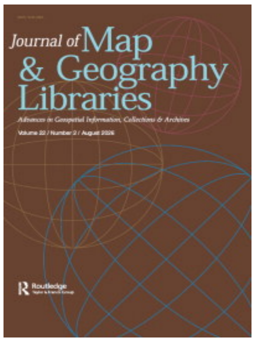
2025-09-19

# GeoAI Research in the Global South: MappingProductivity and Trends Through Bibliometric Analysis

Islam, Md. Nazmul

Taylor & Francis




Routledge
Taylor & Francis Group

Journal of Map & Geography Libraries

Advances in Geospatial Information, Collections & Archives

ISSN: 1542-0353 (Print) 1542-0361 (Online) Journal homepage: www.tandfonline.com/journals/wmgl20

# GeoAI Research in the Global South: Mapping Productivity and Trends Through Bibliometric Analysis

**Md. Nazmul Islam, Md. Ashiqur Rahman, Md. Shahajada Masud Anowarul Haque, Mohammed Khalid Alam & Josiline Chigwada**

**To cite this article:** Md. Nazmul Islam, Md. Ashiqur Rahman, Md. Shahajada Masud Anowarul Haque, Mohammed Khalid Alam & Josiline Chigwada (09 Mar 2026): GeoAI Research in the Global South: Mapping Productivity and Trends Through Bibliometric Analysis, Journal of Map & Geography Libraries, DOI: 10.1080/15420353.2026.2636272

**To link to this article:** https://doi.org/10.1080/15420353.2026.2636272

JOURNAL OF MAP & GEOGRAPHY LIBRARIES
https://doi.org/10.1080/15420353.2026.2636272



# GeoAI Research in the Global South: Mapping Productivity and Trends Through Bibliometric Analysis

Md. Nazmul Islam[a], Md. Ashiqur Rahman[b], Md. Shahajada Masud Anowarul Haque[c], Mohammed Khalid Alam[a] and Josiline Chigwada[d]

[a]Department of Information Science and Library Management, University of Rajshahi, Rajshahi, Bangladesh; [b]Deputy Librarian, Green University Library, Kanchon, Bangladesh; [c]Independent University, Dhaka, Bangladesh; [d]University of South Africa, Pretoria, South Africa

**ABSTRACT**

This study conducts a bibliometric analysis of the development and evolution of research on Geospatial Artificial Intelligence (GeoAI) literature in the Global South region, examining growth patterns, collaboration, and thematic priorities. The data for this bibliometric analysis were specifically compiled from Web of Science and include publications on context-specific themes that include 'challenges, barriers, opportunities, as well as applications' related to GeoAI authored by 1,316 authors and published through 110 sources from 2011 to 2025. The data reveals a high average annual growth rate of 29.67%, which marks an increase in publications since 2016. This could be attributed to advancements in technology and satellite imagery. The collaboration pattern was also exhibited, with an average of 8.97 authors per publication, with over half of all publications authored by international collaborations. The topics with identifiable major hotspots include South Africa, China, and the USA, with many citations per publication in Qatar and Egypt. Thematic analysis revealed that remote sensing, machine learning, and deep learning emerged as dominant themes, predominantly in the context of environmental, disaster, and agricultural applications. Although research articles on GeoAI are gradually growing in the Global South, there are still infrastructure, quality, and capacity development challenges.

**ARTICLE HISTORY**
Received 19 September 2025
Revised 11 February 2026
Accepted 19 February 2026

**KEYWORDS**
Artificial intelligence (AI); GeoAI; global south; global north; mapping; bibliometric analysis

## Introduction

GeoAI research develops a radical change in how spatial data is gathered, analyzed, and applied to real-world problem-solving (Mai et al. 2025a, 2025b). According to recent studies, GeoAI involves geographic information systems, remote sensing, big data, and AI techniques like machine learning and deep learning in solving geographic-related issues (Choi 2023;

**CONTACT** Josiline Chigwada josyphiri@gmail.com University of South Africa, Pretoria, South Africa.

Janowicz et al. 2020; Lundvall 2025; Song et al. 2023). In addition, it has been applied in different sectors like urban development, ecological monitoring, calamity risk management, agriculture, and public health (Boulos, Peng, and VoPham 2019; Boutayeb and Khadimi 2024; Lundvall 2025; Ye et al. 2025). Consequently, geospatial information science is defined as a study that deals particularly with the development and application of information technologies for spaces and Earth's processes (Salvacion 2025). Geospatial analysis mainly lays a basis for Earth Observation on various key themes such as environmental vulnerability, economics, urban planning, hazards, and agriculture (Bera et al. 2021; Getu and Bhat 2021; Karmaoui, el Jaafari, et al. 2023; Kussul et al. 2017; Kyprioti et al. 2021).

AI-driven GSA enables a number of applications like irrigation, crop health, soil, water, erosion control management, among others (de Andrade et al. 2021; Karmaoui 2022; Navinkumar et al. 2021; Che Nordin et al. 2021; Roy and Saha 2021; Xiang et al. 2021). The development brings an accelerated pace to precision agriculture with deep learning and computer vision (Peng and Wang 2021) and uses indices such as NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) (Karmaoui, Moumane, et al. 2023; Talukdar et al. 2021). In general, the relevance of GeoAI on the international scale is presented, but more importantly, the role involved within the agricultural sector.

GeoAI enables evidence-driven decision-making for both developed and developing countries, offering enhanced precision in analysis and prediction models. Nevertheless, the use of GeoAI in the Global South is influenced by unique socio-economic, political, and infrastructural conditions (Huang 2025; Okolo 2023; Tonnarelli and Mora 2025). The application of GeoAI has been hindered in several nations due to a lack of high-quality geospatial data, inadequate infrastructural connectivity and research budgets, and a shortage of experts in this field (Huang 2025). Nevertheless, GeoAI applications bear enormous potency in dealing with crises such as climate change, food security, rapid urbanization, or health care emergencies in the Global South (Olawade et al. 2024). Thus, the interest in GeoAI applications persists, especially related to sustainable development.

Spatial data infrastructure (SDI) contributes toward the creation and building of smart cities through the combination of geospatial data on planning, resource usage, and sustainability (Dissanayake et al. 2025). New data and communication tools have expanded the use of SDI by more groups and governments around the world (Rajabifard and Williamson 2001). Recent studies have shown that GeoAI is increasing the digital divide between Global North and South (Huang 2025), creating new forms of asymmetry in knowledge production. This bibliometric study is

**Table 1.** Quantitative and qualitative indicators used in the current study.

| S.N. | Indicators | Description |
|---|---|---|
| 1. | Annual growth | Trend of yearly publication output. |
| 2. | Most relevant sources | Journals or proceedings with the highest number of GeoAI papers. |
| 3. | Local impact of sources | Source influence based on local citations, H-index, G-index. |
| 4. | Researcher collaboration network | Coauthorship clusters among Global South researchers. |
| 5. | Most relevant affiliations | Institutions producing the most GeoAI publications. |
| 6. | Countries by MCP/SCP | Country contributions based on international vs. single-country publications. |
| 7. | Country collaboration density | Visualization of inter-country collaboration patterns. |
| 8. | Three-field Plot (Authors–Keywords–Sources) | Links among top authors, frequent keywords, and productive sources. |
| 9. | Three-field Plot (Countries–Authors–Affiliations) | Connections between countries, authors, and institutions. |
| 10. | Keyword word cloud | Most frequent keywords related to GeoAI. |
| 11. | Thematic map | Classification of themes as basic, emerging, niche, or motor themes. |
| 12. | Average citations per article per year | Citation velocity of publications. |
| 13. | Most cited countries | Countries ranked by total GeoAI-related citations. |
| 14. | Region of corresponding authors | Geographic distribution of corresponding authors. |
| 15. | Network centrality & community structure | Influential nodes and communities in collaboration/keyword networks. |

conducted into digital divide frameworks that explain why GeoAI adoption and research capacity vary drastically across regions with different infrastructural and institutional capabilities (Table 1).

A bibliometric study is the best tool to explore such trends since it allows for the mapping of knowledge production networks, institutional rankings, and thematic evolution using large publication datasets (Donthu et al. 2021). It helps identify collaboration patterns, citations, or research impact at the macro-level, which otherwise could not be traced.

## *Research Activity in GeoAI*

GeoAI research has grown quickly since the mid-2010s. This growth is driven by better AI algorithms, cloud computing, and more geospatial big data (Boutayeb and Khadimi 2024; Mai et al. 2025a). Research on GeoAI covers various fields, such as land maps, farming, tracking diseases, predicting disasters, and smart cities (Boutayeb and Khadimi 2024; Espinel et al. 2024; Mai et al. 2025b; Saleh et al. 2025). Most early research comes from institutions in North America and Europe. Research scholars in the Global South are now contributing more case studies and applied research relevant to local contexts. For example, in Africa, GeoAI is used to monitor deforestation and biodiversity loss, in South Asia to predict flood risk, and in Latin America to analyze urban growth patterns (Ayadi, Forouheshfar, and Moghadas 2025; Huang 2025; Song et al. 2023; Tonnarelli and Mora 2025). Analysis of the number of publications on GeoAI research from the Global South is, however, a small part of the overall publications, mainly within collaborative research initiatives led by research institutions from the Global North.

### Opportunities in Implementing GeoAI

GeoAI offers significant and varied opportunities to the Global South, with cost-effective, scalable solutions appropriate to data-constrained environments. Its application with remote sensing and open-source GIS platforms, including Collect Earth (developed by the Food and Agriculture Organization and utilizing Google Earth archives), allows land use monitoring, land cover change detection, and ecosystem assessment in countries lacking extensive technical expertise or infrastructure (Sughiarta et al. 2024).

It enhances food security through more effective resource utilization by predicting crop yields, detecting pest infestations, and monitoring soil health in precision agriculture (Vaiyapuri and Julie 2025). These competencies are also improved by the use of climate information services. The climate information services assist farmers on the continent of Africa in planting and harvesting times based on weather changes (Warner et al. 2022).

GeoAI has relevance in the health sector, which has proved to be effective in disease surveillance using AI. This adds to efficiency in predictions related to outbreaks of diseases like malaria. They make use of location data and machine learning to enable quicker and more focused responses (Blanford 2024). One exciting example of the use of Earth observations and GeoAI is the improved prediction of disease outbreaks, such as malaria, cholera, and yellow fever, across vast expanses of administrative territories in Africa, with very high predictive performance (Pezanowski et al. 2024). GeoAI also contributes to climate change adaptation and environmental monitoring. More sophisticated remote sensing data, in addition to AI algorithms, forms the backbone for early warnings against flooding, droughts, wildfires, and other environmental hazards, and improves disaster preparedness and resilience among vulnerable populations (Adeoye et al. 2023). Other examples include the Space for Climate Observatory, which further uses satellite and socio-environmental data in co-developed decision-support tools to provide information on local-scale climate action and adaptation policies (Space4Climate 2023).

Furthermore, the increase in the availability of open-access, high-resolution geospatial datasets such as OpenEarthMap benchmark and regional initiatives like GeoSUR in Latin America-has democratized access to key data resources, allowing researchers and practitioners across the Global South to engage with and apply GeoAI at scale (Xia et al. 2022). These datasets linked with cloud-based computing platforms and free open-source software will increasingly facilitate advanced large-scale geospatial analytics without the need for expensive infrastructure investments.

## *Challenges in Implementing GeoAI*

GeoAI has the potential for contributing to the sustainable development in the Global South. However, its adoption is hampered by some structural and systemic factors. Data unavailability is a significant challenge. Few countries can afford quality geospatial data, which leads to a lack of accurate and reliable models in GeoAI, which has limited capacity (Arakpogun et al. 2021). Problems are worsened by poor infrastructure, lack of adequate bandwidth, costly broadband internet, and lack of local clouds, which also create a problem for spatial analysis on a larger scale (Ade-Ibijola and Okonkwo 2023). Lack of competent staff is the other major issue. Few professionals have expertise in all three domains of AI, data science, and geospatial technology; this makes the successful operation of GeoAI very challenging for such institutions. This challenge has been further threatened by the lack of research funding for research in this field and the slow development of policies associated with both AI and geospatial innovation (Demaidi 2025). Some of the issues that are intertwined with challenges and hurdles that GeoAI encounters are associated with issues of data privacy and equity of algorithms (Oluoch 2024).

Arguably, these challenges have underlined the urgent need for increased investment in infrastructure, training, and guidelines regarding the responsible use of GeoAI in the Global South. This also reiterates a strong need for international collaboration that would allow shared learning, technology transfer, and the development of necessary skills in the long run. A bibliometric study will be useful in this context since it identifies prevailing knowledge gaps (Islam et al. 2021), visualizes research trends, and provides a benchmark for future research and policy works (Islam et al. 2024) related to GeoAI.

The current research on the Bibliometric analysis represents the systematic approach to assess the context pertaining to the GeoAI research environment in the Global South (Chotisarn and Phuthong 2025; Dissanayake et al. 2025; Luppichini et al. 2025; Rejeb et al. 2023; Zhou et al. 2024). This will allow the authors to identify the evolution and diffusion of the knowledge regarding GeoAI, based on the publication dynamics, prominent authors, institutions, countries, and thematic clusters (Aas, Alstad, and Vasseljen 2025; Schiuma et al. 2023; Skute et al. 2019). This research is important in the Global South, where output has been lower compared to global trends because of unequal production and infrastructure in science, technology, and innovation. There should be an understanding that GeoAI research has also been developing in these regions. Consequently, this study carried out a bibliometric analysis of GeoAI research in the Global South to predict research productivity trends and future directions for research.

