Current Knowledge and Research Gap in Land Use Land Cover Changes and Biodiversity of Mountain Ecosystem: A Bibliometric Review

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Abstract: - Land use and cover change (LULCC) are critical global issues and a significant driver of biodiversity loss and imbalance in mountain ecosystems. Mountains are usually rich in biodiversity and can provide a wide range of ecosystem services with multifunctional benefits for human well-being. South Africa, one of the world's most biodiverse countries, has the majority of its mountain areas facing challenges such as biodiversity loss, uncontrolled development, and land degradation, frequently resulting in economic loss and an unsustainable environment. This study aims to understand current knowledge and identify the gaps in the research on LULCC, biodiversity, and mountain ecosystems. Notable keywords such as LULCC, biodiversity, mountain ecosystem, conservation, and agriculture were used in the search engine. Abstracts and references were analyzed, and literature and citations with high frequency were identified. The study used data from the Web of Science Core Collection and Scopus. Between 2000 and 2023, 1937 publications were analyzed. Top authors, journals, and relevant categories were discussed. The study found that Remote Sensing journals have the highest number of published articles, with 124 publications providing significant contributions to the study. The analysis highlighted gaps in the need to focus on research on remote sensing applications for mapping and monitoring species variation, regenerative agriculture to improve biodiversity and urban development, and collaborative research in mountain biodiversity management. The discussion focuses on the need for African countries' involvement in this research. Finally, mapping, monitoring, evaluation, and increased awareness can help sustain mountain biodiversity and ecosystem development and avert future environmental problems.

Key-Words: - biodiversity, climate change, mountain ecosystem, land use land cover change, remote sensing

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1 Introduction

Land use and land cover change (LUCC) are significant global concerns affecting most developing countries, including sub-Saharan Africa. South Africa is known for its considerable inequalities in spatial development and pattern due to historical context, which has affected its richness in biodiversity (Armitage et al., 2020). Research has shown that biodiversity has the potential to benefit and improve human health in the area of reducing the spread of some pathogens found among human populations [1]. The conflict between urban development and biodiversity conservation is associated with the issues of development control, land fragmentation, and land degradation, which threaten sustainable development [2], [3]. The increase and conversion of land use, coupled with uncontrolled development, is a severe problem that severely threatens the current and future sustainability of the city system and the livelihood of people in South Africa [4]. A range of studies have indicated that various human activities serve as key drivers of biodiversity loss, fragmentation, and land degradation, such as soil erosion and nutrient loss from agricultural and grazing lands [5], [6]. The high demand for, amongst others, residential, commercial, institutional, economic, and industrial activities, as well as rapid population growth, has increased pressure on the land and aggravated the process of biodiversity loss [7].

Mountain is an elevated part of the earth's surface, of at least 300m to 2500m or above generally with steep sides with significant exposed bedrock, it is a special geographical area which attract different land-human relationships [4], [8]. Land use is closelyrelated to human activities and is usually defined as transforming, managing, and maintaining land through human ventures [9]. Due to inappropriate and uncontrollable land use, anthropogenic factors are major causes of biodiversity loss [10]. Human activities resulting in these losses are deforestation, removal of natural vegetation, overgrazing, agricultural intensification, and siting of buildings on floodplains, eventually leading to land deterioration and environmental problems [11]. Other factors causing biodiversity loss besides anthropogenic factors include ecology, land topography, and climate change [12], [13]. Mountains provide significant and valuable ecosystem services that benefit well-being through provisioning, such as energy and food sources, and regulations that regulate biosphere processes, such as climate and other environmental elements. Also, cultural benefits include recreation, religion, health, and aesthetics. These services and functions become beneficial when accessible to human beings and living organisms that need them [14].

Mountain ecosystems constitute diverse ecological systems that beneficial to plants and animals, they are also essential due to the multifunctional benefits they provide for the people and other living organisms around them, the region's economic development, and the social interaction among the beneficiaries [15]. Studies show that there could be trade-off synergy or unbiased relationships among different ecosystem services; trade-off synergies mean that a negative response from one ecosystem can change the course of other ecosystem services, and an increase in the provisioning of one service may cost the reduction of others [16]. For example, the attempt to improve food or forage production may cause a loss of hazard protection and soil nutrients.

Further, carbon sequestration may improve tree production but decrease water content, soil constituents, food, and forage production. Such trade-off synergies and relationships can occur when services respond to alterations connected to spatial relationships. At times, there is a synergistic relationship; in a situation where more than one service is enhanced at the same time, for example, when the same similar factor affects both services and they respond to the factor in the same way, the relationship becomes advantageous and a "win-win situation to both services.

Various development processes can drive significant changes in mountain ecosystems as human activities can interfere with the structure, pattern, and method of land area and mountain ecosystems, eventually affecting the provisioning services that could produce multifunctional benefits [17]. The monitoring of LULCC through remote sensing (RS) can provide insights into land patterns, fragmentation, biodiversity loss, and conservation, which can, in turn, provide fundamental information for environmental, land, and mountain ecological planning and development, given the benefits provided by the mountain ecosystem and the less attention it receives, [18]. The anthropogenic effects cause LULCC and biodiversity loss over time [19]. It is critical to encourage sustainable development and improve the mountain region's ecological environment.

Based on the literature, there are numerous studies focused on those issues relating to LULCC, biodiversity, ecosystems, and mountainous regions [18], [20], [21]. Also, a few studies drivers of LULCC, biodiversity, and ecosystems [22], [23], [24], [25] and importance of biodiversity [20], mountain region assessment and benefits of mountain biodiversity research have been done. However, fewer studies focus on using remote sensing applications to map and monitor LULCC and biodiversity change and their impacts on mountain ecosystems. Also, detailed studies on bibliometric reviews using remote sensing applications on the mountain biodiversity and ecology and its LULCC need to be conducted. For examples, a recent review by [26] focused on the impact of land use changes on the ecological environment in rural areas. He emphasized how urban expansion has altered the land use pattern. He concluded that remote sensing applications have enormous potential as a robust technical tool to map, investigate, and monitor land use change, land ecology, and other environmental changes.

