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Analyzing emerging trends in geospatial artificial intelligence through interpretable text mining

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Abstract

Geospatial Artificial Intelligence (GeoAI) has rapidly emerged as a multidisciplinary field that integrates geographic information systems, remote sensing, and artificial intelligence to address complex spatial problems. Applications of GeoAI now extend across environmental monitoring, urban planning, disaster management, healthcare, and sustainability analytics. This study investigates emerging trends and research directions in GeoAI through an interpretable text mining framework implemented in SAS Viya. A dataset consisting of 52 scholarly articles published between 2015 and 2025 was compiled from Google Scholar, arXiv, Semantic Scholar, and the United States Geological Survey (USGS). The analytical workflow incorporated domain-specific concepts, text parsing, topic discovery through Singular Value Decomposition (SVD), and rule-based categorization. Five major thematic categories were identified: Data Fusion and Integration, Environmental Monitoring, Methods Innovation, Remote Sensing Applications, and Urban Planning and Smart Cities. Each document was assigned a relevancy score based on category-specific rule matching, enabling systematic ranking and comparative analysis. The findings indicate strong research concentration in Methods Innovation and Remote Sensing Applications, reflecting increasing adoption of deep learning, neural networks, and scalable spatial analytics. Emerging interest in urban planning, sustainability, and multi-source data integration further demonstrates the expanding interdisciplinary nature of GeoAI research. The study highlights how automated text analytics combined with expert interpretation can provide meaningful insights into evolving research landscapes and technological developments in GeoAI.

Keywords: GeoAI, SAS Viya, geographic information systems, text mining, remote sensing, spatial analytics

Introduction

Geospatial Artificial Intelligence (GeoAI) represents an emerging frontier that combines geographic information science, spatial analytics, and artificial intelligence to address increasingly complex geographic and environmental challenges. By integrating machine learning, deep learning, remote sensing, and geographic information systems (GIS), GeoAI enables advanced analysis of spatial data for applications such as smart city development, environmental monitoring, disaster response, transportation systems, healthcare analytics, and land-use management.

The rapid growth of spatial data generated through satellites, sensors, drones, mobile devices, and social media platforms has significantly accelerated the development of GeoAI technologies. Organizations in both the public and private sectors increasingly rely on geospatial analytics to improve strategic planning, optimize operations, and support data-driven decision-making. At the same time, advances in artificial intelligence and high-performance computing have enabled the processing of large-scale geospatial datasets with greater speed and accuracy than traditional GIS methods.

As GeoAI continues to evolve, understanding its emerging trends, dominant applications, and methodological developments becomes increasingly important. However, the expanding volume of scholarly literature makes manual review and synthesis challenging. Automated text mining techniques provide an effective approach for identifying thematic patterns, research gaps, and technological shifts across large collections of academic publications.

This study applies SAS Viya text analytics tools to examine the evolving landscape of GeoAI research between 2015 and 2025. Through text parsing, concept extraction, topic modeling, and rule-based categorization, the study identifies dominant research themes, emerging technologies, and interdisciplinary applications within GeoAI literature. The objective is to provide a structured and interpretable overview of current developments and future directions in the field. Specifically, this study is guided by the following research questions:

RQ1: What are the dominant thematic categories in GeoAI research published between 2015 and 2025?

RQ2: How have the distribution and prominence of these themes shifted over time within the sampled corpus?

RQ3: Which methodological approaches and application domains are accelerating within the GeoAI literature, and where do notable gaps remain?

Literature Review

Geospatial Artificial Intelligence (GeoAI) has rapidly evolved into a transformative interdisciplinary field that extends beyond traditional geographic information systems and computational geography. The increasing availability of geospatial big data, combined with advances in machine learning and deep learning, has accelerated the adoption of GeoAI across numerous scientific and industrial domains.

VoPham et al. (2018) and Hu et al. (2019) emphasized that GeoAI integrates spatial science with artificial intelligence to solve complex geographic problems using data-intensive analytical methods. These approaches combine GIS, remote sensing, machine learning, and spatial statistics to improve predictive modeling and spatial decision-making.

Remote sensing and satellite imagery remain central to GeoAI applications. Oh et al. (2017) highlighted the importance of remote sensing technologies for land-use classification, climate analysis, and environmental monitoring. More recent studies by Rudewicz (2024) and Thakur et al. (2024) demonstrated how AI-driven spatial analysis enhances disaster management, ecosystem monitoring, and geospatial intelligence systems.

