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ADVANCES IN GLOBAL LAND USE SYSTEMS DEVELOPMENT AND SUSTAINABILITY: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

Aim of the study

Land-use systems have a significant impact on environmental, economic, and societal issues worldwide. With agricultural activities, urban development, and conservation efforts, the complex nature of land use influences key global challenges, including climate change, food security, and biodiversity loss. As the world confronts these issues, it is essential to understand the trends, innovations, and emerging frontiers in land use systems. These developments not only reflect the evolving relationship between humans and the environment but also offer potential pathways toward sustainability and resilience.

Material and methods

This study uses R's Biblioshiny package to critically examine an extensive bibliographic database of 1814 publications on global land use systems development and sustainability (GLUSDS) from the Web of Science (WoS).

Results and conclusions

Findings indicate that the scientific productivity of GLUSDS has been increasing between 2004 and 2023. The five most influential sources, constituting *'Sustainability', 'Land Use Policy', 'Land', 'Science of the Total Environment' and 'Ecological Indicators'* produce and disseminate information that drives policy responses, innovations and future research perspectives. Similarly, the most cited papers demonstrate the complexity and encompassing nature of land use systems development and sustainability. There was a low (high) level of cooperation between (among) the leading scholars in the field. Compared to emerging nations, industrialised nations such as China, the United States, the United Kingdom, and Germany have a far greater impact on land use science. Current research trends demonstrate the utilization of *'digital technolo-*

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gies (DTs)' through the application of Geographic Information Systems (GIS) and integrated remote sensing techniques, Geo-detectors, regression models, artificial intelligence, as well as social and economic models to comprehensively identify, monitor and advance knowledge in land use science, management and sustainability. Thus, we support initiatives like *'Citizen Science'* that promote the adoption of cutting-edge theories, methods, instruments, and procedures that support the sustainable use of lands and other natural resources. Limited scientific investments and productivity from industrialized and emerging nations call for further studies in land system science and management.

Keywords: biblioshiny, emerging frontiers, global, land system science, sustainable development

INTRODUCTION

Land-use systems have a significant impact on environmental, economic, and societal outcomes worldwide (Zscheischler and Rogga, 2021). With agricultural activities, urban development, and conservation efforts, the complex nature of land use influences key global challenges, including climate change, food security, and biodiversity loss (Quintana et al., 2021). As the world confronts these issues, it is essential to understand the trends, innovations, and emerging frontiers in land-use systems (Schirpke et al., 2023). These developments not only reflect the evolving relationship between humans and the environment but also offer potential pathways toward sustainability and resilience (Zscheischler and Rogga, 2021). To inform policy and guide effective land management, it is crucial to comprehend the efforts made to enhance scientific productivity and investments toward global land-use systems development and sustainability (GLUSDS). Land use was previously largely driven by subsistence agriculture, which evolved to accommodate the growing population and economic development (Schirpke et al., 2023). The Industrial Revolution marked a significant turning point, introducing mechanised farming and contributing to extensive environmental degradation (Hsieh and Rossi-Hansberg, 2023). In recent decades, there has been a pronounced shift towards urbanisation, which has profound implications for land use planning and management. The impact of human decisions at varying scales, from local landowners to national land use planning and international trade agreements, is profoundly manifested in land system changes. The consequences of these changes resonate globally, altering the provision of vital ecosystem services, regulating natural hazards, and shaping cultural landscapes (Verburg et al., 2015). Consequently, the evolving global land use systems are both a cause and a consequence of the intricate interplay between socio-ecological processes. This historical evolution underscores the adaptability of land use systems and highlights the escalating challenges posed by limited land resources, emphasising the need for innovative and sustainable approaches to land management (Hsieh and Rossi-Hansberg, 2023).

Global land use systems have undergone significant changes over time, influenced by technological advancements, socioeconomic transformations, and environmental challenges (Long et al., 2021). A multidisciplinary approach to land use planning, which integrates technological, policy, and economic considerations, has become crucial in addressing the complexities of modern land use management (Oh and Lu, 2023). As technology continues to advance, evolving policy landscapes and calls for sustainable and equitable land management practices persist. In adapting to these changes and balancing competing demands on land resources, it will be vital to secure a sustainable future for human societies and the environment (Oreggioni et al., 2021). As a successor to the Land Use and Land Cover Change (LULCC) (1994–2005) and the Global Change and Terrestrial Ecosystems project, GLP has been instrumental in shaping the discourse on land system science (LSS). Arising from the convergence of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), GLP serves as a pivotal platform for synthesizing insights, methodologies, and knowledge within the LSS community (Dear et al., 2013). Addressing the evolving

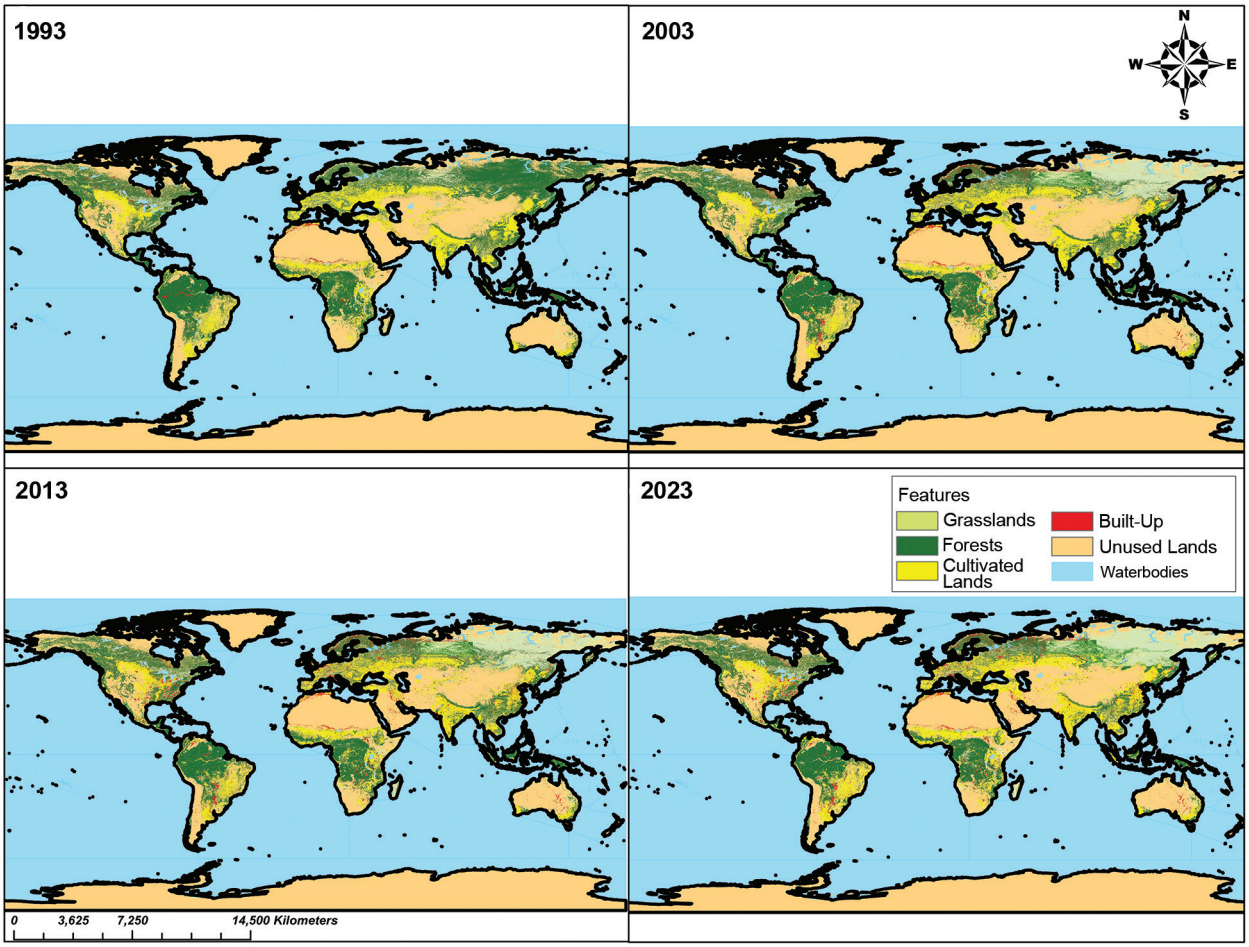

Fig. 1. Global land use and land cover change (LULCC) between 1993 and 2023 (source: Authors' own elaboration, using using ENVI 5.3 and ArcGIS 10.8)

challenges of understanding and managing global land use systems, GLP carries forward the legacy of its predecessors. Fig. 1 presents the spatial distribution of global LULCC between 1993 and 2023 using Landsat datasets archived in Google Earth Engine (GEE) (https://code.earthengine.google.com/) and ArcGIS 10.8 software.