In this context, this bibliometric literature review aims to enhance an understanding of the existing scientific knowledge and research works on mountain ecosystems to sustainably support the continuing human well-being in their biodiverse environment. Further, the study identified the main limitations hindering mountain-related ecosystem assessment and the way forward for future research works. In addition, to identify the publication trends, the top journals and most frequently used keywords, relationships among critical components of the study, and related information. The study sets to address and evaluate 1.) the history application and trend in the studies of LULCC and biodiversity of mountain ecosystems globally. Then, 2.) Based on the streamlined research articles, identify the significant research hotspots, top authors, top collaborations, most cited documents, and evolutions of topics. 3.) Identify potential direction for future research, including ways for improvement in the field of study. A bibliometric search, a systematic and statistical method used, provides information and objective scientific analysis of up-to-date research hotspots and guidelines for areas of focus for future research.

2 Material and Method

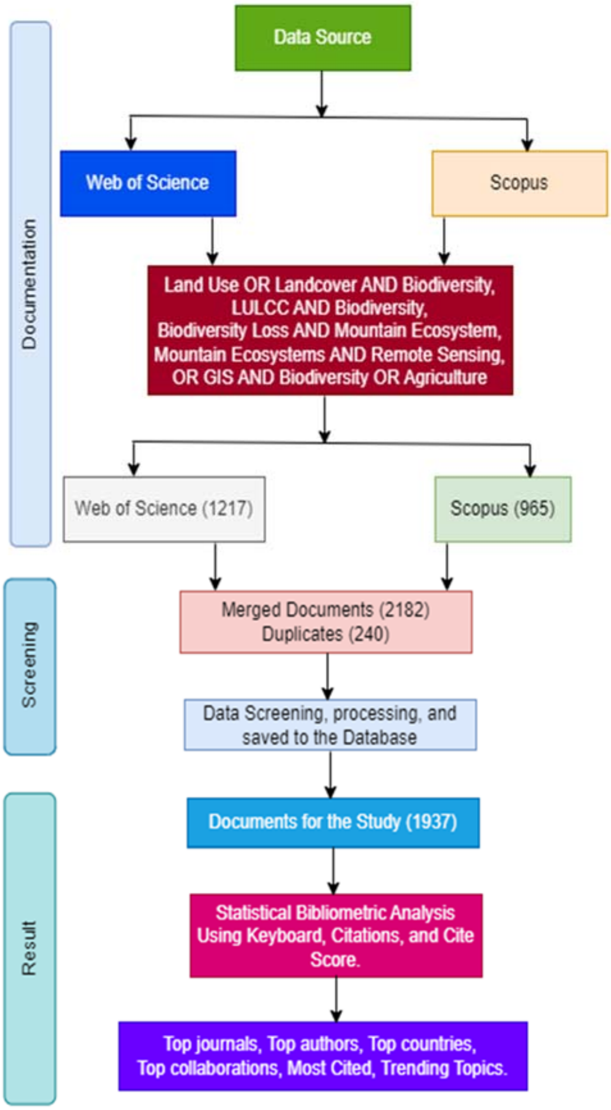

Figure 1: Methodology flowchart of the study.

The bibliometric method enables researchers to understand applications in new and current knowledge [27]. The research used the preferred reporting items for systematic reviews and meta-analysis for the systematic literature reviews. The framework was used to explain what and how the research was done, and it provided a procedure for systematic review research, which includes how abstract, introduction, methodology, results, and conclusions need to be outlined so that the outcome could be replicated. The literature was sourced from the Web of Science (WOS) and Scopus databases, the two databases with the largest bibliometric data sources, dating for almost two decades. The distribution of the sources and records of the articles is displayed in Figure 1. The search was done using dfferent combinations of primary keywords. A set of criteria and combinations of search terms guided the search. The search criteria were based on the year 2000 – September 2023, type of publication (research articles, review articles, and conference papers), and language (English).

In addition, the research was focused on identifying top authors in the field to facilitate future collaborations and multidisciplinary research. Furthermore, the research was focused on identifying peer-reviewed articles, which explained the delimitation of research articles, review articles and conference papers. We focused on the global study of related topics before narrowing it down to South Africa, one of the world's most biodiverse countries. The search terms included: (Land use, Land cover, and biodiversity* OR, mountain ecosystems* OR, agriculture* land use, land cover change and biodiversity*, biodiversity loss and mountain ecosystems, mountain ecosystems, and remote sensing or geographic information system and biodiversity*). The asterisks (*) were added to ensure a comprehensive search and inclusion of all the relevant articles synonymous with the search words. Through the search settings of Web of Science (http://www.webofknowledge.com), and Scopus (http://www.scopus.com), after the merging using R-studio 4.3.1 software [28]. Additional screening was done by checking the abstract and ensuring that the selected articles were in line with the focus of the research. The contents of the articles were later screened for eligibility after removing 240 duplicates; on 5th September 2023, 1937, articles were left for analysis.

The bibliometric analysis enables the structural distribution, qualitative relationship, and management of information of literature, and later, the discussion of structures, characteristics, and laws regarding science through statistics and mathematics methods. Some fundamental analyses include key authors, institutions, and journals, publication trends, frequencies of notable keywords, citations, and co-citations [26]. To address the three research objectives for this study, we focus on understanding the current status, providing an overview of scholarly up-to-date efforts in a particular area or field of study, and then identifying the research gap(s). The schematic diagram in Figure 1 explains a methodology and workflow study.

3 Results

This study presents a bibliometric analysis of 1937 published document types (articles, reviews, book chapters, and early access) retrieved from Scopus and WOS core cdlection databases. All the data collected were streamlined to cover the key words relevant to the study. This information is summarised in Figure 2; with a document annual growth rate of 14.71%, the documents have a total number of 9004 authors, while 1905 authors contributed to multi-authored documents, with co-authors per document index of 5.7 and international co-authorship at 27.71%. Also, in a single-authored document with the contributions of 119 authors, the authors' keywords were LULCC, land cover change clustered into 8788 authors' keywords (ID), and 6776 authors' keywords (DE) in the field of biodiversity of mountain ecosystems. The selection of the number of authors' keywords in bibliometric analysis was based on Zipf's law.

Furthermore, 412 sources of journals, books, and reviews and document average age of 5. 3 and annual citation per document is 57.75.

The critical bibliographic information such as author name, publication year, article title, journal name, keywords, abstract digital object identifier (DOI), and uniform resource locator (URL) were exported into an Excel spreadsheet. Further, information on the study area location (country and continent) and other related words, such as remote sensing algorithms and biophysical parameters being investigated, were extracted after scanning the articles. Information presented in Figure 2 shows the trends in related studies on LULCC, biodiversity, and mountain ecosystems.

