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The Application Progress of Big Data in Land System Research: Based on the Web of Science Database

Huiqing HAN, Yingjia ZHANG, Changying YIN – Guiyang, PR China[1]

ABSTRACT. With the rapid development of information technology, big data has become a vital driving force in land system research. Based on the Web of Science Core Collection database, this study adopts bibliometric methods combined with visualization tools such as CiteSpace and VOSviewer to systematically review the application evolution, research hotspots, and collaboration networks of big data technology in land system studies. A total of 317 relevant articles published between 2013 and 2024 were selected and analyzed from the perspectives of annual publication trends, keyword co-occurrence, author-institution collaboration networks, and thematic clustering. The results reveal that big data applications in land system research have undergone a transition from initial exploration to rapid growth and are now entering a mature stage. Research themes have expanded from early land use change detection to broader areas including ecosystem service evaluation, urban expansion simulation, agricultural monitoring, and carbon emission analysis. Practical applications frequently utilize remote sensing data, geographic information systems, machine learning, and artificial intelligence to support spatial modeling, predictive analysis, and land planning tasks. The study also finds that the Chinese Academy of Sciences ranks among the global leaders in terms of research output and collaborative influence, with research institutions displaying a "core–periphery" structure. Keyword evolution indicates an increasing trend toward intelligent technological methods and interdisciplinary integration. This study contributes to a better understanding of

[1] Prof. Huiqing Han, PhD, School of Architecture and Urban Planning, Guizhou Institute of Technology, Guiyang, PR China, e-mail: hhuiqing2006@126.com
Prof. Yingjia Zhang, PhD, School of Architecture and Urban Planning, Guizhou Institute of Technology, Guiyang, PR China, e-mail: zyj575657@163.com
Prof. Changying Yin, PhD, School of Architecture and Urban Planning, Guizhou Institute of Technology, Guiyang, PR China, e-mail: 420451331@qq.com

the co-evolution of big data and land system research and provides systematic references and theoretical support for future academic research, policy-making, and spatial governance.

Keywords: Big data; Land system, Bibliometric analysis, CiteSpace/VOSviewer, Research hotspots, Evolution pathways.

1. Introduction

Against the backdrop of rapid advances in information technology, Big Data is permeating natural and social sciences at an unprecedented speed and scale, reshaping traditional research paradigms (Lazaros et al. 2025, Dritsas and Trigka 2025). As the core carrier of interactions between human activities and the natural environment, the study of land systems increasingly highlights characteristics of complexity, systemicity, and dynamism. Issues such as Land Use/Land Cover Change, land use efficiency, urban–rural spatial transformation, and ecosystem service changes are profoundly influenced by natural factors and shaped by socio-economic conditions, policy mechanisms, and technological innovation (Erb et al. 2024, Chen et al. 2025). In this context, where multi-source data integration and cross-scale analysis are becoming increasingly vital, big data technologies offer unprecedented support for land system research, with their application prospects and challenges gradually becoming a central focus of academic inquiry (Yin et al. 2025).

In recent years, a wide array of big data types – including remote sensing imagery, geographic information systems, social media data, satellite navigation data, Internet of Things data, statistical yearbooks, and policy documents – have been extensively applied in land system research. These data types have expanded both spatial and temporal research scales and enhanced the ability to interpret and predict complex system evolution processes (Mohammad El-Basioni et al. 2024, Behera et al. 2025). At the same time, big data–driven modeling and empirical analysis, empowered by machine learning, artificial intelligence, and high-performance computing, are gradually replacing traditional field surveys and sample-based statistics, achieving significant results in areas such as land use change prediction, land planning optimization, ecological risk warning, and carbon emission evaluation (Mukhopadhyay et al. 2025).

Given this background, bibliometrics – a quantitative tool for analyzing the development and research trends of disciplines – has in recent years been widely applied to construct scientific knowledge maps, trace research evolution paths, and examine interdisciplinary integration (Jiang et al. 2025). By analyzing publication trends, keyword co-occurrence, author collaboration networks, citation relationships, and thematic clusters, bibliometric methods can systematically reveal the evolutionary trajectory, research frontiers, and future trends of big data applications in land system studies. This approach provides researchers with a comprehensive cognitive framework and strategic guidance (Li et al. 2023).

Previous studies have employed bibliometric methods to review topics such as land use change, urban expansion, and ecosystem service assessment, and have explored the evolution of research techniques such as remote sensing and artificial intelligence (Cheng et al. 2021, Zhu et al. 2025). For example, Chen et al. (2025) used CiteSpace to analyze the key pathways in land use/land cover change research and pointed out that the diversification of data sources and the intelligentization of methodological systems are key directions for future development. Jiang et al. (2024), in their analysis of land use efficiency studies, noted that the introduction of big data technologies has enhanced research precision and scope, though more work is needed in mechanism analysis and policy linkage. Despite these efforts, there remains a lack of systematic bibliometric reviews focusing specifically on the application of big data in land system research, particularly those offering comprehensive analysis of application domains and hotspot trends.

In response, this study – drawing on the Web of Science Core Collection and utilizing bibliometric methods and visualization tools (such as CiteSpace and VOSviewer – systematically reviews and analyzes the evolution, research hotspots, key authors, and institutional collaboration networks in the application of big data technologies to land system research. It aims to address the following core questions: (1) What is the trajectory of big data application in land system studies? What are the characteristics of its developmental stages, growth trends, and thematic shifts? (2) What are the current research hotspots? How do their spatial scales, study subjects, and application scenarios vary? (3) What research gaps and challenges remain? Which research directions and technological pathways should be prioritized in the future?

Through this analysis, the objectives of the study are threefold: First, to provide the academic community with a comprehensive overview of the interdisciplinary field of big data and land systems, identifying research frontiers and emerging trends; Second, to offer an efficient reference system for future researchers seeking literature and knowledge resources; Third, to support policymakers and practitioners with theoretical insights and technical guidance, thereby enhancing the scientific, forward-looking, and intelligent governance of land systems. In summary, the key innovation of this study lies in integrating bibliometric analysis with the interdisciplinary field of big data and land system research, overcoming the thematic and methodological limitations of previous reviews. It offers a systematic analytical framework and empirical foundation for understanding the knowledge evolution and research paradigms of this domain. We hope this research provides valuable insights for the future integration of big data resources, methodological optimization, and interdisciplinary collaboration in land system studies.

2. Research Methods

2.1. Data Source and Dataset Construction

This study employs the Web of Science (WOS) as the sole literature source for bibliometric analysis. WOS is widely recognized as one of the most authoritative and standardized academic databases for scientometric and knowledge mapping studies because of its rigorous journal selection criteria, comprehensive citation indexing system, and compatibility with bibliometric software such as CiteSpace and VOSviewer (Xue et al. 2024). Compared with other databases, WOS provides highly standardized bibliographic records and complete citation information, which are essential for co-citation analysis, keyword clustering, and temporal evolution analysis. Therefore, it has been extensively adopted in bibliometric research across environmental science, geography, and land system science.

To improve the comprehensiveness and accuracy of the dataset, the search strategy was refined by combining core concepts related to both "big data" and "land systems." The retrieval was conducted in June 2025 using the Topic Search (TS), which includes the Title, Abstract, Author Keywords, and Keywords Plus fields. The final search query was as follows:

TS = (("big data" OR "data mining" OR "machine learning" OR "artificial intelligence" OR "remote sensing big data" OR "geospatial big data" OR "spatial data" OR "GIS" OR "deep learning") AND ("land system*" OR "land use" OR "land cover" OR "land management" OR "land change" OR "landscape" OR "urban land" OR "rural land" OR "territorial space"))

The publication period was limited to 2013–2024, and only articles and review papers written in English were included. The initial retrieval yielded 486 records. To ensure the reliability and relevance of the dataset, several filtering procedures were conducted. First, duplicated records and publications with incomplete bibliographic information were removed. Second, irrelevant studies unrelated to land system research were excluded through manual screening of titles, abstracts, and keywords. Third, conference abstracts, editorial materials, book reviews, and non-English publications were excluded. After the screening process, a final dataset of 317 high-quality publications was retained for subsequent analysis (Table 1).