Evidence presented (i.e., Fig.1 with further details in Table 1.A) shows considerable shifts in some classes over the past three decades. The distribution (Table 1.A) shows that cultivated land, built-up, grassland and water bodies have been increasing steadily at a rate of +12.22%, +4.64%, +12.28% and +0.02%, respectively, over the past 30 years. Contrarily, a reduction in areas covered by unused land (-0.07%) and forests (-10.87%) could be observed over the same period. These changes are mainly driven by policy mixes linked to socio-political, cultural, economic, technological advancements, and biophysical or climate-induced factors. For instance, increase in built-up areas in Siberia can be attributed to the vast availability of natural resources in the region, such as oil, gas, and gold, have attracted transnational and multinational companies looking to exploit these resources. As a result, there is a growing demand for labor in the area, leading to an influx of workers and their families. Another key factor contributing to this development is associated with improved transportation

and infrastructure, such as building new roads, railways, and airports by the Russian government in the region. These have made it easier for people to travel and settle in the area. Improved infrastructure has also facilitated the movement of goods and services, further attracting businesses and investors to Siberia. As a result, previously isolated and remote areas in Siberia are now more accessible, leading to a surge in population growth and economic activity. Moreso, the changing climate and environmental conditions in Siberia are also driving the increase in settlements in the region. As global temperatures rise, the Arctic ice is melting, opening up new shipping routes and opportunities for economic development in Siberia. This, in turn, has attracted more people to the region in search of job opportunities and a better quality of life. Additionally, some regions in Siberia are experiencing milder winters, making it more hospitable for settlement and agriculture.

Innovations in land-use management (LUM) are crucial in addressing the contemporary challenges faced by global land-use systems (Spangler et al., 2020). Technological advancements, such as Geographic Information Systems (GIS), remote sensing, and drone technology, have revolutionised land use planning and monitoring, enabling more precise and efficient management of land resources (Kumar et al., 2022). These technologies provide detailed, real-time data on land use patterns, environmental conditions, and resource availability, facilitating better decision-making (Schirpke et al., 2023). Additionally, sustainable farming techniques, including agroforestry, organic farming, and permaculture, are increasingly being adopted to improve agricultural productivity while preserving the ecological balance (Dinesha et al., 2024). In urban areas, innovations, such as green infrastructure, smart city designs, and vertical farming, are being implemented to enhance urban sustainability and resilience (Oh and Lu, 2023). Table 1 presents information on some major studies conducted on global land use systems development, key approaches utilized, policy implications and future research perspectives that drive the current study.

Table 1. Some major global land use development and sustainability studies (source: Authors own elaboration)

Author (s)/ Year	Title	Objective	Methodology	Policy implications/Future Directions
Wu et al. (2023)	Global Land-Use and Sustainability Implications of Enhanced Bioenergy Import: A Case Study of China	*Assess potential impacts on local and global land systems, considering food security, greenhouse gas emissions, and resource demands. *Investigate and compare the effects of different strategies for increasing bioenergy imports to China in alignment with the 1.5°C – compatible bioenergy demand.	*Utilized the Global Biosphere Management Model (GLOBIOM) to simulate and analyze the consequences of various bioenergy import scenarios from different regions across the globe	1. China's rising bioenergy imports could affect local and global land systems differently. 2. Strict and stern trade regulations might convert up to 25% of unmanaged forests into managed ones in supplier regions. 3. Trade-offs like impacts on food security, greenhouse gas emissions, and resource demand must be weighed. Implications: The study underscores the need to weigh sustainability trade-offs in bioenergy trade decisions, suggesting economically optimized biomass imports to balance environmental and economic considerations.

Author (s)/ Year	Title	Objective	Methodology	Policy implications/Future Directions
Nguyen et al. (2023)	Security Risks from Climate Change and Environmental Degradation: Implications for Sustainable Land Use Transformation in the Global South	Examine data demonstrating the security risks associated with loss of biodiversity and climate change in the Global South. *Offers insights for the future on how to employ a variety of land use techniques in order to boost adaptability.	* Evaluation of the body of current literature	1. The conservation of resources and biodiversity, agroforestry, and agricultural diversification should be the main goals of land use in rural areas. 2. Adapting to changing climatic conditions requires making use of neglected species and cultivars that are climate-resilient. 3. Putting these solutions into practice is essential to improving resilience in vulnerable communities and increasing the well-being of the environment.
Haregeweyn et al. (2023)	Progress and challenges in sustainable land management initiatives (SLM): A global review	* Evaluate the state of sustainable land management (SLM) efforts worldwide, paying particular attention to the distribution of land, the future, and the difficulties associated with SLM research and practices.	* Examined 1181 scholarly research publications and 1900 SLM practices from international databases, including WOCAT. *Investigated variables such as priority regions for water erosion, land use types, and the Human Development Index.	1. Demand comprehensive research on national SLM issues to support efficient distribution. 2. Promote the integration of SLM databases with scientific research to improve evidence quickly. 3. Determine the barriers to achieving various SLM benefits and policy improvements. 4. Emphasize the necessity of standardised data and technologies to guarantee uniform soil erosion assessment worldwide.
Li et al. (2022)	Global trends and local variations in land take per person	*To comprehend the dynamics of urbanisation processes and provide guidance for sustainable urban development strategies, examine local differences in land take per person in urban regions as well as worldwide trends.	* Relating changes in built-up land to land take per person and population dynamics across more than 75,000 administrative regions worldwide. * GHSL was used to measure land-use intensity as the number of people per unit of built-up land, based on population and built-up land statistics. * Developed models that connect variations in land take per person and population to built-up land changes, investigating sensitivity through different methods.	1. Noted how variations in land take per person affect the expansion of built-up land. 2. Identified patterns of urban densification in large cities, leading to urban polarisation with sparser rural regions. 3. Demanded a careful examination of urban densification strategies that go beyond land use, taking into account possible trade-offs with human well-being. 4. Draw attention to the need for detailed knowledge at lower spatial dimensions for sustainable urban development, taking into account both local and global contexts.

Table 1. cont.

Author (s)/ Year	Title	Objective	Methodology	Policy implications/Future Directions
Estoque et al. (2021)	Monitoring global land-use efficiency in the context of the UN 2030 Agenda for Sustainable Development	* Measure land-use efficiency in relation to the UN 2030 Agenda for Sustainable Development, with emphasis on the land-use efficiency indicator of the ratio of land consumption rate to population growth rate (LCRPGR) (SDG 11.3.1).	* Assessed Earth observation data from 1975 to 2015 to investigate temporal and geographical variations in LCRPGR. * Applied remote sensing to urban areas and analysed population statistics for the years 1975, 2000, and 2015. *Employed GIS data to establish SDG-based regional classifications and national borders. *Key Findings: -In terms of LCRPGR, „Europe and Northern America" had the greatest values between 1975 and 2000 and between 2000 and 2015; „Eastern and South-Eastern Asia" exhibited progress. *There were variations in regional correlations between land consumption and population growth, despite a strong global connection between LCR and PGR.	1. Results contribute to SDG monitoring and provide insights for SDG indicator 11.3.1, land use and urbanization studies. 2. Highlighted the importance of considering changes in in situ natural capital and external impacts of urbanization for an improved understanding of land-use efficiency. 3. One of the limitations of the SDGs' land-use efficiency model is that it excludes changes in in situ natural capital, the external impacts of cities, and metropolitan areas.
Kastner et al. (2021)	Global Agricultural Trade and Land System Sustainability: Implications for Ecosystem Carbon Storage, Biodiversity, and Human Nutrition	*This review explores the impact of global agricultural trade on land systems, addressing implications for ecosystem carbon storage, biodiversity, and human nutrition. The study aims to provide a comprehensive understanding of the diverse sustainability dimensions influenced by international trade of agricultural products.	*Systematic Literature Review and content analysis	1. Research should focus on essential micronutrients and trade's impact on nutrient availability. 2. Assessments must consider trade's influence on entire ecosystems and services. 3. Studies on trade and biodiversity should use diverse metrics. 4. Fine-resolution assessments are crucial for understanding localised impacts of agricultural trade. 5. Use precise methods to identify intervention points along supply chains. 6. Link global studies with local processes for a holistic view of trade impacts. 7. Emphasise interdisciplinary research for better trade-off management.

Advancements in Land Use Science (LUS) represent a paradigm shift in land use management, moving towards efficient, productive, environmentally sustainable, and socially equitable practices (Alinda et al., 2024). Similarly, emerging fields in LUS are increasingly recognised for their prospect of revolutionising traditional practices and contributions to global sustainability goals (Kumar et al., 2022). One such field involves the integration of renewable energy projects into land-use planning, addressing the pressing need for sustainable energy sources (Hsieh and Rossi-Hansberg, 2023). Additionally, innovative agricultural practices such as vertical farming and urban agriculture are gaining momentum, offering solutions for food production in space-constrained urban environments while reducing the carbon footprint associated with traditional farming and transportation (Hasnat and Hossain 2021). The expansion of protected natural areas and the promotion of ecotourism are also emerging as key land-use strategies that aim to conserve biodiversity and provide economic incentives for sustainable land management (Monkkonen et al., 2023). These emerging fields highlight the shift towards more integrated and multifunctional land use approaches, balancing the needs for development, conservation, and sustainability in the face of a rapidly changing global context (Zscheischler and Rogga, 2021). This, therefore, underscores the need to carry out this study to explore the scientific productivity, impact, emerging frontiers, and issues on GLUSDS. This review study enriches the existing literature on the rare and underdeveloped topic of land use systems development and sustainability across the globe. Consequent to this aim, we attempt to:

1. Analyse the research output or contributions of various authors, journals and nations towards the development of global land use systems and sustainability.
2. Investigate the degree of collaboration, impact, co-occurrence analyses, and emerging frontiers driving smart land use tools, theories and practice.
3. Examine how these trends, smart tools and emerging frontiers create avenues for innovation and enhance scientific research in related fields.