Figure 2: Summary of Information on the data collection from WOS and Scopus Database for the study with title search; Land use Land cover, LULCC, biodiversity, and mountain ecosystems from January 2000 to September 2023

3.1 History and Current Publishing Trends of Scientific Publications

Figure 3 shows a steady increase in publications, especially from 2004 until September 2023. The average growth rate of publications is 14.71%. The annual publication trends show a development process, which showed slow and little progress from the beginning of 2000 till 2004, revealing an initial take-off process in the article-publication stage. At this stage, the number of article publications was less than 10. There needs to be more progress in the next stage; from 2004 to 2008, there was a slight increase in the number of publications, with almost 20. The next four years, from 2008 to 2012, show a steady increase of almost 40 publications. From 2012, the number of publications began to increase steadily; between 2012 and 2016, there were over 70 articles. In the years after 2016 till September 2023, about 635 articles were published on the related topics of the research. The rapid increase in publications on the topic from 2012 was related to increased awareness of various factors affecting LULCC, mountain ecosystems, and biodiversity, such as climate change, poverty, loss of agricultural land use, etc. A slight decrease from 2021 to 2022 could result from research focusing on the feedback from the COVID-19 pandemic, its causes and effects, and the prevention of future occurrences. There is a possibility that before the end of 2023, publications will bounce back and begin to increase again. One of the objectives of this study is to provide development trends, nodes of different collaborations, and cluster distributions of related keywords at different phases in the years under consideration in this research.

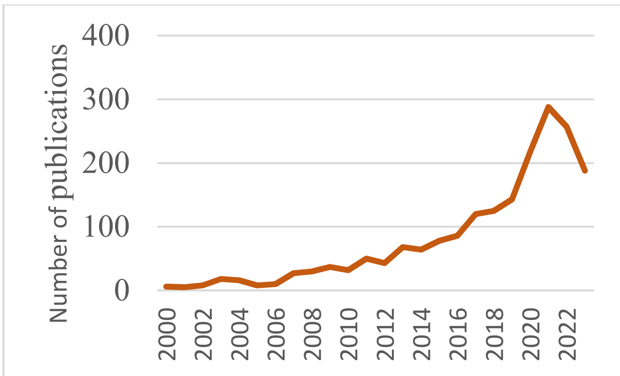

Figure 3: History and Current Publishing Trends of Scientific Publications

3.2 Top Authors

Table 1 shows the most published authors whose significant achievements have contributed to research on land use, land cover change, and biodiversity of mountain ecosystems, revealing a better understanding of the field. Price's law comprehensively describes the relative relationship between authors and papers, which guides the estimate of the scale of high-yield authors with writing ability [29]. The analysis of the data revealed that 9004 authors have published articles. The table reveals that the most prolific author is Yan Zhang, who has 22 publications in the field. Others, who are Yun Wang (20), X Wang (19), Xuexia Li (14), Yuanyuan Li (13), and Jiajia Liu (13 publications), represent the top six prolific authors in the field. According to the number of publications and the bibliometric analysis, the Chinese institutions occupied the top spot with the most published articles, amounting to 136 publications.

Table 1: Top 10 influential authors based on record

S/N	Authors	Total Paper Published	Total Citation
1	Zhang Y.	22	453
2	Wang Y.	20	242
3	Wang X.	19	1477
4	Li X.	14	595
5	Li Y.	13	554
6	Liu J.	13	472
7	Zhang L.	12	167
8	Wang L.	11	396
9	Zhang C.	11	345
10	Thuiller W.	10	1395
11	Li J.	10	235
12	Liu Y.	10	1591
13	Zhang M	10	428

It was posited through Price's law that paper publications by scientists who produced more than $0.749N_{\max}^{0.5}$ papers equal half of the total number of papers. With Price's law, the publication threshold is obtainable using (Xu & Xiao 2022):

$$TP_n = 0.749\sqrt{N_{\max}} \quad (1)$$

where TP_n and N_{max} are the core author's threshold number and the most productive author's number of publications.

3.3 Most Global Cited Scientific Research Contributions and Spatial Distributions Contributions per Country

The contributions of different countries to the field of LU LCC to the biodiversity of the mountainous ecosystem studies were analyzed from 2000 to September 2023. Table 2 reveals the top thirteen countries globally cited and research contributions and the percentages each takes in the overall scientific production. It also includes the number of articles, frequency of countries' production, total citations (TC), average article citations (AAC), single-country publications (SCP), and multiple countries publications (MCP). These indicators show the authority and accomplishment of each country in the research on the topic. The analysis reveals that the USA has contributed 294 articles, accounting for 13.47% of the TCP. At the same time, China produced 230, and Germany produced 143, accounting for 10.54% and 6.55% of the TCP, respectively, within the period under study. Italy, Netherlands, and Switzerland ranked 10th,11th, and 12th; they produced 79, 46, and 62 articles, which account for 3.62%, 2.11%, and 2.84%. These results show the dominance of European countries, the USA and Canada from North America, and China from Asia in the producing countries. South Africa ranks 13th with 43 articles, representing 1.97% of the TCP, and the only African country in the ranking of the first 20 countries. The total citation and average article citation indicate a country's impact in a particular research field. The top five most cited countries include the USA (TC=24500 and AAC=83.30), UK (10862 and AAC=97.00), Germany (TC=8931 and AAC=62.50), Australia (TC=7984 and AAC=80.40) and China (TC=6394 and AAC=27.80) respectively. Also, the results show that despite high publication numbers from single countries, there is still considerable collaboration and partnerships between countries, with the USA leading in collaborating with other countries.

