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Mapping the Research Landscape of Land Use and Land Cover Change: A Bibliometric Analysis

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ABSTRACT

The Land Use and Land Cover (LULC) change is a crucial phenomenon in environmental science, reflecting the interplay between human activities and natural ecosystems. This bibliometric review examines research trends, thematic focus, and methodologies in LULC studies published between 1993 and 2023 through a systematic search criteria and PRISMA framework. Data were retrieved from Scopus and Web of Science and filtered for peer-reviewed journal articles, yielding 2,655 records. Analysis using R Bibliometrix and VOSviewer revealed a significant surge in the LULC studies after 2000, particularly from 2011 to 2020, aligned with advances in GIS and remote sensing tools. The results showed that leading journals are *'Environmental Monitoring and Assessment'* in Scopus and *'Ecological Indicators'* in Web of Science (WoS). The most relevant author is Burkhard Benjamin, who appears in both databases. The key themes include climate change, biodiversity loss, and sustainable land management, highlighting the growing interdisciplinary nature of LULC research. Emerging topics encompass urbanization, climate impacts, and ecosystem services, and spatially explicit modeling approaches, such as cellular automata, have gained prominence recently. The collaborative networks indicate China, notably Beijing Normal University and the Chinese Academy of Sciences, as leading contributors. Despite major progress, gaps remain in integrating interdisciplinary perspectives and systematic classifications of LULC trends. This review underscores the importance of bibliometric analysis in guiding future LULC research and calls for stronger collaborations and policy-oriented frameworks to address global challenges. Bridging technological innovations, with socio-environmental considerations, is essential in fostering resilience in land management practices.

1 Introduction

The Land Use/Land Cover (LULC) change is one of the most prominent and observable phenomena worldwide in the Anthropocene era. Land cover is the finest descriptor for earth-surface materials available globally. It is one of the most important concepts in environmental sciences due to its ability to directly portray surface materials that represent human land use. Land use transforms natural environments into built environments through various means, including human activities, like agriculture, urbanization, and forestry. On the contrary, land cover refers to the physical state of the earth's surface, natural and artificial, i.e., vegetation, water bodies, soil, and man-made objects (Lambin et al., 2003; Turner et al., 2007). Information on LULC is essential for environmental monitoring, land management, and understanding the implications of human activities on ecosystems and climate (Foley et al., 2005). The study of LULC is essential to achieving Sustainable Land Management (SLM). SLM is a wide-ranging, multidisciplinary concept. According to the United Nations (UN) 1992 Rio Earth Summit, SLM is defined as "the use of land resources, including soils, water, animals and plants for the production of goods to meet changing human needs while ensuring the long-term productive potential of these resources and the maintenance of their environmental functions". SLM plays a key role in halting desertification, reducing the pace of land degradation, and restoring degraded land (Olsson et al., 2019; Eekhout and de Vente, 2022). SLM pathways are most dependent on LULC. The patterns and drivers of LULC determine effective strategies for sustainable land management (SLM).

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LULC studies emerged at the beginning of the 20th century, when many scientific descriptions of LULC change using aerial photographs, were systematically conducted, leading to an efficient examination of land change (Coppin et al., 2004). In the latter half of the century, remote sensing and GIS progressed to provide accurate global mapping and monitoring of LULC change (Meyer & Turner, 1994). The early research found its basis in field observations and historical records, which, although valuable, were limited in space and time (Mather, 1992). An important turning point is non-invasive research, marked by the development of remote sensing technologies since the 1950s. The launch of Earth observation satellites made it possible to obtain high-resolution images of the Earth's surface, which enabled the land cover dynamics to be more detailed and systematic (Lillesand et al., 2015). Such technologies have been critical in detecting and measuring spatially explicit land cover changes, such as deforestation, urbanization, and agricultural expansion globally (Lambin et al., 2001; Hansen et al., 2013).

In recent years, LULC research has been driven by technological development, which incorporates new concepts, data, and methods. In this regard, one of the most important drivers is the publicly available high-resolution satellite imagery (Hansen et al., 2013). Open-access data from Landsat and Sentinel combined with data processing software have enabled researchers all over the world to perform quick and accurate large-scale analyses (Wulder et al., 2012). At the same time, increasing interest in climate change policy has also propelled the LULC research outputs (Meyfroidt et al., 2018).

Research on LULC has also influenced other fields, like perturbations to carbon and nitrogen cycles and hydrological process-mediated climate dynamics (Foley et al. 2005; Turner et al., 2007). It also directly helps to understand the impact of Anthropocene land cover changes (e.g., deforestation, urbanization, agricultural expansion, habitat fragmentation, etc.) (Lambin & Geist, 2006; Turner et al., 2007). On the other hand, research on LULC assists in having a better understanding of the socio-politico-economic determinants of the land use change, and subsequent formulation of relevant policies and management strategies (Meyfroidt, 2013).

In addition, there is growing recognition of land use changes' interactions with environmental processes (e.g., climate change and biodiversity loss) that establish feedback loops (Ellis, 2011). The interactions on these feedback loops are rather complex, nonlinear, and mostly unpredictable (Lambin & Geist, 2006). In contrast, another emergent theme across the discipline is an increased emphasis on spatially explicit land use modeling and simulation. Tools to simulate the temporal dynamics of land use change and predict the analysis of intervention/ counterfactual scenarios are spatial models (cellular automata, agent-based, and land change models) (Verburg et al., 2002). In providing the next-level behavior by adding the dimension of aggregate human population behavior and often levels of complexity through multiple biophysical and socio-economic variables, these models hold some prospect of better-describing drivers and outcomes of land use change (Brown et al., 2005).

Moreover, the LULC study is interdisciplinary and draws attention from geography, ecology, economics, sociology, and political science. This interdisciplinarity approach reflects the complexity and multiscale nature of land use dynamics and their drivers (Verburg et al., 2011). Furthermore, an increasing trend of merging LULC studies in interdisciplinary research has emerged; these studies have been connected to climate science, biodiversity conservation, ecosystem services, and other fields of natural sciences. Researchers and practitioners alike are increasingly recognizing that even narrow land-use responses to changes in carbon emissions, habitat loss, and human well-being may overlook broader environmental and social impacts of changes implemented (Ellis, 2011). Research literature and new paradigms of this interdisciplinary trend have fostered collaborative research agendas and frameworks to view global environmental challenges as complex, interrelated problems (DeFries et al., 2004).

Even though numerous empirical studies can be found in this domain of research in the literature, few studies have been conducted to systematically classify and identify the major developments, trends, and emerging areas of future research in LULC. While some studies have concentrated on examining specific themes or regions, the sequential evolution, thematic turnover, and the future of the global research landscape remain poorly understood (Lechner et al., 2020; Newbold et al., 2015). However, many studies do not integrate interdisciplinary methods and approaches used across different fields (Meyfroidt, 2016). To address this inadequacy, this article tries to present a systematic bibliometric review that elucidates evolutionary patterns, salient themes, and future directions of LULC research.

