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RESEARCH ARTICLE

Navigating the landscape of global sustainable livelihood research: past insights and future trajectory

Tong Li[1,2,3,4] · Ranjay K. Singh[5,6] · Lizhen Cui[2,4] · Zhihong Xu[3] · Hongdou Liu[3] · Francesco Fava[7] · Shalander Kumar[8] · Xiufang Song[9] · Li Tang[1,2,3,4] · Yanfen Wang[1,4,10] · Yanbin Hao[2,4] · Xiaoyong Cui[2,4]

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Abstract
Sustainable livelihoods (SL) have emerged as a crucial area of focus in global environmental change research, aligning with the Sustainable Development Goals (SDGs). This field is rapidly gaining prominence in sustainability science and has become one of the primary research paradigms. In our study, we conducted scientometrics analysis using the ISI Web of Science core collection database to examine research patterns and frontier areas in SL research. We selected 6441 papers and 265,759 references related to SL published from 1991 to 2020. To achieve this, we employed advanced quantitative analysis tools such as CiteSpace and VOSviewer to quantitatively analyze and visualize the evolution of literature in the SL research field. Our overarching objectives were to understand historical research characteristics, identify the knowledge base, and determine future research trends. The results revealed an exponential increase in SL research documentation since 1991, with the Consortium of International Agricultural Research Center (CGIAR) contributing the highest volume of research documents and citations. Key journals in this field included World Development, Global Environmental Change, Ecological Economics, and Ecology and Society. Notably, Singh RK and Shackleton CM emerged as prolific authors in SL research. Through our analysis, we identified six primary clusters of research areas: livelihoods, conservation, food security, management, climate change, and ecosystem services. Additionally, we found that tags such as rural household, agricultural intensification, cultural intensification, and livelihoods vulnerability remained relevant and represented active research hotspots. By analyzing keyword score relevance, we identified frontier areas in SL research, including mass tourism, solar home systems, artisanal and small-scale mining, forest quality, marine-protected areas, agricultural sustainability, sustainable rangeland management, and indigenous knowledge. These findings provide valuable insights to stakeholders regarding the historical, current, and future trends in SL research, offering strategic opportunities to enhance the sustainability of livelihoods for farmers and rural communities in alignment with the SDGs.

Keywords Frontiers of livelihoods · Environment management · Principal component analysis · Visualization · Farmers and rural communities

Introduction

Sustainable livelihoods (SL) are activities that restore, enhance, and maintain long-term viability, assets, and engagement when people's lives are threatened and stressed, without depleting resources and ensuring opportunity for future generations (Chambers and Conway 1991; Scoones 2009). In tandem with these, socio-environmental sustainability, which is the ability to sustain social well-being and equality without compromising environmental integrity, becomes integral to sustainable livelihoods. Understanding that livelihoods depend heavily on environmental resources and services, socio-environmental sustainability therefore affects the range and quality of livelihood opportunities available, while the way livelihood activities are undertaken can also impact socio-environmental sustainability. Thus, sustainable livelihoods and socio-environmental sustainability are deeply interrelated and should be viewed through a holistic lens.

The development of SL can be traced back to the earliest studies on poverty by Sen (1981), Reutlinger (1984),

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Extended author information available on the last page of the article