METHODOLOGY

Data source

Considering the extent of works of literature and research progress on GLUSDS, we utilised a bibliometric approach to attain the objectives presented above. Table 2 captures data generated from the Web of Science (WoS) core database between 2004 and 2023. It details information, search terms and how documents/data acquired were refined for further analysis. The WoS is known for its reputable, established, and widely-known bibliographic and citation database, archived in a well-structured format. The choice of opting for this specific period (2004–2023) is primarily linked to the validity and reliability of advancements, tools and scientific production of GLUSDS-related studies. A review of the extracted data revealed that scientific studies conducted prior to the years under consideration were scarce. Additionally, review studies that comprehensively explore GLUSDS remain underdeveloped or largely unexplored. This study covers the most recent periods and advances in the field, which may have been overlooked in previous studies. It further utilises a broader search criterion across various disciplines/fields (Table 2). We restricted the choice of language to 'English' to ensure uniformity in data coverage; thus, by using one standardised parameter, we do not have to deal with over and under-representation of studies published in local dialects.

Bibliometric technique: Application of R Studio's Biblioshiny software/package

This technique, using the provided package or software, has been applied in numerous studies to document advancements in various disciplines during specific periods. Both studies by Sarfo et al. (2024), who reported on China's rural revitalization paradox, and Effah et al. (2023), who focused on the sustainability reporting domain, utilised R Studio's Biblioshiny Java software. This software integrates the bibliometrix package functions and facilitates the creation of web-based applications. Using a bibliometric approach, Lu et al. (2022) studied ecological networks in nature conservation between 1990 and 2020. Similarly, Pham et al. (2022) used this and a social networking approach to examine land quality for sustainable devel-

Table 2. Steps utilised for data acquisition processes based on WoS core database between 2004 and 2023 (source: Authors' own elaboration)

Steps	Field(s)	Search terms	Refined by/document type	No. of documents
Step 1	*All	„global land use system*" (Topic) or „land use management" (Topic) or „land use science" (Topic) or „land use" (Topic) and „ land cover change" (Topic) and „sustainable development" or „global sustainability" (Topic)	*Overall output	2,221
Step 2			*Solely entails articles/ review articles and book chapters.	2,204
Step 3	*Environmental Sciences, Environmental Studies, Ecology, Water Resources, Geosciences, Multidisciplinary, Soil Science, Green Sustainable Science Technology, Biodiversity Conservation, Remote Sensing, Geography, Environmental, Engineering Geological, Energy Fuels, Evolutionary Biology, Food Science Technology, Social Sciences Interdisciplinary, Mathematics, Interdisciplinary Applications, Agricultural Economics Policy, Instruments Instrumentation, Humanities Multidisciplinary, Management, Paleontology and Area Studies.		* Web of Science Categories for the given disciplines (i.e., papers indexed in Science Citation Index Expanded (SCIE); Social Science Citation Index (SSCI); Arts and Humanities Citation Index (A & HCI); Emerging Sources Citation Index (ESCI) journals.	1,829
Step 4			*Solely papers written in English	1,814

opment. This study employed the same standardised technique to identify and quantify the co-occurrence of keywords based on the articles generated in line with the search terms presented in Table 2 and information titles, abstracts, year of publication, and publishing units according to the data generated from the WoS database. Fig. 2 presents the workflow of the bibliometric analysis carried out through R Studio's Biblioshiny software. Despite the availability of descriptive statistics regarding the significant contributions and research output of various authors, journals, institutions, and nations through the WoS web-based platform, this study refines and submits these reports and contributions to content analysis.

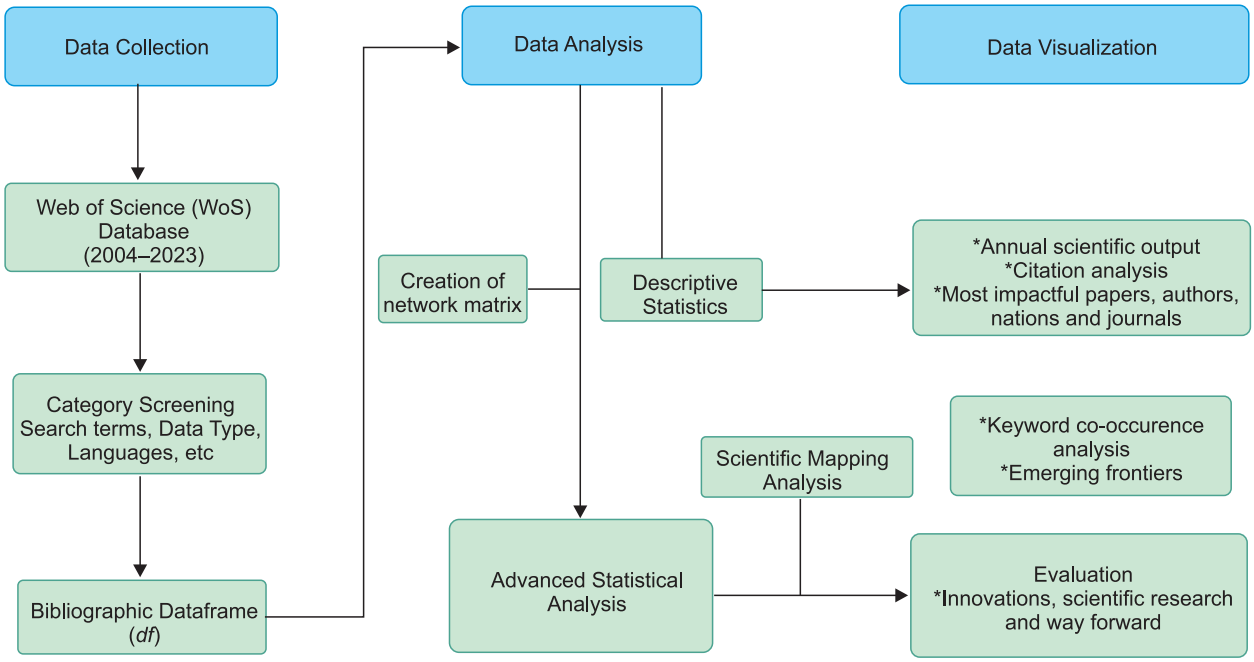

Fig. 2. Bibliometric analysis procedures utilised in this study (source: Author' own elaboration)

RESULTS

This section presents findings based on this study's objectives to (i) analyse the research output or contributions of various authors, journals, and nations towards the development of global land use systems and sustainability, (ii) investigate the degree of collaboration, impact, co-occurrence of analyses, and emerging frontiers influencing smart land-use tools, theories and practice, and (iii) examine how these trends, smart tools and emerging frontiers create avenues for innovation and enhance scientific research in related fields. In this part, a comprehensive analysis of scholarly reviews, contributions and research breakthroughs in the domain of global land use systems development is undertaken.

Annual distribution of GLUSDS publications and citations

Figure 3 illustrates global research productivity of land use systems development and sustainability between 2004 and 2023. Empirical data demonstrates that both scientific productivity and citations have experienced a consistent upward trend throughout the study period. Land use persists as a prominent subject in the contemporary era due to the escalating pressure exerted upon finite resources and the necessity of harmonising economic development with environmental preservation. As populations continue to grow and urban areas expand, competition for land for agriculture, housing, industry, and natural habitats intensifies. This leads to conflicts over land ownership, land grabbing, deforestation, loss of biodiversity, and climate change. Governments, policymakers, and stakeholders must address these issues by implementing sustainable land use planning, promoting land rights and inclusive decision-making processes, and integrating land use policies with broader sustainable development goals. The intricate interplay between social, economic, and environmental factors makes land use a complex and crucial issue that requires careful consideration and collaboration to ensure the long-term well-being of both present and future generations. These have greatly influenced scientific productivity (Fig. 3) on GLUSDS among different authors, institutions and nations.

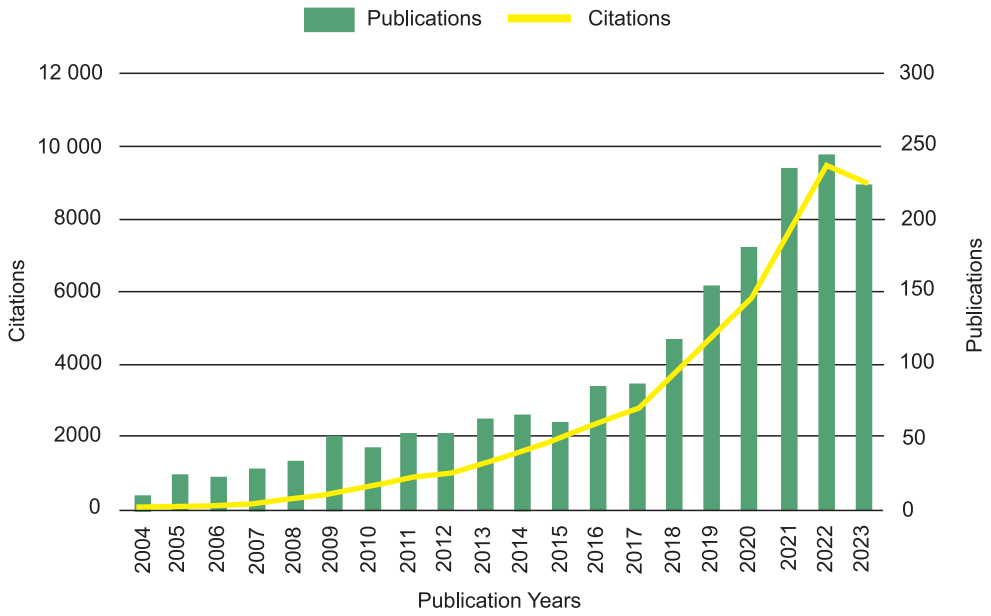

Fig. 3. Trends in global research productivity of land use systems development and sustainability between 2004 and 2022 (source: Authors' own elaboration)

Productivity of various academic journals

Given the 1,814 number of articles/book chapters based on our keyword search in the WoS database, the top 25 most influential sources that actively publish articles/book chapters in this field of study are presented in Table 2 and Fig. 4. Out of this total, the top 15 journals (Fig. 4) contributed a total of 707 articles (i.e., more than a quarter of the total number of articles) to this field, representing 38.9%. Similarly, the top 5 journals *'Sustainability'*, *'Land Use Policy'*, *'Land'*, *'Science of the Total Environment'*, *and 'Ecological Indicators'* contributed 22.7% (i.e., 412 articles) to this sample.