This research argues that bibliometric analysis provides a pertinent approach for synthesizing the large and expanding literature on LULC. Bibliometric analysis, therefore, represents an opportunity for generating valuable information about changes in research topics and the collaboration networks of scholars, as well as the impact of different research outputs (Chen et al., 2016). This also provides the scope for suggesting key research themes and pointing out adequate gaps in existing literature and guidelines to provide potential future directions (Donthu et al., 2021), which will help researchers, policy-makers, and practitioners working towards sustainable land management.

This article attempts to provide a comprehensive bibliometric review of LULC research in this regard and the central research question around which this review is structured: What are the major trends, developments, and future directions in LULC research? Through specific objectives, (1) temporal trends in LULC research publications are analyzed; (2) the most influential studies and key contributors of the field are identified; and (3) emergent themes and potential promising future directions for sustainable LULC research are explored. Significant publications available between 1993 and 2023 were examined within this context. The publications selected in this study were both qualitative and quantitative. This article synthesizes recent advances in LULC research by reviewing the selected articles to serve as a baseline of current trends and assess where this field is heading. The results from this article inform future research and policy efforts concerning SLM.

2. Materials and Methods

The current study utilized two separate databases: Scopus and Web of Science (WoS). The study employed these two databases because they encompass a wide range of reputable, peer-reviewed journals from all scientific domains (Falagas et al., 2008; Mongeon & Paul-Hus, 2016). The goal of the search strategy in the databases was to retrieve all pertinent publications regarding the LULC studies. The keywords used for the search were: "land use change" OR "land cover change" OR "LUCC" OR "Geographic Information System" OR "GIS" OR "Remote Sensing" OR "RS" (see Table 1). The time span for the search output was restricted to 1993 to 2023. To ensure data quality and reliability, the analytical units were limited to reports published in peer-reviewed journals (Podsakoff et al., 2005). Books, book chapters, review articles, conference proceedings, and other nonpeer-reviewed publications were excluded only to cover original research as much as possible and omit potentially less stringent or non-standardized sources (Moher et al., 2009)

Table 1. Search criteria for bibliometric review.

Database	Search Sequence
First Search Criteria (Key concept: “land use changes” OR "land cover changes” and “GIS” OR “RS”)	
Scopus	TITLE-ABS-KEY ("land use changes" OR "land cover changes" OR "LUCC") AND TITLE-ABS-KEY ("Geographic Information System" OR "GIS") AND TITLE-ABS-KEY ("Remote Sensing" OR "RS")
WoS	TS = ("land use changes" OR "land cover changes" OR "LUCC") AND TS = ("Geographic Information System" OR "GIS") AND TS = ("Remote Sensing" OR "RS")

To screen these initial results systematically, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method was used (Moher et al., 2009). This process provides a systematic and transparent procedure for identifying and selecting studies to be included in the bibliometric reviews. The PRISMA flow diagram for the current study (Figure 1) visualizes the screening process, which shows the selection process with several studies identified, screened, assessed for eligibility, and included in qualitative and quantitative synthesis with reasons for exclusions at each stage (Page et al., 2021).

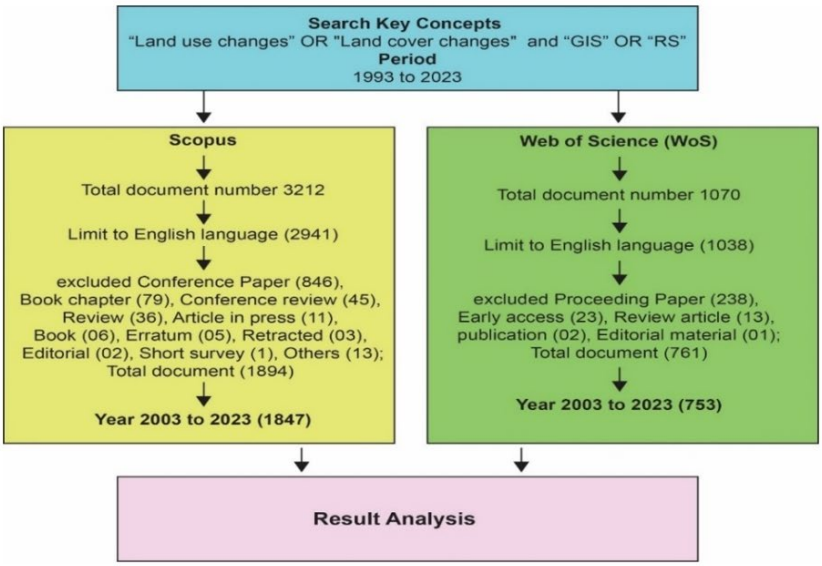

Figure 1 The PRISMA Framework of screening process of documents.

Figure 1illustrates the systematic screening of documents retrieved from two major databases– Scopus and Web of Science using a PRISMA-based approach. The initial search applied key concepts (“Land use changes” OR “Land cover changes”) combined with “GIS” OR “RS,” capturing publications from 1993 to 2023. For Scopus, an initial 3,212 records were retrieved and refined to 2,941 when limited to English, followed by the removal of conference papers, book chapters, and other non-peer-reviewed materials, yielding 1,894 documents. Restricting the timeframe to 2003–2023 further narrowed this set to 1,847. Similarly, 1,070 records were initially obtained for Web of Science, reduced to 1,038 by applying an English language filter. Additional exclusions (such as proceedings, early-access materials, and retracted publications) resulted in 761 documents, which were limited by publication year (2003–2023), producing 753 remaining records. The final sets from Scopus and Web of Science were, subsequently, integrated for result analysis, ensuring that only relevant, peer-reviewed, and English-language articles, within the specified period, were included in the review. This PRISMA flowchart, thus, provided a transparent overview of the selection criteria and steps taken to derive a focused corpus of literature on Land Use and Land Cover research involving GIS and remote sensing tools.

3. Results

3.1 Temporal Network

Figure 2 depicts the annual publication count of articles indexed in Scopus (blue) and WoS (orange) from 1993 to 2023. Between 1993 and 2000, a limited number of published articles emerged, suggesting constrained research on the LULC transformation. From 2001 to 2010, there was a modest increase in the need for awareness regarding sustainable land use. The graph indicates that this trend accelerated significantly between 2011 and 2016, attributable to global climate initiatives, like the Paris Agreement of 2015. From 2017 to 2020, this escalated rapidly, attaining a plateau that closely aligned with the volume of multidisciplinary research and policy significance. Between 2021 and 2023, the number of publications declined or remained stable, suggesting a potential consolidation within the academic community or a change in funding priorities. The graph indicates that Scopus consistently indexed more papers than WoS from 2012 to 2020, implying broader topical coverage by Scopus. The data indicates the dynamics of LULC research, which has shown a remarkable rise in publications over the past decade, showing heightened academic and policy interests. However, a recent deceleration may indicate a stabilization and maturation of land use and land cover (LULC) research.