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Chambers and Conway (1991), and others in the 1980s and early 1990s. These studies not only focused on income poverty in the traditional sense but also highlighted the developmental capability poverty (i.e., lack of ability to choose and accomplish basic livelihood activities), pointing out that socio-environmental sustainability is a key factor in ensuring these capabilities (Fantini 2023), which is the basic prototype of the SL research framework (Chambers and Conway 1991). With the convention of the United Nations Conference on Environment and Development, the Brundtland Commission first explicitly introduced the concept of sustainable development and livelihoods in 1987 in "our common future" (Borowy 2013). In 1992, the United Nations Conference on Environment and Development introduced the concept of sustainable livelihoods provided by Chambers and Conway (1991) into the action agenda advocating stable livelihoods as the main goal of poverty eradication. The subsequent conferences such as the International Conference on Population and Development (ICPD (1994)), the World Summit for Social Development (WSSD, UN (1995a) (Boroey 2013)), and the World Conference on Women (UN (1995b)) further emphasized the importance of sustainable livelihoods for poverty reduction policies and sustainable human development. Further, the United Nations Millennium Declaration, adopted in 2000, explicitly set the goal of halving extreme poverty by 2015 from the 1990 level and achieving sustainable livelihoods. Following Millennium Development Goals' evaluation, in 2015, the United Nations further formulated 2030 Agenda for Sustainable Development, which emphasized the achievement of sustainable livelihoods as the core of global sustainable development (UN 2015). Such global efforts reflected the importance and could lead the concept of sustainable development to integrate more meaningfully with global poverty and providing target guidance for achieving global sustainable livelihoods.

In recent years, research interest in sustainable livelihoods approaches (SLA) has received widespread attention (Hahn et al. 2009). Many development agencies have researched sustainable livelihoods in both empirical and theoretical frameworks. Currently, there are three accepted mainstream approaches: the Sustainable Livelihoods Approach established by the UK's Department for International Development (DFID) in 2000, the US Cooperative for American Remittances to Everywhere (CARE), and the United Nations Development Program (UNDP) on Sustainable Livelihoods Approach. These frameworks integrate socio-environmental sustainability by recognizing its crucial role in shaping livelihood strategies and outcomes. Other organizations and institutions, such as the Food and Agriculture Organization and the World Bank, have developed different frameworks for sustainable livelihoods analysis, both independently and collaboratively. Some researchers, such as Scoones (1998), Bebbington (1999), and Ellis (2000), have developed frameworks of sustainable livelihoods analysis. Scoones (2009) argues that research focusing on livelihood assets and their components is an important avenue for sustainable livelihoods and related research. Compared to traditional livelihood studies, SLA that captures poverty more inclusively at the micro-level contains five main components: a vulnerability context, livelihood assets, transforming structure and processes, livelihood strategies, and outcomes (DFID 1999; Carney 2002). The vulnerability context refers to the variable external environment which is out of an individual's control. Specifically, it includes shock, trends, and seasonality. Livelihood assets include human (H), physical (P), social (S), financial (F), and natural (N) assets (DFID 1999). People's decisions and the activities, that people endeavor to achieve their goals, are described as livelihood strategies (Zhao et al. 2020). Overall, this framework views poor farmers as surviving or earning a living in the context of vulnerability, where they have certain livelihood assets, and their access to livelihood assets is determined by the collective, institutional, and organizational environment. At the same time, this context also influences the livelihood strategies (the way assets are allocated and utilized) of farmers or communities to meet their livelihood objectives. Using the DFID SLA framework, a large number of qualitative or quantitative studies followed different perspectives including livelihoods and poverty (Biddulph 2015; Li et al. 2020), livelihood diversity (Wei et al. 2018; Zhang et al. 2020), livelihood vulnerability (Rogers and Xue 2015; Gai et al. 2020), land use and farm livelihoods (Wang et al. 2013; Liu et al. 2020), energy consumption and rural livelihoods (Mottet et al. 2018), and ecological construction and livelihoods (Shang et al. 2014; Cao et al. 2017). Sustainable livelihood framework (SLF) has been advocated to be applied at spatial scales including from individual to family and country level (Siegel 2005). Ferrol-Schulte et al. (2013) applied SL analysis methods to cover diverse social-ecological systems, while Cherni and Hill (2009) followed this to know relationship between farm household livelihoods and renewable energy in remote rural community. Few of the studies have also proposed to apply the index (Singh and Hiremath 2010) in revealing the dynamics of sustainable livelihoods. The ecological security, economic efficiency, and social equity were considered as the major components to effectively balance the common concerns of economists, environmentalists, and egalitarians (Singh and Hiremath 2010) which can provide a reference for achieving sustainable development (You and Zhang 2017). In this context, the theories of evolution and development on sustainability to bring different researchers' perspectives to the forefront of public attention has been attempted (Sneddon 2000).