The increasing availability of heterogeneous spatial data sources has further expanded GeoAI capabilities. Social media data, volunteered geographic information (VGI), sensor networks, and mobile geolocation

data are increasingly integrated with traditional GIS datasets to support urban analytics, transportation modeling, public health analysis, and environmental assessment (VoPham et al., 2018; Hu et al., 2019). Machine learning techniques such as convolutional neural networks (CNNs), deep neural networks (DNNs), ensemble learning, and transformer-based architectures are now widely applied within GeoAI. Hu et al. (2019) demonstrated that spatially aware deep learning models significantly improve object detection, land-cover mapping, and spatiotemporal prediction accuracy. Similarly, Li et al. (2022) emphasized the growing role of machine vision and deep learning in large-scale image analysis for geographic applications. Recent research also highlights increasing interest in explainable and scalable GeoAI systems. Mai et al. (2025) discussed the future of GeoAI as an integration of multi-source data fusion, spatial reasoning, and foundation models capable of handling complex geographic representations. Zhang et al. (2025) further explored the emergence of geoscience foundation models trained on massive multimodal datasets to improve Earth system simulations and environmental forecasting.

Overall, the literature indicates that GeoAI is evolving toward more integrated, scalable, and intelligent systems capable of supporting sustainable development, urban planning, environmental protection, and public decision-making. These developments underscore the importance of systematic analysis of GeoAI research trends, which this study addresses through interpretable text mining techniques implemented in SAS Viya.

Data Collection

Research articles published between 2015 and 2025 were collected from multiple scholarly sources, including Google Scholar, arXiv, Semantic Scholar, and the United States Geological Survey (USGS). Both manual retrieval and API-based collection methods were employed to compile the dataset. While arXiv allowed unrestricted access to publications, Semantic Scholar required API authentication for metadata extraction.

Search Strategy

The search process utilized targeted keywords combined using Boolean operators to capture both methodological and application-oriented studies within the GeoAI domain. Two primary search strings were constructed: the first, (“GeoAI” OR “Geospatial Artificial Intelligence” OR “Spatial AI” OR “GIS AI”), identified the core research area, while the second, (“Trends in GeoAI” OR “Applications of GeoAI”) narrowed results toward review-oriented and applied studies. The two strings were combined using the AND operator and executed against each source through a custom Python script that automated query submission and metadata retrieval. 265+130 (e.g., Semantic Scholar), searches were limited to titles, abstracts, and author keywords. Google Scholar was queried using full-text search due to its more restricted API.

Inclusion and Exclusion Criteria

Articles were retained if they satisfied all inclusion criteria: (a) published between January 2015 and October 2025; (b) written in English; (c) peer-reviewed journal articles, conference proceedings, or preprints on established repositories (arXiv, USGS technical reports); and (d) substantively addressed the intersection of artificial intelligence or machine learning with geospatial data, geographic information systems, or remote sensing. Articles were excluded if they (a) were duplicates across databases; (b) discussed AI or GIS in isolation without a clear geospatial-AI intersection; (c) were editorials, book reviews, or short commentaries under three pages; or (d) could not be retrieved in full text.

Several steps were taken to mitigate selection bias. Multiple databases were queried to reduce over-reliance on a single indexing service, and both established venues and preprint repositories were included to capture rapidly emerging work. Inclusion decisions were guided by written criteria rather than ad hoc judgment, and borderline cases were flagged for a second review by another team member. The authors acknowledge that reliance on English-language sources and the use of database-specific relevance ranking (particularly in Google Scholar) may still bias the sample toward highly cited or English-language work.

The final dataset consisted of 52 scholarly articles and conference papers. For each document, metadata including title, publication year, authors, journal source, hyperlinks, and publication location were collected and stored in Microsoft Excel (Figure 1). Extracted textual content from abstracts, introductions, methodologies, and conclusions was also included for analysis. In cases where full-text documents exceeded spreadsheet limitations, key sections relevant to thematic analysis were selectively extracted. The compiled dataset was subsequently imported into SAS Viya for preprocessing, text parsing, and thematic analysis.