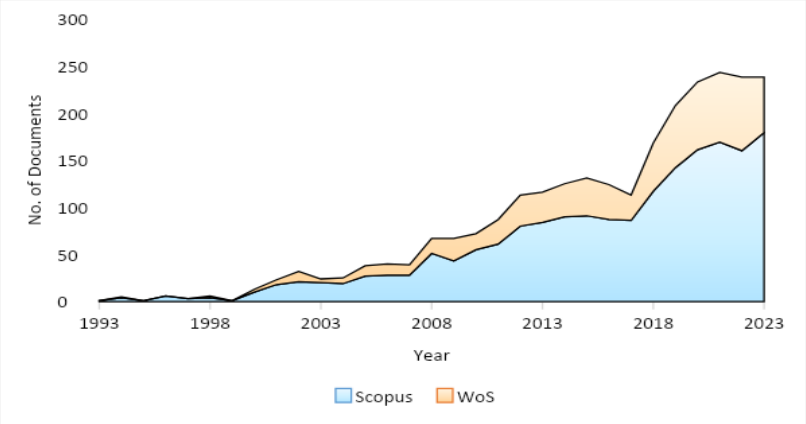

Figure 2. The temporal distribution of yearly published documents related to LULC (1993-2023).

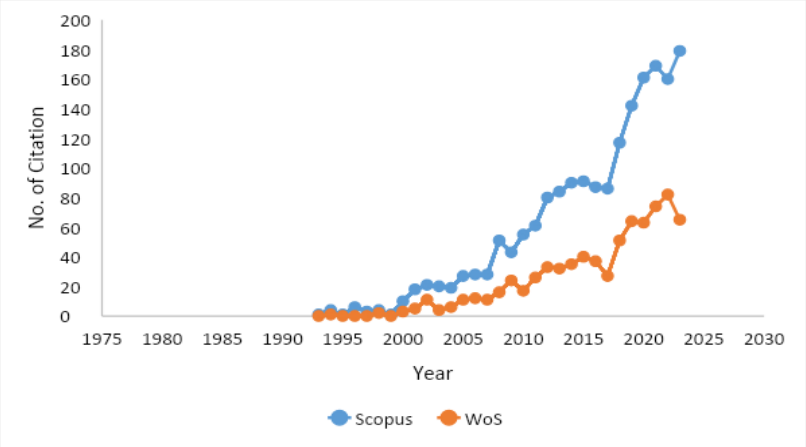

Figure 3. The temporal trend of citation of articles related to LULC (1993-2023).

Figure 3 represents the temporal trend in citations per article indicating a progressive increase in citations, reflecting a corresponding rise in research impact. Between 1993 to the end of 2005, both databases consistently reported low and stable citation counts, with annual totals remaining below 20. Citations have increased steadily from 2005 to 2010, with Scopus showing a rapid rise than WoS. The annual evolution of citations in both databases showed a comparable rise from 2010 to 2015; however, Scopus surpassed 60 citations per year per field by 2015, whereas WoS remained below this threshold, exceeding 40 citations per year per field at that time. Citation growth continued from 2015 to 2020, with Scopus exceeding 100 citations annually in 2018 and nearing 160 by the end of the decade. Indeed, WoS exhibited a similar trend, reaching approximately 80 citations per year by 2020. In 2022, both databases reached their highest citation levels with Scopus approaching 200 citations per record (primary/secondary) and around 100 citations in 2023, there was a slight decrease in the citation, suggesting a potential saturation or changes in citation practices.

3.2 Source Network

3.2.1 Highest Cited Articles in the Field of LULC

Table 2 presents LULC publications most frequently mentioned in Scopus and WoS. The article "Mapping Ecosystem Service Supply, Demand, and Budgets" by Burkhard et al. (2012) is the most frequently cited publication in Scopus. This publication has been cited 1,546 times since 2012, within the timeframe above an average of 119 citations per year. Borrelli et al. (2014) average of 119 citations per year. Borrelli et al. (2014) have since received 1,317 citations (an average of 165 per year) for their work, "An Assessment of the Global Impact of 21st-Century Land Use Change on Soil Erosion." Fry et al. (2013) report “Completion of the 2006 National Land Cover Database for the Conterminous United States” has garnered 1,203 citations to date, averaging 86 citations annually, as noted by Zhu et al. (2011). The Land use and land cover change in Greater Dhaka by Dewan & Yamaguchi (2009) has received 775 citations, averaging 48 citations per year. Lastly, "Land Use Change Analysis in the Zhujiang Delta of China" by Weng (2002) has garnered 731 citations, with an average annual citation rate of 32.

In WoS, Burkhard et al. (2012) rank first, with 1,323 citations and an annual citation rate of 102. The third reference is Shalaby & Tateishi (2007) concerning Egypt, which has accumulated 528 citations and an average of 29 citations annually. The present analysis indicates that Burkhard et al. (2012) is also a mostly cited article in WoS like the Scopus database. Consequently, Ozawa's (2012) research has influenced both databases. While WoS citations are generally more minor, leading articles on both platforms consistently reach their peaks. The steady citation frequency of articles dating back to 2002 demonstrates the enduring impact of these publications on LULC research.

Table 2. Most cited articles in the field of LULC

Sl. No.	Title	Author and Year	Source	Citations	Citations/ per year
		Scopus			
1.	Mapping ecosystem service supply, demand and budgets	*Burkhard et al. (2012)*	Ecological Indicators	1546	119
2.	An assessment of the global impact of 21st century land use change on soil erosion	*Borrelli et al. (2014)*	Nature Communications	1317	165
3.	Completion of the 2006 National Land Cover Database for the conterminous United States	*Fry et al. (2011)*	PE & RS, Photogrammetric Engineering & Remote Sensing	1203	86
4.	Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to p9romote sustainable urbanization	*Dewan & Yamaguchi (2009)*	Applied Geography	775	48
5.	Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling	*Weng (2002)*	Journal of Environmental Management	731	32
		WoS			
1.	Mapping ecosystem service supply, demand and budgets	*Burkhard et al. (2012)*	Ecological Indicators	1323	102
2.	Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt	*Shalaby & Tateishi (2007)*	Applied Geography	528	29
3.	Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing	*Xiao et al. (2006)*	Landscape and Urban Planning	486	26
4.	Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization	*Deng et al. (2009)*	Landscape and Urban Planning	476	30
5.	DINAMICA—a stochastic cellular automata model designed to simulate the landscape dynamics in an Amazonian colonization frontier	*Soares-Filho et al. (2002)*	Ecological Modelling	367	16

3.2.2 Highest Cited Journals in the field of LULC

Table 3 represents the articles with their Total Citations and Impact Factors for 2022–2023. Scopus indicates that the journal "*Environmental Monitoring and Assessment*" has the highest number of articles (93) and a total of 3,134 citations. In contrast, the *"Egyptian Journal of Remote Sensing and Space Science"* publishes merely 37 articles, but accumulates a total of 2,726 citations, resulting in a much-elevated impact factor of 4.4. A manifestation of elevated connectedness, as observed in the comparison of some SWOT research sites, is exemplified by the *"Egyptian Journal of Remote Sensing and Space Science"*, which possesses an impact factor as previously indicated. In addition, *"Applied Geography"* comprises 18 articles and has garnered 2,701 citations, resulting in an impact factor of 4.9, which reflects the quality and reach of its publications. Despite these, the *"Landscape and Urban Planning"* has published only 15 articles potentially attributable to the length of specific reviews, its impact factor is 9.1, and 2,328 citations over the analyzed period underscore its significance as one of the foremost publications in the LULC research arena.