Table 1. *Summary of data sources and selection criteria.*

Category Specific	Specific Standard Requirements
Research database	Web of science core collection
Searching period	January 2013 to December 2024
Language	"English"
Searching keywords	("big data") and ("land")
Document types	"Articles" and "Review Articles"
Data extraction	Export with full records and cited references in plain text format
Sample size	317

2.2. Research framework and analytical methods

This study integrates bibliometric analysis and scientific knowledge mapping to systematically investigate the development trajectory, knowledge structure, research hotspots, and frontier trends of big data applications in land system research (Pang et al. 2025). The analytical framework was designed to correspond directly to the research questions regarding publication evolution, collaboration patterns, thematic structures, and emerging research frontiers.

Bibliometric analysis

Bibliometric analysis was employed to address the research question concerning the developmental characteristics and academic influence of big data applications in land system studies. Statistical analyses were conducted on annual publications, citation frequencies, source journals, countries, institutions, and authors. Specifically, the following analyses were performed:

- annual publication trend analysis: to reveal the temporal growth trajectory and developmental stages of the field from 2013 to 2024,
- author and institutional collaboration analysis: to identify influential scholars, major research institutions, and collaborative relationships,
- source journal analysis: to determine the major publication outlets and disciplinary distribution of the research,
- highly cited literature analysis: to identify foundational studies and key theoretical contributions.

Keyword co-occurrence and clustering analysis

Keyword co-occurrence analysis was used to explore the thematic structure and core research topics of the field. Both Author Keywords and Keywords Plus were extracted and analyzed to identify high-frequency terms and their association strength. Co-occurrence matrices were generated using VOSviewer, and keyword clustering was performed using the Log-Likelihood Ratio (LLR) algorithm in CiteSpace.

To identify the dynamic evolution of research themes, timeline visualization and burst detection analyses were conducted. These analyses enabled the identification of shifting research priorities and emerging topics over different periods, thereby addressing research questions related to thematic evolution and frontier development.

Scientific knowledge mapping and visualization

Two complementary bibliometric visualization tools, CiteSpace and VOSviewer, were used to construct scientific knowledge maps and network visualizations.

In CiteSpace, the parameter settings were as follows: time slicing = 2013–2024, years per slice = 1, node types = keywords, authors, institutions, and references, selection criteria = Top 50 most cited or occurring items per slice and pruning methods = Pathfinder and Pruning sliced networks. Burst detection and timeline visualization functions were further employed to identify emerging research frontiers and temporal knowledge evolution.

In VOSviewer, fractional counting was adopted, and the minimum occurrence threshold for keywords was set to 5. Network visualization, overlay visualization, and density visualization were used to analyze co-authorship networks, institutional collaboration structures, keyword co-occurrence relationships, and co-citation patterns. Cluster resolution parameters were adjusted automatically by the software to optimize cluster differentiation and readability.

The combined use of CiteSpace and VOSviewer enabled a multidimensional exploration of the knowledge structure and research network characteristics of big data applications in land system science. CiteSpace emphasized temporal evolution and frontier detection, whereas VOSviewer highlighted network relationships and cluster structures.

Topic evolution and frontier identification

To further investigate the evolution of research themes, the study period was divided into three stages: the initial development stage (2013–2016), the rapid expansion stage (2017–2020), and the intelligent integration stage (2021–2024). Comparative analyses were conducted across these stages to examine changes in research focus and methodological approaches.

By integrating keyword burst analysis, co-citation clustering, and timeline visualization results, the study identified several emerging research frontiers, including artificial intelligence-driven land modeling, fine-scale land identification using remote sensing big data, and the integration of social sensing data with land governance and policy analysis. These analytical procedures directly addressed the research objective of identifying future development directions and knowledge frontiers in the field.

3. Results

3.1. Publication Trends

As shown in Figure 1, publications on big data applications in land system research increased continuously from 2013 to 2024, indicating the rapid expansion and increasing maturity of this interdisciplinary field. During 2013–2015, the relatively small number of publications suggests that research mainly focused on exploratory attempts to integrate big data technologies into land system studies. This stage was constrained by limited data accessibility, insufficient computational capacity, and immature analytical frameworks.

From 2016 onward, publication growth accelerated significantly, especially after 2019, reflecting the combined influence of advances in cloud computing, remote sensing platforms, and artificial intelligence technologies. The rapid increase during 2020–2022 also coincided with the growing global demand for data-driven land governance, urban planning, and ecological monitoring under climate change and rapid urbanization contexts. The record number of publications in 2024 indicates that the field has gradually shifted from methodological experimentation toward integrated applications and decision-support research. This trend suggests that big data is no longer merely a technical tool in land system research but is becoming a core driving force for understanding complex human–land interactions and supporting sustainable spatial governance.

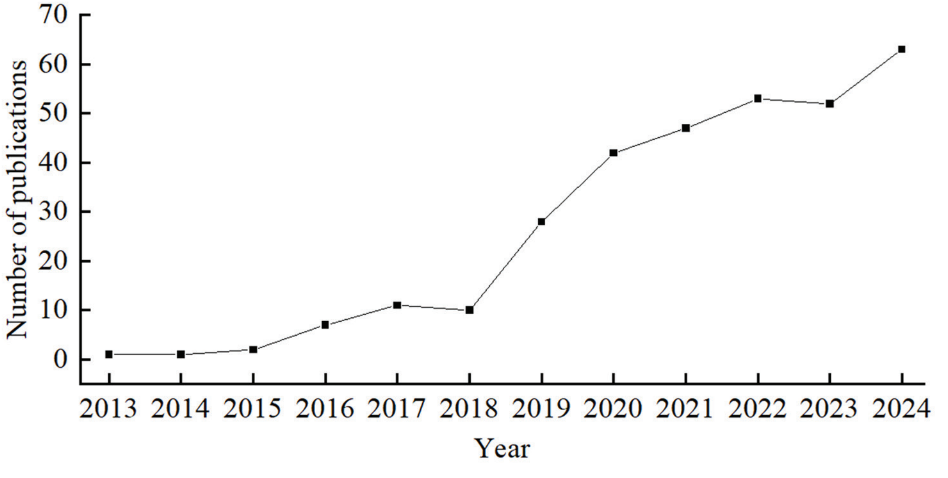

Figure 1. *The annual publication trends from 2013 to 2024.*

3.2. Institutional Collaboration Network Analysis

As shown in Figure *2*, the institutional collaboration network in the field of big data and land system research from 2013 to 2024 exhibits a typical core–periphery structure. The Chinese Academy of Sciences occupies the central position within the collaboration network, highlighting its leading role and strong research coordination capacity in this field. Its affiliated institutes, such as the Institute of Geographic Sciences and Natural Resources Research and the Aerospace Information Research Institute, serve as key nodes within the network, forming a central research cluster. Chinese Academy of Sciences has established close collaborative relationships with The University of Hong Kong, Zhejiang University, and various Ministry of Education-affiliated institutions, as well as universities such as Beijing Normal University and Wuhan University. This reflects a growing trend toward inter-institutional and cross-regional collaboration in the field. Although institutions like Tsinghua University, Peking University, and China University of Geosciences are situated on the periphery of the network, they are nonetheless actively involved in multiple collaborative projects. In the visualization, node size represents the volume of publications, while line thickness indicates the strength of collaboration. Overall, the collaboration network demonstrates significant imbalance, with a small number of core institutions playing a dominant role in knowledge production and resource integration. This collaborative structure reflects an organizational model centered on Chinese Academy of Sciences, characterized by multi-institutional synergy, and showcases China's concentrated research capacity and cooperative potential in the domain of big data-driven land system research.