Title of Paper	Link to Paper	Authors	Number of Authors	Year published	Type of Paper (, Name of Journal/Conference	Text
GeoAI: spatially explicit artificial intelligence techniques forge	https://www.tandfonline	Krzysztof Janowicz, Song	5	2019	Journal	International Journal of Geographi
A five-year milestone: reflections on advances and limitations	https://www.tandfonline	Hu, Yingjie, Michael Good	10	2024	Journal	Annals of GIS
Geospatial Intelligence: A Comprehensive Review of Emerginc and Applications in 2024	https://ijrp.com/upload	Nitya Thakur, Aditya Virk,	3	2024	Journal	International Journal of Research I
Special Issue on the Recent Trends of GeoAI Techniques for SDGs	https://file.scipopen.com	FAN Hongchao, MENG Li , CHENG Tao	3	2024	Journal	Journal of Geodesy and Geoinform
Advancing AI-Driven Geospatial Analysis and Data Generativ	https://www.mdpi.com/	Hartwig H. Hochmair 1,Le	3	2025	Journal	International Journal of Geo-Inform
GeoAI for Large-Scale Image Analysis and Machine Vision: F	https://www.mdpi.com/	Wenwen Hi, Chia-Yu Hsu	2	2022	Journal	International Journal of Geo-Inform
A review of spatially-explicit GeoAI applications in Urban Geo	https://www.sciencedir	Pengyuan Liu, Filip Biljeć	2	2022	Journal	International of Applied Earth Observa
GeoAI: Intergration of Artificial Intelligence, Machine Learning	https://www.mdpi.com/	Yosoon Choi	1	2023	Journal	Applied Sciences
Advances in geocomputation and geospatial artificial intellige	https://www.sciencedir	Yongze Song, Margaret K	5	2023	Journal	International Journal of Applied Ea
						Geospatial Artificial Intel
Towards the next generation of Geospatial Artificial Intelligenc	https://www.sciencedir	Gengchen Mai, Yiqun Xie	9	2025	Journal	Geospatial Artificial Intel Remote Sensing (RS) pl
Emerging Technology Trends in Geocomputation Methods: A	https://link.springer.co	Simone Corrado and Fran	2	2023	Conference	International Conference on Comp
						The main focus of this s
GeoAI at ACM SIGSPATIAL: Progress, Challenges, and Fut	https://dl.acm.org/doi/1	Yingjie Hu, Song Gao, Da	6	2019	Conference	ACM SIGSPATIAL
						Geospatial artificial intell While the field of artificia ACM SIGSPATIAL 2017
						Many global challenges
						In recent years, Geospa Artificial intelligence (AI Having identified resear
A comprehensive GeoAI review: Progress, Challenges and C	https://arxiv.org/abs/24	Anasse Boutayeb, Iyad La	3	2024	Preprint	arXiv
						Terms such as learning, AI-in-the-Loop Planning
						The rise of Electric Vehic
						Brooks [5] categorized p
AI-in-the-Loop Planning for Transportation Electrification: Cas	https://arxiv.org/abs/25	Seung Jun Choi	1	2025	Preprint	arXiv
						This study presents mu

Figure 1: Research Articles Snapshots.

SAS Viya, a cloud-native analytics platform, was used to process scholarly publications and extract latent semantic structures that reveal thematic patterns in GeoAI research. Figure 2 shows a typical text analytics pipeline in Sas Viya. The workflow began with importing the dataset from Excel, where the text column was designated as the primary variable. A “concepts” node was introduced to define domain-specific phrases and synonyms, enriching the analysis and bridging raw text with parsing. In the “text parsing” stage, documents were tokenized, parts of speech identified, and domain terms managed, producing a structured representation of the corpus and enabling term maps (Figure 3) to visualize relationships such as “AI model,” “urban,” and “climate.” The parsed data was then transformed into a term-document frequency

matrix, and Singular Value Decomposition (SVD) was applied to reduce dimensionality and uncover latent topics. These topics were refined through domain expertise into five categories: Data Fusion and Integration, Environmental Monitoring, Methods Innovation, Remote Sensing Applications, and Urban Planning/Smart Cities using Boolean rules to classify documents and calculate relevancy scores.