Table 3. Most relevant sources pertaining to global land use systems development and sustainability (source: Authors' own elaboration)

Peer-reviewed journals/sources	Number of articles
Sustainability	98
Land Use Policy	92
Land	88
Science of The Total Environment	70
Ecological Indicators	64
Remote Sensing	37
Journal of Environmental Management	36
International Journal of Environmental Research and Public Health	33
Water	32

Peer-reviewed journals/sources	Number of articles
Environmental Monitoring and Assessment	30
Land Degradation & Development	30
Catena	25
Environmental Earth Sciences	25
Journal of Hydrology	24
Agriculture Ecosystems & Environment	23
Journal of Cleaner Production	23
Geoderma	22
Applied Geography	18
Ecosystem Services	16
Environmental Science and Pollution Research	16
Ecological Modelling	15
Environmental Management	15
Frontiers In Environmental Science	15
Physics and Chemistry of The Earth	13
Environment Development and Sustainability	12

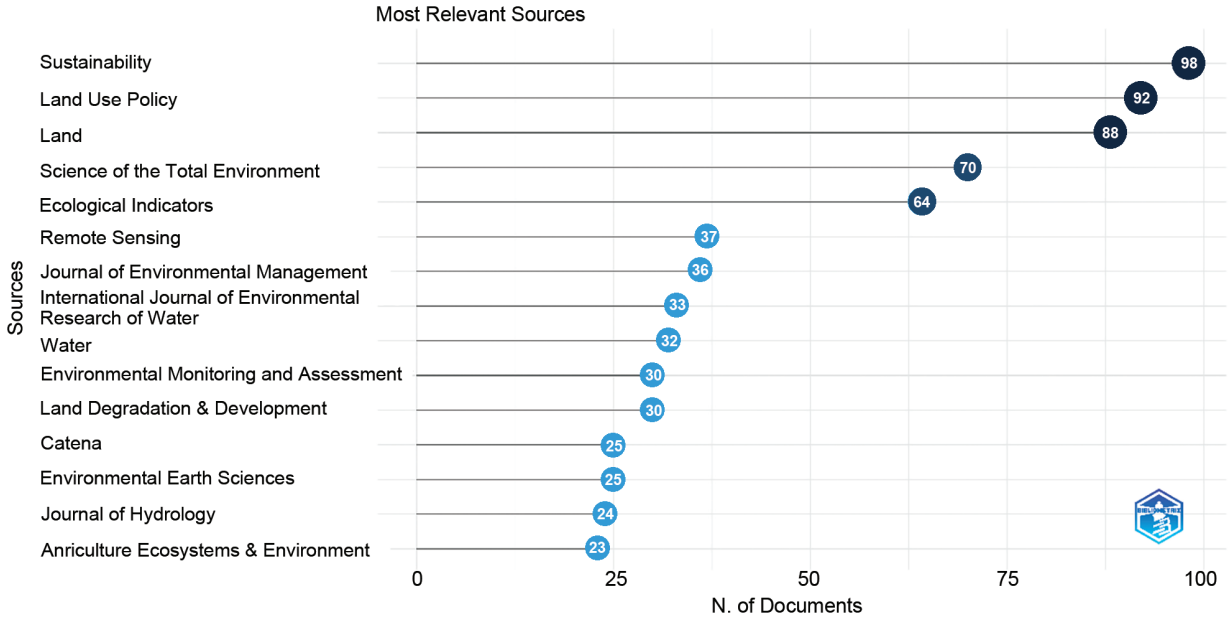

Fig. 4. Most influential sources in relation to global land use systems development and sustainability based on WoS database (2004–2023) (source: Authors' own elaboration)

Global land use systems development and sustainability studies citation analysis

Figure 5 depicts the 15 most influential authors whose efforts have considerably impacted the field between 2004 and 2023. The productivity levels and associated impacts are reflected in the total number of publications, considering the year the article or book chapter was indexed or published in the WoS database, along with the corresponding number of citations received. Indicatively, Zhang, Y. (14), Wang, Y (13), Li, X (9), Zhang, H. (9), and Kumar, P. (8) are the top-performing authors with the highest number of publications on GLUSDS.

Moreover, Table 3 presents the top 25 most cited/impactful papers in GLUSDS studies between 2004 and 2023. The paper titled *'Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management*,' authored by Tscharntke et al. (2005), stands out as the most cited, accumulating over 2829 citations. In contrast, the least cited paper in the study received 200 citations. Interestingly, only a few relevant sources (i.e., solely four journals – *Science of the Total Environment*, *Ecological Indicators*, *Catena and Agriculture Ecosystems and Environment*) (Fig. 4) appeared to have papers cited in the top 25 most impactful studies (Table 3).

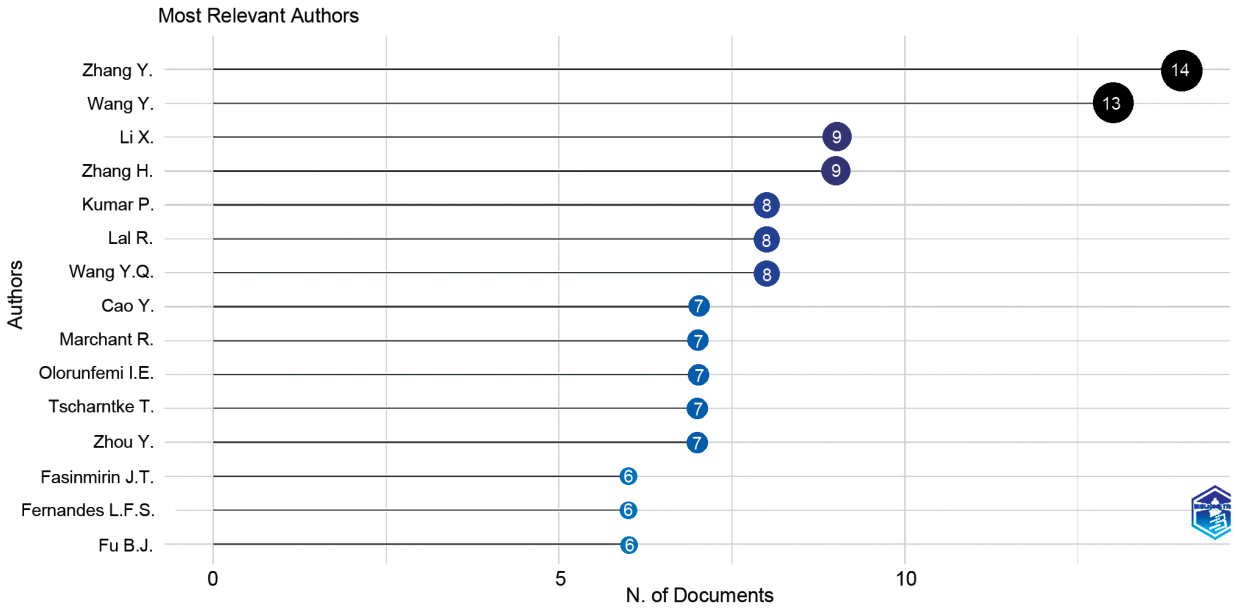

Fig. 5. Top 15 performing authors in relation to global land use systems development and sustainability studies based on WoS database (2004–2023) (source: Authors' own elaboration)

Table 4. Most cited global land use systems development and sustainability-related studies based on WoS database (2004–2023) (source: Authors' own elaboration)

No.	Paper	Author/Publication Year/Journal	DOI	Total citations (TC)	TC per year
1	Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management	Tscharntke (2005), Ecol Lett	10.1111/j.1461-0248.2005.00782.x	2829	141.45
2	Soil structure and management: a review	Bronick (2005), Geoderma	10.1016/j.geoderma.2004.03.005	2611	130.55
3	China and India lead in greening of the world through land-use management	Chen (2019), Nat Sustain	10.1038/s41893-019-0220-7	1391	231.83
4	Defining place attachment: A tripartite organizing framework	Scannell (2010), J Environ Psychol	10.1016/j.jenvp.2009.09.006	1278	85.20
5	Effects of landscape structure and land-use intensity on similarity of plant and animal communities	Dormann (2007), Global Ecol Biogeogr	10.1111/j.1466-8238.2007.00344.x	1104	61.33
6	Functional group diversity of bee pollinators increases crop yield	Hoehn (2008), P Roy Soc B-Biol Sci	10.1098/rspb.2008.0405	471	27.71
7	A Review of the Application of Optical and Radar Remote Sensing Data Fusion to Land Use Mapping and Monitoring	Joshi (2016), Remote Sens-Basel	10.3390/rs8010070	394	43.78
8	Modeling urban land use change by the integration of cellular automaton and Markov model	Guan (2011), Ecol Model	10.1016/j.ecolmodel.2011.09.009	386	27.57
9	Relative impacts of land-use, management intensity and fertilization upon soil microbial community structure in agricultural systems	Jangid (2008), Soil Biol Biochem	10.1016/j.soilbio.2008.07.030	386	22.71
10	The distribution and morphology of microplastics in coastal soils adjacent to the Bohai Sea and the Yellow Sea	Zhou (2018), Geoderma	10.1016/j.geoderma.2018.02.015	361	51.57
11	Effects of land use, land cover and rainfall regimes on the surface runoff and soil loss on karst slopes in southwest China	Peng (2012), Catena	10.1016/j.catena.2011.11.001	303	23.31

Table 4. cont.