Due to global environmental change, potential climate vulnerability has become a most inclusive ecological problem, such as extreme climate events (Mathew et al. 2018), water

shortages (Baba and Hack 2019), food insecurity (Algur et al. 2021), energy transition (Qi et al. 2017), and loss of biodiversity (Bernardino et al. 2020). The compounding impacts and process of these factors seriously limit the sustainability of livelihoods (Zampaligre and Fuchs 2019). Research on sustainable livelihoods has become particularly important to deepen the understanding of these potential risk factors. Despite the increasing number of publications on SL research, little attention has been paid to these comprehensive research area. The current research on SL has focused mainly on the analysis of the progress, content, and framework (methodology) of international SL research, with most papers using mostly descriptive and statistical analysis in their methodology and research frameworks (Liu et al. 2020; Makate et al. 2017; Yang et al. 2019). Although there are some works on the attributes of SL studies, overall synthesis and future projections (Siegel 2005; Zhang et al. 2019) and few initial bibliometric analysis work on SL research have been undertaken (Zhang et al. 2019); there is a lack of in-depth systematic interpretation regarding the hotspots and evolution path of SL research, as well as projections of future research scenarios. Keeping these gaps in view, in this research, we aimed (i) to review the progress status and determined the development trend of SL research through secondary literature by assessing the knowledge base, (ii) understanding the evolution of SL research development, and (iii) identifying frontier research areas and hot spot in this field, with a particular further emphasis on exploring the relationship between socio-environmental sustainability and SL. Therefore, it is important to precisely assess the research progress on SL and analyze the attributes and characteristics of its knowledge evolution to advance the research in the field of SL. These can guide future research directions and may also help in shaping projects and programs on sustainable livelihoods. These findings can play an important disciplinary reference role for an in-depth understanding of past and present sustainable livelihoods research. This could also accurately grasp future research directions, especially for scholars, governments, and international organizations to provide important guidance and reference for faster and improved poverty eradication issues. Thus, the insights generated over the interfaces of SL research can be helpful to policy makers in addressing some pressing issues on SL studies by integrating evolved knowledge with initiatives and policies while achieving the Sustainable Development Goals (SDGs) 2030 (Sianes et al. 2022).

Research methodology

Study approach and framework

As a research methodology, scientometrics are important quantitative tools for analyzing the progress of a research topic from a macro to a more micro perspective (Li et al. 2021; Romasanta et al. 2020). The macro perspective covers analysis of the whole research, such as several papers, categories, re-research countries, institutions, and journals, using scientific peer-reviewed literature. Contrarily, the micro perspective is attributed with interpretation of keywords, co-cited literature, and focused literature. The scientometric approach helps to understand the evolutionary characteristics of research over time (Saritas and Burmaoglu 2015) and also allows a systematic and better judgment of a scientific research field comprehensively (Chen 2017).

In this study, comprehensive research framework was adopted for literature search and processing, as depicted in Fig. 1. We began with the selection of the ISI Web of Science Core Collection database due to its extensive coverage of peer-reviewed research articles across various disciplines, including sustainable livelihoods (SL). Our inclusion criteria required articles to be in English, published between 1900 and December 2020, and be classified as research articles or reviews. Crucially, the phrase "sustainable livelihood" had to be present in the title or abstract, which was ensured by our advanced search formula: "TS = sustain* AND TS = livelihood*". This process resulted in an initial total of 6674 articles. We then proceeded to the next phase, which involved filtering by document type and excluding any documents not categorized as "articles" or "reviews." This led to the final selection of 6441 valid and pertinent articles for our study. These articles, exported as "plain text" with full record and cited reference, contained the author, title, institute, keywords, journal, source document, abstract, and cited references. An expert consultation was made to further validate the relevance and quality of the selected articles.

Scientometrics analysis methods

We used Microsoft Excel, *R* 3.6.2 software (Biblioshiny package), CiteSpace5.7.R2, and VOSviewer to mine, quantify, process and analyze the data, and visualize the reviewed literature. The Scientometrics analysis followed following methods.