## *Conceptual Framework*

The concept of "digital divide" arose in the mid-1990s, particularly after the publication of the NTIA report "Falling through the Net" in 1995 (Schweitzer 2025). The digital divide theory is basically concerned with the inequality that arises between people who are able to use modern technologies of information and communication, such as computers, and those who cannot (van Deursen and van Dijk 2012). In a knowledge-based society, access to ICT is fundamental. The lack of adequate ICT infrastructure leads to a digital divide phenomenon, putting a country at a disadvantage, thus constraining overall development (Giebel 2013).

The existing divide is now being observed on different dimensions, including the access to technology, quality of access, as well as the possible use of the technologies for development. This gap has come to be referred to as the "AI divide," and this represents a more serious issue and greater challenge than the "digital divide," since it has the potential to "reshape the economy, society, and politics" across the world (Ajuzieogu 2025). With the evolution of AI from less advanced to more advanced levels, a significant gap has emerged regarding the imbalanced use of these technologies (Ajuzieogu 2025). The divide now extends not only to the usage of the Internet but also involves skills, literacy, and the use of technologies (Bélanger and Carter 2008). With the advent of the GeoAI era, the divide continues to be shaped by divergences in skills, technical knowledge, data access, and computational power (Huang et.al 2025). The increasing complexities in the nature of the digital divide, resulting from variations in accessibility, skills, and socio-political factors are increasing existing inequalities in the social and economic structure of society by destabilizing the benefits derived from GeoAI (Fuchs and Horak 2008). Location is an essential consideration that defines accessibility in the digital era. In rural areas, lack of infrastructure results in inferior Internet speeds, thereby making such regions literally cut off, thereby increasing regional inequality with regard to economic development and accessibility of digital services (Halford and Savage 2010). Education (DiMaggio & Hargittai 2001), age (Hunsaker and Hargittai 2018), cultural, and linguistic divisions (Fantin and Girardello 2008), apart from previous factors, add to this limited accessibility, thereby making a compelling need for a common, shared resource in the digital era.

The evolution and use of artificial intelligence technologies are mainly the result of rich nations and giant corporations. This is also true for GeoAI, which combines geometric/spatial analysis with machine learning algorithms. The race to be top-notch in technological developments has increased the complexities of the geopolitical environment. In this challenging environment, China and USA as representatives of the Global South and the Global North, is recognized as major actors in developing AI and GeoAI research (Lundvall 2025). The global battle in developing AI is probably going to widen the existing gap between the Global South and the top AI countries. This is potentially going to increase the gap because some countries are left behind in accessing high-tech technologies for their advantage. The disparity mainly results from unequal access to quality data, computing resources, and educational opportunities (cited in Lundvall 2025). Moreover, the gap between developing countries, known as the Global South, and developed nations is gradually increasing because the worldwide trend is steadily changing, with capital-surplus industrialized nations receiving more capital inflows, thereby limiting the investments needed for income growth and job creation, especially in labor-abundant developing countries (ILO 2001).

In particular, with regard to GeoAI research in the Global South, the digital divide is evident in terms of accessibility, skills, and output. This is because most countries in the Global South still have limited accessibility to high-resolution satellite imagery, cloud infrastructure, and geospatial data storage, which are essential prerequisites for undertaking GeoAI research (Wang et al. 2024). In this regard, a bibliometric analysis is necessary (Zupic and Čater 2015), particularly within GeoAI research, because the growing divide between the North and the South, as well as the imbalances in the utilization of resources, directly affect who controls knowledge, who has access to research, and which areas are left behind. The Global South has limited accessibility to high-resolution satellite imagery, cloud infrastructure, and geospatial data storage, thereby limiting their full participation within GeoAI research. Mapping publication patterns, collaboration, and themes using bibliometrics can assist in identifying these inequities, pointing out where a research gap exists in order to address these issues in bridging the digital divide in GeoAI.

## *Research Questions*

In the Global South, the development of GeoAI research presents both opportunities and challenges. A bibliometric study is needed to measure and map the thematic focus to gain a comprehensive understanding of these context-specific patterns (e.g. challenge, barrier, opportunity, application). Consequently, a bibliometric analysis of GeoAI-based publications reveals not only the increasing volume of outputs but also the cumulative role of collaboration, citation patterns, and thematic variety in shaping the context-specific GeoAI field. The year 2011 represents the first year that GeoAI related publications by Global South authors appeared in the indexing databases.

Analyzing these trends is important for showing the Global South's place in worldwide research premises. It will help find ways to strengthen research capacity. To achieve this, the following research questions were formulated:

- How has GeoAI context-specific research in the Global South evolved in terms of growth, productivity, and thematic development between 2011 and 2025?
- What patterns of collaboration and authorship characterize GeoAI research in the Global South, and how do they compare to those in the Global North?
- Which institutions, countries, and authors exert the greatest scholarly influence in the domain, and how is this influence reflected in citation patterns?
- What thematic areas and contents dominate GeoAI research incorporating in the Global South, and what future directions are suggested by these trends?

## Research Methods

### Research Design

This study uses a bibliometric technique to map how GeoAI research in the Global South has developed, its structure, and main themes. Bibliometric analysis is useful for studying large amounts of literature. It helps to display the trends in productivity, collaboration, and influence, as well as key themes and knowledge structures.

### Data Source and Retrieval

The primary platform for data collection was the Web of Science (WoS) core collection and Scopus, because of its balanced coverage of peer-reviewed and high-quality scholarly output. During the preliminary screening, Scopus was excluded because a significant number of retrieved records (15 records) overlapped with entries on WoS, Using a single database is a widely accepted practice in bibliometric research, primarily to maintain consistency and avoid methodological complications arising from mixed data sources.

The WoS database was thoroughly searched using this query:

*TS = ((“GeoAI” OR “Geospatial Artificial Intelligence” OR “Geospatial AI” OR “Machine learning” OR “Deep learning” OR “Neural Network”) AND (“developing countries” OR “Global South” OR “low-income countries” OR “Africa” OR “Asia” OR “Latin America” OR “Papua New Guinea” OR “Fiji” OR “Solomon Islands” OR “Vanuatu”) AND (“challenges” OR “barriers” OR “limitations” OR “opportunities” OR “applications”))*

Therefore, selecting WoS as the sole data source adheres to standard bibliometric best practice recommendations for single-database datasets, aiming to avoid duplication, variations in metadata formats, and different indexing biases inherent to each database. The search was conducted on August 1, 2025. Initially, 163 records were identified. To ensure methodological transparency, explicit inclusion and exclusion criteria were applied during the screening process. Studies were included if they (i) were indexed in the Web of Science Core Collection, (ii) were published between 2011 and 2025, (iii) were written in English, and (iv) explicitly addressed GeoAI or geospatial artificial intelligence–related themes (e.g. machine learning, deep learning, neural networks) within the context of the Global South or developing regions. Records were excluded if (i) they were duplicates identified during preliminary cross-database screening, (ii) were published in languages other than English, (iii) fell outside the defined publication period, or (iv) did not demonstrate a clear thematic relevance to GeoAI applications, challenges, barriers, or opportunities in Global South contexts. Following the application of these screening criteria, 154 documents were retained for final analysis. Records were refined by publication year (2011–2025) and by language, with English only. Other languages were excluded due to a language barrier. After screening and refinement, 154 documents formed the final dataset. These represented 110 publication sources and were authored by 1,316 unique contributors.

### *Data Preparation and Tools*

The data from WoS was exported in BibTeX format and analyzed using Biblioshiny, an R online tool for the analysis of bibliometrix, and Microsoft Excel. Biblioshiny analysis employed standard bibliometric indicators, including the number of publications by authors, collaboration metrics, citations per paper, and coauthor networks. Additionally, Biblioshiny employed Visualization tools, including three-field plots, density maps, and thematic maps, to discuss structural patterns of authorship, institutional affiliation, and thematic assignments. On the other hand, the analysis employed Microsoft Excel, which facilitated the initial data cleaning, generation of descriptive statistics, and calculation of growth rates. To ensure replicability, all the parameters used for analysis were standardized in

Biblioshiny. The following are the quantitative and qualitative parameters used to judge the outcome of the research (Islam et al. 2022):

### *Analytical Approach*

The methodological approach for this work was a combination of quantitative and qualitative methods. Examples of quantitative indicators include publication growth rates, citations per article, and coauthorship indices, among others, which provide an overview at a macro level of research output and impact. Qualitative interpretation of thematic maps and word clouds identified the key research areas, challenges, and emerging opportunities. This approach allowed the GeoAI knowledge landscape to be captured synergistically in the Global South.

## Results

### *Growth and Productivity of Global South GeoAI Literature*

The bibliometric study of GeoAI research within the Global South between 2011 and 2025 reveals a growing scholarly landscape characterized by similar patterns of authorship, collaboration, and citation. The figures reveal 154 scholarly articles from 110 sources published over the years, with an outstanding growth rate of 29.67%, highlighting scholarly collaborations and growing competence in research across the domain.

Figure 1 presents the distribution of research outputs in this GeoAI dataset from 1,316 authors, 10 of whom are single authors, reflecting that GeoAI research is highly collaborative. 8.97 coauthors per article, along with the high level of international coauthorship (56.49%) present in this dataset, further underlined the shared research culture, indicating

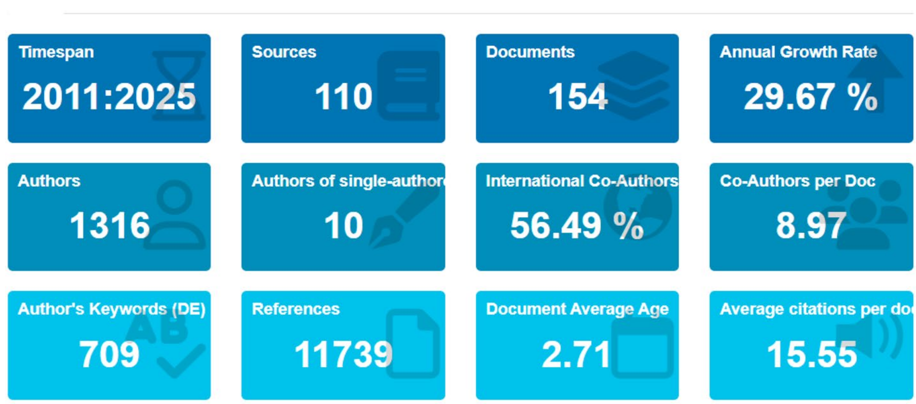



Figure 1. Description of datasets.

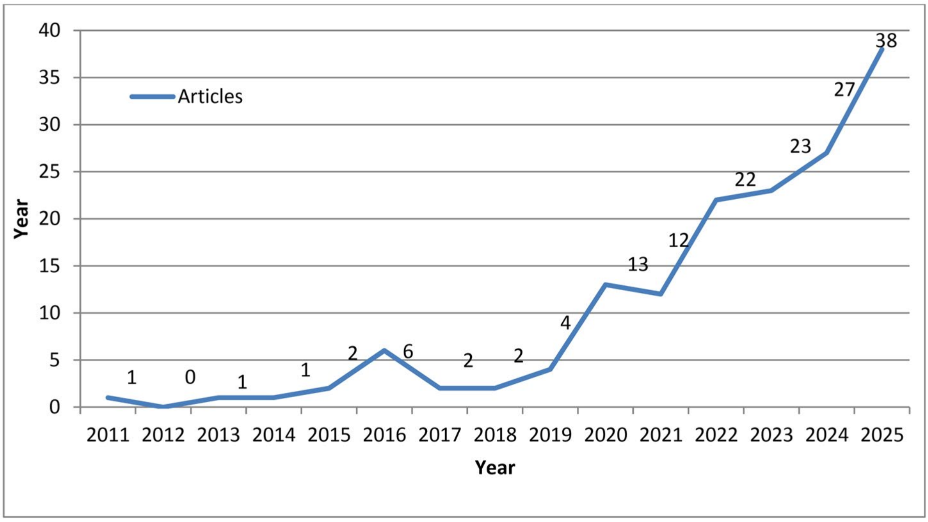



**Figure 2.** Growth of GeoAI-related papers annually.

its international and interdisciplinary nature. The Scholarly research variance in the domain is underscored by 709 different author keywords, revealing the extensive thematic scope and inclusion of subfields. Nevertheless, the foundation of its research entails 11,739 references, indicating its connection to past research and the diverse backgrounds of the domain.

The dataset contains cited documents with an average age of 2.71, suggesting possible influences of recent technological advancements like AI and geospatial sciences. On average, a citation of each document is 15.55, symbolically reflecting a tremendous scholarly impact, recognition, and possible policy and practical relevance of research endeavors. The annual scientific output ranging from 2011 to 2025 shows a sharp growth trend, thus reflecting its growing application and diversification. The output of this research was limited in the early stages, with a total of five scientific papers published annually from 2011 to 2015, and most described the basic application of machine learning technology in geospatial data processing. However, since 2016, this growth rate has accelerated due to the dramatic expansion of AI technology and access to high-resolution satellite images.

As indicated in Figure 2, the period from 2018 to 2020 marked a significant expansion, during which publication output doubled in magnitude compared to previous years. Such a rapid increase has been observed due to increased investments by institutions, international collaborations, and special funding for priority research areas in the region, including disaster risk management, urbanization tracking, and climate change adaptation efforts (Boutayeb and Khadimi 2024). By 2023, the publication output per year had surpassed 25 articles, with the highest number in 2024, at an average annual rate of increase of 29.67%. This consistent growth pattern indicates an overall increase in participation and adoption of GeoAI in the knowledge community.