Table 2: Most Global Cited Scientific Research Contributions and Spatial Distributions Contributions per Country

Rank	Country	Articles	Frequency Country Production	Total Citation	Average Article Citation	SCP	MCP	TCP in Percentage
1	USA	294	1347	24500	83.30	223	71	13.47
2	Germany	143	677	8931	62.50	90	53	6.55
3	China	230	648	6394	27.80	192	38	10.54
4	UK	112	565	10862	97.00	70	42	5.13
5	Australia	99	517	7984	80.40	57	42	4.54
6	Spain	90	294	4347	48.30	59	31	4.13
8	France	54	267	3503	64.90	34	26	2.48
9	Canada	53	253	2886	54.50	34	14	2.43
10	Italy	79	246	3656	46.30	67	12	3.62
11	Netherland	46	212	3712	80.70	27	19	2.11
12	Switzerland	62	195	4888	78.80	46	16	2.84
13	South Africa	43	146	1865	43.40	30	13	1.97

Note: total citations (TC); average article citations (AAC); single country publications (SCP); multiple country publications (MCP)

3.4 Countries' Collaborations

Regarding collaborations between countries, Figure 4 shows the spatial distribution of the articles published on LULCC, biodiversity, mountain ecosystems, and related studies from 2000 to September 2013. The figures' distributions indicate that apart from the fact that the USA collaborates with many countries, especially in Europe, there are also many collaborations between countries like Germany, the UK, Italy, France, Sweden, and Spain. Australia is also in collaboration with so many countries across the continents. However, Sub-Saharan African countries, such as South Africa and Ethiopia, are still at the fundamental stage of research regarding the topic, with fewer collaborations and relatively lower article output with other countries. This information can be traced to low and poor development in infrastructure such as electricity, internet connectivity, and relatively lower funding for research. Also, South Africa has led multiple collaboration publications (MCPs) in the African continent, as shown in Figure 5, indicating a low researcher collaboration within and outside Africa.

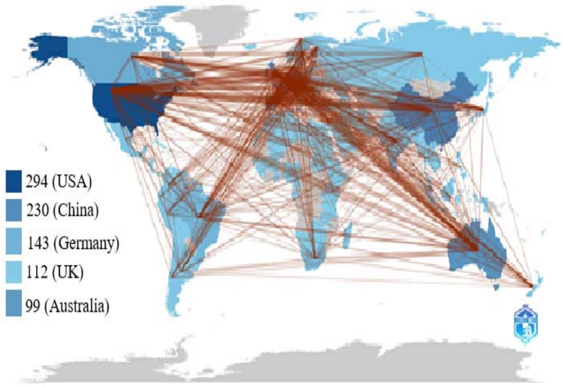

Figure 4: Spatial distribution map showing collaborations between countries on research with LULCC biodiversity and mountain ecosystem generated using the R-bi bliometrix tool (Note: Grey -coloured area has no data capture) [30].

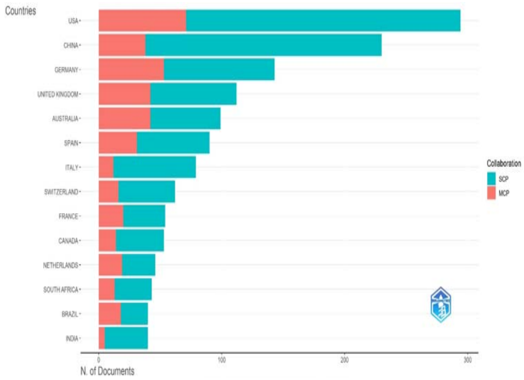

Figure 5. The authors' countries contributed to research with LULCC biodiversity and mountain ecosystem generated using the R-bibliometrix tool [30].

3.5 Temporal Distributions of Journal Analysis

The documents on LULCC, biodiversi ty, and mountain ecosystems include articles, book chapters, conference pa pers, and reviews. Though the result revealed the 27 most relevant sources with a cum ulative frequency of 949, this study is limited to the top 10. T able 3 summarises the 10 top journal sources in the niche of the study . Remote sensing is t he top-ranked journal with the m ost scientific publications, with 124 outputs representing 13.07% of the top-p ublished journals. The second and third top-ranked are Sustainabilit y and Global Change Biology, representing 10.01% and 8.96% respectively. However, 8th to 10th m ost ranked publ ished less than 40, Diversity-Basel, Biodiversity and Conservation, and Biolo gical Conservation published 3.79%, 3.69% and 3.48% respectively. This information indicates that the top four are doing we ll in disseminating scientific knowledge in the research of LULCC and the biodiversity of the mountain ecosystem. The impact factors varied from source to year, and most of the sources were classified under quartile 1, indicating t op ranking. Bradford's law shows that the focus of s cientific publications on a specific issue or area is not in the same direction. The law predicts that the number of journals in th e second and third zones will be n and n2 times larger than the first zone. This inform ation makes it possible to predict the total num ber of journals cont aining papers on a subject once the number in the core and middle zones of the journal is kno wn. In addition, there is a possibilit y of predicting missing relevant information from the number of known journals. Half of the jour nal sources published below 30 each are grouped in zone 2 on Bradford's law core sources log rank.

Table 3: Most Relevant Sources

S/N	Journals	No Scientific Publication	Percentage in the overall publication	Impact Factor of JCR	Impact Factor of SJR
1	Remote sensing	124	13.07	5.349 (Q1)	1.136 (Q1)
2	Sustainability	95	10.01	3.9 (Q1)	0.664 (Q1)
3	Global Change Biology	85	8.96	13.213 (Q1)	4.609 (Q1)
4	Land	78	8.22	3.905 (Q2)	0.647 (Q2)
5	Journal of Applied Ecology	58	6.11	5.89 (Q1)	1.967 (Q1)
6	Ecological Indicator	50	2.27	6.263 (Q1)	1.396 (Q1)
7	Global Ecology and Conservation	40	4.22	3.97 (Q1)	1.045 (Q1)
8	Diversity-Basel	36	3.79	3.031 (Q2)	0.641 (Q1)
9	Biodiversity and Conservation	35	3.69	4.296 (Q1)	1.095 (Q1)
10	Biological Conservation	33	3.48	7.499 (Q1)	2.146 (Q1)

Note: JCR – Journal Citation Report (a source for Impact Factor based on citation counts). SJR – SCImago Journal Rank (It is a portal that includes country scientific indicators developed from information on the Scopus database), Q – Quartile.