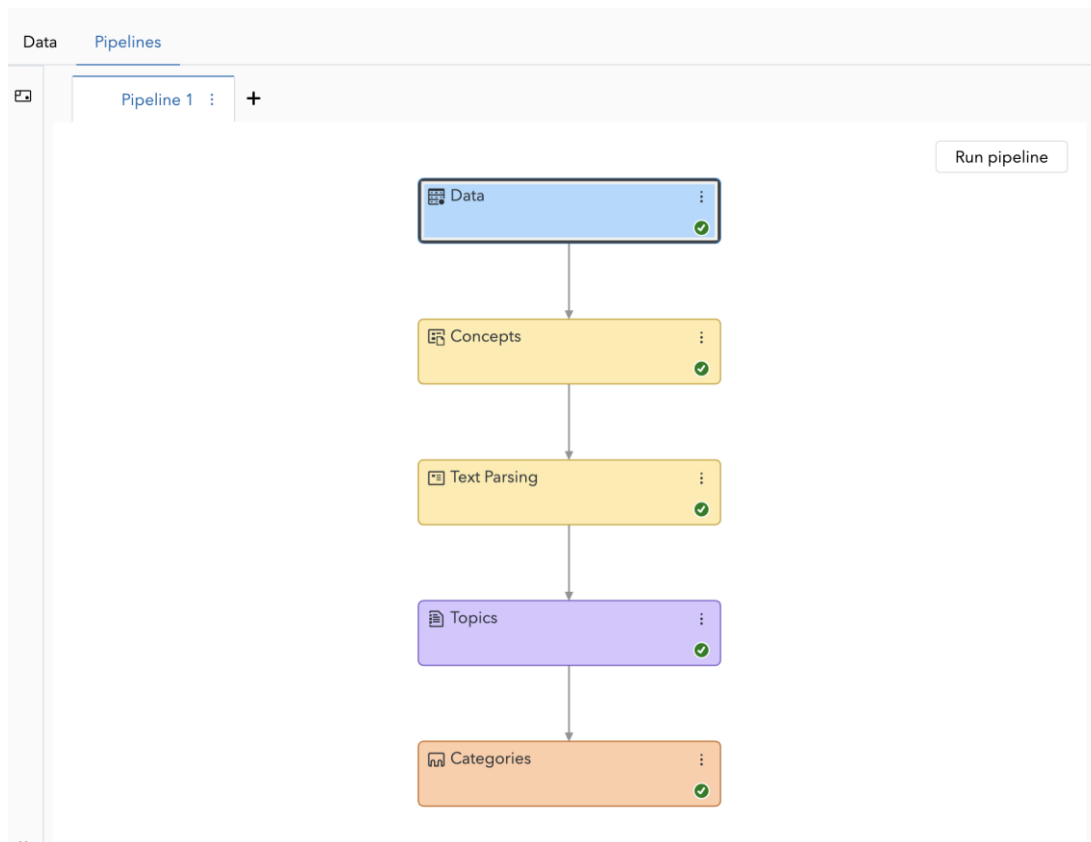


Figure 2: Text analytics pipeline in SAS Viya.

Category Rule Development

Category definitions were developed through a two-step process. First, the SVD topic output was inspected by the research team to identify recurring semantic clusters. Second, each cluster was mapped to a candidate category label informed by the reviewed literature. For each category, a Boolean rule was authored in the SAS Viya Categories node, combining primary terms (which must appear) with supporting terms (which contribute to the score when co-present). Table 1 summarizes the rule structure used for each of the five categories.

Table 1. Category rules used in the SAS Viya Categories node.

Category	Boolean Rule (Simplified)	Representative Terms
Data Fusion and Integration	(fusion OR integration OR multi-source OR multimodal)	data fusion, integration, multimodal, heterogeneous data, sensor networks, VGI
Environmental Monitoring	(environmental OR ecosystem OR climate OR pollution OR deforestation)	environmental monitoring, climate, ecosystem, land cover, deforestation, pollution
Methods Innovation	(deep learning OR explainable AI OR convolutional neural network OR self-supervised learning)	deep learning, CNN, transformer, foundation model, neural network, architecture
Remote Sensing Applications	(“remote sensing” OR satellite imagery OR earth observation OR change detection)	remote sensing, satellite imagery, semantic segmentation, object detection, land use
Urban Planning and Smart Cities	(urban OR city OR “smart city” OR “urban growth”)	urban planning, smart city, mobility, generative AI, spatial simulation

The relevancy score for each document-category pair was computed by SAS Viya as the sum of matches to the terms specified in the rule, with each unique matching term contributing to the score. A document could be assigned to more than one category when its content satisfied multiple rules, which was expected given the interdisciplinary nature of GeoAI. Scores were subsequently used to rank documents within each category for closer inspection (Figure 5).

Rule Validation

To assess the validity of the rule-based classifier, a random sample of 15 articles (approximately 29% of the corpus) was independently labeled by a human against the five categories. Manual labels were then compared to the SAS Viya assignments. Agreement was measured qualitatively at this exploratory stage; the rule-based system correctly identified the primary category for 13 of the 15 sampled articles. Discrepancies were reviewed, and category rules were revised to incorporate additional supporting terms where systematic gaps were observed. In parallel, rule-based assignments were cross-checked against the SVD topic distribution to confirm alignment between the unsupervised structure of the corpus and the supervised rule outputs.