### *Publication Sources Analysis*

Among the 110 publication sets, there is a group that is represented as a significant producer of intellectual contributions, providing foundations for the development of the area. Journals such as Remote Sensing, ISPRS Journal of Photogrammetry and Remote Sensing, and Sensors occupy a prominent position in terms of publication volume and citation, indicating a strong technology-oriented nature of research on GeoAI, with a primary interest in remote sensing technology, spatial data analysis, and sensor integration. IEEE and ACM conference proceedings are other important contributors, which have citation influence based on interdisciplinary collaboration in research.

The evaluation of local citation influence offers insight into which journals, authors, or publications have had the most influence within a given research area. In a bibliometric study, local citations can be described as how often a given record in a dataset is cited by other records within the same dataset. Through local citation analysis, along with other associated bibliometric indicators, one can identify which core literature shapes the field, track intellectual trends, and inform decisions on which research to read, cite, and share in journals most relevant to maximizing scholarly relevance and engagement (Zhou and Leydesdorff 2007). Source impact analysis through local citations in Figure 3 shows that *'Remote Sensing – Basel'* significantly tops all sources

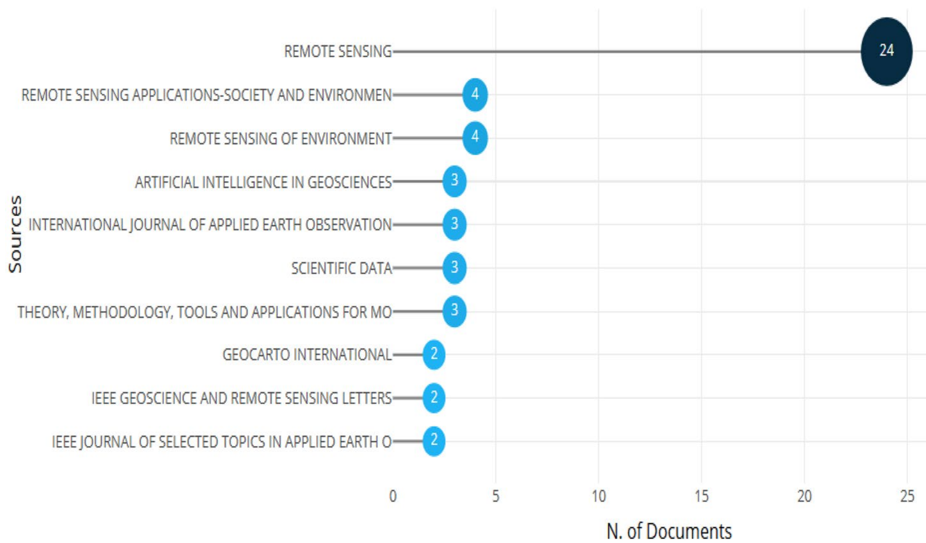



**Figure 3.** Most relevant sources for GeoAI-related papers.

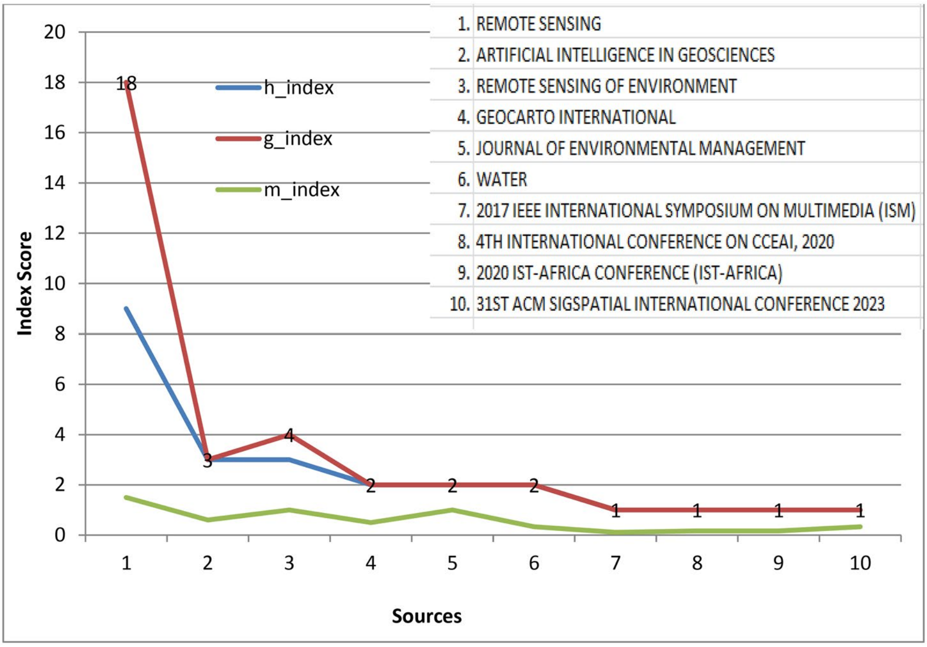



**Figure 4.** Sources local impact based on local citation and various indices.

in terms of citations, followed by *'Remote Sensing of Environment'*. However, when based on h-index in Figure 4, *'Remote Sensing'* remained at the top, not only in total citation numbers but in sustained publication impact as well. Meanwhile, other sources, such as Artificial Intelligence in Geosciences, appear to have fair citation counts but a good h-index, indicating a small but sustained impact factor across a series of articles These metrics show that total citations measure overall impact, while the h-index reflects both productivity and influence.

### *Global South Authors Analysis*

In a study (Kaur et al. 2015), the authors discovered a complex relationship between the volume of scientific publications and their impact. It showed that a higher quantity of publications does not necessarily correlate with higher quality or better scientific impact. Likely, the current study shows in Figure 5 that in Global South GeoAI research, a few highly productive authors present most of the output. Dube T, Li X, Wang Y, and Zhang X lead the research production with four articles each as the most productive writers in the dataset. Local citation analysis exhibits distinct but interrelated influential authors, considering their productivity. Bourdeau JE, Nwaila GT, and Zhang SE lead the research outputs as the most locally cited authors, each with three citations across regional scholarly networks.

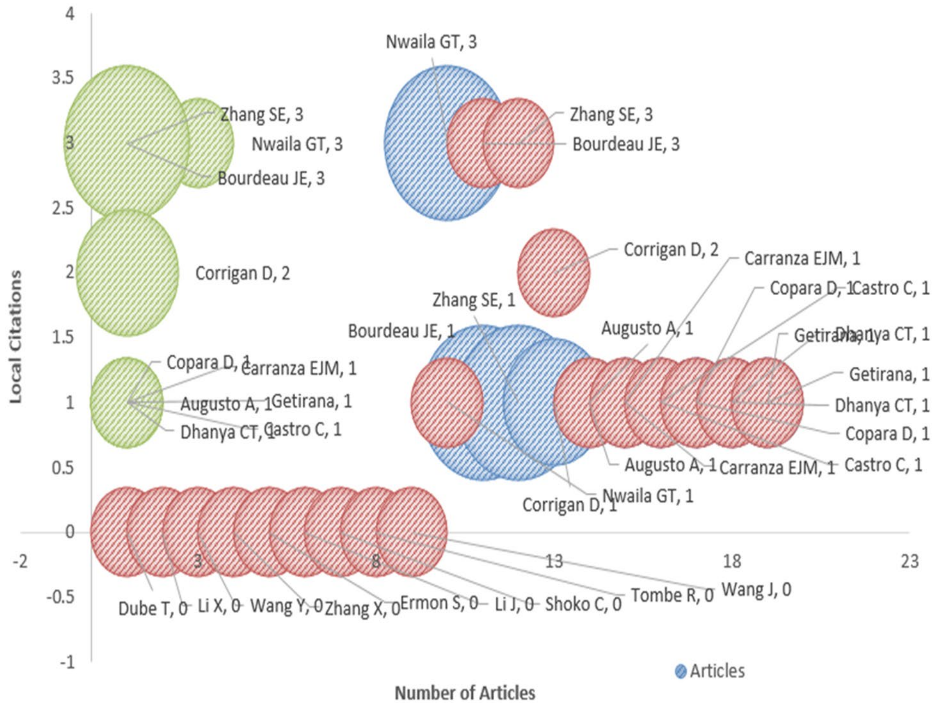



Figure 5. Quantity vs. quality: Divergent trends in publication volume and local citation impact.

However, other authors, such as Dube T, Li X, Wang Y, and Zhang X, although being very productive authors, with four articles each, do not match this high volume of publications with a similar local citation count, as shown in Figure 5. In contrast, Bourdeau JE and Corrigan D, present higher local citations with a lower number of articles, showing the impact of their papers. Nwaila GT is the only author who has been listed among the top authors by both article count and local citation count, indicating a balance between productivity and impact. Moreover, a number of authors listed in the citation impact list have only one paper. This means that sometimes a single, impactful study can be as influential as many publications combined. Therefore, no straight correlation exists between article count and local citation impact in the dataset. This is not an unusual phenomenon in bibliometric distributions, where only a few blockbuster studies significantly impact the citation metrics. This bibliometric distribution highlights the complexity of research impact in the Global South, where research productivity and citation impact significantly influence research discourses. This also suggests the need to construct networks that enhance the visibility and inclusion of locally dominant authors, thereby fostering regional knowledge exchange and shared innovation. The authors' collaboration network reveals the core authors, the most networked teams, and the level of

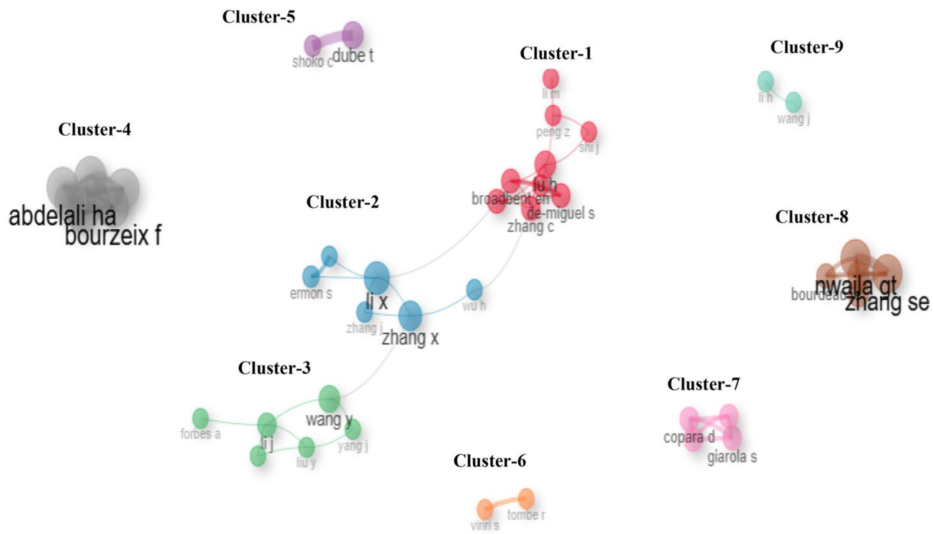



Figure 6. Collaboration network of researchers from the Global South.

network connectivity among authors. The network helps identify highly active research communities, as well as domains where new research can be sparked through collaborations (Duan 2024).

Figure 6 illustrates a network of authors from the Global South. Here, each circle in the network symbolizes an individual author, and each connection line portrays coauthorship among authors. The colors in the network represent different regions or communities where authors tend to collaborate with one another rather than with those in other regions/clusters. The size of the names reflects their importance or centrality within the network.

Nine variously connected clusters may be differentiated within the collaboration network. The most international cluster, Cluster 1, colored red, acts as a bridge between different parts of the network, represented by Zhang C, Lu H, Peng Z, and De-Miguel S. Cluster 2, in blue, is driven by Li X, Zhang X, and Wu H, connecting Asia to US/Europe. Cluster 3, in green, is centered on Wang Y and connects Asian scholars to other groups. Cluster 4–9 are more local and smaller: Cluster 4 in grey includes Abdelali HA and Bourzeix F; Cluster 5 in purple includes Dube T and Shoko C; Cluster 6 in orange includes Vinnis F and Tombe R; Cluster 7 in pink includes Copara D and Giarola S; Cluster 8 in brown includes Nwaila GT and Zhang SE; and Cluster 9 in teal includes Li H and Wang J. They are internally tight but essentially isolated from the rest of the network.