3.6 Most ten globally cited published documents on topic

Table 4 summarizes the top globally cited published documents on LULCC and biodiversity of mountain ecosystem studies during the selected years of understudy. The chosen research is one of the top 10 globally cited published documents in the research performance analysis. There is a need to convert remote-sensing imagery to tangible information and combine it with other data sets to achieve accurate results; in an overview of the development of object-based methods to delineate an available usable object from imagery and combine image processing and geographic information science (GIS) functionalities to utilize spectral and contextual information in an integrative way in the 1970s. The literature revealed that through OBIA (Object-based image analysis) after 2000, GIS and image processing started proliferating with more published articles [31]. In another review, a synthesis of 688 published studies was done to show that drivers of global environmental change, such as carbon dioxide, climate, land use, biotic invasion, and nitrogen deposition, usually affect competition among plants and animals, increase the intensity of pathogens infection, exert a multitrophic effect on the decomposer food web, weaken mutualism among plants and enhance herbivory among predation. The authors further show that higher-order effects among multiple drivers predict future global environmental change simultaneously. Extrapolating these complex impacts across entire networks of species interactions yields unanticipated effects on ecosystems. They finally concluded that to predict the impact of global environmental change on ecosystem processes and communities, the most significant single challenge will be determining how biotic and abiotic context alters the direction and magnitude of GEC effects on biotic interactions [22]. In a study in Oregon, USA, the researchers developed a spatially explicit model tool to proffer solutions to the difficulty of quantifying and incorporating ecosystem services into management decisions. The tool integrates the valuation of ecosystem services and trade-offs (InVEST) model to predict changes in biodiversity conservation, ecosystem services, and commodity production. The model was a study relating to LULCC and stakeholders-defined scenarios. The authors found that the same scenarios affect biodiversity conservation and ecosystem services, and only a tiny trade-off exists between them. Scenarios with more development had higher commodity production value, whereas payments for carbon sequestration eradicated this trade-off. The author concluded that the method can make decisions regarding natural resources secured, efficient, and practical [20].

In the United Kingdom, a study contradicts a general model prediction of amplified warming in high-elevation areas, referring to insufficient data on mountain observation and monitoring due to the inherent complexities of mountain climate and less research covering high-elevation regions. The authors' review revealed that other important physical mechanisms could potentially contribute to elevation-dependent warming (EDW), including vapor absorption and latent heat release, surface heat loss and temperature changes, aerosols, snow albedo, and surface-based feedback. The combination of mechanisms could cause contrasting patterns of EDW depending on the region. They finally proposed an improved observation through satellite images, which will help monitor mountain controlling mechanisms and trends, then model simulation. A thorough understanding of EDW could help address climate change and its effect on mountain ecosystems [32]. A global study on the drivers threatening insect biodiversity may lead to the extinction of global insects by 40% in the next few decades. The authors discovered that Lepidoptera, Hymenoptera, and dung beetles are some of the terrestrial ecosystems that are taxa most affected. At the same time, Odonata, Plecoptera, Trichoptera, and Ephemeroptera are the aquatic species most affected. Simultaneously, plenty of small adaptable and generalist species are growing and occupying spaces left behind by the declined species. The main drivers, in order of importance, are:

1. Habitat loss and conversion to intensive agriculture and urbanization.

2. Pollution, mainly caused by synthetic pesticides and fertilizers.
3. Biological factors, including pathogens and introduced species.
4. Climate change. In order of importance, the main drivers are
1. habitat loss and conversion to intensive agriculture and urbanization;
2. pollution, mainly by synthetic pesticides and fertilizers;
3. biological factors, including pathogens and introduced species, and
4. climate change.

Climate change is the only significant driver, and it affects the smaller species in mountain temperate regions and colder climes. The study suggested changes in the current agricultural practice, reduction of pesticides, a more sustainable ecologically-based practice to reduce the rate of species decline, and remediation technology to safeguard the urban environment and agricultural land [33].

In Australia, a study on landscape modification and habitat fragmentation as crucial drivers of species loss. The authors monitor the effect by focusing on individual species, the process threatening them, human-perceived landscape patterns, and their correlation with species and assemblage. Factors like habitat degradation and loss, changes in biology and behavior, and interaction among species are endogenous and exogenous threats to species decline. They found out that species and pattern-oriented in the study of landscape ecology are complementary and that there are links within a wide range of interconnected themes. More research and management priorities will improve species conservation in modified landscapes [34]. In another study in Switzerland and the USA, the researchers studied the threats to the natural flood plain, one of the most biodiverse ecosystems on earth. They listed habitat modification, species invasion, pollution, and flood control mechanisms as some of the activities leading to floodplain degradation. In Europe and North America, floodplains have almost gone into functional extinction as 90% has been cultivated, and in the developing world, changing hydrology is disappearing floodplains; by 2025, pollution, increase in species invasion, and intensification in hydrological cycle as a result of the rise in human of population would lead to further degradation of the floodplain. Sahelian Africa, Southeast Asia, and North America will soon be the most threatened floodplain areas. The authors recommended an urgent need to preserve floodplain rivers as a strategic global resource to prevent the drastic extinction of riparian and aquatic species and ecosystem services in the nearest decades [24].

In the USA, an ecological and archeologic history of the Kelp forest's reasons and trend of deforestation are studied by researchers; overfishing and vertebrate apex predators usually trigger the herbivore population increase, leading to prevalent deforestation in the forest; such has produced a lasting impact of species depauperate system. This type of deforestation has increased for the past 20 - 30 years, and continuous fishing has shifted harvesting targets from apex predators to invertebrate prey. An activity to expand the sea urchin harvesting returned the Kelp forest to its location, but the vertebrate apex predator is missing. Three North American case studies of the forest were reviewed to determine their historical link with humans and predict the status of the forest by 2025. The archeologic study revealed that fishing has impacted much more than thought and for so long the forest, resulting in the loss of apex predators, small-scale deforestations, and outbreaks of aquatic urchin population. Over 200 years, commercial exploitation for foreign business led to the excision of marine urchin predators. This activity causes the decline of the forest over a large, vast area. Southern California rarely experiences deforestation despite its long association with the coastal Kelp forest. This stability may be due to functional severances among herbivores and predators, and the forest may also likely resist invasion by strange species. In their species-depauperate, the western part of the North Atlantic introduced algal competitor carpet and threatened future kelp dominance; there, the strange predators and herbivores became established dominants in the system. Climate change has also greatly impacted the forest ecosystem, which requires controlling greenhouse gas emissions, but overfishing remains the most controllable threat [25]. Also, in the USA, researchers highlighted the importance of protecting and valuing ecosystems to attain multifunctional benefits for all and the necessity of developing scientific bases, financial mechanisms, and policies for incorporating natural capital

into land use and other resource decisions. They developed a conceptual framework and strategic plans to showcase the benefits of ecosystem services incorporating the knowledge of accounting in capital for decisions for individuals, corporate bodies, communities, and government at all levels [35].
In Belgium, researchers estimated the changes in agricultural activities and urbanization and identified the unmeasured changes in land cover and climate-driven land cover modification affected by LULCC. They discovered that this change is driven by synergetic factors due to scarce resources, thereby causing pressure on production, policy intervention, several opportunities created by markets, an inability to develop coping mechanisms, and changes in attitudes and social groups. The change leading to ecosystem goods and services changes feedback on the LULCC driving forces. The change can be understood through complex adaptive systems and transition concepts , and place-based research on LULCC requires an understanding of the narrative perspective and an agent-based system. The research argued that systemic analysis of LULCC locally can bring discoveries and help predict and explain future change [23].