Biblioshiny

Biblioshiny allows relevant scientific measurement and visualization using an interactive web interface (Agbo et al. 2021). We used Biblioshiny to systematically assess the research countries and institutions, influential journals, and important authors reported in the analyzed articles and documents relating to SL.

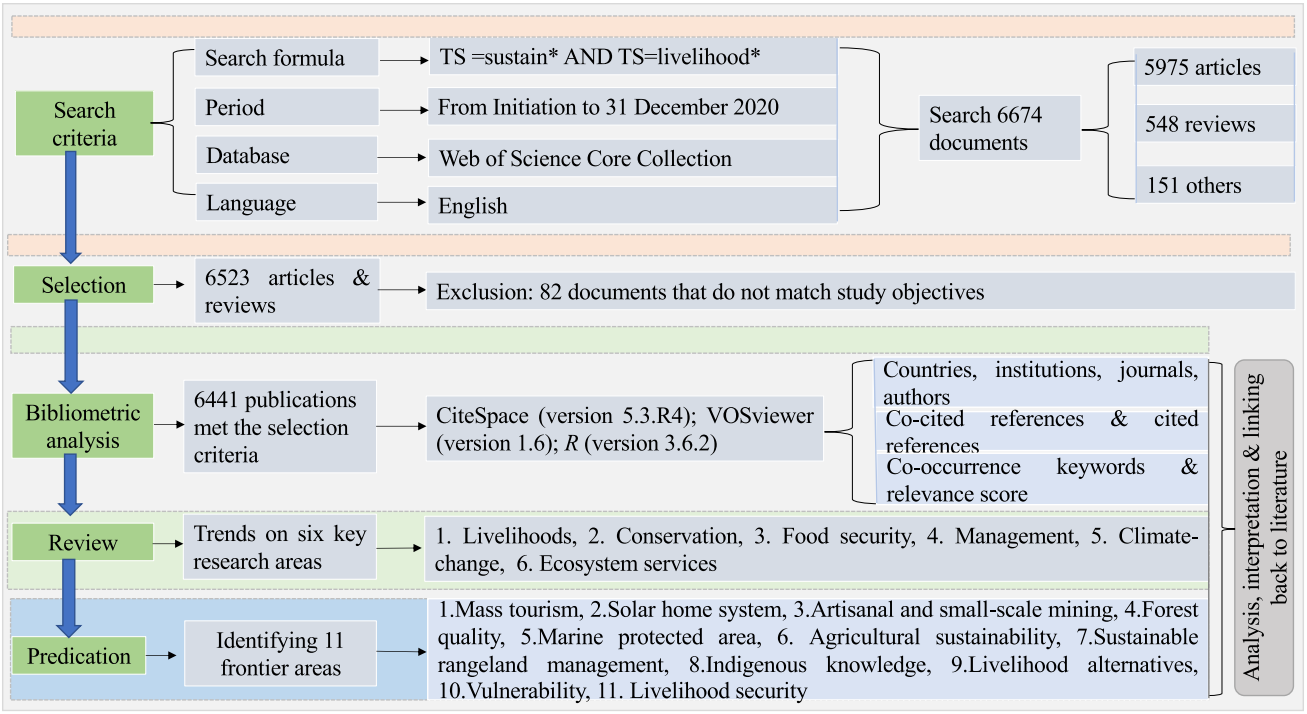


Fig. 1 Research framework and methodological strategies of study on global sustainable livelihoods research