No.	Paper	Author/Publication Year/Journal	DOI	Total citations (TC)	TC per year
12	Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis	Torralba (2016), Agr Ecosyst Environ	10.1016/j.agee.2016.06.002	294	32.67
13	Half of global methane emissions come from highly variable aquatic ecosystem sources	Rosentreter (2021), Nat Geosci	10.1038/s41561-021-00715-2	294	73.50
14	Managing the middle: A shift in conservation priorities based on the global human modification gradient	Kennedy (2019), Global Change Biol	10.1111/gcb.14549	289	48.17
15	Structure and Functioning of Dryland Ecosystems in a Changing World	Maestre (2016), Annu Rev Ecol Evol S	10.1146/annurev-ecolsys-121415-032311	275	30.56
16	Enzyme activities as affected by soil properties and land use in a tropical watershed	Acosta-Martínez (2007), Appl Soil Ecol	10.1016/j.apsoil.2006.05.012	255	14.17
17	Runoff and sediment losses from 27 upland catchments in Southeast Asia: impact of rapid land use changes and conservation practices	Valentin (2008), Agr Ecosyst Environ	10.1016/j.agee.2008.06.004	238	14.00
18	Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data	Abd El-Kawy (2011), Appl Geogr	10.1016/j.apgeog.2010.10.012	237	16.93
19	Phosphorus mitigation to control river eutrophication: murky waters, inconvenient truths, and „postnormal" science	Jarvie (2013), J Environ Qual	10.2134/jeq2012.0085	235	19.58
20	Carbon losses from soil and its consequences for land-use management	Dawson (2007), Sci Total Environ	10.1016/j.scitotenv.2007.03.023	234	13.00
21	The Use of Crowdsourcing to Improve Global Land Cover	Fritz (2009), Remote Sens-Basel	10.3390/rs1030345	232	14.50
22	Relationships between land use patterns and water quality in the Taizi River basin, China	Bu (2014), Ecol Indic	10.1016/j.ecolind.2014.02.003	229	20.82

No.	Paper	Author/Publication Year/Journal	DOI	Total citations (TC)	TC per year
23	Public health impacts of the severe haze in Equatorial Asia in September–October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure	Koplitz (2016), Environ Res Lett	10.1088/1748-9326/11/9/094023	221	24.56
24	Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria	Arowolo (2018), Sci Total Environ	10.1016/j.scitotenv.2018.04.277	208	29.71
25	Bats and birds increase crop yield in tropical agroforestry landscapes	Maas (2013), Ecol Lett	10.1111/ele.12194	200	16.67

Authorship and country-based collaborative network analyses

The collaborative network analysis performed was aimed at exploring the level of collaboration among the leading authors and nations within the scope of this study. Here, the size of each circle indicates the dominance of each author, whereas the length and thickness of the nodes or connecting lines denote the degree of collaboration between the top-performing or most influential authors in the field. In addition, a moderate or subtle degree of collaboration exists among (i.e., within/intra) the leading authors in the same country/institution. The illustration (Fig. 6) clearly shows a low level of collaboration between the leading authors in the field of global land use systems development and sustainability based on the data generated from the WoS core database. However, as seen in Figure 6, there was a collaboration between Olorunfemi IE, Fasinmirin JT, and other researchers on the paper titled "Dynamics of land use land cover and its impact on carbon stocks in Sub-Saharan Africa: an overview." They record that more than two-thirds of the SSA population relies on forests, yet there is an acceleration in deforestation, leading to diminished ecosystem resilience (Olorunfemi et al., 2022).

Synonymously with Fig. 6, a low level of collaboration exists between the leading nations, contributing immensely to the development and sustainability of global land use systems. Evidence presented in Fig. 7 depicts China, the USA, Germany, the United Kingdom (UK), Canada, The Netherlands, Australia, France, Sweden, Ethiopia, South Africa, Ghana, and a host of other nations as the most influential nations based on a single country (SC) and multiple countries (MC) productivity levels. It is worth noting that the country of affiliation for the corresponding authors concerning the articles used for the analysis in this study reflects the dominance of nations and the level of collaboration in the field of land use science and sustainability. A strong level of collaboration exists between authors who originate from China and the USA based on the thickness and proximity of connecting lines/nodes between both countries.

Per regional analysis, there is some moderate to high level of collaboration between European countries and countries from other continents. Similarly, several nations within Africa, Oceania, North America, and other continents have low investments and scientific output in global land use systems development and sustainability; hence, the lack of representation or trace of collaboration is based on the evidence presented in Fig. 7.

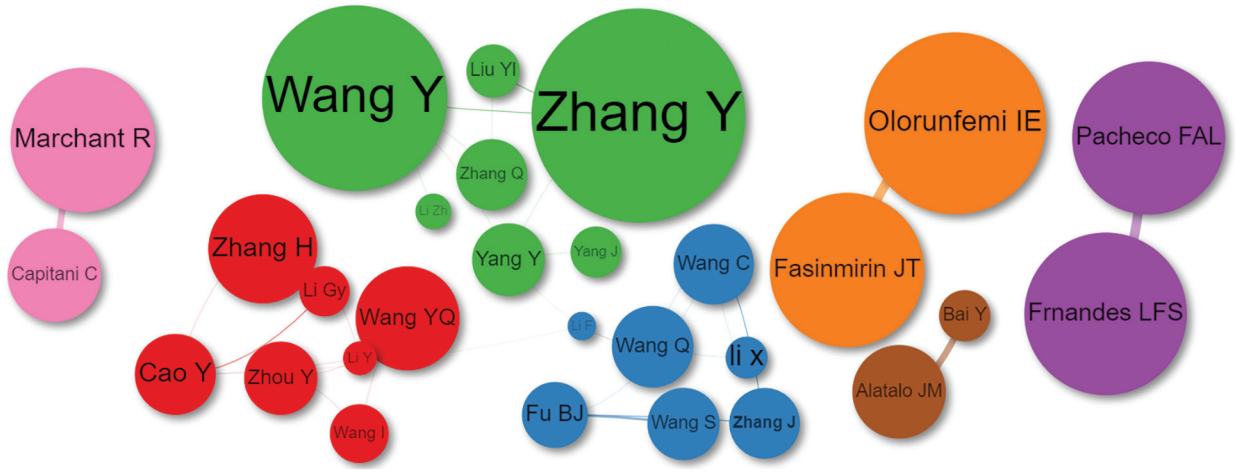

Fig. 6. Degree of collaboration between/among the top performing authors in global land use systems and sustainability studies based on WoS database (2004–2023) (source: Authors' own elaboration)

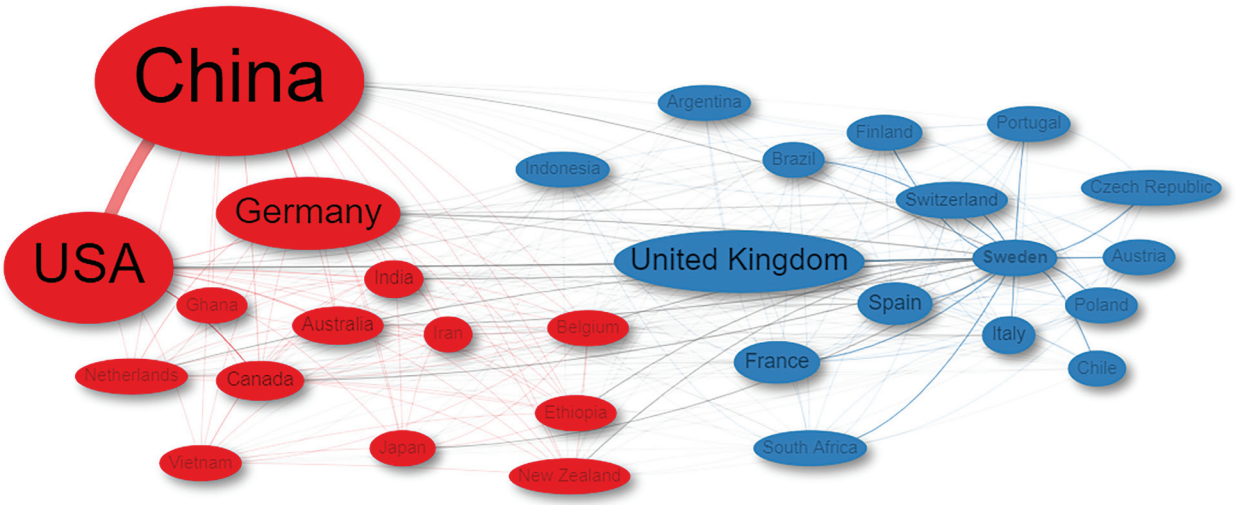

Fig. 7. Productive nations' research collaboration in global land use systems and sustainability studies based on the WoS database (2004–2023) (source: Authors' own elaboration)

Word frequency and keyword co-occurrence analysis

Frequently used keywords (Fig. 8) over time, considering 1,814 articles/book chapters generated or utilised for this study's analysis based on the WoS database between 2004 – 2023, showcase the recurrent use of certain keywords and how they have been synergized or applied in other fields based on the complexity, encompassing a multidisciplinary nature of land use and sustainability-related concepts. Fig. 8 shows *'Land Use'*, *'Land Use Management'*, *'Ecosystem Services'*, *'Climate Change'*, and *'Remote Sensing'* over the given study duration (2004–2023), have been captured among keywords in the total number of articles used for this study's analysis. For instance, *'Land Use'* occurred more than 150