Table 2 demonstrates network centrality and community structure of global south researchers. The high betweenness nodes represent those authors who link various research communities. The importance of Cluster 1, Cluster 2, and Cluster 3 lies in their role as network connectors, thereby facilitating research collaboration among various nodes. These nodes, if

**Table 2.** Network centrality and community structure.

| Node | Cluster | Betweenness | Closeness | PageRank |
|---|---|---|---|---|
| Broadbent en | 1 | 0 | 0.017 | 0.029 |
| De-miguel s | 1 | 0 | 0.017 | 0.029 |
| Fang j | 1 | 56 | 0.02 | 0.03 |
| Kumar a | 1 | 0 | 0.017 | 0.025 |
| Li m | 1 | 0 | 0.011 | 0.01 |
| Lu h | 1 | 51 | 0.018 | 0.037 |
| Peng z | 1 | 19 | 0.014 | 0.022 |
| Shi j | 1 | 0 | 0.014 | 0.014 |
| Zhang c | 1 | 32.5 | 0.019 | 0.03 |
| Li x | 2 | 76 | 0.021 | 0.032 |
| Zhang x | 2 | 88.5 | 0.02 | 0.028 |
| Ermon s | 2 | 0 | 0.015 | 0.02 |
| Lobell d | 2 | 0 | 0.015 | 0.02 |
| Wu h | 2 | 32 | 0.019 | 0.014 |
| Zhang j | 2 | 0 | 0.017 | 0.015 |
| Wang y | 3 | 76 | 0.017 | 0.024 |
| Li j | 3 | 43 | 0.014 | 0.035 |
| Forbes a | 3 | 0 | 0.011 | 0.011 |
| Liu y | 3 | 2 | 0.011 | 0.026 |
| Ma x | 3 | 0 | 0.011 | 0.018 |
| Yang j | 3 | 8 | 0.013 | 0.018 |
| Dube t | 4 | 0 | 1 | 0.023 |
| Shoko c | 4 | 0 | 1 | 0.023 |
| Tombe r | 5 | 0 | 1 | 0.023 |
| Viriri s | 5 | 0 | 1 | 0.023 |
| Nwaila gt | 6 | 0 | 0.25 | 0.027 |
| Zhang se | 6 | 0 | 0.25 | 0.027 |
| Bourdeau je | 6 | 0 | 0.25 | 0.019 |
| Carranza ejm | 6 | 0 | 0.25 | 0.022 |
| Ghorbani y | 6 | 0 | 0.25 | 0.022 |
| Copara d | 7 | 0 | 0.333 | 0.023 |
| Giarola s | 7 | 0 | 0.333 | 0.023 |
| Hawkes a | 7 | 0 | 0.333 | 0.023 |
| Moya d | 7 | 0 | 0.333 | 0.023 |
| Abdelali ha | 8 | 0 | 0.167 | 0.023 |
| Amazirh a | 8 | 0 | 0.167 | 0.023 |
| Bourzeix f | 8 | 0 | 0.167 | 0.023 |
| Chehbouni a | 8 | 0 | 0.167 | 0.023 |
| El-battay a | 8 | 0 | 0.167 | 0.023 |
| Hajji h | 8 | 0 | 0.167 | 0.023 |
| Laamrani a | 8 | 0 | 0.167 | 0.023 |
| Wang j | 9 | 0 | 1 | 0.023 |
| Li h | 9 | 0 | 1 | 0.023 |

removed, could result in compartmentalization, similar to an air route connecting two or more different airports. There are various research communities, such as Cluster 4 and Cluster 9, with zero betweenness and very high closeness. This signifies that there are research communities that are predominantly working together as a team. The authors with relatively higher PageRank are Lu H, Li J, and Li X; apart from being network connectors, they are connected with important authors.

## *Global South Authors' Countries*

Analysis of the country affiliations of the corresponding authors reveals that the Global South comprises 61%, outpacing the Global North, which comprises 39%, as represented in Table 3.

**Table 3.** Region of corresponding authors.

| Region | Articles by corresponding authors | % of Total articles |
|---|---|---|
| Global South | 94 | 61% |
| Global North | 60 | 39% |

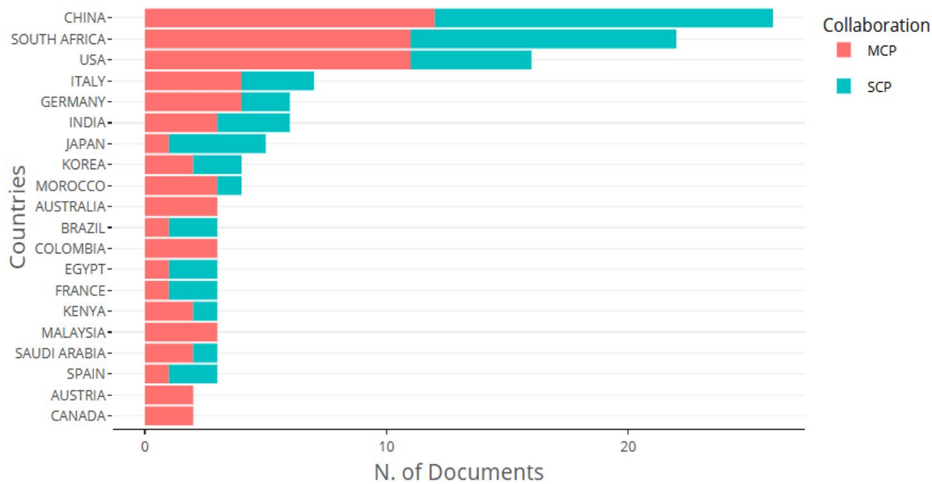



**Figure 7.** Corresponding authors' countries by MCP and SCP.

The study on collaboration patterns in GeoAI research also identifies the complex relationship between Single Country Publications (SCPs) and Multiple Country Publications (MCPs) in countries and regions (Sweileh et al. 2016). Considering all countries, Multiple Country Publications constitute a slight majority, accounting for 53.9% of all publications (Total = 83 out of 154 publications) (Figure 7).

China (16.9%) and South Africa (14.3%) display balanced compositions of collaborative publications between local and international partnerships, while South Africa has recently been recognized as a prime regional hub. The US and several European countries have large numbers of international collaboration publications, thereby emphasizing their status as global collaboration partners. Conversely, newer Global South nations, such as Morocco, Kenya, and Saudi Arabia, rely on cross-national collaborations to improve their research publications. Nations such as Bangladesh, Nigeria, and the Philippines have established publishing channels for their research works within their national boundaries, due to their early stages or nationally focused research ecosystems.

Table 4 shows that the Global South contributes nearly two-thirds (63.6%) of the total research output, underlining its increasingly significant role in scholarly production. While both the Global South and Global North exhibit significant international collaboration tendencies, they have MCP ratios of 53.06% and 55.36%, respectively. Countries such as China and South Africa exhibit significant domestic research output. Conversely, several Global North nations display high MCP percentages, reflecting their deeply embedded global research networks. This parity in collaboration patterns highlights a convergence in research globalization, with the Global South emerging as a pivotal hub for independent and partnered scientific endeavors.

A density visualization of a collaboration network represents the intensity of the connections between researchers, institutions, or countries in terms of their coauthorship patterns. Brighter or denser areas highlight zones of higher collaboration activity, allowing one to easily notice where partnerships are most concentrated (van Eck and Waltman 2010). Figure 8 illustrates the density of research collaborations among countries. The visualization displays a core-periphery pattern with a few countries serving as anchors of global collaboration, while many others contribute at regional or emerging levels. A gradient effect, from red to light orange, highlights how the intensity of collaboration diminishes as it moves outward from the central hubs.

At the center of the network, the USA, South Africa, China, and the UK appear as the largest nodes, colored a deep red, as they represent the largest number of collaborations. Around them, there are other nations

**Table 4.** Production dominance: Global South vs Global North.

| Region | Total articles | Percentage | SCP | SCP % | MCP | MCP % |
|---|---|---|---|---|---|---|
| Global South | 98 | 63.60% | 46 | 46.94% | 52 | 53.06% |
| Global North | 56 | 36.40% | 25 | 44.64% | 31 | 55.36% |
| Total | 154 | 100% | 71 | 46.10% | 83 | 53.90% |

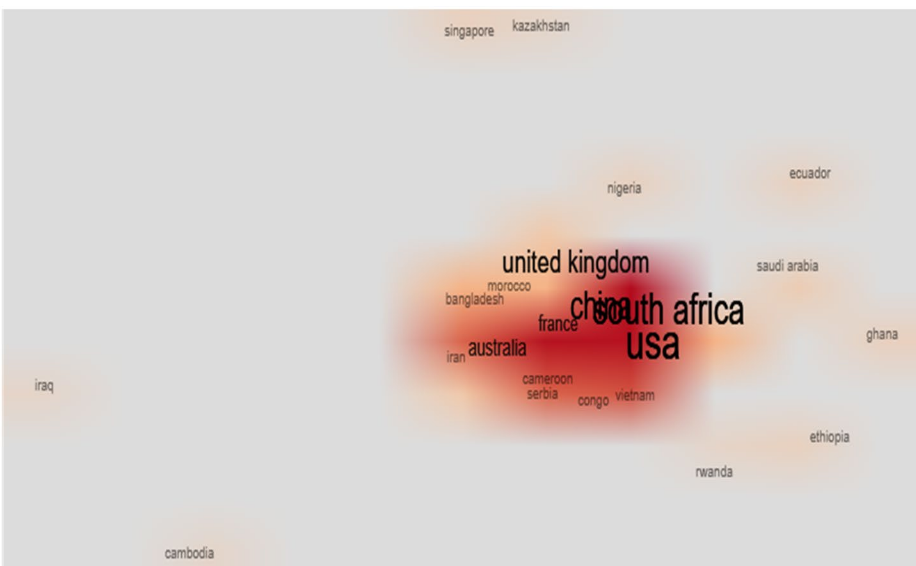



**Figure 8.** Countries' collaboration network by density visualization.

like Australia, France, Morocco, Bangladesh, and Iran, which form a secondary mass, where they engage with both primary participants as well as neighbors. In the outer ring, other nations, such as Saudi Arabia, Ghana, Ethiopia, Rwanda, and Cambodia, are represented in lighter shades.

### Citation Analysis

Citation analysis can help to assess the performance of research. It involves analyzing the number of citations a given publication receives to understand the level of recognition and quality of the publication. Over the past few years, several essential factors have been identified to assess the significance and quality of articles based on their citation rates (Islam et al. 2025). MeanTCperArt and MeanTCperYear measure citation analysis to help judge the quality of articles from an academic perspective. MeanTCperArt can be defined as the mean total citations per article. This helps to understand the overall visibility and impact of publications in a collection. On the other hand, the MeanTCperYear measure calculates the average number of citations an article receives per year since its publication. In contrast, MeanTCperYear denotes the average annual citations an article receives since it was published. It takes into account article ages, ensuring a well-balanced comparison of old and new publications (Aria and Cuccurullo 2017).

The earliest published works, including the seminal works in 2011, demonstrated the impact with 27 citations per paper (Table 5). The highest citation rate occurred in 2017 with two papers that earned an average of 156.5 citations. The average citations increased from 45.83 to 62 from 2016 to 2018 as the development of GeoAI accelerated. From 2020 to 2023, the citation rate became moderate (13.73–14.96 per paper) with the increasing number of published works. Naturally, papers published in 2024 and 2025 show lower citation counts (4.74 and 1.47) because they have

**Table 5.** Average citations per year/article.

| Year | MeanTCperArt | N | MeanTCperYear | CitableYears |
|---|---|---|---|---|
| 2011 | 27.00 | 1 | 1.80 | 15 |
| 2013 | 12.00 | 1 | 0.92 | 13 |
| 2014 | 5.00 | 1 | 0.42 | 12 |
| 2015 | 5.00 | 2 | 0.45 | 11 |
| 2016 | 45.83 | 6 | 4.58 | 10 |
| 2017 | 156.50 | 2 | 17.39 | 9 |
| 2018 | 62.00 | 2 | 7.75 | 8 |
| 2019 | 11.75 | 4 | 1.68 | 7 |
| 2020 | 27.31 | 13 | 4.55 | 6 |
| 2021 | 33.00 | 12 | 6.60 | 5 |
| 2022 | 13.73 | 22 | 3.43 | 4 |
| 2023 | 14.96 | 23 | 4.99 | 3 |
| 2024 | 4.74 | 27 | 2.37 | 2 |
| 2025 | 1.47 | 38 | 1.47 | 1 |

had less time to be cited, indicating that these newer works are still in the process of establishing their impact.

Average Article Citations (AAC) reflects the typical number of citations an article receives. Dividing total citations received from all sources indexed globally by the total number of articles, it offers a clear view of a country's or author's research impact. This approach supports fair comparisons across journals, researchers, or time periods, even when publication volumes differ.

As shown in Table 6, the USA leads in total citations, reflecting its large research output. In contrast, Egypt and Qatar stand out for citation efficiency, achieving strong impact despite publishing fewer papers. South Africa ranks second in total citations, indicating a notable regional influence. Qatar records the highest Average Article Citations (AAC = 98), while Egypt, Colombia, Denmark, and Ethiopia also demonstrate strong per-paper impact. Overall, the USA, Egypt, Qatar, Colombia, and Denmark show a balanced combination of research volume and quality.

On the other hand, China and Germany publish many papers, but with a lower impact per article. Malaysia, Singapore, Ethiopia, or Morocco can enhance their impact by publishing more.

The fact that the total number of citations in the Global South (1,305) is higher than that in the Global North (1,089) as presented in Table 7 reflects the stronger average citation frequency per article in the Global South (19.01) than in the Global North (12.36), with extremely high-impact values in the latter, including Qatar (98.0) and Egypt (65.0) as seen in Table 6. There are 19 Global South nations in the dataset as opposed to 13 in the Global North.