Results/Findings

The SAS Viya workflow successfully revealed thematic patterns in GeoAI literature by progressing from concepts to text parsing to topic discovery and categorization. The concepts stage enriched analysis by linking domain-specific terms, while text parsing structured the corpus and highlighted contextual relationships. Topic discovery through SVD uncovered latent themes, which were refined into categories representing major research directions. The resulting topics (Figure 4) included both system-generated and user-defined themes such as urban planning, deep learning models, environmental exposure, and spatial

representation, providing a clear foundation for identifying and analyzing emerging trends in GeoAI research.

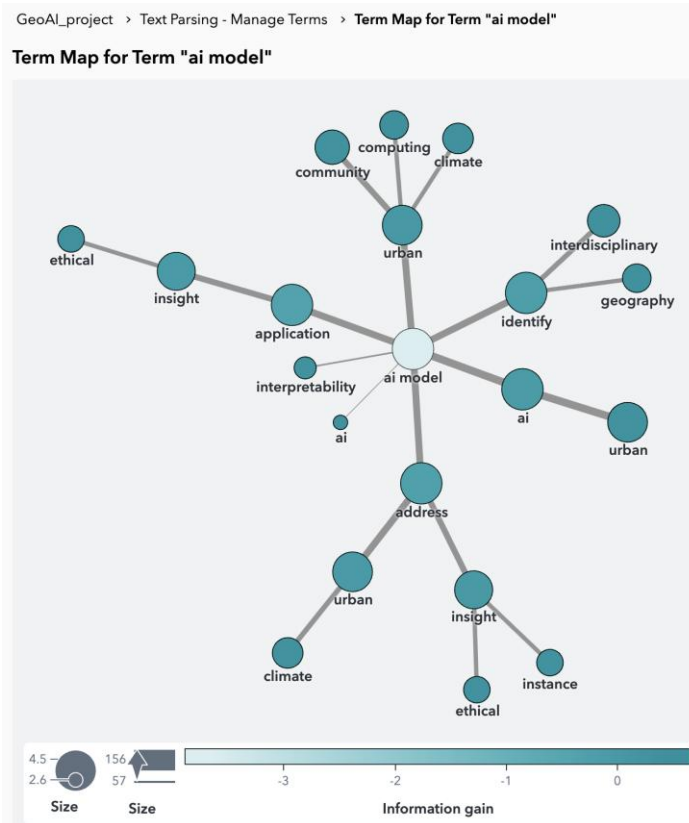


Figure 3: Term Map of AI model

GeoAI_project > Topics

Topics

Topics (16)

Topic	Created by
☐ urban, planning, ai, +technology, ai	System
☐ data, geospatial, +disaster, +propose, +event	System
☐ +encode, spatial, +space, +representation, +task	System
☐ +question, +reuse, arti, +moonshot, +spatially explicit model	System
☐ +event, knowledge, knowledge-driven, +knowledge graph, +graph	System
☐ +workshop, learning, +image, +geography, ai	System
☐ deep learning, +geoai model, big data, +neural network, environmental	User
☐ +exposure, health, +big, environmental, geoai	System
☐ +fine-tune, model, +foundation, +model,	System

Figure 4: Topics Generated by System and User

In the categories node, each research article was scored based on rule-based term matches, with the score representing the total frequency of category-specific keywords found in the text (Figure 5). Research papers on generative AI in urban contexts scored highly under Urban Planning, while those discussing satellite

imagery and object detection were grouped under Remote Sensing. This output validates the effectiveness of the category rules and highlights the diversity of GeoAI research themes.

"Categories" Results

Summary Output Data

Data sources

Output Tables

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__uniqueid__	Text	Category N...	keywords	Score	Category le...	Title of Paper
1701	The two fields of urban planning and artificial ...	Urban planning smart cities	urban planning urban planning urban planning...	49	Urban planning smart cities	Generative AI Meets Future Cities: Towards...
1002	Experts have extensively explored the ...	Remote Sensing Applications	Object detection Object Detection ...	30	Remote Sensing Applications	A Review of the Integration Between ...
601	GeoAI, or geospatial artificial ...	Methods_innovat ion	deep learning convolutional neural network...	30	Methods_innovat ion	GeoAI for Large-Scale Image Analysis and ...
1602	There are growing opportunities t...	Data fusion and integration	satellite Sensor satellite satellite satellite sens...	23	Data fusion and integration	Data Acquisition and Processing for GeoAI ...
2002	GeoAI is a new emerging research area ...	Remote Sensing Applications	object detection object detection remote sensin...	17	Remote Sensing Applications	Geospatial Artificial Intelligence ...
1602	There are growing opportunities t...	Remote Sensing Applications	remote sensing satellite imagery satellite imager...	17	Remote Sensing Applications	Data Acquisition and Processing for GeoAI ...
2102	Over the years, early detection of forest and land	Data fusion and integration	satellite satellite satellite satell...	16	Data fusion and integration	Geospatial Artificial Intelligence for

Figure 5: Categories sorted by relevancy score

Figure 6 shows that within this corpus, Methods Innovation and Remote Sensing Applications dominate with 42 matches each, followed by Data Fusion and Integration with 38, while Urban Planning and Environmental Monitoring are moderately represented. Within the limits of a 52-article sample, this pattern points to the most active research areas surfaced by the category rules in SAS Viya. To identify emerging trends, a focused literature review was conducted on the three papers with the highest relevancy scores in each category.