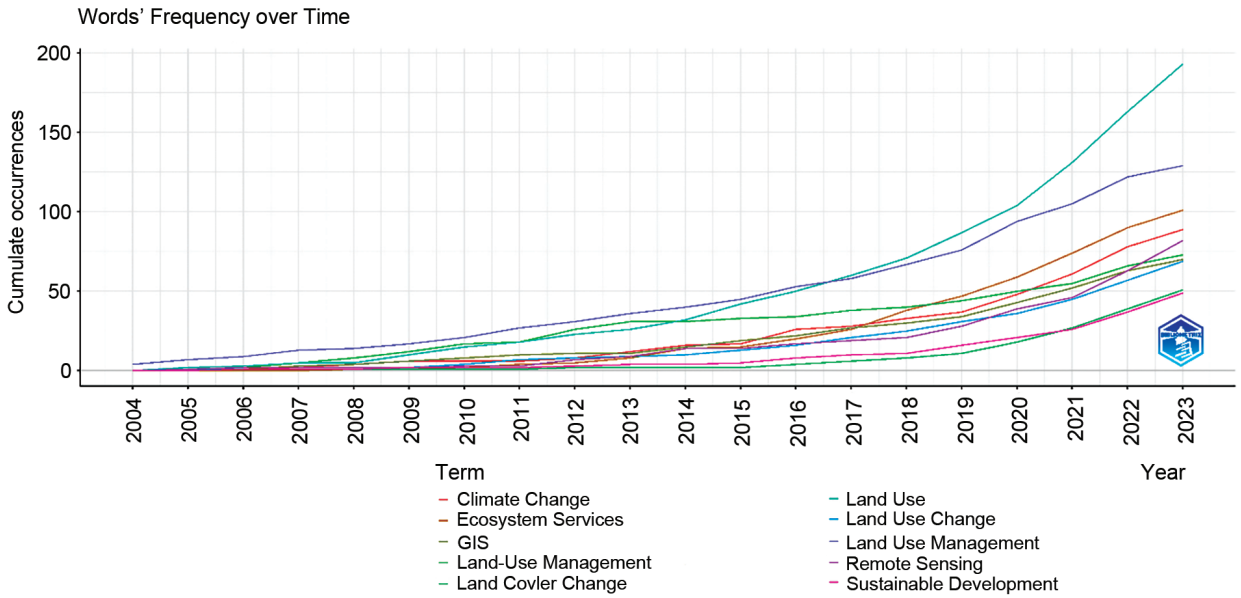

Fig. 8. Most frequently used words in global land use systems and sustainability studies based on WoS database (2004–2023) (source: Authors' own elaboration)

times in most of these studies, whereas *'Land Use Management', and 'Ecosystems Services, Climate Change and 'Remote Sensing'* occurred more than 100 and 50 times, respectively. Similarly, other keywords frequently occurring in most global land use systems development and sustainability studies entailed *'GIS', 'Land Cover Change' and 'Sustainable Development.'* Based on the distribution presented (Fig. 8), these keywords have attracted academic interest, particularly in recent years.

The keyword co-occurrence analysis was also employed to demonstrate the centrality and the synergy of keywords within the study sample. Per the analysis given in Fig. 9, the thickness or size of the widths of the connecting lines to each keyword or concept demonstrates the degree of co-occurrence based on the given study sample. Indicatively, the top 10 widely used concept/keyword pair within the understudied field (Fig. 9) based on the width/thickness of the connecting lines/nodes constitute '*Land Use-Land Cover'*, *'Land Use – Climate Change', 'Land Use – Ecosystem Services', 'GIS – Spatial Planning', 'GIS – Remote Sensing', 'Land Use – Remote Sensing', 'Land Use – Urbanization', 'Land Use – Water Quality', 'Ecosystem Services – Sustainable Development' and 'Land Use – Land Use Management'.* Within the development and sustainability of the sector, these pairs delve into environmental, technological, economic, socio-cultural, and political variables. In a similar vein, they offer insight into the complex and dynamic nature of land use systems.

Keywords timeline classifications

A host of topics have increasingly and persistently made waves over time. Timeline keyword classifications based on results presented in Fig. 10 show trending topics and emerging frontiers in global land use systems development and sustainability-related studies. The size of the nodes in Fig. 10 shows the frequency or occurrence of these trending topics. Considering scientific research productivity related to the scope of this study being non-uniformly sparse and worse moving back in time, it is evident that a host of topics related to land use gained massive weight/prominence since the late 2000s, specifically in 2010. Between 2010 and 2020, topics generating substantial attention, as evidenced by a count exceeding 50, were *'Sustainability', 'Biodiversity',*

'Land Use Management', 'Watershed Management', 'Land Use Planning', 'Soil Organic Carbon', 'Impact Assessments', 'Sensitivity Analysis', 'Land Use Change', 'Global Change', 'Landscape Ecology' and a host of other topics. Topics that gained more popularity post-2020 era entail *'Land use', 'Ecological Services', 'Climate Change', 'Ecological Service Value (ESV)', 'Remote Sensing', 'Sustainable Development Goals (SDGs)', 'Land Cover Change (LCC)', 'Random Forest (RF)', 'Geodetector', and 'Plus Model.'*

DISCUSSION

In this section, we analyse the scientific output of the most influential authors, journals, and nations based on the results obtained. Generally, evidence (Table 2 and Fig. 3) presented based on the given search terms "global land use system*" (Topic) or "land use management" (Topic) or "land use science" (Topic) or "land use" (Topic) and " land cover change" (Topic) and "sustainable development" or "global sustainability" (Topic) indicate scientific productivity increased steadily between 2004 and 2023. Indicatively, publications and citations during the study period have increased at a rate of 2377.7% and 7433%, respectively (refer to Table 2.A for research output distribution). This implies that there was an average annual contribution rate of about 125% and a 412.9% yearly average citation rate. It is worth noting that since no citation was recorded for 2004, 2005 was assumed as the base year for computing the overall citation rates. Interestingly, scientific productivity of journals and citation analyses (Fig. 3) depict the difference between quantity (i.e., number of studies conducted/published) and quality (i.e., impact of publication among the scientific community which can be attributed to the number of citations). Evidence of strong shifts (Figs. 5–7) towards China, as the largest developing nation, and Chinese authors can be attributed to these key reasons;

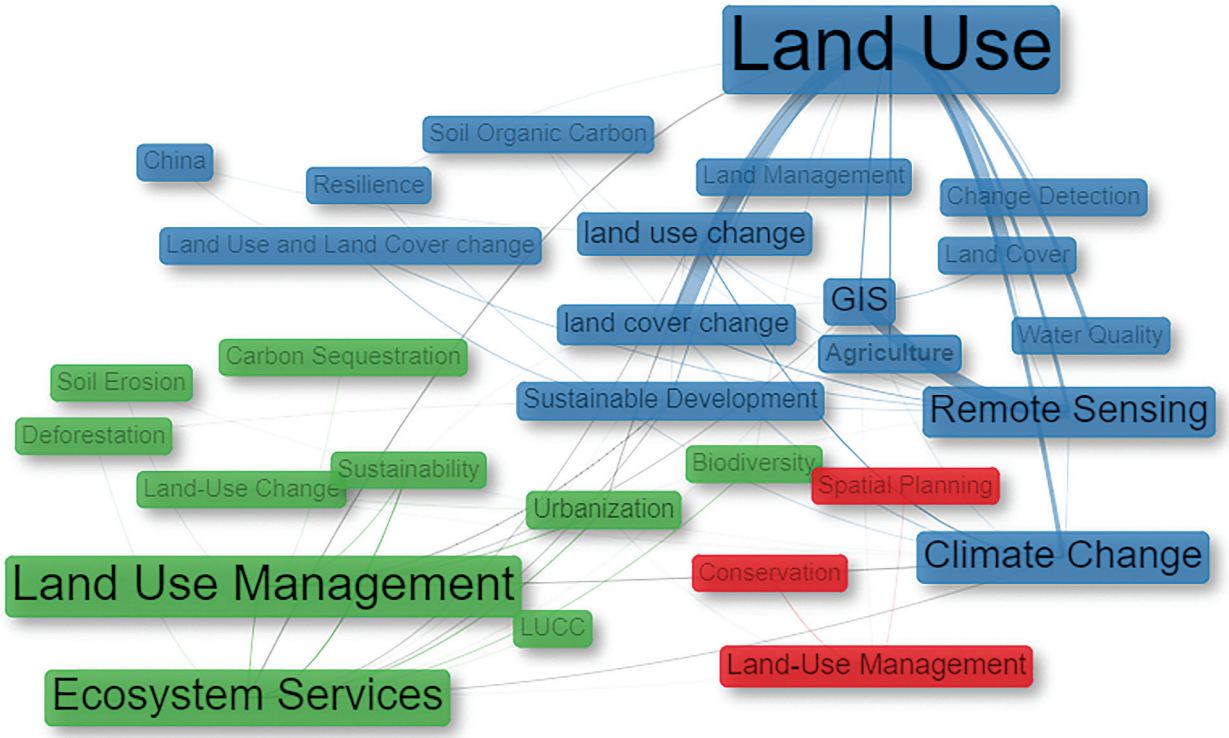

Fig. 9. Keyword co-occurrence analysis in global land use systems and sustainability studies based on WoS database (2004–2023) (source: Authors' own elaboration)