The scatter plot below (Figure 9) illustrates the positioning of countries on the axes, with total citations (TC) plotted horizontally and average

**Table 6.** Top 10 most cited countries on GeoAI.

| Country | TC | Average article citations (AAC) |
|---|---|---|
| USA | 768 | 48.00 |
| South Africa | 371 | 16.90 |
| Egypt | 195 | 65.00 |
| China | 166 | 6.40 |
| Colombia | 135 | 45.00 |
| India | 106 | 17.70 |
| Qatar | 98 | 98.00 |
| Denmark | 85 | 42.50 |
| Malaysia | 71 | 23.70 |
| Germany | 54 | 9.00 |

**Table 7.** Citation volumes of works by corresponding authors from Global North and Global South countries.

| Region | Total citations (TC) | Average per article citations | No. of countries |
|---|---|---|---|
| Global North | 1,089 | 12.36 | 13 |
| Global South | 1,305 | 19.01 | 19 |

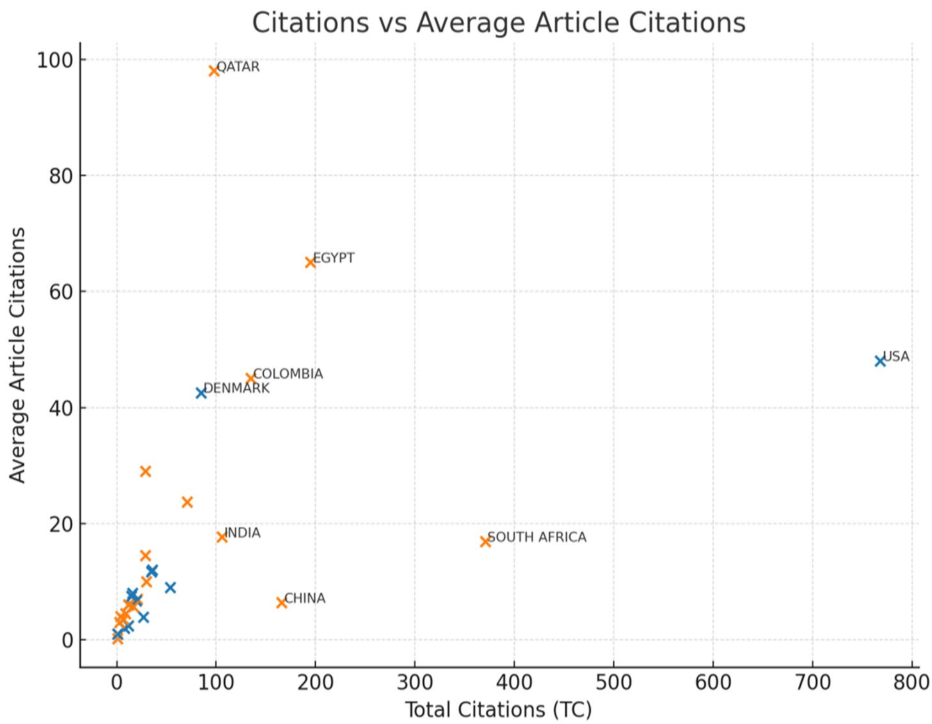



**Figure 9.** Citations vs average article citations.

article citations plotted vertically, allowing us to assess the magnitude and resultant effects of the research at a glance.

The USA is in the top-right corner, reflecting strong total citations and strong impact per article. Some countries in the Global South, such as Qatar and Egypt, are noted for their low number of publications but a large average number of citations, indicating the significance of their key publications. On the other hand, nations such as China and Germany are noted for their large number of citations but lower article influence. Countries such as Kazakhstan, Morocco, and Sweden are seen in the lower left region, which represents their low influence in both volume and impact. From this plot, it can be realized that it is not merely a matter of numerous publications if a nation is to be considered as having a large research influence, since a nation can produce a smaller number of publications, but their influence can be substantial.

## *Affiliations Analysis*

Institutional impact analysis shows a globally distributed but geographically heterogeneous pattern, as shown in Figure 10. By examining the affiliations used by publication databases, it is possible to identify which institutions are most represented, helping to pinpoint key coauthors. This is crucial

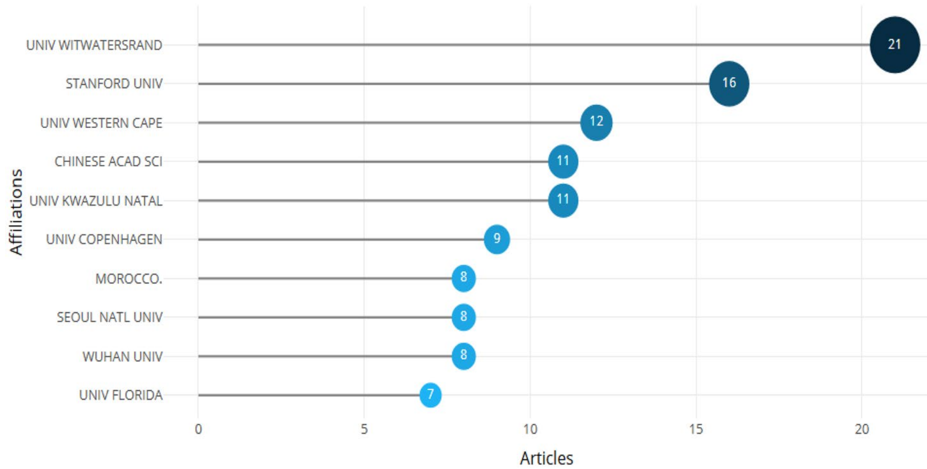



**Figure 10.** Most relevant affiliations.

for institutional funding, as it indicates where proficiency and impactful work are, thereby helping to inform allocation or collaborative efforts (Yu et al. 2020).

Figure 10 presents that University of the Witwatersrand (South Africa) is a major contributor with 21 publications. It is a leading institution in carrying out GeoAI research on the African continent. Stanford University (USA) appears second with 16 publications, highlighting its dynamic and leading role as a top research institution worldwide. The University of the Western Cape (South Africa), with 12 publications, the Chinese Academy of Sciences, with 11 publications, and the University of KwaZulu-Natal (South Africa), with 11 publications, are also highly dynamic in terms of regional influence in this context. Regional influence and leading roles are also shown by Euro-Asian institutions, including the University of Copenhagen (Denmark), with 9 publications, Seoul National University (8 publications), and Wuhan University (8 publications). On the other hand, Moroccan universities (8) and the University of Florida (7) also display North African and North American contributions.

### *Sankey Diagram of GeoAI Bibliographic Data*

The Three-Field Plot, also known as the Sankey Diagram, offers an ideal representation to depict the relationships between entities such as authors, keywords, sources, and so on. From Figure 11, the left-hand column lists the author name (AU) based on their publication count. The bigger blocks of the publication volumes indicate more contributions. The middle column presents the prominent keywords (KW) that the author frequently associates with. The right-hand column denotes the journals/conferences (SO) where the author's work is published. The connection between the plots

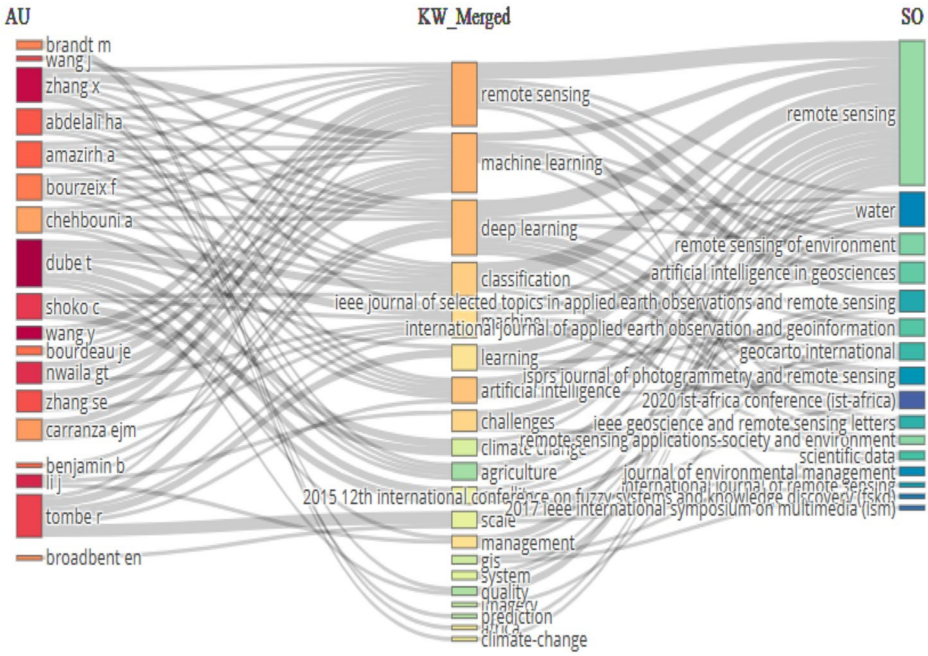



**Figure 11.** Three-field plot: Authors, keywords and sources.

through lines indicates how the author is associated with specific themes and journals/publications. Thicker lines portray stronger or more intense connections. For instance, Brandt M is associated with 'remote sensing'. Zhang X is involved in 'deep learning', 'classification' in various journals. Overlapping of themes is seen when authors apply similar keywords, such as 'remote sensing'. This is also evident when authors are indexed in similar journals, such as Remote Sensing of Environment and Water. In summary, though a visual representation, remote sensing is presented as one of the major areas of research. In addition, it gives an outlook on influential authors of those journals, such as Brandt M, Wang J, and Zhang X. There is also a growing emphasis on the importance of keywords, such as machine learning or deep learning, in various major journals, like *Water, Remote Sensing of Environment, Artificial Intelligence in Geosciences,* and others.

Similar to the visualizations by Author, Keywords, and Sources, Figure 12 displays a Sankey diagram illustrating the relationships between Country, Author, and Affiliation. The diagram clearly illustrates how the research contributions represent nations, scholars, and institutions. On the left, countries like South Africa, China, and the USA have bigger blocks, indicating a larger number of publications output. Conversely, countries such as Vietnam and Morocco are shown as smaller blocks, yet their contributions are notable. The middle portion reflects Broadbent, EN, Li X, Wang Y, and Zhang X as prolific authors, whose links trace back to their respective countries of origin.

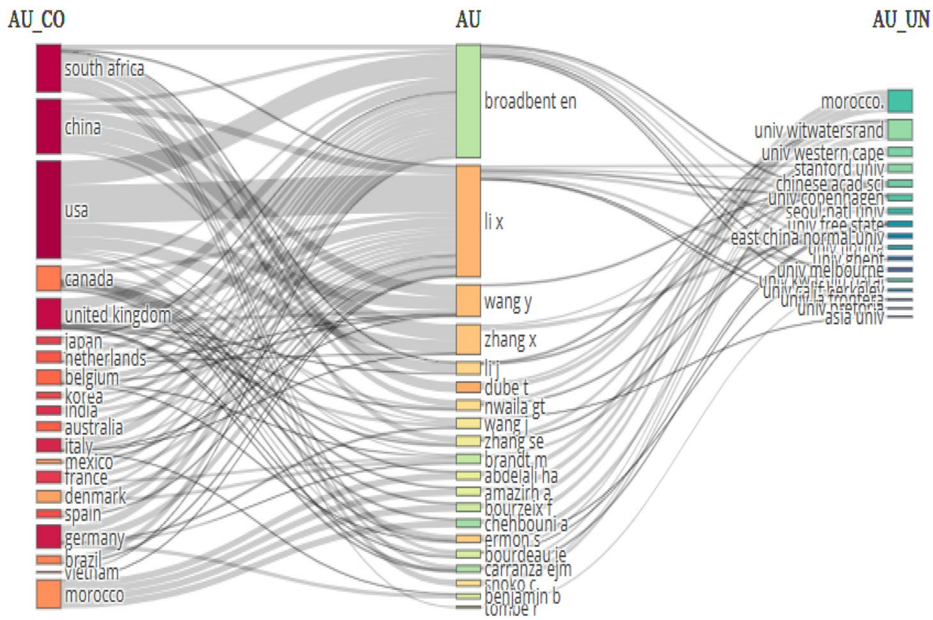



Figure 12. Three-field plot: Countries, author and affiliation.

On the right side, affiliations such as the University of Witwatersrand, Stanford University, the Chinese Academy of Sciences, and the University of Cape Town emerge as critical nodes. The flow of connections plots both local and international collaborations, as seen in the case of Broadbent's two ties with both South Africa and the USA, which demonstrate extreme levels of global collaboration. The plot highlights the importance of major players in influencing the field, while also illustrating network collaborations that bridge geographical and institutional boundaries.

## *Content and Thematic Analysis*

As essential tools in content and thematic analysis, word clouds and thematic maps reveal insight into texts, but in distinct ways. Word clouds reveal those words that appear most frequently to give a quick snapshot of dominant ideas; thematic maps go deeper in showing how concepts connect and form patterns, offering better views of relationships and meaning within the data. A word cloud is something easily understood that represents a collection of texts, which indicates the frequency of each particular term mentioned within it. The size and boldness of a word depend on its level of appearance. It helps researchers easily discover the main themes, trends, or areas of focus without the need to read through every single document. (Mathews et al. 2015).

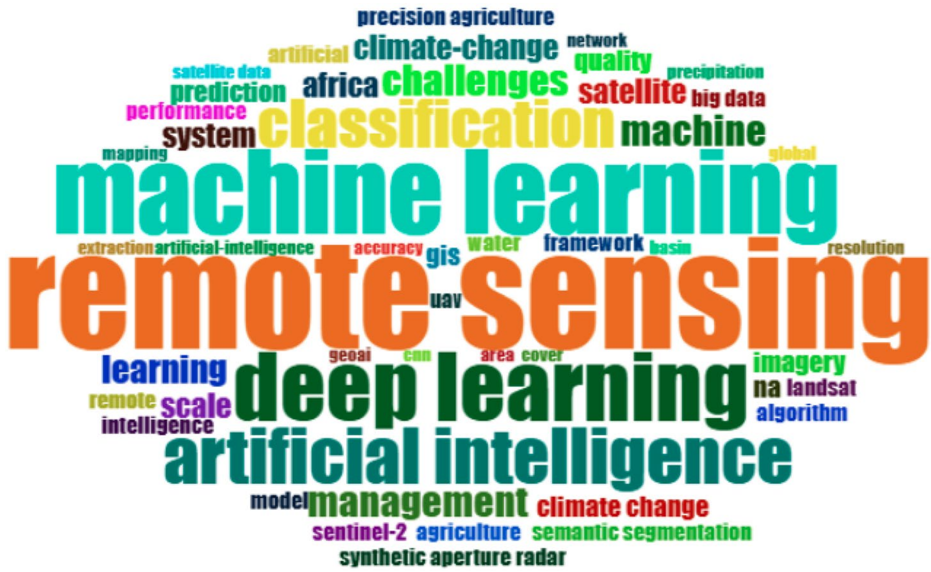



**Figure 13.** Word Cloud on GeoAI topics.

Research in GeoAI is predominantly focused on applying machine learning and deep learning to remote sensing for spatial data analysis. The Word Cloud in Figure 13 illustrates an emphasis on classification, prediction, and algorithm development, indicating the use of robust models and techniques. The presence of words like "environment" and "agriculture" indicates that applications of GeoAI are addressing the challenges of sustainability and resource management. The use of multiple data sources, such as satellite images, radar, and UAV images, illustrates the dependence of GeoAI on the fusion of data from multiple sensors. Words such as "challenges," "quality," and "performance" illustrate some of the apprehensions about data credibility and performance.