Table 4: Most ten globally cited published documents on the topic

Rank	Description/Title	TC	TC per Year	Reference
1	Object-Based Image Analysis for Remote Sensing.	2983	213.07	[31]
2	Global Change and Species Interactions in Terrestrial Ecosystems.	1620	101.25	[22]
3	Modeling Multiple Ecosystem Services, Biodiversity Conservation, Commodity, and Trade-offs at Landscape Scales. Production.	1589	105.93	[20]
4	Elevation-Dependent Warming in Mountain Region of the World.	1582	175.78	[32] P
5	Worldwide Declines of the Entomofauna; A Review of its Drivers.	1576	315.20	[33]
6	Landscape Modification and Habitat Fragmentation: A Synthesis.	1535	90.29	[34]
7	Riverine Flood Plains: Present State and Future Trends.	1288	58.55	[24]
8	Kelp Forest Ecosystems: Biodiversity, Stability Resilience and Future.	1275	57.95	[25]
9	Ecosystem Services in Decision Making: Time to Deliver.	1231	82.07	[35]
10	Dynamics of Land Use Land Cover Change in Tropical Regions.	1111	52.50	[23]

3.7 Authors' Keywords and Co-Occurrence Network

The selected authors' keywords co-occurrence network in biodiversity, climate change, ecosystems, and ecosystem studies are presented into clusters and nodes, which show the frequency of authors' keywords in Figure 6. In addition, lines between nodes indicate the strength and relationship of the clusters. The clustering is done using [36].

$$V(c_1,...,c_n) = \frac{1}{2m}\sum_{i\prec j}\delta(c_i,c_j)\omega_{ij}\left(c_{ij} - \gamma\frac{c_i c_j}{2m}\right) \tag{2}$$

$$\omega_{ij} = \frac{2m}{c_i}c_j \tag{3}$$

where y and c_i are the cluster resolution and the element I cluster, respectively. The larger the y, the finer the classification and the more the cluster obtained. The V represents the bibliographic matrix, w_{ij} represents the co-citation weight between authors i and j; the δ represents the coefficient of the cluster resolution, and the m represents the number of researchers or authors.

Furthermore, in Figure 7, the co-occurrence network reveals the term of the keywords; the more prominent nodes such as biodiversity, climate change, and ecosystem suggest the higher frequency of authors' keywords and their significance in LULCC and ecosystem studies toward precision agriculture (vegetation, grassland, forestry), conservation, and land use studies average connectivities. Other notable keywords include mountain region, remote sensing, species richness, climate effect, environmental change, anthropogenic change, land use, conservation management, species diversity, and other topics with tiny nodes showing weak connectivity. However, parameters for monitoring LULCC, biodiversity, species richness, and other standard tools such as cameras, field spectroscopy, methods such as decision trees vegetation index NDVI (normalized difference vegetation index), multispectral, extensive data machine learning, artificial intelligence, synthetic aperture radar, and lidar are missing on the authors' keywords. Both figures depict the direction and multidisciplinary nature of related research. It also shows the low attention paid to the range of remote sensing tools to monitor the entire environment, especially the mountain region.

3.8 The Trending Topics and Thematic Evolution

The trending topic and the thematic evolutions present the development and focus of research studies in a specific field over time. Accordingly, authors' keywords form the trending issues and later result in the thematic evolution of published articles. The top 10 trending topics are presented in Figure 8, and the frequency of their appearance from 2000 till September 2023. While species richness came 11th, mountain region came 12th, and RS came 13th. In Figure 9, the thematic graph has two axes: the x-axis development degree (density) and the y-axis relevance degree (centrality). The graph was in quadrants: niche themes, motor themes, emerging or declining themes, and basic themes. The niche themes, such as climate change and conservation, represent recognized topics around our study; biodiversity, climate change, and ecosystems cut across niche, and the motor themes were relevant topical areas with continuous

Future studies may thus focus on using these new remote sensing methods to investigate critical factors affecting the environment and monitor mountain change.

Figure 6: Authors' keywords LULCC and biodiversity of mountain ecosystem studies with LULCC biodiversity, and mountain ecosystem generated using the R-bibliometrix tool developed by Aria and Cuccurullo [30] year 2000 and September 2023.

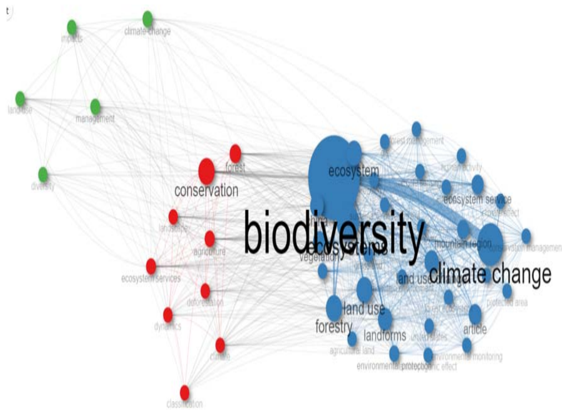

Figure 7: Co-occurrence network with authors' keywords on LULCC and biodiversity of mountain ecosystem studies generated with the R-bibliometrix tool [30].

significant growth. The emerging and declining themes encompassed new area s of resea rch focus that may be gradually declining. Finally, the basic themes, with conservation, ecosystem services, and forests, are vital subjects that are relevant but still require focus for further research.

The use of different re mote sensing tools (spatial variation) to monitor biodiversity (species richness, habitat loss) is still missing in most of the resear ch output in the last decade, narrowing it down to the multifunctional benefits the mountain region can offer the beneficiaries/ residents. There is a need to monitor this critical feature to m aximize the benefits and guide against future m isuse. The results revealed that biodiversity, ecosystem, and climate change have been stable trends since 2015 and have be come prominent in relatively most critical global issues. It is quite surprising that while LU LCC has fre quencies of 147 an d 121, land cover change has a frequency of 20.