Figure 2. *Institutional cooperation in the research field from 2013 to 2024.*

3.3. Keyword Co-Occurrence Analysis

Figure 3 illustrates the co-occurrence network of high-frequency keywords related to the application of big data in land system research from 2013 to

2024, revealing the evolution of research themes and areas of focus. The overall network exhibits a highly clustered structure, forming several dense thematic clusters. Keywords such as "land use", "ecosystem services", and "agriculture" occupy central positions in the network with prominent nodes and dense connections, indicating their role as core research themes in the field. "Big data", representing the key technological approach, is closely associated with methodological keywords like "classification", "patterns", and "cellular automata", reflecting its primary use in land pattern recognition, classification modeling, and spatial simulation. The frequent co-occurrence of "cellular automata" particularly highlights its significant value in spatial dynamic modeling. In addition, the presence of keywords such as "remote sensing", "urbanization", "biodiversity", and "accuracy" demonstrates the increasing role of remote sensing data and multi-source information integration in land cover monitoring and ecosystem assessment. Overall, the keyword co-occurrence network reveals a characteristic of "thematic concentration with methodological diversity." It spans multiple research dimensions, including land use change, ecosystem service evaluation, agricultural system analysis, spatial simulation, and remote sensing integration. Big data technologies are increasingly embedded in various aspects of land system research, driving the field toward higher precision, broader spatial scales, and greater intelligence.

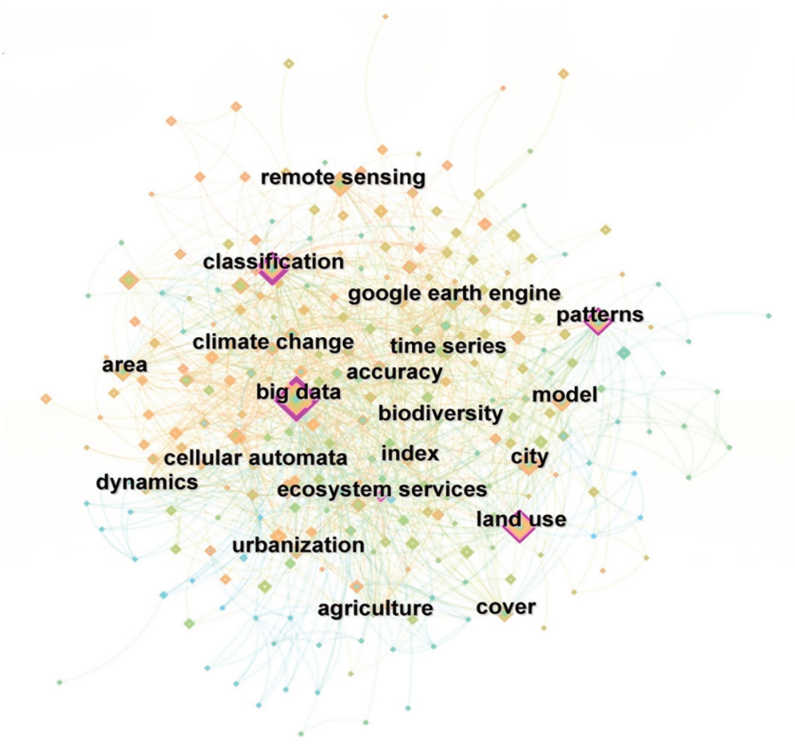

Figure 3. *Co-occurrence of keywords in research areas from 2013 to 2024.*

3.4. Keyword Cluster Analysis

Figure 4 presents the cluster structure of high-frequency keywords in land system research from 2013 to 2024, revealing not only the thematic distribution of the field but also the underlying transformation of research paradigms driven by big data technologies. The identified clusters demonstrate a clear transition from technology-oriented infrastructure construction toward application-oriented and governance-oriented research.

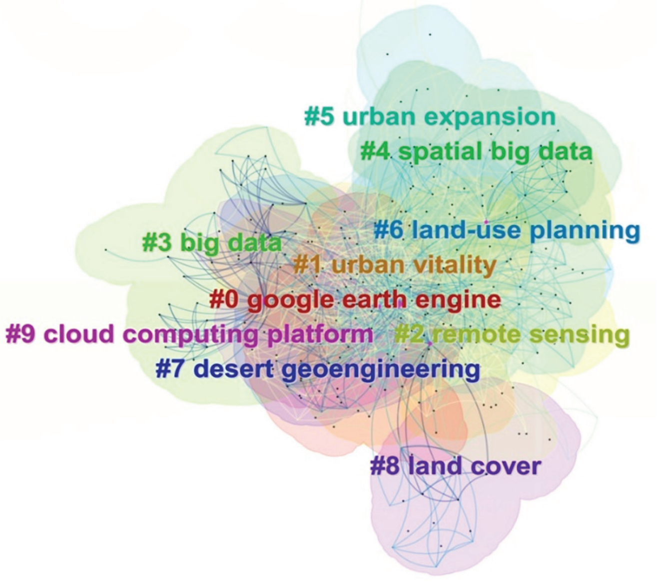

Figure 4. *Keyword clustering in research areas from 2013 to 2024.*

Clusters such as #0 Google Earth Engine and #9 Cloud Computing Platform indicate that cloud-based geospatial computing has become a critical infrastructure for land system studies. Their prominence reflects the increasing dependence of land research on large-scale, real-time data processing capabilities, which has fundamentally changed traditional land analysis methods characterized by small datasets and static observations. Similarly, clusters #3 Big Data and #4 Spatial Big Data suggest that research is evolving from simple data accumulation toward spatially integrated and intelligence-driven analytical systems. This shift highlights the growing importance of combining spatial heterogeneity, temporal dynamics, and human activity data in land system modeling.

Application-oriented clusters, including #1 Urban Vitality and #5 Urban Expansion, reveal that urban land systems have become one of the main scenarios for big data applications. This trend reflects increasing academic and policy attention to urban sustainability, smart city governance, and dynamic monitoring of human activities. The emergence of these clusters indicates that land system research is increasingly linked with socioeconomic processes and urban governance needs, rather than focusing solely on physical land change.

In addition, clusters such as #2 Remote Sensing and #6 Land-Use Planning demonstrate that remote sensing technologies are no longer limited to land cover monitoring but are gradually becoming decision-support tools for spatial planning and policy evaluation. Emerging clusters such as #7 Desert Geoengineering further imply that big data applications are expanding into climate adaptation and ecological restoration in vulnerable environments. Overall, the cluster structure reflects the evolution of land system research toward greater interdisciplinarity, intelligent analysis, and policy-oriented integration.