In bibliometric analysis, the thematic mapping classifies research topics to divulge their role and development within the area. Different types of themes show how the placement and evolution of topics are done. Motor themes mean discipline, which is central and well-developed. The niche themes become specialized and highly developed, but more isolated. The marginal and underdeveloped themes are emerging or declining, signaling a new opportunity or fading interest. Basic themes are the fundamental topics with broad relevance but less maturity. These disciplines form the basis for other research. Such categorization can help the researcher trace the main areas, find out the new trends, and set the future direction of research (Cobo et al. 2011).

Figure 14 illustrates the thematic map of GeoAI research in the Global South from 2011 to 2025. Two major, interlinked clusters can be identified on this map. One of these is related to satellite and remote sensing technology,

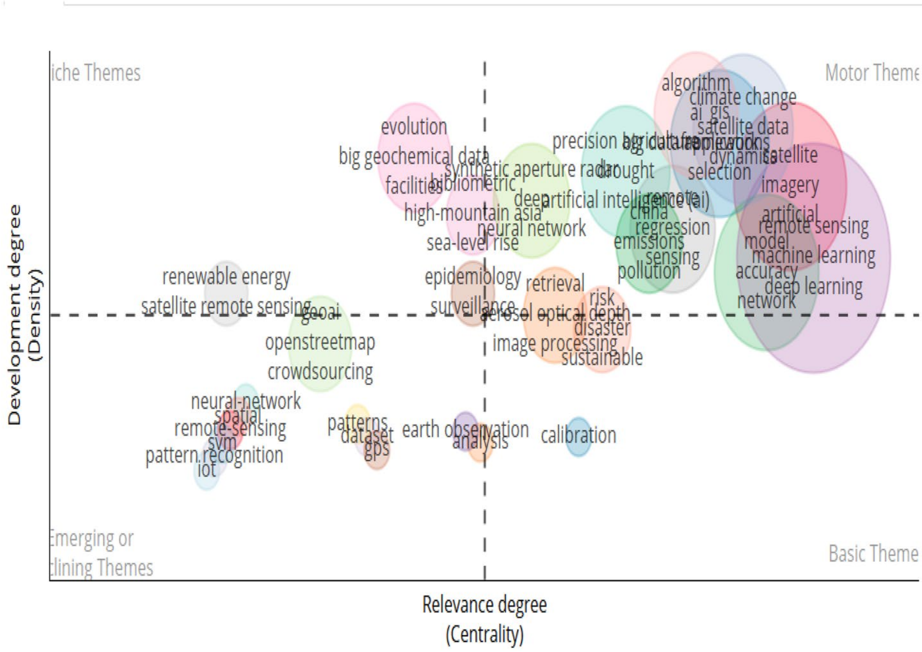



**Figure 14.** Thematic map on GeoAI topics.

which highlights earth observation applications for environmental surveillance, land-use mapping, and disaster response. The other one is related to artificial intelligence and data analysis, indicating a paradigm shift from traditional methods of AI to deep learning. These two clusters collectively indicate the successful integration of AI and geospatial technology for environmental applications, addressing practical environmental and planning challenges.

## Findings and Discussion

### *Key Findings*

The study points out several critical results:

- Growth and Productivity: GeoAI in the Global South has witnessed substantial research output, with an average annual rate of 29.67%. There has been a significant turning point between 2018 and 2020, during which outputs doubled due to increased funding, international collaboration, and technological advancements. By 2024, annual publications surpassed 25, highlighting the field's growth.
- Collaborations and Authorship: The high average of 8.97 coauthors per publication and an even higher degree of international collaboration at 56.49% reveal an exceptionally collaborative culture. It appears that while certain individuals, such as Dube T and Li X, publish a

high number of articles, others, like Bourdeau JE, publish fewer but can achieve a better local citation impact.

- Institutional and Country Leadership: The key hubs were South Africa, China, and the USA, and University of the Witwatersrand was the major contributor to Global South publications. Bangladesh and Nigeria are yet to develop and primarily publish local work, while Morocco and Kenya heavily depend on international publishing infrastructures.
- Citation Trends: The number of publications by the Global South outshines that of the Global North by a considerable margin (63.6% vs 36.4%), and there are mean citation rates that are relatively high in each region (19.01 vs 12.36). The impact of Qatar and Egypt's publications is exceptionally high, given lower publication rates.
- Thematic Development: The themes of GeoAI include remote sensing, machine learning, and deep learning. They are generally applied in environmental monitoring, disaster risk management, and agriculture. The thematic maps illustrate themes of AI-related spatial analysis, as well as some niche themes of GeoAI, which might focus on classification or predictive models of sophisticated themes.

## Discussion

### *Quality vs Quantity*

The comparative analysis of the authors' publication output and their local citation impact brings out an interesting trend: that publishing more articles does not necessarily guarantee greater citation influence. For instance, authors such as Dube T, Li X, Wang Y, and Zhang X lead in the number of publications but are not among the most cited local authors. On the other hand, authors such as Bourdeau JE and Corrigan D have fewer publications but higher citation impact per publication than others. This reflects the fact that article quality is a significant factor. Interestingly, Nwaila GT is a balanced contributor. He is found both in publications and citation influence. This reflects a significant connection between productivity and citation impact. These findings suggest that, although publications are important, a work's relevance holds more significance than the number of publications by scholars.

### *Global South vs Global North*

Corresponding authors' analysis reveals a remarkable shift in research leadership: 61% of all the publications are by institutions in the Global

South, surpassing the Global North's 39%. As shown in Table 3, emerging economies such as China and South Africa have become increasingly important drivers in shaping the GeoAI knowledge landscape. Traditionally, the Global North has had greater access to resources, infrastructure, and well-established scholarly networks, which typically facilitate higher citation counts. The evidence shows the Global South is competitive with, or surpassing, the North in total citation counts among the represented countries, indicating a shifting global research landscape. It is important to note that this comparison between the Global South and Global North is limited to the 154 articles included in the present dataset and does not reflect overall global scholarly output.

From an academic perspective, this trend may be driven by several factors. There could be heightened global collaborations that amplify the visibility of research from the Global South. Some nations may also be producing impactful niche research, for example, Qatar and Egypt, which could increase the number of citations from the area despite the lower number of publications. The emergence of new research centers in the Global South could also be driving the number of publications in impactful areas, such as public health, the environment, and applied science research. Generally, all these points indicate a paradigm shift in the geography of research, with the Global South not only being the 'recipient' of knowledge but also the 'influential contributor' whose scholarly works are gaining widespread recognition worldwide.

### *Collaboration Network of Global South Authors*

The collaboration network for Global South authors consists of nine clusters, with the first three being the most collaborative and global. Key researchers who facilitate interaction between several clusters include core authors such as Fang J, Lu H, Peng Z, Zhang C, Li X, Li J, and Wang Y, as shown in Table 2. Some of the smaller clusters are more localized, with authors being well interconnected. PageRank scores denote influential authors who are the core figures within several communities.

Together, these patterns show how the landscape of scholarship is evolving, with the Global South no longer just receiving knowledge but also playing a vibrant and influential role in the global GeoAI research landscape.

### *Combined Bibliometric Mapping Insight*

The integrated analysis of the Three-Field Plots presents the entire research area, highlighting the research concentrations and the network of collaboration within the subject area. Plot 1 (Authors–Keywords–Sources) indicates there is a strong thematic focus on the use of remote sensing methods, machine learning, and deep learning. These keywords constitute the backbone or the core area of the research. Key contributors to these publications include Brandt M, Wang J, Zhang X, and Abdelali HA. They tend to publish their work frequently in top-ranking journals, such as Remote Sensing, Remote Sensing of Environment, and Water. This area represents the concentrated research in environmental monitoring and geospatial technologies as presented in selected publication sources.

The second plot is Countries—Authors—Affiliations. This plot contributes to the thematic analysis and serves as a visual representation of the authors' origins and affiliations. The authors from South Africa, China, and the USA comprise the majority in terms of publication numbers. These authors' affiliations also include major institutions such as the University of Witwatersrand, Stanford University, and the Chinese Academy of Sciences, as well as East China Normal University. Authors such as Broadbent EN display bi-national affiliations, engaging in collaborations between African and North American institutions. This indicates that collaborations in research extend globally and across disciplines.

Overall, these visualizations highlight how research themes and institutional connections come together. They show that high-impact work in remote sensing and AI-based environmental studies is largely shaped by a core group of authors who are strategically linked to influential institutions across major regions of the world.

## *Volume vs Impact of Research*

The United States clearly stands out in the upper-right quadrant (Figure 9), showing both a high number of total citations and a strong average citation rate per article. Several Global South countries, notably Qatar and Egypt, also perform impressively, earning very high average citations from a more modest number of publications. This pattern points to a smaller set of highly influential studies. By comparison, countries such as China and Germany accumulate many citations overall but show lower impact per article, suggesting wider output with more evenly distributed influence. Other nations, including Kazakhstan, Morocco, and Sweden, contribute fewer papers and attract relatively limited citations. Taken together, the figure makes an important point: research influence does not depend only on how much is published. Some Global South countries achieve exceptional impact per article, showing that research quality can match—or even exceed—sheer publication volume.

### *Insights of Word Cloud and Thematic Map*

The word cloud and the thematic map, collectively, reflect how researchers in GeoAI from the Global South are specifically interested in methodological approaches, with prominent words like "remote sensing," "machine learning," and "deep learning" reflecting how integration of AI with geospatial platforms. to supplement this, organized groups in the thematic map, like satellite technology and remote sensing, with artificial intelligence for data processing, connect technology enablers with application areas like agriculture, urban planning, and resource management. While the research is methodologically sound, with a strong emphasis on technology, yet applications in socio-economics and policies are still unexplored, opening up possibilities for more region-specific research to converge technology advancements with adapting to climate adaptation, sustainable development, and equitable access to geospatial tools.

As Huang (2025) demonstrates, GeoAI is rapidly expanding this gap by increasing its demands for sophisticated computational capabilities. Moreover, even when technology is readily available, the presence of AI and machine learning experts is often inadequate in Global South institutions, as evidenced by the shortage of qualified personnel and insufficient funding for research in AI and related fields (Huang 2025). Furthermore, the digital divide affects the issue of knowledge production asymmetry because the Global South authors publish fewer articles and have lower profiles on the most prestigious journals, while they cannot easily align with global research agendas even when their research focuses on issues critical to their regions. These imbalances and inequalities in GeoAI development and deployment can be understood in the context of the digital divide, which explains the underlying biases in access and the ability to generate viable results from technology (Huang 2025).

In this research, GeoAI is a techno-innovation that is spreading unevenly across different regions of the globe. With regard to the result, it was evident that there was a sharp increase in growth after 2016, making it clear that Global South institutions were in the early majority stage of innovation adoption, where there was a proof of concept developed by North American institutions together with innovators and early adopters in Europe. Among the difficulties identified, it can be argued that they include a lack of infrastructure, poor data, lack of funds, and gaps in policies, which act as a hindrance in innovation diffusion. It is apparent that GeoAI encompasses the integration of a wide range of complex technologies, including AI, remote sensing technologies, GIS, and cloud computing. On the other hand, despite the associated potential benefits, such as precision agriculture and disaster prediction, a high cost may obscure advantages for resource-constrained institutions. Regarding the potential for use, it is noted that research infrastructure in a wide range of Global South settings did not originally envision use related to big data and/or AI. Trialability has been impacted by a whole range of data quality issues.

### *Limitations of the Study*

There are operational limitations to this research that need to be addressed. First, all the analyses here are based on a dataset that has been clearly established using a Global South intensive search approach. Thus, the presence of Global North publications is based on only those articles in which Global North authors were involved in GeoAI research targeted at the Global South. Thus, any comparison at the regional level, such as the number of publishing outputs or citations, applies solely to the above-mentioned subset of Global North publishing and does not denote the full-scale GeoAI productivity of Global North regions. Second, citation differences between regions have also been appropriately reworded to exclude the implication that publications from the Global South are superior to those from the Global North in a global perspective. It is not wise to interpret a dataset and draw such a conclusion relating to relative publication competitiveness across two regions of the world. Third, although the results provide a thorough distribution map regarding the focus on the Global South in GeoAI, they lack global patterns. There are no acceptable global studies on GeoAI bibliometric research that can serve for comparison. As a consequence, the results cannot or should not be compared with global standards. There are no global reference studies regarding GeoAI.

