop strategies for preventing and controlling the transmission of disease (Saran et al., 2020). The rapid development of geospatial technology produces large amounts of geospatial data. Utilizing big data technology and cloud platforms allows geoscience researchers to model, process and analyze large amounts of geospatial data to improve more accurate research results (C. Yang et al., 2017). Caldecott et al. (2022) see the potential for geospatial technology in the economic sector to improve financial analysis, which is needed as a basis for decision-making. This research suggests at least five characteristics of geospatial data and analysis to improve financial analysis, namely scalability, comparability, timeliness, durability, and constant improvability. Geospatial technology offers opportunities to monitor air pollution levels by integrating air sensor technology and GIS at spatio-temporal scales to map and assess exposure geospatially (Y.M. Park et al., 2021). Overcoming various challenges in geospatial technology in both GEOINT and remote sensing, as well as taking advantage of existing opportunities, can facilitate the exchange and analysis of geospatial data in real environments, thereby helping policymakers determine appropriate strategies and decision-making.

3.4 Application of geoint and remote sensing in climate change analysis

Geospatial technology broadly provides a platform for monitoring extreme weather events as it can view environmental changes as a whole. Providing information on environmental changes is the role of geospatial technology in climate change analysis. This

information will be used for strategic planning and decision-making to mitigate and prevent the impacts of climate change in the wider and longer term. Climate change is closely related to global warming, which is the increase in the average temperature of the earth's surface caused by the combustion activities of fossil fuels, causing an increase in the concentration of greenhouse gases due to heat trapped in the atmosphere (Tripathi et al., 2022). The issue of global warming has encouraged many countries to reduce greenhouse gas emissions, to mitigate climate change (Willockx et al., 2022). Increased transportation and mobility of urban communities also contribute to increased greenhouse gas emissions or carbon emissions (Raubal, 2020) that significantly accelerate the increase in global warming (J. Park & Yang, 2020). Therefore, it is necessary to find the right strategy to reduce the carbon dioxide footprint in the future. In several studies, global warming has resulted in a rise in the earth's temperature which causes glaciers at the poles and ice-covered mountain peaks to melt more quickly and contributes to sea level rise (Garg et al., 2022; Schuler et al., 2020). Monitoring changes in topographic features due to glacier melting can use remote sensing satellites and GIS techniques, by estimating the rate of glacier melting (Kumar et al., 2021; Su et al., 2021).

Another impact of climate change is causing a global increase in temperatures and an increase in the frequency of rainfall intensity, leading to an increase in the potential for flood hazards (Crăciun et al., 2022). Flooding is the most frequent natural disaster due to climate change that occurs most frequently and is felt by the public in various parts of the world. The potential danger of flooding that has occurred recently has often hit countries that have never been hit by floods before (Weday et al., 2023). To map areas with flood hazards and risks, geospatial data from GIS and remote sensing techniques is often used, which can be used by policymakers as a basis for decision-making for flood hazard mitigation and prevention (Flores & Crompvoets, 2020; Weday et al., 2023). Apart from mapping flood-prone areas, the use of geospatial technology in mitigating natural disasters due to floods can also be used to predict and map the occurrence of floods (Al-Aizari et al., 2022), as well as developing an evacuation plan during floods (Dias et al., 2021). Climate change also has a huge impact on agricultural systems and affects ecosystems and biodiversity. According to research by Halder & Bandyopadhyay (2021), changes in agricultural systems and ecosystems can occur due to urbanization and population surges (Zhong et al., 2022). In the face of climate change, a country's ability can be seen from its level of vulnerability to climate change. According to Bera et al. (2021), Geospatial technology, especially GIS and remote sensing, is needed to help understand the impact of climate change on community vulnerability so that it can be used to support the development of sustainable resource management strategies and carry out disaster mitigation efforts. Appropriate evacuation plans are necessary to be implemented to ensure community safety when a disaster occurs, so empirical data is needed to support decision-making in appropriate planning and implementation.

4. Conclusions

Geospatial technologies, such as remote sensing and GEOINT, can be used to improve understanding of conditions and situations in a region, assist in natural disaster mitigation and response, also support environmental conservation efforts, including real-time observations of weather and climate change. There are many benefits from the development of geospatial technology, which includes equipment, software and devices for generating geospatial data. New opportunities for geospatial applications and services can emerge when geospatial technologies are integrated with geospatial data processing. Analysis of the results of geospatial data processing from the use of geospatial technology can be used as a basis for decision-making based on risk assessments. These results can be used to solve problems such as planning ecosystem resilience, reducing vulnerability due to natural disasters, controlling the spread of disease, and other strategic actions. By addressing the various issues in geospatial technology, both GEOINT and remote sensing,

and taking advantage of existing opportunities, exchanging and analysing geospatial data in real environments can become easier. This will help policymakers in determining strategies and making decisions.

Geospatial technology such as remote sensing and GIS play an important role in monitoring and analyzing climate change. The consequences of climate change often bring adverse impacts on global conditions. The use of geospatial data can be used to help understand the impacts of climate change such as greenhouse gas emissions, glacier melting and flood risk. The resulting geospatial data information can be used to map flood-prone areas, predict floods, and conduct evacuation planning when a disaster occurs. Geospatial data can also be used to help understand community vulnerability to climate change and support the development of disaster mitigation strategies.

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