3.5. Evolutionary Path of Keywords

Figure 5 illustrates the evolutionary path of keywords in land system research utilizing big data from 2013 to 2024, revealing the developmental stages and logical progression of various research themes. Keywords are grouped into clusters, each representing a specific research direction, while color transitions indicate periods of activity and temporal characteristics. From 2013 to 2016, research focused on foundational themes such as “land use”, “classification”, “cellular automata” and “big data”. These studies mainly centered on land use change simulation and spatial classification, reflecting a phase of methodological exploration in the early application of big data within land system research. During 2017 to 2020, the research emphasis shifted toward keywords like “Google Earth Engine”, “remote sensing” and “spatial big data” suggesting that technological platforms and remote sensing data integration became key breakthroughs. This phase highlighted the empowering role of big data in processing and visualization capabilities within land system studies. From 2021 to 2024, keywords gradually converged around terms such as “ecosystem services”, “urban expansion”, “land-use planning” and “cloud computing platform”. This indicates a move toward integrated applications, emphasizing the practical value of big data in areas such as urban expansion monitoring, ecosystem assessment, and spatial planning. Simultaneously, the emergence of new themes like “urban vitality” and “desert geoengineering” suggests that land system research is entering a new phase of diversification and interdisciplinary integration. Overall, the keyword evolution path clearly delineates a transition from methodology-driven to application-oriented research. Big data has evolved from a supporting tool into a core component of land system research, playing a pivotal role across key processes such as model construction, data integration, and decision-making support.

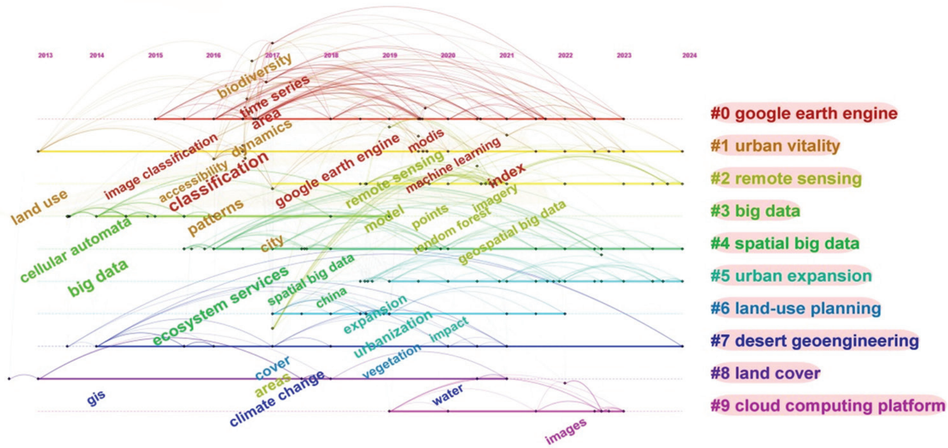

Figure 5. *Burst keywords in research areas from 2013 to 2024.*

3.6. Burst Keywords Analysis

Figure 6 presents the top 10 keywords with the highest burst intensity in land system research from 2013 to 2024, revealing the phased evolution of research hotspots and the dynamic shift of academic attention. Burst keywords refer to terms that experienced a significant surge in citation frequency during specific periods, often indicating rapidly developing research frontiers or technological breakthroughs. From the temporal distribution, 2019 marked a peak year for keyword bursts, with terms such as “information”, “social media data”, “landscape”, and “mobile phone” appearing prominently. This reflects a significant shift in data source structures, as the introduction of social media and mobile terminal data expanded both the research paradigm and data support systems in land system studies. Among these, “information” exhibited the strongest burst intensity (2.8), highlighting the fundamental role of information acquisition, integration, and management in land system research. Keywords such as “patterns” (2.25) and “urban expansion” (2.34) burst at different stages – the former emphasizing the importance of spatial pattern recognition, and the latter signaling that urban growth has become a central research topic, especially showing a sustained upward trend from 2022 to 2024. The emergence of “Google Earth Engine” (bursting in 2020) and “cellular automata” (bursting in 2014) reflects the widespread application of cloud-based remote sensing platforms and spatial simulation methods in land modeling and prediction, supporting data-driven land change analyses. Notably, the keyword “dynamics” has shown a continuous burst since 2022, indicating a shifting research focus toward in-depth exploration of internal evolution mechanisms and nonlinear response processes within land systems. Overall, the temporal sequence of burst keywords outlines a clear evolutionary path in land system research: from data acquisition and integration (e.g., social media data, mobile phone), to spatial modeling and simulation (e.g., cellular automata, patterns), and further to system dynamics and functional assessment (e.g., urban expansion, dynamics). This trajectory vividly reflects the paradigm transformation and shifting technological focus in the context of big data.

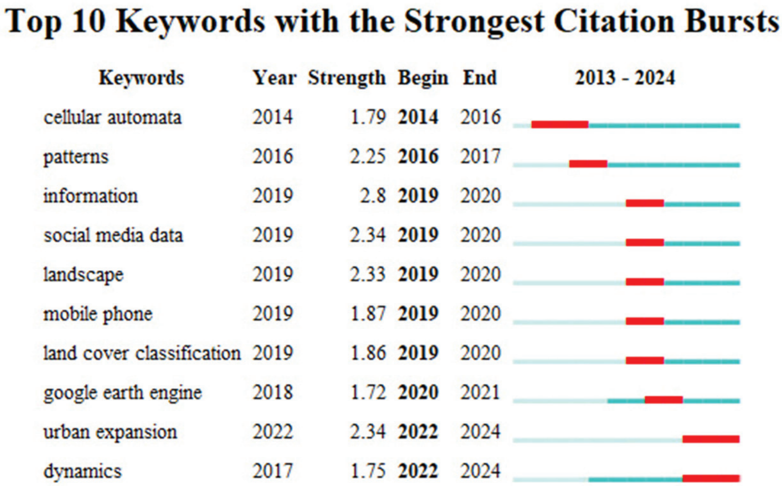

Figure 6. *Burst keywords in research areas from 2013 to 2024.*

3.7. Publication Statistics of Major Institutions

Table 2 summarizes the top ten research institutions in terms of publication volume in land system studies from the perspective of big data between 2013 and 2024. It includes their publication counts, network centrality, and research starting years, revealing the global research landscape and distribution of leading forces. The results show that all top ten institutions are based in China, indicating that China holds a significant leading position in the integration of land system and big data research. Among them, the Chinese Academy of Sciences ranks first with 45 publications and a centrality of 0.22, demonstrating its role as a core hub in the global academic collaboration network. Its research in this interdisciplinary field began as early as 2017, reflecting its early involvement and continuous leadership in driving technological paths and research topics. Following closely are the University of Chinese Academy of Sciences and the Ministry of Education, each with 19 publications, but with centralities of 0.06 and 0.09 respectively, indicating that the latter has a more significant dissemination effect within the academic network. Wuhan University (17 publications, 0.07 centrality) and Beijing Normal University (14 publications, 0.09 centrality), leveraging their strengths in remote sensing and geographic information science, continue to promote spatial data-driven land system analysis. Institutions such as the Institute of Geographic Sciences and

Natural Resources Research and the Aerospace Information Research Institute of the Chinese Academy of Sciences excel in foundational data processing and simulation modeling, providing critical technical support for the research. Additionally, although the University of Hong Kong and Tsinghua University have relatively fewer publications (12 and 11 respectively), their centralities are 0.13 and 0.03, reflecting their important connecting roles in international collaboration. Notably, the University of Hong Kong has rapidly increased its global network influence since 2019, and its research outputs enjoy high international visibility. Overall, this table reflects China's systematic layout and diverse breakthroughs in the interdisciplinary research of land systems and big data. The Chinese Academy of Sciences system institutions play key roles in technological leadership, resource integration, and international cooperation, further consolidating China's dominant position in the global land system science field.