In the WoS database, *"Ecological Indicators"* leads with 1,661 citations from merely 7 articles, indicating a substantial impact factor of 6.9, reflecting a limited number of very influential publications. In addition, *"Applied Geography"* and *"Landscape and Urban Planning"* are both high achievers on the Web of Science (WoS), mirroring their notable profiles from Scopus and demonstrating their inter-platform influence. The journal *"Sustainability"* (impact factor: 3.9; citations: 703) is indexed solely in WoS, exhibiting a moderate impact factor and citation count, suggesting that advanced research focuses on sustainability in the field of LULC changes.

Analysis of the two databases indicates that *'Environmental Monitoring and Assessment'* possesses a more significant representation in Scopus. However, it exhibits a low ranking in Source Normalized Impact Per Paper (SNIP) in Web of Science (WoS). The journals *"Landscape and Urban Planning"* and *"Applied Geography"*, ranked as the foremost in both databases, underscore their significant contributions to LULC research. This illustrates the varying roles of journals across different databases, with few achieving a considerable performance in the quality and quantity of the subject matter.

Table 3. Most cited journals in the field of LULC.

Sl. No.	Source/Journal	Articles	Citations	Impact Factor (2022-2023)
	Scopus			
1.	Environmental Monitoring and Assessment	93	3134	3.0
2.	Egyptian Journal of Remote Sensing and Space Science	37	2726	4.4
3.	Applied Geography	18	2701	4.9
4.	International Journal of Remote Sensing	23	2341	3.4
5.	Landscape and Urban Planning	15	2328	9.1
	WoS			
1.	Ecological Indicators	7	1661	6.9
2.	Applied Geography	12	1646	4.9
3.	Landscape and Urban Planning	6	1489	9.1
4.	Environmental Monitoring and Assessment	39	952	3.0
5.	Sustainability	34	703	3.9

3.2.3 Most Relevant Authors in the field of LULC

Table 4 represents the Scopus and WoS statistics of the top cited authors in LULC research, including their publications, citation counts, and h-index. In the Scopus database, Burkhard possesses the most significant citation counts, with two papers and 1,587 citations, averaging 794 citations per paper. His affiliation with the Institute for the Conservation of Natural Resources at the University of Christian Albrechts Kiel and an h-index of 45 underscores his esteemed reputation. Kroll (2009), possessing an h-index of 111 and a highly referenced work with 1,546 citations, likely makes significant contributions outside the LULC.

Burkhard is also notable in the WoS database, having authored three documents mentioned 1,464 times. Nonetheless, his h-index (16) is comparatively low relative to other authors on this list, suggesting potentially more recent impactful contributions. In three extensively referenced studies, elevated h-indices frequently indicate consistency in remote sensing technologies, exemplified by 13 h-index for Adel Shalaby at Chiba University and 51 h-index for Xiao, also associated with Chiba University. Burkhard excels in both databases, while Kroll, Müller, and Nedkov demonstrate that a single influential article can suffice to create an impact. The disparate citation counts and h-index ratings across several databases underscore the diversity of effect among these researchers.

3.3 Spatial Networks

3.3.1 Distribution of Institutions in the Field of LULC

The most relevant institutions when it comes to published LULC articles are visualized in Figure 4 (a and b), in terms of the amount of LULC publications published in Scopus and Web of Science (WoS) by these institutions. In the Scopus database, the leading institution for publication on LULC research was Beijing Normal University, with the Chinese Academy of Sciences and Nanjing University following closely. The high-profile note of Beijing Normal University in the field certainly highlights its central importance for LULC research. More high values for national priorities are shown by both IEOs, such as emissions mitigation, amplified by committed initiatives and resources (the Chinese Academy of Sciences and Nanjing University). Additionally, in the WoS database, the Chinese Academy of Sciences currently holds a dominant

Table 4. The most cited authors in the field of LULC.

Sl. No	Author	Documents	Citations	Citations/ Article	Affiliation	h-index
			Scopus			
1.	Burkhard, Benjamin	2	1587	794	Institute for the Conservation of Natural Resources, Department of Ecosystem Management, Ecology Centre, Christian Albrechts University Kiel, Olshausenstr, Germany	45
2.	Kroll, Franziska	1	1546	1546	Regierungspräsidium Darmstadt, Abteilung Arbeitsschutz und Umwelt Frankfurt, Germany	111
3.	Müller, Felix	1	1546	1546	PD Dr. med., M.D. Medical Doctor at Universitäre Psychiatrische Kliniken Basel, Switzerland	52
4.	Nedkov, Stoyan	1	1546	1546	Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Bulgaria	44
5.	Tateishi, Ryutaro	2	1188	594	Institute of Color & Image Technology, Chiba University, Japan	18
			WoS			
1.	Burkhard, Benjamin	3	1464	488	Institute for the Conservation of Natural Resources, Department of Ecosystem Management, Ecology Centre, Christian Albrechts University Kiel, Olshausenstr, Germany	16
2.	Shalaby, Adel	4	626	157	Center for Environmental Remote Sensing CEReS, Chiba University, Japan	13
3.	Xiao, JY	3	576	192	Graduate School of Science and Technology, Chiba University, Japan	51
4.	Deng, Jin S	3	560	187	Environmental and Resource College, Zhejiang University	74
5.	Soares, BS	4	420	105	Department of Cartography, Federal University of Minas Gerais, Brazil	20

position in LULC research, and its most productive institution is the IGSNRR (Institute of Geographic Sciences and Natural Resources Research). The congruity of results across both databases reflects the consolidation of Chinese institutions toward unified action in the LULC studies.

(a and b), where the size of each node indicates the number of articles published, and the thickness of a link represents the strength of co- authorship among different countries.

While there are some differences in labeling between Scopus and Web of Science, the patterns converge on national-level

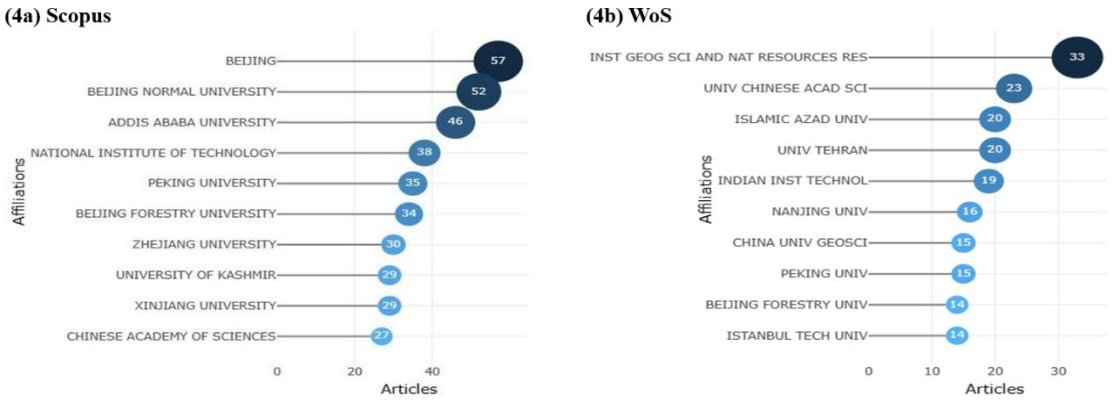

Figure 4. The most relevant institutions in the field of LULC.