Categories	Terms	# of Matches in Documents
Data fusion and integration	satellite", "sensor", "heterogeneous", "multi-modal"	38
Environment monitoring	"environmental monitoring", "climate change", "pollution detection", "sustainability assessment"	19
Methods innovation	"deep learning", "explainable AI", "self-supervised learning", "convolutional neural network"	42
Remote Sensing Applications	"remote sensing", "satellite imagery", "earth observation", "land cover classification", "change detection", "object detection"	42
Urban planning	"urban planning", "city planning", "smart cities", "urban growth", "infrastructure planning", "transportation networks"	23

Figure 6: Frequency of Rule-based Term Matches per Category

Category 1: Data fusion and integration

This category highlights how GeoAI relies on data fusion and integration by combining diverse geospatial sources; satellite imagery, sensor networks, volunteered Geographic Information to improve model

accuracy and support decision making in sustainability, healthcare, etc. García Pereira et al. (2020), emphasizes the challenge of transforming raw Earth observation data from multiple satellites and sensors into high-quality labeled datasets suitable for deep learning models. This process exemplifies data fusion, as it integrates heterogeneous imagery with varying spatial, spectral, and temporal resolutions to support sustainable farming decisions. Similarly, Purbahapsari et al. (2022), demonstrates integration by training AI models on Sentinel-2 satellite imagery and overlaying results with forest area and company concession maps. This fusion of satellite data with contextual land-use information improves fire detection accuracy and supports rapid response and enforcement. The third paper, Sahana (2022), extends the concept of data fusion into public health by combining geospatial datasets (such as environmental exposure, population distribution, and healthcare infrastructure) with AI models to identify health risks and improve resource allocation. Collectively, these papers highlight the importance of synthesizing heterogeneous data into usable formats for AI models, showing that integration is central to GeoAI's effectiveness across domains.

Category 2: Environment Monitoring

GeoAI and advanced geospatial intelligence techniques are increasingly being applied to environmental monitoring, emphasizing the integration of AI, big data, and foundation models to track, analyze, and predict environmental changes. Thakur et al. (2024), underscores how GeoAI has transformed environmental monitoring by enabling multi-temporal analysis of satellite imagery to detect land use and land cover changes, track deforestation, and assess ecosystem health. Hosen et al. (2023) highlight how big data platforms and AI algorithms enhance spatial analytics for environmental applications. By integrating heterogeneous datasets (satellite imagery, sensor data, and socio-environmental information), these systems provide decision support for managing natural resources, monitoring pollution, and addressing environmental risks. Zhang et al. (2025), focus on the emergence of geoscience foundation models (GFM) that integrate massive, multi-modal datasets to simulate Earth system dynamics. These models leverage transformers and pre-training strategies to capture complex environmental processes, offering improved predictions of climate patterns, ecosystem responses, and environmental hazards. They collectively highlight the role of multi-source data fusion, advanced analytics, and scalable AI architectures in addressing global challenges such as climate change, deforestation, and resource management.

Category 3: Methods Innovation

The third category, Methods Innovation, encompasses the different innovative applications and methods that have been used to advance GeoAI and geospatial information systems. For this category, the top three article's scores were 30, 14 and 13. In the first article, "GeoAI for Large-Scale Image Analysis and Machine Vision: Recent Progress of Artificial Intelligence in Geography" (Li & Hsu, 2022), the main methods discussed were neural network methods like shallow machine learning and deep learning, which are used increasingly for GeoAI applications. The second article: "GeoAI at ACM SIGSPATIAL: The New Frontier of Geospatial Artificial Intelligence Research" (Lunga et al., 2022), highlights innovations such as new geospatial data infrastructures, and the use of unsupervised learning to reduce the need for labeled data. The article "A Review of Spatially-Explicit GeoAI applications in Urban Geography" (Liu & Biljecki, 2022) discusses the use of Deep neural networks and location encoding as methods for GeoAI. Across these three articles, the most notable methodological trend is the increasing adoption of neural network methods, especially deep learning.