## Conclusion

Geospatial Artificial Intelligence (GeoAI) is a rapidly developing area that encompasses the integration of artificial intelligence with geospatial technologies, including Geographic Information Systems (GIS), remote sensing, and spatial analysis. Despite the growing pace of GeoAI as a whole, its development within the Global South regions, which include Africa, Latin America, Asia, and a part of Oceania, has been comparatively underexplored. It is essential to comprehend the research activities, opportunities, and challenges in these areas. It ensures the implementation of good policies, investment in some cases, and the establishment of strong academic networks.

The bibliometric analysis of GeoAI research in the Global South reveals a complex relationship between productivity and impact. Some authors publish extensively, but their citation counts are relatively low.

This indicates that the quality and relevance of each work are more crucial than the number of publications. Researchers with fewer publications may get many citations, which justifies the fact that the impact of every article is very important in the field. Thus, balanced cases can be seen, for instance, from Nwaila GT, indicating how productivity can be matched with impact. They are typical cases of effective scholarly work.

From the findings of the 154 articles included in the study, the Global South is turning out to be an important source of contributions to GeoAI research, representing the largest number of publications and even outdating the Global North in cumulative citations. This can largely be attributed to enhanced global collaboration patterns, the high-quality niche research of small nations such as Qatar and Egypt, and the development of new research hotspots in Asia and Africa. The collaboration map also highlights the significance of central connectors (authors with high betweenness and PageRank), who play a crucial role in connecting different research groups and disseminating knowledge, as well as smaller and more compact clusters that focus on local cohesion. This can well describe a more equitable and globally distributed landscape of research, where the footprints of research are not merely restricted to the traditional North-centric institutions.

Thematic and methodological analyses reveal that the community is highly interested in computation and AI-related research, particularly in remote sensing, machine learning, and deep learning, for applications such as environmental monitoring, precision agriculture, and urban planning. Nevertheless, there are some areas that need to be explored, specifically in socio-economic applications and policies, which could open a potential window for new research, bringing together new advancements with regional issues such as climate adaptation, sustainable development, and equitable access to geospatial technologies. In future research applications for GeoAI in the Global South, there could be a paramount need for interdisciplinary collaboration with a focus on research with high impact.

## Author contributions

CRediT: **Md. Nazmul Islam**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Md. Ashiqur Rahman**: Conceptualization, Data curation, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Md. Shahajada Masud Anowarul Haque**: Conceptualization, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Mohammed Khalid Alam**: Conceptualization, Data curation, Investigation, Software, Validation, Writing – original draft, Writing – review & editing; **Josiline Chigwada**: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

## Disclosure Statement

No potential conflict of interest was reported by the author(s).

## ORCID

Md. Nazmul Islam http://orcid.org/0000-0003-0528-8296
Md. Ashiqur Rahman http://orcid.org/0009-0005-1511-497X
Md. Shahajada Masud Anowarul Haque http://orcid.org/0000-0001-6415-8665
Mohammed Khalid Alam http://orcid.org/0000-0001-6762-4959
Josiline Chigwada http://orcid.org/0000-0003-0964-3582

## References

Aas, Hanne Kristin, Knut Alstad, and Nina Cathrine Aagesen Vasseljen. 2025. "Mapping Lesson Study as a Research Field: A Bibliometric Review." *International Journal for Lesson & Learning Studies* 14 (5): 47–58. https://doi.org/10.1108/IJLLS-09-2024-0218.

Ade-Ibijola, Abejide, and Chinedu Okonkwo. 2023. "Artificial Intelligence in Africa: Emerging Challenges." In *Responsible AI in Africa: Social and Cultural Studies of Robots and AI*, edited by Damian Okaibedi Eke, Kutoma Wakunuma, and Simisola Akintoye, 101–117. Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-031-08215-3_5.

Adeoye, Idowu Afolabi, Nurudeen Yemi Hussain, Blessing Austin-Gabriel, Adebimpe Bolatito Ige, Peter Adeyemo Adepoju. 2023. "Geospatial AI and Data Analytics for Satellite-Based Disaster Prediction and Risk Assessment." *Open Access Research Journal of Engineering and Technology*, 4 (2): 058–066. https://doi.org/10.53022/oarjet.2023.4.2.0058.

Ajuzieogu, Uchechukwu. 2025. "Digital Divide 2.0: Distributional Consequences of Unequal AI Access." *SAAGEX*. https://doi.org/10.13140/RG.2.2.30033.03680.

Andrade, Vinícius Henrique Gomes Zuppa de., Marc Redmile-Gordon, Bruno Henrique Groenner Barbosa, Fernando Dini Andreote, Luiz Fernando Wurdig Roesch, and Victor Satler Pylro. 2021. "Artificially Intelligent Soil Quality and Health Indices for 'Next Generation' Food Production Systems." *Trends in Food Science & Technology* 107: 195–200. https://doi.org/10.1016/j.tifs.2020.10.018.

Arakpogun, Emmanuel Ogiemwonyi, Ziad Elsahn, Femi Olan, and Farid Elsahn. 2021. "Artificial Intelligence in Africa: Challenges and Opportunities." In *The Fourth Industrial Revolution: Implementation of Artificial Intelligence for Growing Business Success*, edited by Allam Hamdan, Aboul Ella Hassanien, Anjum Razzaque, and Bahaaeddin Alareeni, 375–388. Cham: Springer. https://doi.org/10.1007/978-3-030-62796-6_22.

Aria, Massimo, and Corrado Cuccurullo. 2017. "Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis." *Journal of Informetrics* 11 (4): 959–975. https://doi.org/10.1016/j.joi.2017.08.007.

Ayadi, Rym, Yeganeh Forouheshfar, and Omid Moghadas. 2025. "Enhancing System Resilience to Climate Change through Artificial Intelligence: A Systematic Literature Review." *Frontiers in Climate* 7: 1-26. https://doi.org/10.3389/fclim.2025.1585331.

Bélanger, F., and L. Carter. 2008. "Trust and Risk in E-Government Adoption." *The Journal of Strategic Information Systems* 17 (2): 165–176. https://doi.org/10.1016/j.jsis.2007.12.002.

Bera, Aparna, Ajay Kumar Taloor, Gowhar Meraj, Shruti Kanga, Suraj Kumar Singh, Bojan Đurin, and Subhash Anand. 2021. "Climate Vulnerability and Economic Determinants: Linkages and Risk Reduction in Sagar Island, India; A Geospatial Approach." *Quaternary Science Advances* 4: 100038. https://doi.org/10.1016/j.qsa.2021.100038.

Blanford, Justine I. 2024. "Managing Vector-Borne Diseases in a geoAI-Enabled Society." *Acta Tropica* 260: 107406. https://doi.org/10.1016/j.actatropica.2024.107406.

Boulos, K. M. N., G. Peng, and T. VoPham. 2019. "An Overview of GeoAI Applications in Health and Healthcare." *International Journal of Health Geographics* 18 (7): 1-9. https://doi.org/10.1186/s12942-019-0171-2.

Boutayeb, A., and E. A. Khadimi. 2024. "A Comprehensive GeoAI Review: Progress, Challenges and Outlooks." ArXiv. https://doi.org/10.48550/arXiv.2412.11643.

Che Nordin, Nur Farahin, Nuruol Syuhadaa Mohd, Suhana Koting, Zubaidah Ismail, Mohsen Sherif, and Ahmed El-Shafie. 2021. "Groundwater Quality Forecasting Modelling Using Artificial Intelligence: A Review." *Groundwater for Sustainable Development* 14: 100643. https://doi.org/10.1016/j.gsd.2021.100643.

Choi, Y. 2023. "GeoAI: Integration of Artificial Intelligence, Machine Learning, and Deep Learning with GIS." *Applied Sciences* 13 (6): 3895. https://doi.org/10.3390/app13063895.

Chotisarn, N., and T. Phuthong. 2025. "A Bibliometric Analysis Insight into the Intellectual Dynamics of Artificial Intelligence for the Micro, Small, and Medium Enterprises." *Cogent Business & Management* 12 (1): 1-44. https://doi.org/10.1080/23311975.2025.2491684.

Cobo, M. J., A. G. López-Herrera, E. Herrera-Viedma, and F. Herrera. 2011. "Science Mapping Software Tools: Review, Analysis, and Cooperative Study among Tools." *Journal of the American Society for Information Science and Technology* 62 (7): 1382–1402. https://doi.org/10.1002/asi.21525.

Demaidi, M. N. 2025. "Artificial Intelligence National Strategy in a Developing Country." *AI & Society* 40 (2): 423–435. https://doi.org/10.1007/s00146-023-01779-x.

Deursen, Alexander J. A. M. van, and Jan A. G. M. van Dijk. 2012. "The Digital Divide." In *International Encyclopedia of the Social & Behavioral Sciences*, edited by James D. Wright. 2nd ed. Orlando, USA: Elsevier.

DiMaggio, P., and E. Hargittai. 2001. "From the 'Digital Divide' to 'Digital Inequality': Studying Internet Use as Penetration Increases." In Working Paper Series, 15, No. 15, vol. 4. Center for Arts and Cultural Policy Studies, Woodrow Wilson School, Princeton University. https://doi.org/10.31235/osf.io/rhqmu.

Dissanayake, D., M. Ranagalage, J. Jayasundara, P. S. K. Rajapakshe, N. S. K. Herath, S. A. Marasinghe, W. M. S. B. Wanninayake, H. U. K. Dilanjani, A. L. W. M. Perera, and Y. Herath. 2025. "A Comprehensive Bibliometric Analysis of Spatial Data Infrastructure in a Smart City Context." *Land* 14 (3): 492. https://doi.org/10.3390/land14030492.

Donthu, Naveen, Satish Kumar, Debmalya Mukherjee, Nitesh Pandey, and Weng Marc Lim. 2021. "How to Conduct a Bibliometric Analysis: An Overview and Guidelines." *Journal of Business Research* 133: 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070.

Duan, C. 2024. "Analyses of Scientific Collaboration Networks among Authors, Institutions, and Countries in FinTech Studies: A Bibliometric Review." *FinTech* 3 (2): 249–273. https://doi.org/10.3390/fintech3020015.

Eck, N. J. Van, and L. Waltman. 2010. "Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping." *Scientometrics* 84 (2): 523–538. https://doi.org/10.1007/s11192-009-0146-3.

Espinel, Ramón, Gricelda Herrera-Franco, José Luis Rivadeneira García, and Paulo Escandón-Panchana. 2024. "Artificial Intelligence in Agricultural Mapping: A Review." *Agriculture* 14 (7): 1071. https://doi.org/10.3390/agriculture14071071.

Fantin, M., and G. Girardello. 2008. "Digital Literacy and Cultural Mediations to the Digital Divide." In *Digital Literacy: Tools and Methodologies for Information Society*, edited by Pier Cesare Rivoltella, 310–340. Hershey, PA: IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-59904-798-0.ch018.

Fuchs, C., and E. Horak. 2008. "Africa and the Digital Divide." *Telematics and Informatics* 25 (2): 99–116. https://doi.org/10.1016/j.tele.2006.06.004.

Getu, Kenu, and H. Gangadhara Bhat. 2021. "Analysis of Spatio-Temporal Dynamics of Urban Sprawl and Growth Pattern Using Geospatial Technologies and Landscape Metrics in Bahir Dar, Northwest Ethiopia." *Land Use Policy* 109: 105676. https://doi.org/10.1016/j.landusepol.2021.105676.

Giebel, M. 2013. "Digital Divide, Knowledge and Innovations." *Journal of Information, Information Technology, and Organizations* 8: 1–24. https://ssrn.com/abstract=2091123.

Halford, S., and M. Savage. 2010. "Reconceptualizing Digital Social Inequality." *Information, Communication & Society* 13 (7): 937–955. https://doi.org/10.1080/1369118X.2010.499956.

Huang, Xiao, Siqin Wang, and Yongze Song. 2025. "Digital Divide and GeoAI." In *GeoAI and Human Geography: The Dawn of a New Spatial Intelligence Era*, edited by Xiao Huang, Siqin Wang, John Wilson, and Peter Kedron, 361–371. Cham: Springer. https://doi.org/10.1007/978-3-031-87421-5_25.

Huang, Xiao. 2025. "Geospatial Artificial Intelligence (GeoAI) Is Widening the Digital Divide." *Annals of the American Association of Geographers* 115 (9): 2017–2029. https://doi.org/10.1080/24694452.2025.2527316.

Hunsaker, A., and E. Hargittai. 2018. "A Review of Internet Use among Older Adults." *New Media & Society* 20 (10): 3937–3954. https://doi.org/10.1177/1461444818787348.

International Labour Organization. 2001. "Reducing the Decent Work Deficit: A Global Challenge." Geneva: International Labour Office. http://www.ilo.org/public/libdoc/ilo/P/09383/09383(2001-89)76.pdf

Islam, Md Nazmul, Md Shahidul Islam, and Pradip Bikash Roy. 2022. "Assessment of Public Health Research Output by Bangladeshi Authors: A Scientometric Study." *Data Science and Informetrics* 2 (2): 14–35. http://dsi.nseac.com/vol2_no2.html.

Islam, Md Nazmul, Md Shariful Islam, and Partha Biplob Roy. 2021. "Scientometric Analysis of Public Health Literature A Study Based on Scopus Database." Library Philosophy and Practice (e-Journal). https://digitalcommons.unl.edu/libphilprac/5105/

Islam, Md Nazmul, Md Shariful Islam, and Partha Biplob Roy. 2024. "A Bibliometric Technique for Analyzing Trends in Public Health Research." *Data Science and Informetrics* 4 (3): 89–103. https://doi.org/10.1016/j.dsim.2025.01.010.