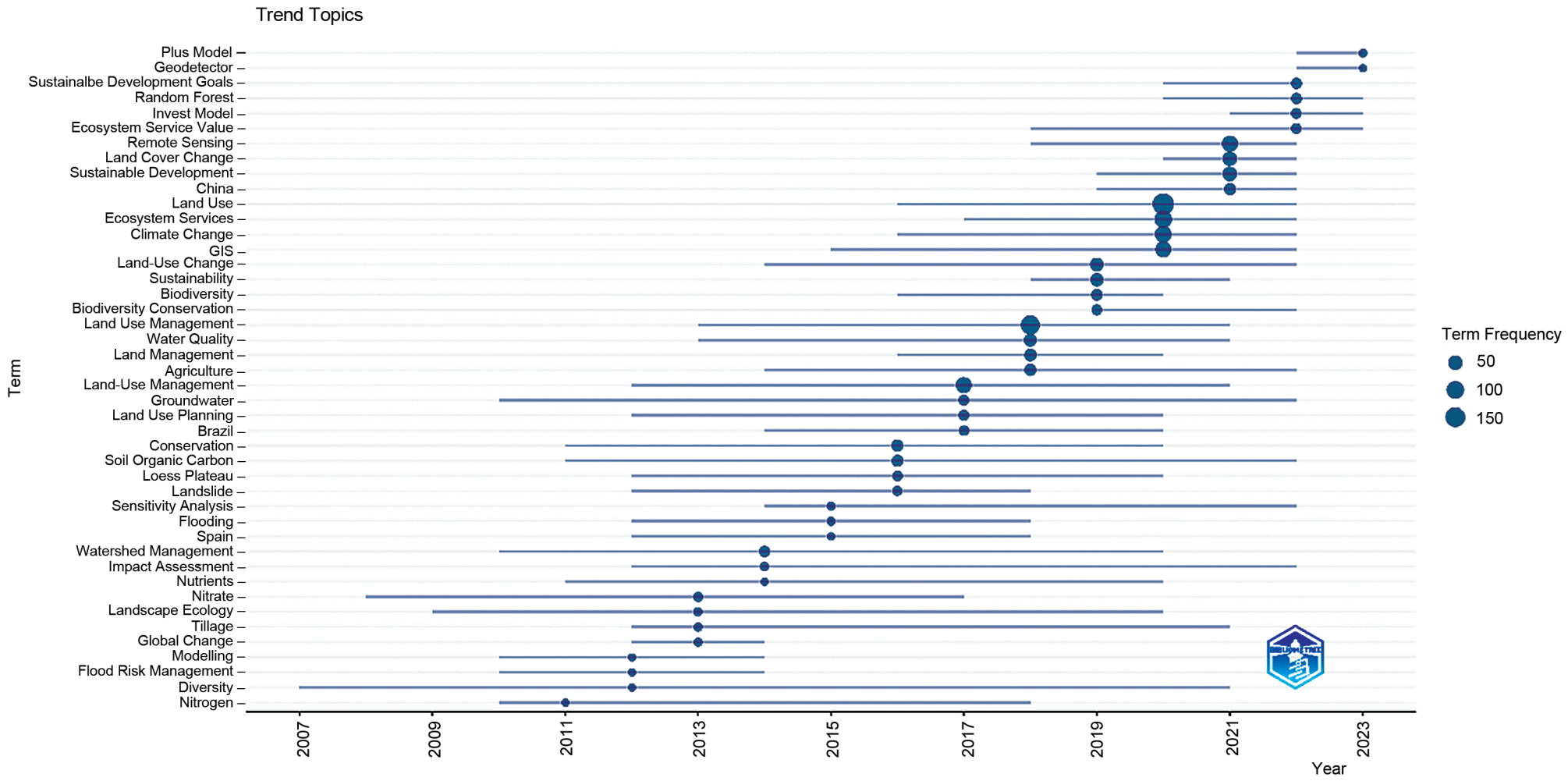

Fig. 10. Keywords timeline classifications in global land use systems and sustainability studies based on WoS database (2004–2023) (source: Authors' own elaboration)

thus (i) increasing impact of Chinese-based scientists and institutional demands, (ii) emerging of some key MDPI journals (Fig. 4), and (iii) institutionalisation of ecological civilization or restoration projects, calls for strong urban-rural linkages (URLs) and sustenance of effective land use policies/reformation initiatives, amid rapid urbanisation and industrialization trends in the development of smart or eco-cities in China and other nations in the Global South. This study acknowledges or recognizes the difference in socio-cultural, economic and political settings that influence land use management in different parts of the world. In addition, the given study period (2004–2023) may partly influence these trends despite building on previous representative works. Efforts and investments made by various stakeholders, as well as calls for innovative approaches and further studies, among other global, continental, national, and locally-driven initiatives like attaining UN 17 SDGs by 2030. Given that all activities occur on land, efforts to develop and sustain global land use systems amid extreme weather conditions or climate stressors and disturbances (specifically addressing SDGs 13 and 15) emphasise the necessity for increased contributions from various stakeholders. Scientific contributions serve as policy responses or feedback that report, evaluate, design, and address '*Life on land'* and its related events.

The results presented in Table 2 clearly demonstrate that the highly cited papers have significantly influenced numerous studies across different nations, sectors, and disciplines. This underscores the complexity and all-encompassing nature of land use systems. Tscharntke et al. (2005), in a landscape study dubbed 'Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management', expounded on the essence of understanding the challenges and principles of agricultural land use for maintaining biodiversity, ecosystem functions, and endpoints. They highlighted agriculture's impact on land management and identified some knowledge gaps and future research perspectives at various scales. They emphasised the need for further investigation into the relative significance of local and landscape management in relation to biodiversity and ecosystem services. These calls have inspired numerous studies that explore the interplay between different land use systems and ecosystem functions/endpoints, as illustrated in Figures 9 and 10. In a review study, Bronick and Lal (2005) discussed how soil structure could be modified through a host of land use practices and environmental changes. They dwelt on the role pedology plays in sustainable food production across the globe and its contribution to societal welfare. They recommended a holistic approach to sustainable land utilisation, initiatives that regulate various practices that exert pressure on soil resources. Considering the major contribution of soil structure on multiple fronts, pedology plays a vital role in land use systems management and sustainability.

Contemporarily, both industrialised and emerging nations across different continents are actively working towards regrowth initiatives that dwell on green and circular economies, which are geared towards promoting quality of life for all ecosystems or ecological processes. These initiatives have attracted massive investments, political commitment, and scientific productivity to transform different landscapes and trickle direct and indirect benefits. These gains or prospects include reducing susceptibility levels, improving air quality, averting land degradation, and supporting adaptive capacity mechanisms. Dormann et al. (2007) proposed land management strategies for nature conservation in Europe. Their study utilised some ecological models to evaluate the land use patterns, degree, composition, and configuration and their implications on plant and animal species and communities. They demonstrated how these parameters impact ecological processes and contribute to overall functionality and sustainability. Similar progress has been observed in China and India, according to Chen et al. (2019), in their land use management project published in Nature Sustainability. The researchers discovered significant greening patterns in both countries by examining satellite data. As the largest developing country, China has made substantial efforts to preserve and expand its forests and croplands in alignment with the Sustainable Development Goals (SDGs). These initiatives, according to Scannell and Gifford (2010), advance efforts made towards the realisation of alleviating poverty (SDG 1), addressing hunger issues (SDG 2), child health (SDG 3), safe cities (SDG 11), climate action (SDG 13), and life on land and biodiversity preservation (SDG 15) based on the 2030 target. They advocated the need for reliable and valid representation of

anthropogenic land use practices in Earth system models. For instance, China's land consolidation/reforms development is linked to its targeted poverty alleviation, rural resident land administration, and strong urban-rural linkages or transformation agenda. Land as a production element is critical to the sustenance of all social, economic and ecological processes. Hence, its efficient utilisation and demand amid competitive interests require constant monitoring and assessment through policy initiatives, research and innovation on different fronts.

Advancements in global land use systems development have driven several innovative pairs of research topics (Fig. 9) and policy response initiatives in some internationally oriented journals. The most relevant sources based on the evidence presented in Table 2 depict *'Sustainability', 'Land Use Policy', 'Land', 'Science of the Total Environment' and 'Ecological Indicators'* as the top 5 sources based on their research output. Information captured in Table 2 indicates these journals serve as reference platforms for researchers, academicians, policy-makers, land use strategists, and international donors, among other relevant stakeholders. The aforementioned platforms serve as repositories for important data, models, frameworks, policy-response, and evaluation tools. These resources empower key decision-makers and facilitate informed choices. Additionally, the platforms encourage critical reflection on existing systems, potentially leading to their modification or reconsideration.In addition, these relevant sources serve as avenues that produce new information linked to novel approaches to tackle basic problems at the local, regional, continental and global levels. Similarly, they facilitate the tracking or monitoring research progress amid environmental challenges and sustainable development concerns (Zhu and Hua 2017). For instance, information presented in Fig. 10 covers trending topics captured in the sampled articles, which highlights novel areas in '*land system science'*, '*emerging digital technologies* (i.e., use of integrated remote sensing techniques and Geographic Information Systems)' linked to the application of artificial intelligence (i.e., machine and deep learning techniques) to thoroughly understand land use dynamics and its consequences in other sectors, and *socioeconomic models* (i.e., regression models and other quantitative methods) in an ever-changing world. These 'emerging digital technologies' have been applied in various rural, urban, and peri-urban studies aimed at understanding environmental challenges, such as land degradation and climate stressors (Xie et al., 2020). Furthermore, these systems are utilised for the administration and reporting of risks, vulnerabilities, and disaster-prone areas, including the development of early warning systems. (Girotto et al. 2024). Additionally, these technologies propose feasible frameworks to mitigate future uncertainties by enhancing current efforts to improve the adaptive capacity of individuals, households, regions, and so on. Most used terms or keywords such as *'Sustainability', 'Biodiversity', 'Land Use Management', 'Watershed Management', 'Land Use Planning', 'Modelling', 'Soil Organic Carbon', 'Impact Assessments', 'Sensitivity Analysis', 'Land Use Change', 'Global Change', 'Landscape Ecology'* and a host of other topics. Topics that gained more popularity post-2020 era entail *'Land use', 'Ecological Services', 'Climate Change', 'Ecological Service Value (ESV)', 'Ecological Security Patterns (ESP)', 'Remote Sensing', 'Sustainable Development Goals (SDGs)', 'Land Cover Change (LCC)', 'Random Forest (RF)', 'Earth observation', 'Geodetector', and 'Plus Model'* underscore the complexity, multi-and-transdisciplinary nature of land use systems development, its evolution over time, and how these fields can be synergized to tackle environmental challenges amid sustainability concerns for sustainable utilisation of land and other natural resources.