Category 4: Remote Sensing Applications

This category explores the different types of applications that GeoAI enables through remote sensing methods. In the article "A Review of the Integration Between Geospatial Artificial Intelligence and Remote Sensing", which had a score of 30, Alshiha (2024) provides examples of how AI algorithms, particularly deep learning, enhance tasks such as semantic segmentation, object detection, and defect detection across various geospatial data types. In "Data Acquisition and Processing for GeoAI Models to Support

Sustainable Agriculture Practices,” García Pereira et al. (2020) focus on ways to utilize GeoAI’s remote sensing capabilities through maps creation, land use mapping, geological processes, navigation and place-based studies. In “Geospatial Artificial Intelligence (GeoAI): Applications in healthcare,” Sahana et al. (2022) note several remote sensing applications for healthcare, including identifying air quality, urban planning, and managing natural catastrophes.

Category 5: Urban Planning Smart Cities

This category focuses on how GeoAI is being used in supporting city planning. Wang et al. (2025) discuss how using GeoAI and image generation can generate the optimal or near-optimal community geospatial configuration. In “Leveraging Artificial Intelligence and Big Data for Advanced Spatial Analytics and Decision Support Systems in Geography,” Hosen et al. (2023) describe AI and geospatial data as valuable tools for identifying areas with the highest potential for development, as well as projecting future urban scenarios to help formulate sustainable urban development plans. In “Geospatial Intelligence: A Comprehensive Review of Emerging Trends and Applications in 2024,” Thakur et al. (2024) discuss one of the most significant developments in using GeoAI in urban geography: predictive algorithms integrated with GIS data to simulate urban growth scenarios.

Additional findings

Further analysis of the results by year of publication (Figure 7) reveals emerging trends in GeoAI research. There were quite a number of research papers published in 2025, indicating a strong surge of interest in GeoAI applications. The “Methods Innovation” category shows the highest relevancy score (13) for the research paper, “Artificial Intelligence in Landscape Ecology: Recent Advances, Perspectives, and Opportunities” (Frazier & Song, 2025). This suggests that methodological advancements such as deep learning and explainable AI feature prominently in the most recent portion of the corpus. The paper, “Towards the Next Generation of Geospatial Artificial Intelligence” by Mai et al. (2025) appears across multiple categories including Remote Sensing Applications, Data Fusion and Integration, and Urban Planning, reflecting its interdisciplinary relevance and the growing convergence of GeoAI techniques across domains. The Methods Innovation and Remote Sensing Applications are the most actively explored categories in recent publications, pointing to a shift toward technical development and scalable geospatial analysis in the current research landscape.

"Categories" Results

Summary Output Data

Data sources

Output Tables

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Score	Category le...	Title of Paper	Link to Paper	Authors	Number of ...	↓ Year publi...
10	Remote Sensing Applications	Towards the next generation of Geospatial ...	https://www.sciencedirect.com/science/article/pii/...	Gengchen Mai, Yiqun Xie, Xiaowei Jia, Ni ...	9	2025
13	Methods_innovation	Artificial Intelligence in Landscape ...	https://link.springer.com/article/10.1007/s40823...	Amy E. Frazier, Lei Song	2	2025
3	Urban planning smart cities	Applications of Geospatial AI in Human ...	https://peninsula.press.ae/Journ...	Huda Jassim Haseeb Saleh, Judith Ratu Tan...	3	2025
3	Remote Sensing Applications	Applications of Geospatial AI in Human ...	https://peninsula.press.ae/Journ...	Huda Jassim Haseeb Saleh, Judith Ratu Tan...	3	2025
1	Methods_innovation	Towards the next generation of Geospatial ...	https://www.sciencedirect.com/science/article/pii/...	Gengchen Mai, Yiqun Xie, Xiaowei Jia, Ni ...	9	2025
3	Data fusion and integration	Towards the next generation of Geospatial ...	https://www.sciencedirect.com/science/article/pii/...	Gengchen Mai, Yiqun Xie, Xiaowei Jia, Ni ...	9	2025
3	Urban planning smart cities	Towards the next generation of Geospatial ...	https://www.sciencedirect.com/science/article/pii/...	Gengchen Mai, Yiqun Xie, Xiaowei Jia, Ni ...	9	2025

Figure 7: Categories sorted by Year of Publication

Temporal Shifts Across the 2015–2025 Window

To examine RQ2 more directly, the corpus was segmented into three publication windows: 2015–2018 (early GeoAI period), 2019–2022 (deep learning consolidation), and 2023–2025 (foundation-model era). Within the sample, the early window is dominated by Remote Sensing Applications and Environmental Monitoring, reflecting traditional GIS and satellite-driven work. The middle window shows a marked rise in Methods Innovation as convolutional and deep neural network architectures become standard. The most recent window shows continued strength in Methods Innovation but with a distinct shift toward multi-source fusion, transformer-based models, and generative approaches, alongside noticeably increased representation of Urban Planning and Smart Cities. These patterns should be interpreted as descriptive of the sampled corpus rather than as claims about the entire GeoAI literature.