Table 2. *Top 10 institutional rankings in research from 2013 to 2024.*

No.	Frequency	Centrality	Starting year	Institution
1	45	0.22	2017	Chinese Academy of Sciences
2	19	0.01	2017	University of Chinese Academy of Sciences
3	19	0.09	2019	Ministry of Education – China
4	17	0.07	2016	Wuhan University
5	16	0.01	2017	Institute of Geographic Sciences Natural Resources Research
6	14	0.09	2018	Beijing Normal University
7	14	0.05	2020	Aerospace Information Research Institute
8	12	0.03	2015	China University of Geosciences
9	12	0.03	2020	Tsinghua University
10	11	0.13	2019	University of Hong Kong

3.8. Geographic Distribution of Research by Country

Table 3 summarizes the main publishing countries, their centrality, and research starting years in big data-driven land system studies from 2010 to 2024, systematically revealing the global distribution of research strength and collaboration network patterns in this field. In terms of publication volume, China ranks first with 201 papers, far ahead of other countries, reflecting its sustained investment and research advantages in technologies such as remote sensing monitoring, geographic information systems analysis, and land use simulation. China's centrality reaches 0.67 – the highest globally – indicating its core position in the international collaboration network and its key role in leading and integrating research efforts. The United States ranks second with 48 publications and a centrality of 0.36. Although its output is lower than China's, the U.S. maintains significant global influence due to its strong foundation in methodological innovation, platform development, and model building. Germany, with a relatively smaller publication count (15 papers), has a high centrality of 0.56, showing strong activity in multinational collaborations, mainly focused on urban expansion simulation and environmental system modeling. Countries such as the United Kingdom, Italy, Canada, Australia, South Korea, India, and Malaysia have gradually entered this research field in recent years. While their publication volumes remain generally low, some have established notable visibility in the international collaboration network—for example, Canada's centrality is 0.09. Malaysia, though starting later (2019), has shown growing momentum, reflecting broad global participation and growth potential in this research area. From a temporal perspective, Germany began related research earliest in 2013, followed by China (2015), the United States (2016), and Italy (2014). Developing countries such as India (2020) and Malaysia (2019) started later but have exhibited significant recent growth, demonstrating a trend toward global diffusion of research topics and multipolar collaboration networks. In summary, global big data-driven land system research has established an international pattern characterized by "China-centered, multinational collaborative participation, and increasingly deepening cooperation networks." China leads in research output and collaborative influence and will continue to play a critical role in promoting sustainable development research in global land system science.

Table 3. *Top 10 countries by number of publications from 2013 to 2024.*

No.	Frequency	Centrality	Starting year	Country
1	201	0.67	2015	PEOPLES R CHINA
2	48	0.36	2016	USA
3	15	0.56	2013	GERMANY
4	13	0.04	2016	ENGLAND
5	12	0.02	2014	ITALY
6	11	0.09	2016	CANADA
7	10	0.04	2018	AUSTRALIA
8	10	0.00	2016	SOUTH KOREA
9	8	0.02	2020	INDIA
10	7	0.05	2019	MALAYSIA

3.9. Analysis of highly cited core literature

Table 4 lists the top 10 most co-cited core publications in land system research from 2013 to 2024, reflecting key application pathways of big data technologies in this field and the evolving trends of research hotspots. Topping the list is Gorelick et al. (2017) with the paper "Google Earth Engine: Planetary-scale geospatial analysis for everyone", cited 42 times with a total link strength of 51, demonstrating its widespread influence in large-scale geospatial analysis.

As a cloud-based remote sensing processing platform, Google Earth Engine has significantly enhanced the monitoring efficiency of land use/cover change, marking a milestone tool that drives automated remote sensing analysis. Next, the introduction of social sensing data has emerged as an important development direction. Liu et al. (2015) proposed the "Social sensing" framework, emphasizing the extraction of socioeconomic information from unstructured data sources such as social media, thus expanding the data boundaries and social attribute understanding in land system research.

Table 4. *Top 10 co-cited articles in research areas from 2013 to 2024.*

No.	Title	Co-Citation Frequency	Total link strength	Year	Author
1	Google Earth Engine: Planetary-scale geospatial analysis for everyone	42	51	2017	Gorelick et al.
2	Social sensing: A new approach to understanding our socioeconomic environments	25	49	2015	Liu et al.
3	Sensing spatial distribution of urban land use by integrating points-of-interest and Google Word2Vec model	21	45	2017	Yao et al.
4	Classifying urban land use by integrating remote sensing and social media data	19	56	2017	Liu et al.
5	Deep learning in remote sensing applications: A meta-analysis and review	19	35	2019	Ma et al.
6	A new insight into land use classification based on aggregated mobile phone data	19	48	2014	Pei et al.
7	Random forest in remote sensing: A review of applications and future directions	16	25	2016	Belgiu et al
8	Finer resolution observation and monitoring of global land cover: First mapping results with Landsat TM and ETM+ data	15	35	2013	Gong et al.
9	High-resolution multi-temporal mapping of global urban land using Landsat images based on the Google Earth Engine Platform	15	46	2018	Liu et al.
10	Deep learning in remote sensing: A comprehensive review and list of resources	15	40	2017	Zhu et al.

This approach realizes a deep integration of remote sensing and social sciences, advancing spatial cognition from "surface visibility" toward "social perceivability." Several highly cited publications focus on the intersection of remote sensing and deep learning. Meta-analyses by Ma et al. (2019) and reviews by Zhu et al. (2017) indicate that deep learning models like convolutional neural networks have matured in applications such as remote sensing image classification and land cover identification, becoming a significant driver of methodological innovation. Additionally, spatial behavior analysis using mobile phone data (Pei et al. 2014), the application of random forest algorithms in land mapping (Belgiu and Drăguț 2016), and high-resolution remote sensing datasets (Gong et al. 2013, Liu et al. 2018) are also widely cited, showing that multisource heterogeneous data and machine learning methods have become indispensable technical supports in land system research. Overall, the core directions of current big data research in land systems mainly include:

1. efficient processing of remote sensing data based on cloud platforms,
2. spatial analysis methods integrating social sensing data,
3. deep learning-driven land classification and modeling techniques,
4. multisource data integration and intelligent analysis frameworks.

These high-impact publications not only lay the theoretical foundation for big data methods in land system studies but also clarify the evolutionary trajectory for future research.

3.10. Distribution and Impact of Leading Journals

Table 5 summarizes the distribution of the top ten journals by publication volume in the field of land system research from 2013 to 2024. The statistics show that big data technologies in land system research are primarily concentrated in interdisciplinary fields such as remote sensing, land science, sustainability, and urban studies. Remote Sensing ranks first with 33 papers and a high impact factor of 13.5, highlighting the fundamental role of remote sensing technology in monitoring land use/cover change, urban expansion, and ecosystem service assessment. Its advantages of high spatiotemporal resolution and large-scale coverage have greatly facilitated the widespread application of big data in land systems. Following closely are Land (23 papers, impact factor 5.0) and Sustainability (17 papers, impact factor 12.7), reflecting research hotspots focused on sustainable land management and ecological protection under the global change context. Additionally, journals such as Land Use Policy (15 papers), ISPRS International Journal of Geo-Information (13 papers), and Cities (8 papers) focus respectively on land policy, geographic information system applications, and urban spatial dynamics, demonstrating the deep integration of land system research with spatial decision-making and urban governance. Journals including Journal of Cleaner Production, International Journal of Digital Earth, International Journal of Geographical Information Science, and ISPRS Journal of Photogrammetry and Remote Sensing have relatively fewer publications, but each holds an impact factor above 5.0, representing high academic influence and international recognition. Overall, the journal distribution of big data research in land systems exhibits a pronounced interdisciplinary characteristic, with coordinated advancement in remote sensing, geographic information systems, land science, urban studies, and sustainability. These high-output journals not only form the core platforms for academic exchange but also play key leading roles in promoting the big data-driven transformation of land system research.