In both databases, Beijing Normal University and the Chinese Academy of Sciences emerged as notable contributors to the field of LULC research, demonstrating their significant influence in prioritizing LULC research issues. This example highlights a major institutional effort to systematically focus on environmental sustainability and policy-related research in China.

hubs, including China, India, and the United States, along with leading contributors from Europe (e.g., Germany and Turkey). Other externally engaged regions, such as Malaysia, Egypt, and Ethiopia, are also represented, illustrating the growing collaborative efforts at a regional level.

Figure 6 (a and b) corroborates the above results by mapping global research connections, with red arcs representing cross-

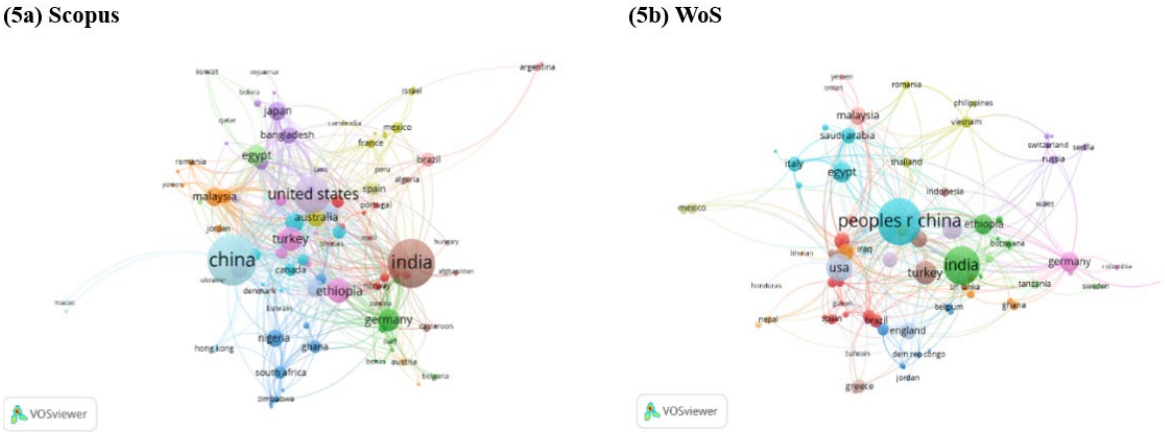

Figure 5. Distribution by country: co-authorship network of the 20 most common top countries in the field of LULC.

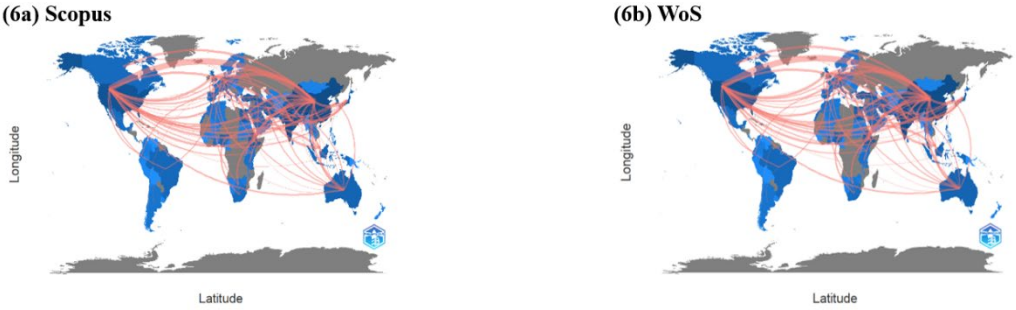

Figure 6. The global network of research collaborations in the field.

3.3.2 Distribution of country-wise co-authorship by country in the field of LULC

The collaboration of the 20 most prolific countries in LULC research *via* co-authorship networks is illustrated in Figure 5

border collaborations, particularly concentrated in North America, Europe, and Asia. The visible links between Africa and Latin America, though, are fewer, suggesting regional differences in LULC research output and engagement. On a

global scale, the long-distance arcs emphasize how LULC studies increasingly rely on (inter) continental efforts, noting that the institution from the key regions serves as the key nodes to address global land-use and land-cover challenges.

3.4 Lexical Networks

3.4.1 Distribution of Knowledge Area in the Field of LULC

LULC documents in Scopus and WoS exhibit analogous data in ratio- and proportion-based demographic formats, detailing the field and distribution of LULC-related papers in Scopus (Table 5) and WoS. A broader array of topics is seen in the Scopus database. Environmental Science (1,115 documents) continues to be predominant and essential, as seen in Table 5. This indicates an expanded scope for LULC, encompassing socio-economics, biology, and environmental factors. A significant trend across various disciplines is the relative application of technical solutions and computational methods in LULC documents categorized under Engineering (182 documents) and Computer Science (146 documents) in Scopus, highlighting a notable interdisciplinary characteristic within this research cohort.

Table 5. Distribution of knowledge area in the field of LULC.

Sl No.	Research Fields (Scopus)	No. of Documents	Research Fields (WoS)	No. of Documents
1	Environmental Science	1115	Environmental Sciences Ecology	554
2	Earth and Planetary Sciences	656	Remote Sensing	138
3	Social Sciences	563	Geology	135
4	Agricultural and Biological Sciences	392	Science Technology Other Topics	87
5	Engineering	182	Water Resources	86
6	Computer Science	146	Imaging Science Photographic Technology	61
7	Energy	103	Physical Geography	59
8	Biochemistry, Genetics, and Molecular Biology	59	Geography	48
9	Multidisciplinary	51	Engineering	42
10	Physics and Astronomy	46	Agriculture	40

In contrast, the WoS database, Environmental Sciences and Ecology, leads with 554 documents, highlighting the significant focus on ecological and environmental aspects of LULC. This underscores the significance of depicting ecological repercussions and environmental adaptation in the LULC analysis. The field of Remote Sensing (138 papers) consistently emphasizes the importance of satellite imagery and technology in monitoring changes in land cover. The focus on the geological dimensions of land use and cover, including soil composition and landform alterations, as evidenced by the proportion of documents from Geology (135 papers), underscores that land cover dynamics cannot be comprehended without analyzing these elements.