CONCLUSIONS

Land, the fundamental component upon which human civilizations thrive, stands at the nexus of intricate interplays between natural processes, socioeconomic dynamics, and environmental sustainability. As the global population burgeons and climate change reshapes the contours of our planet, understanding the issues that influence GLUSDS becomes paramount. This bibliometric-based study examined the major contributions of various authors, journals, and nations towards the development of global land use systems and sustainability. We further investigated the degree of collaboration, impact, co-occurrence analyses, and emerging frontiers driving smart land use tools, theories, and practice, coupled with how these trends,

smart tools, and emerging frontiers create avenues for innovation and enhance scientific research in related fields and other disciplines. Based on the findings generated, the following conclusions are drawn. Results show that GLUSDS's scientific production increased between 2004 and 2023. According to research articles in the discipline, there has been an average annual growth rate of 125% over the given study period, with 412% recorded for citations. The information produced and disseminated by the five most prominent sources – Sustainability, Land Use Policy, Land, Science of the Total Environment, and Ecological Indicators – drives policy responses, innovations, and future research perspectives. Similarly, the most cited studies underscore the complexity and all-encompassing nature of land use systems development and sustainability.

Findings proved a low (high) level of cooperation between (among) the leading scholars in the field. Compared to emerging nations, industrialised nations such as China, the United States, the United Kingdom, and Germany have a far greater impact on land use science. In order to fully identify, monitor, and advance knowledge in land use science, management, and sustainability, current research trends demonstrate the utilisation of *'digital technologies (DTs)'* through the application of Geographic Information Systems (GIS) and integrated remote sensing techniques, Geo-detectors, regression models, artificial intelligence, as well as social and economic models. This review study presents a strong case for dissecting the various facets that underlie this subject in order to establish the groundwork for a thorough comprehension of the history, contemporary, and prospective developments of global land use systems. In an attempt to enhance how technical knowledge related to land system science are communicated and understood or accepted by the society or citizenry (i.e., bridging scientific communication and societal knowledge gaps), we propose the application of *'Citizen Science'* in land use systems development and sustainability-related projects on different scales. Based on the evidence presented, we strongly propose an exchange/collaboration between leading researchers, social units, policy-makers, and independent organisations/agencies to enhance land management and land system science innovation. Enhancing the theoretical and application values associated with land use sustainability requires combining several techniques or models, integrating policy mixes, and utilising big data.

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DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Datasets and links used in this study have been provided in the main text and the supplementary file.

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EWOLUCJA I ZRÓWNOWAŻONY ROZWÓJ GLOBALNYCH SYSTEMÓW UŻYTKOWANIA GRUNTÓW: ANALIZA BIBLIOMETRYCZNA

ABSTRAKT

Cel pracy

Skomplikowany związek między systemami użytkowania gruntów a globalnymi wyzwaniami tworzy złożoną sieć problemów środowiskowych, gospodarczych i społecznych. W miarę rozszerzania się działalności rolniczej, intensyfikacji rozwoju miast i rozwoju wysiłków na rzecz ochrony środowiska, użytkowanie gruntów zaczyna odgrywać kluczową rolę w przeciwdziałaniu zmianom klimatycznym, bezpieczeństwu żywnościowemu i utracie różnorodności biologicznej. Wyzwania te powodują, że konieczne jest zbadanie zmieniających się trendów, innowacji i pojawiających się ograniczeń w systemach użytkowania gruntów. Zmiany te nie tylko podkreślają dynamiczną interakcję między ludźmi a środowiskiem, lecz także dają nadzieję na zrównoważone i elastyczne ścieżki rozwoju.

Materiał i metody

W tym badaniu wykorzystano pakiet Biblioshiny R do krytycznej analizy obszernej bibliograficznej bazy danych zawierającej 1814 publikacji na temat ewolucji i zrównoważonego rozwoju globalnych systemów użytkowania gruntów (ang. GLUSDS) z Web of Science (WoS).

Wyniki i wnioski

Z niniejszej pracy wynika, że rozwój badań w dziedzinie GLUSDS był szczególnie intensywny w latach 2004–2023. Pięć najistotniejszych czasopism naukowych w tym zakresie to: *Sustainability*, *Land Use Policy*, *Land, Science of the Total Environment* oraz *Ecological Indicators*, które zajmują się tą tematyką oraz rozpowszechnianiem wiedzy o niej, mają wpływ na kształtowanie polityki, innowacji i przyszłych perspektyw badawczych. Ponadto najczęściej cytowane artykuły ukazują złożoność i kompleksowy charakter ewolucji i zrównoważonego rozwoju globalnych systemów użytkowania gruntów. Poziom współpracy pomiędzy (wśród) czołowymi naukowcami w tej dziedzinie był niski (wysoki). W porównaniu do krajów rozwijających się, kraje rozwinięte, np. Chiny, Stany Zjednoczone, Wielka Brytania i Niemcy, mają znacznie większy wpływ na naukę o użytkowaniu gruntów. Aktualne trendy badawcze wskazują na wykorzystanie „technologii cyfrowych (ang. DTs)" poprzez zastosowanie systemów informacji geograficznej (ang. GIS) i zintegrowanych technik teledetekcji, geodetektorów, modeli regresji, sztucznej inteligencji, a także modeli społecznych i ekonomicznych w celu kompleksowej identyfikacji, monitorowania i pogłębiania wiedzy z zakresu nauk o użytkowaniu gruntów, zarządzaniu i zrównoważonym rozwoju. Dlatego popieramy inicjatywy takie jak

Citizen Science, które promują przyjęcie najnowszych teorii, metod, instrumentów i procedur wspierających zrównoważone użytkowanie gruntów i innych zasobów naturalnych. Ograniczone inwestycje w naukę i produktywność krajów rozwiniętych i rozwijających się wymagają dalszych badań w dziedzinie nauki i zarządzania systemami gruntów.

Słowa kluczowe: biblioshiny, nowe horyzonty, globalne, nauka o systemach gruntów, zrównoważony rozwój

ADVANCES IN GLOBAL LAND USE SYSTEMS DEVELOPMENT AND SUSTAINABILITY: A BIBLIOMETRIC ANALYSIS

SUPPLEMENTARY FILE

APPENDIX A

Table 1A. Area coverage (km^2) and temporal variations (%) analysis of global land use and land cover change (1993–2023) (source: Authors' own elaboration)

Area coverage (sq.km)				
Features	1993	2003	2013	2023
Cultivated land	37,751,421.96	39,489,187.12	41,398,039.26	42,100,742.23
Unused land	47,432,511.02	47,421,241	47,409,970.98	47,398,700.96
Built-up	14,138,246.64	14,401,316.36	14,595,523.03	14,794,813.49
Grasslands	1,015,803.42	1,098,951.28	1,057,377.35	1,140,525.21
Waterbodies	361,816,000	361,836,002	361,856,004.00	361,876,006
Forests	47,446,016.97	45,353,302.25	43,283,085.39	42,289,212.11

Temporal variations of land cover changes (%)				
Features/Period	1993-2003	2003–2013	2013–2023	1993–2023
Cultivated land	+4.60	+4.83	+1.69	+11.52
Unused land	-0.02	-0.02	-0.02	-0.07
Built-up	+1.86	+1.35	+1.37	+4.64
Grasslands	+8.19	–3.78	+7.86	+12.28
Waterbodies	+0.01	+0.01	+0.01	+0.02
Forests	-4.41	-4.57	-2.29	-10.87

*Total Area Coverage (Absolute) = 509,600,00 km^2

*The mathematical expressions used for the given computations for land use/land cover change and temporal variations are given as follows:

$$Change\ in\ land\ use\ and\ land\ cover\ (\Delta\ LULC) = \frac{LULC_{Current\ Year} - LULC_{Past\ Year}}{LULC_{Past\ Year}} \times 100\% \ldots (Equation\ S1)$$

Table 2A. Scientific productivity trends of global land use systems development and sustainability based on WoS database (2004–2023) (source: Authors' own elaboration)

Year	Publications	Citations
2004	9	0
2005	24	12
2006	21	71
2007	27	200
2008	32	293
2009	50	460
2010	41	679
2011	51	860
2012	52	102
2013	62	128
2014	64	167
2015	59	196
2016	85	242
2017	86	281
2018	116	364
2019	153	469
2020	180	581
2021	235	769
2022	244	952
2023	223	904