Table 5. *Top 10 journals by number of publications in research areas from 2013 to 2024.*

No.	Journal	Frequency	Impact factor
1	Remote sensing	33	13.5
2	Land	23	5.0
3	Sustainability	17	12.7
4	Land Use Policy	15	3.4
5	ISPRS International Journal of Geo-Information	13	7.1
6	Cities	8	9.1
7	Journal of Cleaner Production	6	8.2
8	International Journal of Digital Earth	5	5.7
9	International Journal of Geographical Information Science	5	7.5
10	ISPRS Journal of Photogrammetry and Remote Sensing	5	5.5

4. Hotspot Analysis

Based on keyword co-occurrence analysis, clustering analysis, and burst detection methods, this study systematically identifies five core research hotspots: monitoring and modeling of land use change, integration and application of remote sensing and geospatial big data, urban expansion and spatial planning, big data-driven land management and decision support, and integrated analysis of social big data in land systems.

4.1. Monitoring and Modeling of Land Use Change

Land use change is one of the core topics in land system research. With the widespread availability of high-resolution remote sensing imagery and temporal land use datasets, researchers increasingly use multi-source big data for dynamic monitoring and modeling of land use (Romano et al. 2025). Literature analysis reveals frequent co-occurrence of keywords such as “land use change”, “urban expansion”, and “spatio-temporal modeling”, indicating strong research interest in capturing the spatial patterns, evolution trajectories, and driving mechanisms of land use change through big data (Ding et al. 2022; Liu et al. 2023). Particularly with the introduction of machine learning and deep learning methods, numerous studies have developed data-driven land use prediction models, such as Support Vector Machines, Random Forests, and Convolutional Neural Networks, significantly improving classification accuracy and change prediction capabilities (Son et al. 2022, Şimşek 2025). Furthermore, spatiotemporal modeling approaches for land change simulation, such as the CLUE-S model, CA-Markov model, and SLEUTH model, have also evolved methodologically under big data environments (Kulsoontornrat and Ongsomwang 2021, Behera et al. 2025). Research has progressed from focusing on "static change" toward "dynamic simulation" while further exploring identification and quantitative analysis of "multi-dimensional driving factors" behind land changes.

4.2. Integration and Application of Remote Sensing and Geospatial Big Data

Remote sensing data and geographic information systems, as traditional technical foundations of land system research, are increasingly being integrated with emerging multi-source data under the framework of big data, forming a core methodological pathway for current land system studies (Putty et al. 2025). This is also reflected in the bibliometric results, where keyword clusters such as "remote sensing", "GIS", "spatial data fusion", and "multi-source data integration" occupy a central position, indicating that data integration and spatial intelligence have become key thematic nodes linking different subfields. From an application perspective, this evolution is closely aligned with practical needs in land resource monitoring, spatial planning, and ecological management. First, the wide coverage and high temporal frequency of remote sensing data provide essential technical support for real-time land use classification, land cover change detection, and ecological condition assessment (Zafar et al. 2025). In practical applications such as national land spatial planning and ecological redline monitoring, the integration of multi-source remote sensing datasets (e.g., MODIS, Landsat, and Sentinel) has significantly improved monitoring accuracy and update efficiency, enabling more dynamic and operational land management. Second, the integration of remote sensing with emerging geospatial big data – such as social media check-in data, Points of Interest (POI), and mobile phone signaling data – has expanded land system research from static spatial description to dynamic human – land interaction analysis (Xiong et al. 2025). For instance, POI and land use data fusion is now widely used in urban functional zoning and urban vitality assessment, while mobile phone trajectory data has been applied in urban fringe studies to evaluate the coupling between population mobility and land development intensity (Martinez-Sanchez et al. 2024, Sun et al. 2022, Li et al. 2022). These methods have been further translated into practical tools for urban renewal planning and spatial optimization in rapidly urbanizing regions.

4.3. Urban expansion and spatial planning

Amid accelerated urbanization, urban land expansion and the evolution of spatial structure have become key topics in literature. In the keyword co-occurrence network, terms such as "urban expansion", "urban land", "spatial planning", and "urban growth boundary" have shown significant increases in frequency, highlighting the academic focus on urban spatial dynamics. Big data provides new tools for fine-grained identification of urban expansion processes (Gao et al. 2025, Tian et al. 2024). Researchers have accurately delineated urban boundaries and expansion intensity by analyzing building footprint data, high-resolution remote sensing imagery, and nighttime light data (Guo et al. 2024). Meanwhile, machine learning and spatial autoregressive models are widely used to identify driving mechanisms behind urban expansion, including population growth, industrial agglomeration, and infrastructure layout (Zhou et al. 2025). In the field of urban spatial planning, big data-driven planning simulation and evaluation systems are emerging continuously. For example, combining land suitability analysis with big data-driven Cellular Automata models is applied to simulate future urban land use layouts (Yang et al. 2025); or joint analysis of traffic flow big data and land use data is used to evaluate the rationality of urban functional zoning (Yin et al. 2021). These studies not only provide scientific bases for urban planning but also promote the policy implementation of "smart cities" and "digital land" development.

4.4. Big Data-Driven Land Management and Decision Support

Literature analysis indicates that keywords such as "land governance", "land management", "decision support system", and "policy simulation" form another important research hotspot. With increasing land resource scarcity and advancing sustainable development goals, scholars are paying more attention to how big data can improve land management systems and policy response mechanisms (Yang et al. 2024). At the practical level, land registration information, farmland parcel data, market transaction records, and policy implementation trajectories can all be transformed into structured big data resources to build full lifecycle land monitoring databases (Liu et al. 2023, Junaid et al. 2024). Some studies propose establishing "land big data platforms" to support spatial decision-making, exploring applications such as optimizing land approval efficiency, enhancing the scientific basis of land acquisition compensation, and automating illegal land use monitoring (Väth et al. 2019). Methodologically, there is rapid growth in research integrating System Dynamics, Agent-Based Modeling, and multi-objective optimization algorithms. These methods, combined with big data, enable real-time parameter updates and simulation path adjustments, providing quantitative support for land system reforms and regional development policies (Lai et al. 2022, Liu et al. 2021). Additionally, big data is used to assess the spatial heterogeneity of land systems' impacts on social equity, resource allocation efficiency, and ecological outcomes, forming a complex land system decision-making framework characterized by "multi-scale, multi-agent, and multi-objective" dimensions (Dong et al. 2019, Zwirowicz-Rutkowska and Michalik 2024).

4.5. Integrated Analysis of Social Big Data in Land Systems

In recent years, the value of unstructured social big data – such as social network data, mobility trajectory data, and user-generated content – in land research has become increasingly apparent (Liu et al. 2016, Jiang 2024). Keywords like “social media data”, “human mobility”, “spatial behavior”, and “land use perception” appear frequently, marking the rise of a “people-centered” research paradigm. These data address the lack of social process information in traditional land system studies. For example, spatial tagging and sentiment analysis based on platforms like Weibo, Twitter, and Instagram can explore urban residents’ subjective perceptions and emotional responses to land use changes (Wang et al. 2024); mobile phone or app location data can characterize the intensity, activity patterns, and spatiotemporal evolution of population use across different land types (Ríos and Muñoz 2017, Minallah et al. 2024). Researchers increasingly focus on the interaction between “subjective perception” and “objective land change” attempting to build a people-centered land system research framework. Meanwhile, social big data is widely applied in urban resilience analysis, land function diversity assessment, and ecosystem service perception, thereby expanding the application boundaries of land system research.