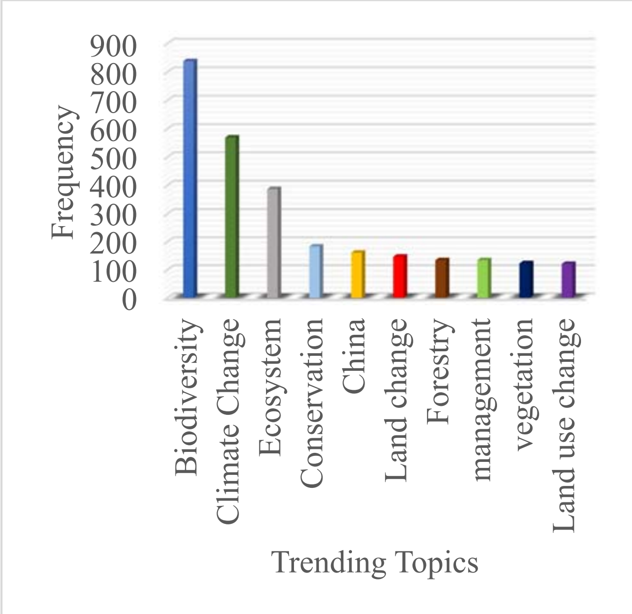

Figure 8: Trending topics in LULCC in t he biodiversity of mountainous ecosystem studies from 2000 to September 2023.

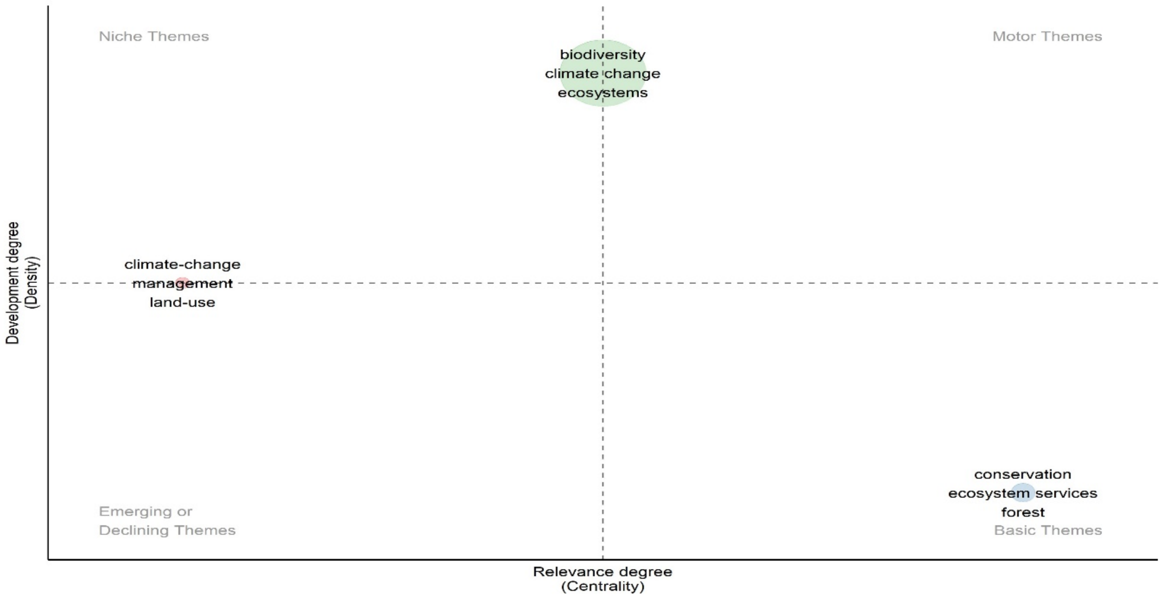

Figure 9: The them atic evolutions of related themes, the development and relevance of the th emes in LULCC research, and the mountainous ecosystem's biodiversity (generated using the R-bibl iometrix tool [30].

4 Discussion

The review study aimed to review the re search trends in LULCC around mountain biodiversity and ecosystems. The trends were revealed using bibliometric analysis of the production of countries' outputs, annual scientific production, most globall y cited documents, spatial distrib utions per country, journal analysis, countries' collaboration, co-occurrence network, and authors' keywords, and thematic evolution in the study of LULLC and biodiversity of the mountain ecosystem. The findings of this review revealed that the trend in annual scientific production in LULCC, biodiversity, and mountain ecosystems in the years under study peaked at around 2021 with 288 articles, with an overall growth rate of 57.75% in average citation per document. The annual scientific production growth rate is 14.71%, signifying that global research in this study area had steadily increased within the study period. Therefore, there has been an increase in the awareness of the importance of monitoring LULCC and the biodiversity of the mountain ecosystem. Globally, there is a significant focus on these topics. There have been increasing calls for remote sensing applications to monitor LULCC, land cover change, climate change, landscape dynamics, biodiversity, ecosystem, and spatiotemporal change in mountainous regions [37].

The results showed that the four most productive countries in publications are the USA, Germany, China, and the United Kingdom. At the same time, the USA, UK, Germany, and Australia ranked top 4 in total citations. Similarly, the review revealed that the USA, China, Germany, the UK, and Australia are leading countries in authors' contributions and countries' collaborations. This latter information may be associated with solid collaborations on research development partnerships that have worked and continue to yield efforts. The USA, China, and Australia are among the top 10 most biodiverse countries in the world, while the UK and Germany are powerful European countries that are top investors in biodiversity [38]. According to the World Economic Forum, the world's gross domestic product (GDP) depends significantly on ecosystem services, and close to 50% of the world's revenue comes from ecosystem services and related resources. It is believed that projects related to ecosystem services and biodiversity can unlock business prospects and provide job opportunities [39].

The spatial distribution map of countries' scientific production showed comparatively lower production in other countries in Asia, South and North America, and Africa during the years under study. However, it is noteworthy to mention that South Africa and Ethiopia are the first two African countries that top the list of most scientific production contributions ranking 13th and 27th. South Africa and Ethiopia are the two most cited African countries, ranking 15th and 33rd in the world. Though African countries have low production and citing ranks, they are known to be rich in biodiversity. South Africa is one of the most biodiverse nations in the world. It has over 95,000 species and is rich in biomes and other ecosystems, with Cape Town being the wealthiest city with biodiversity in the country [40]. Ethiopia possesses more than 6000 species of plants and over a thousand species of farm animals, wild animals, and birds; it is one of the most coffee-producing countries in the world, and many other crops, such as sorghum and wheat [41]. However, the low research outputs in Africa can be generally associated with less focus on research development due to a lack of basic infrastructure and funding supports. The African government budget is usually focused on housing, agriculture, food security, and poverty eradication, and these have become their priorities. Also, low research output is evident from less collaboration support from developed countries [42]. This suggests more motivation and support for collaborations in research development for African countries and more focus on monitoring LULCC and mountain biodiversity and ecosystems. Grant funding is critical for research productivity and outputs [43]. Advanced countries like China, the USA, Australia, and Germany are advanced in monitoring LULCC and mountain biodiversity and ecosystems research [44].