Accelerating and Underrepresented Themes

Themes that appear to be accelerating within the sample include foundation and geoscience foundation models (Zhang et al., 2025), generative approaches applied to urban configuration (Wang et al., 2023), and multimodal data fusion (Mai et al., 2025). Conversely, several topics appear underrepresented in the corpus and warrant deliberate future attention: explainable and interpretable GeoAI beyond post-hoc techniques; fairness, equity, and ethical implications of geospatial predictions and privacy and governance for location data. The relative scarcity of these topics in a 52-article sample does not imply their absence from the broader field, but it does highlight where a targeted follow-up review could contribute.

Interpretation with Respect to Sample Size

Because the analysis is based on 52 articles, category counts and temporal shifts should be read as indicative rather than conclusive. Small changes in inclusion decisions or search terms could shift relative category weights, particularly for categories with modest match counts. The trends reported above are therefore framed as patterns observed within the sampled corpus that motivate further, larger-scale investigation rather than as generalized statements about the entire GeoAI research landscape.

Limitations and future directions

Several limitations should be considered in this study. Due to time constraints, the dataset was limited to 52 research articles. A larger corpus containing over 100 publications would provide broader thematic coverage and improve the robustness of trend analysis.

Additionally, the study relied primarily on abstracts and selected document sections rather than complete full-text analysis. Future research will incorporate larger-scale datasets, automated full-text extraction, and advanced natural language processing methods such as transformer-based topic modeling and citation network analysis.

Future studies may also explore explainable AI techniques, multimodal geospatial learning, and real-time spatial intelligence systems to better understand evolving GeoAI applications.

Conclusion

GeoAI continues to grow as a rapidly evolving interdisciplinary field driven by advances in artificial intelligence, remote sensing, and spatial analytics. This study demonstrated how SAS Viya text analytics can be used to systematically identify emerging trends, applications, and methodological developments within a curated GeoAI corpus, and it responded to the three research questions posed at the outset.

With respect to RQ1, five thematic categories organize the majority of the sampled literature, with Methods Innovation and Remote Sensing Applications receiving the largest share of category matches. With respect to RQ2, category prominence shifts noticeably across the 2015–2025 window: from remote sensing and environmental monitoring in the earlier years, to deep-learning-driven methods innovation in the middle years, and toward foundation models, multimodal fusion, and generative urban applications in the most recent period. With respect to RQ3, methodological approaches centered on transformers, foundation models, and multi-source fusion appear to be accelerating within the corpus, while explainability, ethics, privacy, and Global South applications remain underrepresented.

Implications for Research

For researchers, the results suggest that continued methodological work on deep learning and foundation models has room to grow but should be paired with explicit attention to explainability, uncertainty quantification, and evaluation on heterogeneous geographic contexts. The dispersion of highly ranked papers such as Mai et al. (2025) across multiple categories also indicates that interdisciplinary framings which combine methods innovation with concrete application domains tend to attract broader relevance and may represent a productive direction for future work.

Implications for Practice

For practitioners in domains such as environmental management, urban planning, and public health, the findings underscore that GeoAI is transitioning from experimental methods to operational tools. Practitioners should expect increased availability of geospatial foundation models and pre-trained architectures that can be adapted to local data, and should correspondingly invest in the data-fusion pipelines, labeling workflows, and evaluation processes required to deploy such tools responsibly.

Implications for the Field

At a field level, the observed convergence between AI methods and geospatial application areas suggests that GeoAI is maturing from a collection of adjacent techniques into a more cohesive research program organized around scalable, multimodal, and interpretable systems. Future editions of this analysis, applied to a larger corpus and combined with citation-based methods, could formalize this trajectory and support strategic prioritization by funders and research programs.

By combining automated text mining with expert interpretation, this study provides an interpretable overview of GeoAI research trends observed between 2015 and 2025 within the sampled corpus. As geospatial technologies and AI capabilities continue to advance, GeoAI is well-positioned to play an increasingly important role in sustainable development, environmental management, smart city planning, and spatial decision-making, provided that methodological progress is accompanied by attention to transparency, ethics, and equitable application.

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