3.4.2 Distribution of most occurred keywords in the field of LULC

Figure 7 illustrates the distribution of the most frequently utilized terms in LULC research, derived from Scopus and WoS data. It offers a valuable representation of the domain and the interconnections among various issues within that context. Figure 7(a and b) illustrates that "remote sensing" is the paramount and central term for LULC research in the Scopus database. Upon broader examination, the phrase emerges as a pervasive term inside this network, indicating its essential role in the application of processing land cover change detections. Land use, land cover, land cover change, and Geographic Information Systems (GIS) are pivotal terms encapsulating the LULC study's core, particularly highlighting this topic's interdisciplinary nature through their interrelation. Moreover, essential terms, such as "sustainable development," "urbanization," "climate change," and "biodiversity" signify the extensive range of subjects encompassed within LULC research, underscoring its significance in connecting environmental and socio-economic issues.

Similarly, remote sensing remains the predominant keyword in the WoS database (Figure 7b), indicating its consistent and pivotal significance. Thus, in WoS, "remote sensing" has more robust associations with "land cover" and "GIS," aligning with the results from Scopus. Nevertheless, the network appears less dense than WoS, suggesting a more focused or specialized aggregation of study domains. Nonetheless, WoS includes essential LULC study themes,

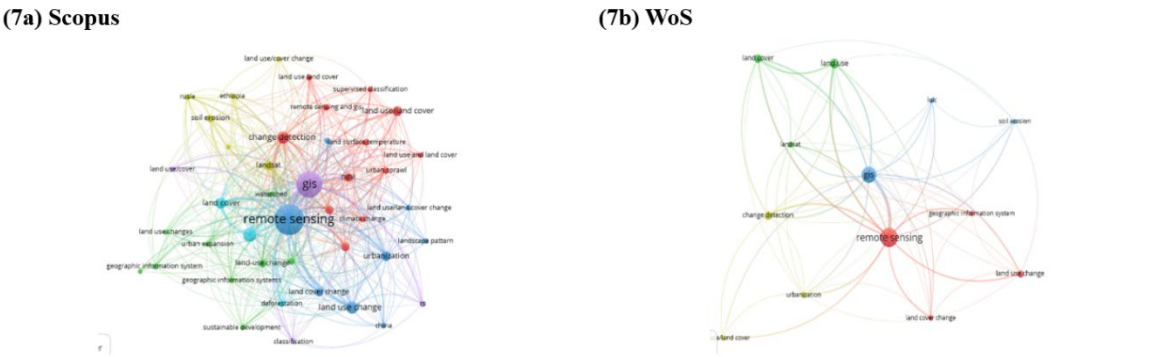

Figure 7. Distribution by most occurring Author's keywords.

However, WoS and Scopus exhibit differences in distributions across specific fields. The Web of Science predominantly emphasizes the technological and physical disciplines, such as remote sensing and geology. Conversely, Scopus encompasses a range of fields beyond environmental sciences, including social sciences and engineering, suggesting that their expertise in LULC research may be mutually beneficial. This divergence among databases enhances the understanding and administration of LULC by offering varied viewpoints and approaches.

such as "soil erosion," "urbanization," and "climate change," so affirming that LULC is a comprehensive and interdisciplinary domain.

The constant pattern of keyword prevalence across both databases illustrates that LULC studies are founded on the concepts of remote sensing and associated technologies and present themselves as an interdisciplinary topic.

3.4.3 Trend of most frequent keywords in the field of LULC

Figure 8 shows keyword trends in LULC research from 2003 to 2023 based on Scopus and WoS data. These trends reflect the changes realized in priorities and the technology being deployed. As shown in Figure 8a, the Scopus database

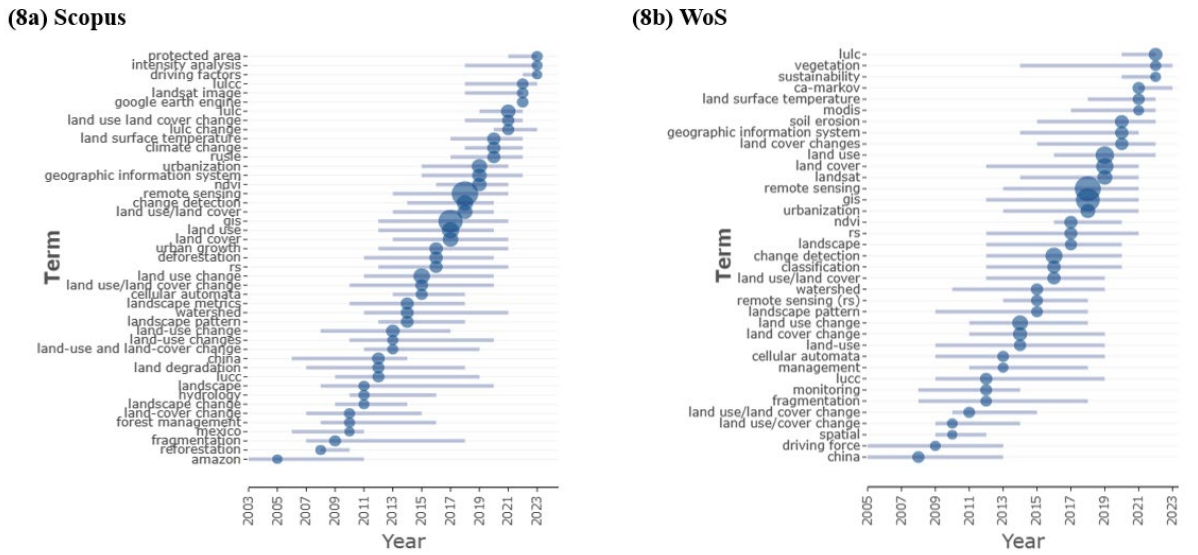

Figure 8. The trend of most frequent keywords in the field of LULC.

indicates a notable increase in the use of "remote sensing" and GIS after 2010, underscoring their increasingly pivotal roles in LULC-associated studies. These trends emphasize the dependence on methodologies to monitor and an alyze land cover expansion, with a subsequent upturn in ground-based technologies. The terms interest, "land use," and "land cover" have steadily shown an increase, but the term "change detection" remained dominant throughout the years. The increasing usage of the terms “urbanization”, “land cover change”, and “land use change” highlights a growing interest in the environmental consequences associated with urban development.

Figure 8b shows similar trends for the WoS database, remote sensing, and GIS following a similar trajectory(increasing significantly). The overall increase in research in both databases highlights the critical role of both in LULC research. Land use, land cover, and change detection appear to be growing exponentially, indicative of the key components of the active monitoring of land uses. The emergence of words, like “urbanization”, “land surface”, and “climate change” marks the boundary where localized effects give rise to potential global consequences of biophysical climate regulation caused by land use changes.

Both Scopus and WoS have consistently recorded a rising application of both subsets of critical technology and theme subjects, which endorses an inclusive and technology-based perspective on addressing the environmental and socio-economic impacts of LULC. Such a predilection aligns well with the multidisciplinary character of global LULC research and a burgeoning concern among the academy with significant issues, such as urbanization and climate change.

3.4.4 Thematic map of the research landscape regarding LULC

The dynamic nature of research domains can be observed through the thematic maps generated by both Scopus and WoS (Figure 9), where the different themes are classified based on development versus significance. The high centrality and density of GIS and Land Use reflect that these two keywords are primary themes on both maps. This suggests that these themes are both mature and foundational to their study area, representing an essential advancement in knowledge and addressing significant issues.