5. Research Limitations

Although big data technologies have brought unprecedented opportunities to land system research – enabling researchers to explore land use processes, mechanisms, and effects with higher spatiotemporal precision, larger sample sizes, and more comprehensive data dimensions – there remain several notable limitations in current related studies regarding theoretical depth, methodological approaches, data integration, and technical applications. These limitations not only affect the practical effectiveness of big data in land system research but also provide critical reflections and directions for future advancements.

5.1. Relatively Weak Theoretical Support System

The bibliometric results in this study indicate that high-frequency keywords and clusters (e.g., “machine learning”, “AI”, and “spatial simulation”) are dominated by method- and tool-oriented themes, while explicitly theory-driven clusters related to land system mechanisms remain relatively weak or marginal. This pattern suggests that the application of big data in land system research is still largely concentrated in technical implementation rather than theoretical integration. At the application level, many studies identified in the highly cited literature rely heavily on machine learning or deep learning models for prediction and pattern recognition but often lack explicit linkage to land system theory or mechanism-based interpretation (Liu et al. 2023). This is also reflected in the co-occurrence network, where "prediction", "model", and "algorithm" clusters appear more central than "mechanism" or "theory", indicating a structural imbalance between empirical modeling and theoretical explanation. As land systems are complex adaptive systems involving coupled natural–social processes, such a bias limit the explanatory depth of current research (Xie et al. 2017, Ibarra-Bonilla et al. 2021). Therefore, consistent with the bibliometric evidence, future research should strengthen theory-guided modeling to shift from pattern detection toward mechanism interpretation and decision-oriented applications.

5.2. Data Heterogeneity and Integration Challenges

The keyword clustering results highlight a strong emphasis on "remote sensing", "spatial data fusion", and "multi-source data", indicating that data integration has become a core research hotspot. However, this also reflects a persistent methodological bottleneck: although multi-source data integration is widely discussed, its practical implementation remains limited. In land system applications, researchers commonly integrate remote sensing, socioeconomic statistics, and social sensing data, but differences in spatial resolution, temporal frequency, and data formats often lead to simplified overlay rather than true fusion (Burgueño-Romero et al. 2025). This is consistent with the relatively fragmented position of "data integration methods" in co-word networks, where it appears less central compared with application-driven clusters such as "urban expansion" or "land use change." Most current studies still lack standardized fusion frameworks, which restricts the transition from descriptive mapping to integrated simulation and scenario analysis (Wang et al. 2021, Zhang et al. 2023).

5.3. Data Quality and Authenticity Issues

Although bibliometric results show rapid growth in "social sensing data", "POI", and "mobile trajectory data" clusters, these data sources are still secondary in terms of network centrality compared with remote sensing and GIS data. This imbalance implies both their emerging importance and unresolved data reliability concerns. In practical applications, unstructured big data such as social media or mobility data are widely used for urban land function identification and human activity analysis, but they are often affected by sampling bias and spatial unevenness (Hu et al. 2023, Zwirowicz-Rutkowska and Michalik 2024). For example, their strong concentration in urban areas is consistent with the bibliometric finding that "urban vitality" and "urban expansion" clusters are more developed than rural-oriented themes, suggesting potential spatial representativeness bias in data-driven conclusions (Kim and Cho 2023). Such limitations reduce the robustness and generalizability of land system interpretations and highlight the need for improved data validation mechanisms in future research (Chen et al. 2021, Tu et al. 2021).

5.4. Spatiotemporal Matching and Scale Selection Dilemmas

The bibliometric analysis shows that "spatial big data", "temporal analysis", and "remote sensing" form highly connected clusters, indicating that spatiotemporal analysis is a dominant methodological direction. However, this also reveals a key methodological inconsistency between data sources and analytical scales. Different data types used in land system research exhibit strong heterogeneity in spatial and temporal resolution, as reflected in the co-occurrence of keywords such as "remote sensing", "mobile data", and "statistical data" within the same analytical cluster. While remote sensing supports regular temporal monitoring, social sensing data provides high-frequency observations, and statistical data often operate at administrative scales, creating intrinsic mismatches in spatiotemporal granularity (Khatami et al. 2020). This inconsistency contributes to the fragmentation observed in cross-scale integration studies and limits the interpretability of multi-source analysis results. Moreover, bibliometric clustering shows that scale-related keywords are not as structurally central as application themes such as "urban expansion" or "land use change", indicating that scale selection remains a secondary consideration in many studies (Yang et al. 2021). This may partly explain persistent issues such as scale sensitivity and the modifiable areal unit problem, which continue to constrain the robustness of land system modeling outcomes (Li et al. 2024).

5.5. Technical Barriers and Challenges in Application Generalization

Although big data processing technologies such as machine learning, artificial intelligence, cloud computing, and graph databases are increasingly mature and have been applied in land system research, these technologies still impose high demands on researchers' mathematical modeling, programming, and algorithmic understanding skills, creating certain "technical barriers" (Yang et al. 2022). Especially in fields like human–land relations and social governance, where researchers mainly come from humanities and social science backgrounds, technical proficiency limitations hinder the widespread adoption of big data technologies (Jia et al. 2025). Additionally, many studies remain at the stage of case studies or technical demonstrations, lacking mechanisms for cross-regional and cross-scale model transfer and method generalization, which limits the development of universally applicable analytical frameworks and technical approaches (Tang et al. 2019).

6. Future Research Prospects

With the continuous advancement of information technology and the ongoing evolution of research paradigms in land system science, the application of big data in land system research has gradually shifted from data-assisted analysis toward the stages of driving mechanism identification and decision support. However, based on the current progress, issues such as insufficient integration of theory and methods, incomplete data systems, and a lack of standardization in technology remain. Therefore, future research needs to deepen and expand across multiple levels and dimensions to promote the deep coupling of land system science and big data technologies, achieving efficient land resource utilization, system optimization, and sustainable governance.

6.1. Establishing a "Data–Theory–Model" Collaborative Driving Research Framework

Future land system research should move beyond the simplistic view of "big data as the answer" toward an integrated research approach combining "data-driven + theoretical explanation + model simulation." This process requires strengthening the integration of big data with fundamental land system science theories, emphasizing the interpretation of causal mechanisms behind the data, and advancing the transition from descriptive statistics to explanatory modeling and predictive simulation (Batista and Marques 2021). For example, combining the "land use–ecological feedback" mechanism from land system science with complex systems theory and introducing causal inference-based structural equation models, Bayesian networks, or causal graphical models can enhance the explanatory power and predictability of models. At the same time, it is necessary to build a dynamically updating "theory–model–data" closed-loop framework to enable continuous knowledge iteration and evolution.

6.2. Enhancing Multi-Source Heterogeneous Data Fusion and Semantic Integration

Future land system research will increasingly rely on multi-source heterogeneous data including remote sensing, geographic information, sensor monitoring, social media behavior data, and natural language policy texts. Against this backdrop, achieving efficient data fusion and semantic alignment will become a key challenge. On one hand, it is necessary to develop multimodal data fusion technologies tailored to land systems, establish unified spatial reference systems and temporal calibration mechanisms, and address issues of scale inconsistency, format heterogeneity, and unequal data quality. On the other hand, developing semantic mining methods based on natural language processing and ontology construction to structurally represent and embed unstructured information such as policies, institutions, and social behaviors into models will improve the ability to characterize nonlinear and complex processes in land systems.