Islam, Md Nazmul, Md Shariful Islam, and Partha Biplob Roy. 2025. "Citation Analysis of Global Public Health Literature." *Data Science and Informetrics.* 5 (2): 95–110. https://doi.org/10.1016/j.dsim.2025.08.004.

Janowicz, K., S. Gao, G. McKenzie, Y. Hu, and B. Bhaduri. 2020. "GeoAI: Spatially Explicit Artificial Intelligence Techniques for Geographic Knowledge Discovery and Beyond." *International Journal of Geographical Information Science* 34 (4): 625–636. https://doi.org/10.1080/13658816.2019.1684500.

Karmaoui, Ahmed, Adil Moumane, Samir el Jaafari, Aziza Menouni, Jamal Al Karkouri, Mohammed Yacoubi, and Lhoussain Hajji. 2023. "Thirty Years of Change in the Land Use and Land Cover of the Ziz Oases (Pre-Sahara of Morocco) Combining Remote Sensing, GIS, and Field Observations." *Land* 12 (12): 2127. https://doi.org/10.3390/land12122127.

Karmaoui, Ahmed, Samir el Jaafari, Hassan Chaachouay, and Lhoussain Hajji. 2023. "A Bibliometric Review of Geospatial Analyses and Artificial Intelligence Literature in Agriculture." *GeoJournal* 88 (S1): 343–360. https://doi.org/10.1007/s10708-023-10859-w.

Karmaoui, Ahmed. 2022. "Ordovician-Cambrian Palaeontological Heritage of Zagora Province: A Bibliometric Analysis from 1984 to 2020 (Anti-Atlas, Morocco)." *Geoheritage* 14 (2): 55. https://doi.org/10.1007/s12371-022-00695-8.

Kaur, J., E. Ferrara, F. Menczer, A. Flammini, and F. Radicchi. 2015. "Quality versus Quantity in Scientific Impact." *Journal of Informetrics* 9 (4): 800–808. https://doi.org/10.1016/j.joi.2015.07.008.

Kussul, Nataliia, Mykola Lavreniuk, Sergii Skakun, and Andrey Shelestov. 2017. "Deep Learning Classification of Land Cover and Crop Types Using Remote Sensing Data." *IEEE Geoscience and Remote Sensing Letters* 14 (5): 778–782. https://doi.org/10.1109/LGRS.2017.2681128.

Kyprioti, Aikaterini P., Alexandros A. Taflanidis, Norberto C. Nadal-Caraballo, and Madison Campbell. 2021. "Storm Hazard Analysis over Extended Geospatial Grids Utilizing Surrogate Models." *Coastal Engineering* 168: 103855. https://doi.org/10.1016/j.coastaleng.2021.103855.

Lu, Feng, Shifen Cheng, and Peixiao Wang. 2025. "GeoAI Enabled Urban Computing: Status and Challenges." *Annals of GIS* 31 (4): 537–555. https://doi.org/10.1080/19475683.2025.2552152.

Lundvall, A. 2025. "GeoAI Development in Global Competition: Navigating Challenges in Data, Resources, and Trust." Positio. https://positio-magazine.eu/2025/10/geoai-development-in-global-competition

Luppichini, Marco, Domenico Capolongo, Giovanni Scardino, Giovanni Scicchitano, and Monica Bini. 2025. "Artificial Intelligence in Geomorphology: A Bibliometric Analysis of Trends, Techniques, and Global Research Patterns." *Geosciences* 15 (9): 331. https://doi.org/10.3390/geosciences15090331.

Mai, Gengchen, Yiqun Xie, Xiaowei Jia, Ni Lao, Jinmeng Rao, Qing Zhu, and Zeping Liu. 2025a. "The Evolution of Geospatial Artificial Intelligence." In *GeoAI and Human Geography: The Dawn of a New Spatial Intelligence Era*, edited by Xiao Huang, Siqin Wang, John Wilson, and Peter Kedron, 13–27. Cham: Springer. https://doi.org/10.1007/978-3-031-87421-5_2.

Mai, Gengchen, Yiqun Xie, Xiaowei Jia, Ni Lao, Jinmeng Rao, Qing Zhu, Zeping Liu, Yao-Yi Chiang, and Junfeng Jiao. 2025b. "Towards the Next Generation of Geospatial Artificial Intelligence." *International Journal of Applied Earth Observation and Geoinformation* 136: 104368. https://doi.org/10.1016/j.jag.2025.104368.

Mathews, Douglas, L. Franzen-Castle, S. Colby, K. Kattelmann, M. Olfert, and A. White. 2015. "Use of Word Clouds as a Novel Approach for Analysis and Presentation of Qualitative Data for Program Evaluation." *Journal of Nutrition Education and Behavior* 47 (4): S26. https://doi.org/10.1016/j.jneb.2015.04.071.

Navinkumar, T. M., R. Ranjith Kumar, and P. V. Gokila. 2021. "Application of Artificial Intelligence Techniques in Irrigation and Crop Health Management for Crop Yield Enhancement." *Materials Today: Proceedings* 45: 2248–2253. https://doi.org/10.1016/j.matpr.2020.10.227.

Okolo, C. T. 2023. "Commentary: AI in the Global South: Opportunities and Challenges towards More Inclusive Governance." Brookings. https://www.brookings.edu/articles/ai-in-the-global-south-opportunities-and-challenges-towards-more-inclusive-governance

Olawade, David B., Ojima Z. Wada, Abimbola O. Ige, Bamise I. Egbewole, Adedayo Olojo, and Bankole I. Oladapo. 2024. "Artificial Intelligence in Environmental Monitoring: Advancements, Challenges, and Future Directions." *Hygiene and Environmental Health Advances* 12: 100114. https://doi.org/10.1016/j.heha.2024.100114.

Oluoch, I. 2024. "Crossing Boundaries: The Ethics of AI and Geographic Information Technologies." *ISPRS International Journal of Geo-Information* 13 (3): 87. https://doi.org/10.3390/ijgi13030087.

Peng, Yingshu, and Yi Wang. 2021. "An Industrial-Grade Solution for Agricultural Image Classification Tasks." *Computers and Electronics in Agriculture* 187: 106253. https://doi.org/10.1016/j.compag.2021.106253.

Pezanowski, S., E. L. Koua, J. C. Okeibunor, and A. S. Gueye. 2024. "Predictors of Disease Outbreaks at Continental-Scale in the African Region: Insights and Predictions with Geospatial Artificial Intelligence Using Earth Observations and Routine Disease Surveillance Data." *Digital Health* 10: 20552076241278939. https://doi.org/10.1177/20552076241278939.

Rajabifard, A., and I. P. Williamson. 2001. "Spatial Data Infrastructure (SDI), SDI Hierarchy, Partnerships, Culture for Sharing." GEOMATICS'80 Conference, Tehran, 29 April-2 May 2001.

Rejeb, A., K. Rejeb, and H. Treiblmaier. 2023. "Mapping Metaverse Research: Identifying Future Research Areas Based on Bibliometric and Topic Modeling Techniques." *Information* 14 (7): 356. https://doi.org/10.3390/info14070356.

Roy, Jagabandhu, and Sunil Saha. 2021. "Integration of Artificial Intelligence with Meta Classifiers for the Gully Erosion Susceptibility Assessment in Hinglo River Basin, Eastern India." *Advances in Space Research* 67 (1): 316–333. https://doi.org/10.1016/j.asr.2020.10.013.

Saleh, H. J. H., J. R. T. Arrang, and O. L. M. Cardoso. 2025. "Applications of Geospatial AI in Human Geography and Spatial Networks: A Literature Review." *EDRAAK* 2025: 76–84. https://doi.org/10.70470/EDRAAK/2025/010.

Salvacion, A. R. 2025. "Geospatial Information Research in the Philippines: A Bibliometric Analysis." *Spatial Information Research* 33 (5): 33-44. https://doi.org/10.1007/s41324-025-00642-z.

Schiuma, G., S. Kumar, R. Sureka, and R. Joshi. 2023. "Research Constituents and Authorship Patterns in the Knowledge Management Research and Practice: A Bibliometric Analysis." *Knowledge Management Research & Practice* 21 (1): 129–145. https://doi.org/10.1080/14778238.2020.1848365.

Schweitzer, Eva Johanna. 2025. "Digital Divide." Britannica. https://www.britannica.com/topic/digital-divide

Skute, Igors, Kasia Zalewska-Kurek, Isabella Hatak, and Petra de Weerd-Nederhof. 2019. "Mapping the Field: A Bibliometric Analysis of the Literature on University–Industry Collaborations." *Journal of Technology Transfer* 44 (3): 916–947. https://doi.org/10.1007/s10961-017-9637-1.

Song, Yongze, Margaret Kalacska, Mateo Gašparović, Jing Yao, and Nasser Najibi. 2023. "Advances in Geocomputation and Geospatial Artificial Intelligence (GeoAI) for Mapping." *International Journal of Applied Earth Observation and Geoinformation* 120: 103300. https://doi.org/10.1016/j.jag.2023.103300.

Space4Climate. 2023. "Space for Climate Observatory (SCO)." https://space4climate.com/sco_uk

Sughiarta, G., A. Kurnianingsih, S. R. Gopaladinne, S. Shrivastava, H. K. R. Gorla, and M. Böhlen. 2024. "GeoAI in Resource-Constrained Environments." 2024 Conference on AI, Science, Engineering, and Technology (AIxSET), 129–136. https://doi.org/10.1109/AIxSET62544.2024.00024.

Sweileh, Waleed M., Adham S. AbuTaha, Ansam F. Sawalha, Suleiman Al-Khalil, Samah W. Al-Jabi, and Sa'ed H. Zyoud. 2016. "Bibliometric Analysis of Worldwide Publications on Multi-, Extensively, and Totally Drug-Resistant Tuberculosis (2006–2015)." *Multidisciplinary Respiratory Medicine* 11 (1): 45. https://doi.org/10.4081/mrm.2016.351.

Talukdar, Swapan, Kutub Uddin Eibek, Shumona Akhter, Sk Ziaul, Abu Reza Md Towfiqul Islam, and Javed Mallick. 2021. "Modeling Fragmentation Probability of Land-Use and

Land-Cover Using the Bagging, Random Forest and Random Subspace in the Teesta River Basin, Bangladesh." *Ecological Indicators* 126: 107612. https://doi.org/10.1016/j.ecolind.2021.107612.

Tonnarelli, F., and L. Mora. 2025. "Responsible AI for Cities: A Case Study of GeoAI in African Informal Settlements." *Journal of Urban Technology* 32 (3): 111–137. https://doi.org/10.1080/10630732.2025.2450755.

Vaiyapuri, T., and G. Julie. 2025. "AI and Geospatial Technologies for Climate Change Mitigation: Opportunities, Challenges, and Pathways to Sustainability." *Procedia Computer Science* 259: 1346–1355. https://doi.org/10.1016/j.procs.2025.04.089.

Wang, Siqin, Xiao Huang, Pengyuan Liu, Mengxi Zhang, Filip Biljecki, Tao Hu, and Xiaokang Fu. 2024. "Mapping the Landscape and Roadmap of Geospatial Artificial Intelligence (GeoAI) in Quantitative Human Geography: An Extensive Systematic Review." *International Journal of Applied Earth Observation and Geoinformation* 128: 103734. https://doi.org/10.1016/j.jag.2024.103734.

Warner, D., S. Moonsammy, and J. Joseph. 2022. "Factors That Influence the Use of Climate Information Services for Agriculture: A Systematic Review." *Climate Services* 28: 100336. https://doi.org/10.1016/j.cliser.2022.100336.

Xia, J., N. Yokoya, and B. Adriano. 2022. "OpenEarthMap: A Benchmark Dataset for Global High-Resolution Land Cover Mapping." ArXiv. https://doi.org/10.48550/arXiv.2210.10732.

Xiang, Xiaojun, Qiong Li, Shahnawaz Khan, and Osamah Ibrahim Khalaf. 2021. "Urban Water Resource Management for Sustainable Environment Planning Using Artificial Intelligence Techniques." *Environmental Impact Assessment Review* 86: 106515. https://doi.org/10.1016/j.eiar.2020.106515.

Ye, Xinyue, Jiaxin Du, Xinyu Li, Shih-Lung Shaw, Yanjie Fu, Xishuang Dong, Zhe Zhang, and Ling Wu. 2025. "Human-Centered GeoAI Foundation Models: Where GeoAI Meets Human Dynamics." *Urban Informatics* 4 (1): 2. https://doi.org/10.1007/s44212-025-00067-x.

Yu, Yuetian, Yujie Li, Zhongheng Zhang, Zhichun Gu, Han Zhong, Qiongfang Zha, Luyu Yang, et al. 2020. "A Bibliometric Analysis Using VOSviewer of Publications on COVID-19." *Annals of Translational Medicine* 8 (13): 816–816. https://doi.org/10.21037/atm-20-4235.

Zhou, P., and L. Leydesdorff. 2007. "The Citation Impacts and Citation Environments of Chinese Journals in Mathematics." *Scientometrics* 72 (2): 185–200. https://doi.org/10.1007/s11192-007-1713-0.

Zhou, W., J. Cenci, and J. Zhang. 2024. "Systematic Bibliometric Analysis of the Cultural Landscape." *Journal of Asian Architecture and Building Engineering* 23 (3): 1142–1164. https://doi.org/10.1080/13467581.2023.2257276.

Zupic, I., and T. Čater. 2015. "Bibliometric Methods in Management and Organization." *Organizational Research Methods* 18 (3): 429–472. https://doi.org/10.1177/1094428114562629.