On the Scopus map (Figure 9a), “forest” and “runoff” emerge as “Motor Themes,” which are well-studied and well-developed within the LULC research domain, whereas “sediment/yield” and “land surface temperature (LST)” emerge as “Niche Themes,” which are established, but less

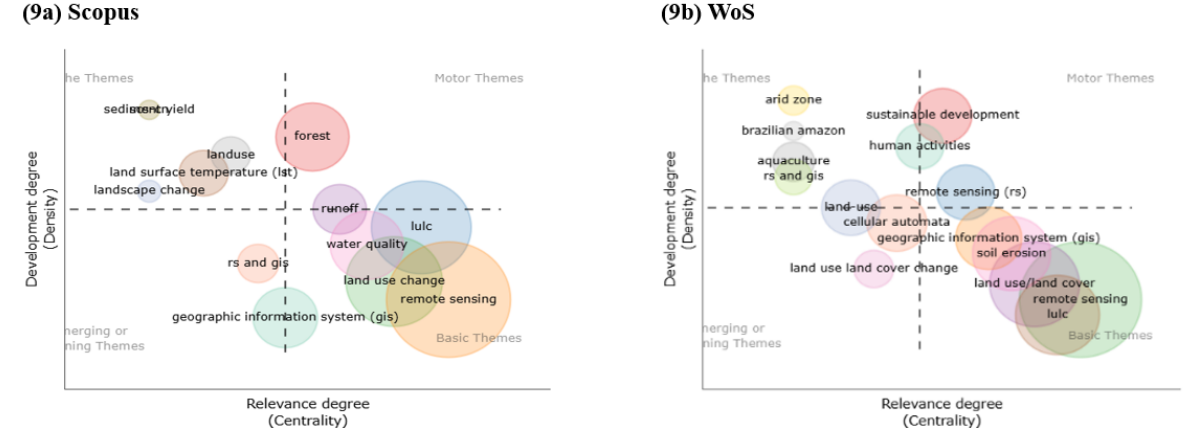

Figure 9. Thematic map illustrating the key research areas in LULC.

developed topics. Qualifying "rs and gis" (remote sensing and GIS) as nascent but of low significance, and "Basic Themes" (e.g., "water quality," "land use change," "remote sensing") as essential but immature, the lower-left quadrant is demarcated "Emerging or Declining Themes."

In contrast, the WoS (Figure 9b) identifies "sustainable development," "human activities", and "remote sensing" as "Motor Themes," indicating a broader, policy-driven scope that connects LULC change and sustainability impacts on people. Here, "dry zones" and "Brazilian Amazon" are acknowledged as specialized geographic or ecosystem-based research domains. Either "land use land cover change" and "cellular automata" are both in the "Emerging or Declining Themes." Basic Themes from the Scopus perspective (right grid) again confirm the presence of "GIS" and "remote sensing," highlighting the almost ubiquitous role of these themes in LULC studies.

Overall, Scopus seems more biased towards biophysical and environmental processes denoted by terms such as "forest" and "sediment/yield." In contrast, WoS takes a more integrated perspective, connecting LULC to sustainable development and human activities. Nonetheless, both databases consistently highlight "remote sensing" and "GIS" as key tools for LULC analysis.

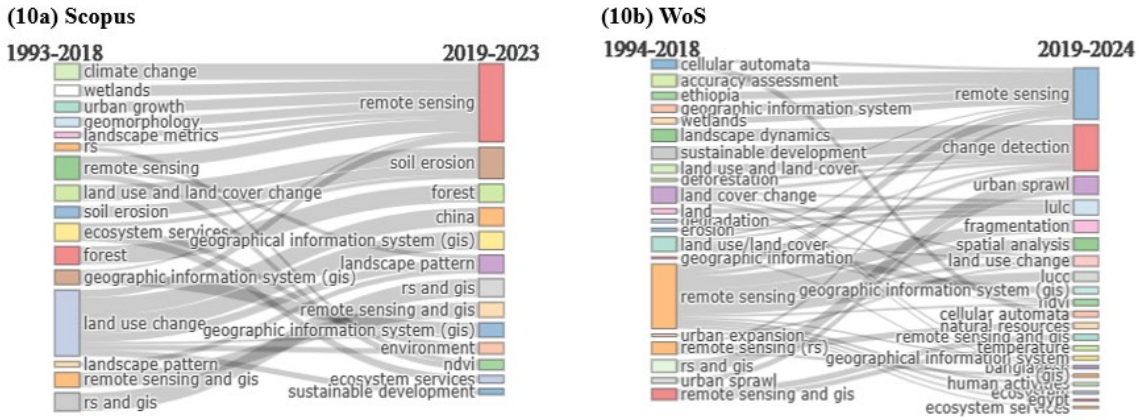

Figure 10. Thematic Evolution research themes in the field of LULC.

3.4.5. Thematic Evolution research themes in the field of LULC

Figure 10 highlights a clear progression in research interests from early periods (1993–2018 in Scopus and 1994–2018 in WoS) to more recent years (2019–2023 in Scopus and 2019–2024 in WoS).

In Scopus (Figure 10a), earlier emphases on "climate change," "wetlands," "urban growth," "geomorphology," and "ecosystem services" have evolved into topics, such as "remote sensing," "soil erosion," and "forest," with a notable focus on "China." This shift underscores a growing reliance on advanced GIS and remote sensing technologies for site-specific environmental challenges and highlights an increasing interest in particular geographic locale.

Meanwhile, the WoS data (Figure 10b) indicates a similar technical trajectory, transitioning from "cellular automata," "accuracy assessment," and "sustainable development" towards newer focal points, like "urban sprawl," "land use change," and "ecosystem services."

The result highlights the progression from core concepts, like climate change, land use change, and remote sensing to more advanced and nuanced themes, like soil erosion, RS and GIS, ecosystem services, fragmentation, spatial analysis, etc. This directly reflects the growing complexities of urbanization and anthropogenic impacts. The result also shows the evolution of the field from the environmentally focused studies to a highly technological sociocultural sensitive domain. Here, Scopus shows considerable focus on certain environmental topics (e.g., "soil erosion," "forest") and geographic areas (especially "China"). On the other hand, WoS shows a broad view including complex socio-spatial dynamics, technological advancements, and ecological services.

4. Discussion

The current study aims to analyze the evolution, trends, and future research directions on Land Use and Land Cover (LULC) over three decades (1993–2023). The key findings of the study are, a. there is a strong growth trend in publications, particularly after 2010 reflecting increasing academia and policy interest in LULC studies, b. technological developments, such as GIS and remote sensing are playing pivotal role to shape the field and, c. several new themes are emerging in the filed including ecosystem services, spatial modeling, and climate impact assessment. Together, these findings suggest the interdisciplinary nature and advancing trajectories of LULC research.