The study observed that the journals Remote Sensing, Sustainability, and Global Change Biology are leading in the sources of LULCC, and biodiversity of mountain ecosystems, sources with high impact factors, and global citation; the sources have proven to create strength for research development in the area of research (He et al. 2019). Other sources have been published on LULCC and the biodiversity of mountain ecosystems, but our study only evaluates relevant journal sources from WOS and Scopus databases. The analysis further revealed that biodiversity, climate change, ecosystem, and conservation were the most frequent keywords for authors in the LULCC field and mountain ecosystems' biodiversity. This information affirmed remote sensing applications' contribution and significance to mountain regions' LULCC, biodiversity, and ecosystem [21].

Because of its adverse effect on almost every aspect of living, climate change has gradually become one of the most topical issues in the last decades [45]. Most advanced nations, such as dominating American countries like the USA, Canada, and Mexico, and Asian countries like China, Japan, and South Korea. Also, Australia, New Zealand, and many other European countries are more focused on research around climate change; very few African countries were included in the list [46]. Climate change continues to impact ecosystems in various ways; for example, it causes an increase in the biosphere's carbon dioxide concentration, biomass, and soil nutrients. In addition, it interacts with other environmental factors to cause land fragmentation and degradation. Mountain ecosystems are changing, and biodiversity is lost due to climate change (for example, changes in temperature, precipitation, soil-water contents, and other extreme events such as droughts, flooding, and fire incidences, causing biomass burning) with other driving forces such as LULCC. These changes threaten our natural environment, food production, economic growth and development, and the health and well-being of living organisms [47]. It is thus essential to understand the dynamics of climate change and human-induced activities such as LULCC, their connections with ecosystems, and biodiversity loss to identify and develop mitigation and adaptation mechanisms that will create environmental management and biospheres' resilience.

5 Gaps and Areas for Future Studies

For the past two and half decades, researchers have produced several publications on LULCC and the biodiversity of mountain ecosystems with many substantial results. Based on the research, we highlighted some gaps, which are focus areas for future studies.

1. Though the results during the survey period showed that remote sensing is one the most frequent authors' keywords, the methods and monitoring approaches such as NDVI, decision trees, neural networks, synthetic Aperture radar, and Lidar are not listed, thereby limiting modeling and future prediction for changes. NDVI is the most typical indicator of monitoring growth or decrease in vegetation, forestry, and agricultural land; the index is good for showing the contrast between vegetation land and soil nutrients and monitoring. The ability of RS and GIS to collect extensive data, map and monitor the environment, and manage and analyze spatial-related databases, thereby helping to plan, develop, conserve, and sustain the environment. Furthermore, it helps to detect and respond to natural disasters and facilitates spatial thinking that can solve real-world problems and inform the right decisions and actions. RS has helped to measure and monitor space, species, vegetation, environmental disasters, climate, ecosystems, biomass, urbanizations, etc., However, several research areas still need to be fully explored regarding using unmanned aerial vehicle imagery fusion for vegetation/agriculture and forestry management, species loss, habitat loss regarding land use, and biodiversity change. The accurate assessment and evaluation form the basis for understanding the impact and dynamics of LULCC, biodiversity loss, and ecosystem services, enabling future planning and prediction and preventing exorbitant spending on infrastructure repairs [48]. RS is used in mapping and measuring species richness and diversity; year in and year out, biological invasions of species threaten human lives, food security, and the global economy. This invasion of alien species is one of the reasons for biodiversity loss and the extinction of native species. Research on remote sensing tools can measure species richness and diversity, prevent the spread of alien species and extinction of native species, develop biodiversity data, and enhance a balanced environment.

2. Another gap is the need for a research focus on regenerative and reclamation agricultural practices to optimize the already used space for agriculture, thereby solving human-wildlife conflict, overgrazing, and loss of biomass or soil nutrients [49]. Intensive agricultural production is one of the factors leading to biodiversity and ecosystem loss in LULCC.

3. The understanding of the mechanism behind the change in the land use land cover and the loss of biodiversity and mountain ecosystems and how much was lost or gained (transitioning) [46] results from the changes at different levels and how it can be addressed or averted in the future are essential for proper documentation. Most current studies focused on the changes but only a little detailed statistical data on the causes and results (effect). Statistical (mainly quantitative) data will give more meaning to ecological and environmental planning [50]. Future opportunities exist to create an ecosystem-based environmental development plan that will also contribute to mitigation and adaptation plans for climate change.

4. Collaborative research on land use, land cover, biodiversity, and mountain ecosystems are insufficient; achieving sustainable environmental and ecological development requires a holistic approach, such as community members, sociologists, geographers, ecologists, economists, politicians, and other stakeholders. A citizen science approach can produce a better and more diverse base for the study. Therefore, future studies recommend a possible inter/transdisciplinary framework to accelerate research development in the low niche area of LULCC, biodiversity, and ecosystem studies.

6 Conclusions

This study reviewed the trend of research on the LULCC and biodiversity of mountain ecosystems using the bibliometric analysis method from January 2000 to September 2023. Findings revealed a steady and consistent increase during the period under study. However, developed countries have produced more outputs on the related topic as compared to developing countries, especially those on the African continent. This trend is almost the same for globally cited documents. The main findings are connected to the effectiveness of monitoring, managing, and sustaining biodiversity to continue to provide information on many benefits in real-time environment planning and development. This study will help other researchers and government agencies in environment, agriculture, and biodiversity conservation to strengthen the planning, development, adaptation, and integration of what needs to be done to improve mountain biodiversity and achieve sustainable development. Hence, this study is vital for optimizing practices in sustaining biodiversity and agricultural production with evolving research developments that focus more on the low-ranking authors' keywords with countries with little or no research on related topics, thereby providing hints for future research. The study's limitations involved the complex assembly of multiple databases and data fusion. This paper shows the potential of the applied methods in the current study, and other research databases should be integrated to reveal more possible research developments within the niche area of the study.

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