6.3. Promoting Deep Integration and Application of Big Data and Artificial Intelligence

The development of artificial intelligence technologies provides strong support for intelligent analysis in land system research. Future studies should actively explore the application of advanced artificial intelligence algorithms such as deep learning, graph neural networks, and reinforcement learning in scenarios including land use change detection, land cover classification, and land use forecasting (Burgueño et al. 2023). For example, convolutional neural networks can be used for automatic interpretation of remote sensing images, recurrent neural networks for land use time series prediction, and graph neural networks for effectively capturing spatial topological relationships among land units (He et al. 2020, Luo et al. 2024). Additionally, the role of explainable artificial intelligence in land system research should be emphasized to ensure interpretability, credibility, and decision-support capability of model outputs (Qian et al. 2024).

6.4. Strengthening Spatiotemporal Scale Matching and Multi-Scale Coupling Analysis

Land system processes exhibit significant spatiotemporal heterogeneity, and different temporal scales (e.g., annual, seasonal, monthly) and spatial scales (e.g., grids, administrative regions, ecological units) greatly influence research outcomes. Future studies need to develop more flexible multi-scale analytical frameworks and modeling tools with scale-adaptive capabilities to achieve coordinated coupling and dynamic transformation among multi-scale data (Li et al. 2024). For example, by combining multi-resolution remote sensing imagery with multi-scale transformation theory, it is possible to more accurately capture land change processes such as urban expansion and agricultural land degradation (Liang et al. 2015). At the same time, employing multi-level nested modeling techniques can identify driving factors at the parcel scale and assess policy effects at the regional scale, thereby effectively linking micro-scale processes with macro-scale patterns (Bawa 2024).

6.5. Accelerating Construction of Big Data Platforms and Open Sharing Mechanisms

Land system research increasingly demands timely and accessible data. In the future, it is essential to build high-quality and sustainable big data platforms that integrate diverse resources such as remote sensing images, land use monitoring, policy databases, and public participation data to form an open and dynamic data ecosystem (Gomes et al. 2020). Governments and research institutions should promote data sharing mechanisms related to land, breaking down “data silos” while ensuring privacy and security, to facilitate interdisciplinary, cross-regional, and cross-sectoral data integration (Jiang 2024). Additionally, emerging technologies like blockchain can be used to establish trustworthy data storage and management systems, enhancing data provenance traceability and result reproducibility, thereby supporting the creation of high-standard data-driven research environments (Kong et al. 2023).

6.6. Emphasizing Data Ethics and Social Impact Assessment

With the widespread application of big data in land system research, issues such as data privacy breaches, algorithmic bias, and decision-making distortions have become increasingly prominent. Future research must pay greater attention to data ethics construction and social impact assessment, especially in policy-sensitive areas involving resident relocation, land expropriation, and spatial planning (Zinman and Lerner 2020). On one hand, ethical boundaries and compliance procedures for data collection and usage should be clearly defined; on the other hand, mechanisms for evaluating algorithmic fairness and incorporating public participation feedback should be established to ensure that the demands of different stakeholders are reasonably expressed and respected during land-related decision-making processes, promoting land governance toward greater fairness, transparency, and sustainability (Robinson et al. 2021).

7. Conclusions

This paper systematically reviews the application progress of big data in land system research, revealing its technological evolution, thematic focuses, and collaboration patterns. The study shows that with the continuous integration of multi-source data such as remote sensing imagery, social media, satellite positioning, and sensors, big data has become deeply embedded in various aspects of land system analysis. This integration not only broadens research perspectives but also enhances the ability to perceive and predict complex human–land systems. In terms of research hotspots, topics such as "land use/land cover change", "ecosystem services", "agricultural land management", and "urban expansion simulation" have become frequent focal points, while methods such as "machine learning", "spatial simulation", and "artificial intelligence" continue to deepen analytical capabilities and methodological innovation. Regarding institutional collaboration, organizations such as the Chinese Academy of Sciences have formed relatively stable cooperative networks in this field, although global academic interaction and cross-regional collaboration still require further strengthening.

In addition, despite the significant progress achieved in this field, current research still faces several challenges, including high data heterogeneity, difficulties in multi-scale integration, insufficient interoperability among different data platforms, and lagging policy response mechanisms. Future studies should strengthen the integration of multiple databases such as Scopus and Google Scholar to improve dataset comprehensiveness and reduce potential bias. At the methodological level, future efforts should focus on standardized integration of multi-source data, intelligent evolution of analytical frameworks, deeper coupling analysis of human–natural systems, and stronger translation of scientific findings into land governance and policy-making practices.

It should be noted that this study used the Web of Science as the sole data source. Although WOS provides standardized and reliable bibliographic information for bibliometric analysis, its emphasis on English-language and high-impact journals may introduce database and language biases. Therefore, some regional or non-English studies may be underrepresented. The high proportion of Chinese authors and institutions identified in this study may reflect China's rapid development in big data and land system research, but it may also be partly influenced by the database coverage characteristics of WOS.

Overall, the integration of big data and land system science is currently undergoing a critical transition from technological expansion toward intelligent and policy-oriented applications. Advancing this field will require multidisciplinary collaboration, broader international participation, and more inclusive data sources to promote theoretical innovation and practical breakthroughs for global sustainable land governance and smart spatial management.

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Napredak primjene velikih podataka u istraživanju zemljišnih sustava: temeljeno na bazi podataka Web of Science

SAŽETAK. S ubrzanim razvojem informacijskih tehnologija veliki podaci (engl. Big Data) postali su važan pokretač istraživanja zemljišnih sustava. Na temelju baze podataka Web of Science Core Collection (WoSCC), u ovom su istraživanju primijenjene bibliometrijske metode u kombinaciji s alatima za vizualizaciju CiteSpace i VOSviewer radi sustavnog pregleda razvoja primjene tehnologija velikih podataka, istraživačkih trendova te mreža suradnje u području istraživanja zemljišnih sustava. Analizirano je ukupno 317 relevantnih znanstvenih radova objavljenih u razdoblju od 2013. do 2024. godine, pri čemu su razmatrani trendovi godišnjeg broja publikacija, suučestalost ključnih riječi, mreže suradnje autora i institucija te tematsko grupiranje istraživanja. Rezultati pokazuju da je primjena velikih podataka u istraživanjima zemljišnih sustava prošla razvojni put od početne faze istraživanja, preko razdoblja ubrzanog rasta, do ulaska u fazu zrelosti. Tematski fokus istraživanja proširio se s ranih analiza promjena korištenja zemljišta na šira područja, uključujući procjenu usluga ekosustava, simulaciju urbanog širenja, praćenje poljoprivrednih sustava i analizu emisija ugljika. U praktičnim primjenama često se koriste podaci daljinskih istraživanja, geografski informacijski sustavi, strojno učenje i umjetna inteligencija radi potpore prostornom modeliranju, prediktivnim analizama i planiranju korištenja zemljišta. Istraživanje također pokazuje da Kineska akademija znanosti zauzima jedno od vodećih mjesta u svijetu prema znanstvenoj produkciji i utjecaju suradnje, pri čemu istraživačke institucije pokazuju strukturu tipa „jezgra–periferija“. Razvoj ključnih riječi upućuje na sve izraženiji trend primjene inteligentnih tehnoloških metoda i interdisciplinarne integracije. Ovaj rad pridonosi boljem razumijevanju koevolucije velikih podataka i istraživanja zemljišnih sustava te pruža sustavne reference i teorijsku podlogu za buduća znanstvena istraživanja, oblikovanje javnih politika i prostorno upravljanje.

Ključne riječi: *veliki podaci, zemljišni sustav, bibliometrijska analiza, CiteSpace/VOSviewer, istraživački trendovi, razvojni putovi.*

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