According to the findings the first stage of LULC studies span from 1993 to 2000. This period represents the infancy stage of the field, during which the fundamental concepts and techniques were developed. This period also reflects the low priority of LULC on the global agenda and restricted access to advance GIS and remote sensing techniques. This period also reflects the low priority of LULC on the global agenda and limited use to advance GIS and remote sensing technologies and methods. The second stage of LULC studies extends from 2001 to 2010 with a growing recognition of the direct consequences environmental changes on LULC as evidenced by high volume of publication. In addition, publicly accessible GIS and remote sensing techniques provided researchers with more robust and efficient tools for analyzing LULC changes (Turner et al., 2007). The third stage of LULC research happened between 2011 and 2016 during which The Paris Agreement (2015) served as a catalyst. In this period, more interdisciplinary researches containing all facets of ecological, social, and economic dimensions of LULC were conducted (Lambin & Meyfroidt, 2011). The fourth stage occurred between 2017 to 2020. This period is marked with interdisciplinary research, policy relevance, and academic legitimacy. This period witnessed the highest number of publications driven by growing awareness of climate change and its impact on LULC changes as well as funding opportunities from international organizations (Foley et al., 2011). However, between 2021 to 2023, number of LULC publications slightly decreased. This could have happened due to consolidation of research efforts, changing patterns in funding or just a natural plateau as the field mature.

This bibliometric study attempts to illustrate the formative stages of LULC studies along with its evolution and future

course. The research shows that the early studies, often descriptive and subject to data availability, have given way to sophisticated, tech-driven studies. The results highlight advances in remote sensing and open-access satellite data that have democratized high-resolution data, including analyses at the global scale. In contrast to prior studies that have primarily examined certain regions or themes, this review has acknowledged global trends and voids in LULC research. It highlights the prominent role of China and other powerhouse countries in developing this field. This analysis shifts from a descriptive study to a predictive modeling and more policy-oriented meta-analysis using a co-citation and keyword analysis.

However, the comparative analysis of Scopus and the WoS database indicates that Scopus covers more documents, mainly attributed to its wider range of journals, including conference proceedings and regional journals. The trend of increasing LULC research is consistent in both databases, with a peak in the last decade, likely influenced by the global focus on climate change and sustainability. However, a recent dip indicates the stabilization of the space, turning towards narrower, high-impact studies.

The keyword analysis reveals that keywords related to remote sensing and geographic information systems were understand environmental monitoring, spatial data analysis, and land management. Thematic grouping of keywords reveals clusters containing urbanization, sustainable development, soil erosion, and climate change. It can be said from the keywords that in Scopus, the main thrust of research is towards induced environmental change, whereas in WoS, the thrust is towards environmental degradation. Both databases contain one high-impact publication, i.e., Landscape and Urban Planning. Both databases contain highly cited authors, like Manuel Canales Pardo, Benjamin Burkhard, Adel Shalaby, and Franziska Kroll. Beijing Normal University (Scopus) and the Institute of Geographic Sciences and Natural Resources Research (WoS) lead the institutional contributions. Chinese institutes dominate LULC research globally, arguably reflecting significant state investment. Other research organizations from universities in Ethiopia, Iran, and Germany were among the contributions. China is a key center of LULC research globally, stimulating significant international collaborations, especially with the United States, Germany, and Australia. India continues to be a strong contributor, signaling its research prowess. North America, Europe, and Oceania are other regions that have made active contributions. Still, South America, Africa, and the Middle East are largely underrepresented, with notable exceptions from Brazil, South Africa, and Saudi Arabia. This analysis highlights the need for multiple databases to overview LULC research comprehensively. It also underlines the necessity for increased research capacity and international cooperation in underrepresented regions for more equitable scientific development and to meet global challenges with the land use in a timely and effective manner.

However, the bibliometric approach used in this study aids mapping the past trends and allows further LULC research. Emerging themes like urban sprawl, biodiversity preservation, and ecosystem services etc., offer clear directions for researchers in this field. Adopting spatially explicit modeling techniques in LULC also represents a paradigm shift in LULC studies, iteratively refining these techniques to simulate complex land-use dynamics (Chen et al., 2019), including CAS and agent-based models. Furthermore, results indicate the interdisciplinary nature of the LULC research, which integrates technological advancements, along with socio-ecological systems. The current study might be useful to find new research gaps in the field of LULC. It also reflects on some major trends in LULC research evolving over the years and trends keeping pace with the needs of global sustainability goals. It may offer insights that could help identify the gaps and address them with interdisciplinary approaches and modern technological integration. It envisages LULC studies as vehicles of policy innovation and sustainable development. LULC research has adapted to align more squarely with broader scientific and policy movements toward sustainability and resilience. To address these international issues, it is necessary to integrate new technologies and interdisciplinary strategies into studies. This review theorizes a vision whereby LULC research stepping out of the academic silo to induce sustainable development policies directly. Transitioning between technological scales and governance approaches, LULC studies act as a transformative most dominant. This is due to the high importance of these technologies to LULC studies. They help to urbanization- pathway to address global sustainability goals. This work is essential because it synthesizes a wealth of literature to provide a comprehensive overview of the development of LULC research and how it matches global environmental priorities. Utilizing the state-of-the-art bibliometric techniques, this research unveils new perspectives regarding the intellectual landscape of the area, recognizing pivotal authors, seminal papers, and thematic developments. By providing an overview of current knowledge on LULC, the results highlight not only the key role played by LULC in tackling climate change and biodiversity loss, but also showcase potential avenues for linking research with actionable land management.

The current study encourages to integrate the LULC studies with other domains, i.e., geography, ecology, and sociology. It also shows that new emerging themes, like ecosystem services and complexities of urbanization can be combined with LULC studies to create sub-domains. Moreover, the study highlights the importance of international collaborative research networks for successful LULC studies.

This review tries to embody the shifting paradigm in the LULC research. The study can be used as a benchmark and a roadmap for future avid scholars and practitioners. Together, the study urges to prioritize technological innovations, interdisciplinary collaboration, and policy integration in advancing the LULC research.

5. Conclusions

The current study reveals that there has been a surge in the number of publications in the field of LULC research in recent years. It also shows that, in the era of Anthropocene, the LULC change clearly reflects the relationship between human, land use and natural ecosystems. The field is crucial for sustainable land management as it can facilitate integration of land resources to meet human needs while ensuring sustainable productivity and ecological stability. In this regard, GIS and remote sensing technologies have offered unparalleled advancements in LULC studies.

The current study shows that the field of LULC research grew significantly seen 2011. It is also found that Beijing Normal University and the Chinese Academy of Sciences, are leading institutional forces in this field. Additionally, international collaborations and inter-disciplinary researches are of immense value. This is evident in the research sub-domains of urbanization, climate change, and biodiversity loss, etc. However, models addressing complex feedback loops along with socio-economic and political dimensions remain under-explored in this field, thus highlighting their importance for future research. The study identifies notable gaps regarding in the development of novel solutions that connect technical advancements and policy-oriented framework to promote sustainable environmental governance. In conclusion, the study serves as a platform for future research in the field of LULC.

Conflicts of Interest

The authors express no conflict of interest.

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