CiteSpace

We applied CiteSpace to take snapshots of the SL field (based on time series) that could help us to connect and infer the changing process and development trends in the SL field (Ouyang et al. 2018; Nyathi et al. 2022). The specific visualization has two main modes: the cluster view and the timeline graph (Chen 2017). The timeline graph was used to cluster and display the evolution of knowledge (i.e., trends) on SL in different periods using mutation detection (Chen et al. 2010). The CiteSpace software helped us to analyze the cited references in SL documents. Taking insights from Chen (2017), we analyzed the clustering and key nodes in the co-cited network of knowledge structure of SL research. This could help us to identify research frontiers from the clustering of many literature knowledge base sources and revealed the essential knowledge nodes contained in SL research frontiers (Zhang and Chen 2020). Clustering tags were extracted from the SL cited literature using the log-likelihood ratio (LLR) algorithm to represent the research frontier knowledge base. The timeline graph was used to sketch the relationship between clusters and the historical span of SL documents in a cluster. The citation burst analysis was applied to assess the number of citations changing over a short period in searched documents (Chen 2017). Using the principle of tantamount to count the frequency of words in the titles, abstracts, keyword identifiers of literature records of papers, and hot words in research frontiers were identified, and the growth rate of these was understood.

VOSviewer

Using VOSviewer software, the "network data" in documents can be analyzed (Martins et al. 2022). This allows in understanding the relationship construction and visual analysis of the document knowledge unit. VOSviewer was applied to draw the scientific knowledge graph to show the relationship between the structure, evolution, and cooperation of SL knowledge field (van Eck and Waltman 2010). Further, the graphic forms of VOSviewer enabled us to develop item density visualization on SL research. While visualizing the item density of SL research, the point with more neighboring items and higher weight of the neighboring items was closer to red, whereas, in the opposite case, its color was closer to blue (McAllister et al 2022; Martins et al. 2022). The analysis of keywords in a paper can reveal the paper's theme, while frequency statistics of it reflect the research status. However, some correlation must exist among the keywords in a paper that can be expressed by the frequency of co-occurrence. It is generally believed that the more the lexical pairs appear in the same document, the closer the relationship between the two topics (Bornmann et al. 2018; Li et al. 2021). Co-occurrence analysis was used to capture the common occurrence of lexical pairs or noun phrases in the SL

literature to determine the relationship between topics. A co-word network composed of these word pairs was constituted by counting the frequency of subject words on SL that appeared in a particular document (Li et al. 2022a; Martins et al. 2022). High-frequency keywords were considered research hotspots and research topics in SL studies (Bin et al. 2021). Through the automatic algorithm of the VOSviewer software, these keywords were analyzed by co-occurrence, and clusters were formed that represent the current research area (van Eck and Waltman 2010). These clusters indicated the most current lines of interest among related researchers.

Another function of this software helped us to calculate the term's relevance in finding the future direction of SL research based on current and past development processes of SL research (Abad-Segura et al. 2020). It also provided a reference point for the exploration of starting direction of the research. More specifically, the keywords were analyzed by their co-occurrence and clustering (Bornmann et al. 2018). These clusters were developed based on the relationship between the link attribute weight of different keywords and the total link strength (Li et al. 2022a). The network of keywords was selected from the total documents based on the co-occurrence method. Specific clusters of the keywords and their links were grouped, and each group was identified with a different color (Li et al. 2023). The size of each cluster represents their relative contribution to the group with keywords, and the thickness of the tie line between two clusters refers to the number of interactions established between two distinct communities (Giannakos et al. 2020). The group of pioneering keywords was identified to establish the basis of the SL studies (Abad-Segura et al. 2020), in addition to the recent keywords. The clusters were labeled using the keyword with the most occurrences and ranked by the percentage of keywords. The weight of the link and the total link strength contributed by each representative keyword were included. In addition, this software also demonstrates the cooperation between countries. The centrality of domestic cooperation was also used as one of the indicators to measure a country's research strength by shown in visualization (Li et al. 2023).

Results and discussion

Temporal evolution of documents

After classifying the retrieved document datasets and eliminating irrelevant documents, a total of 6441 documents and 265,759 references were recorded. The first documented instance of SL research dates back to 1991. Over the past three decades, an average of 6.7 SL research documents were published each year with mean value of 21.26 citations per document, indicating a rapid and exponential growth in the field of SL research (Fig. 2). These documents featured contributions from 19,082 authors, with 939 single-authored papers, and incorporated a total of 13,979 keywords (Table S1).

We can trace the evolution of SL research through three distinct stages from Fig. 2. The foundational stage

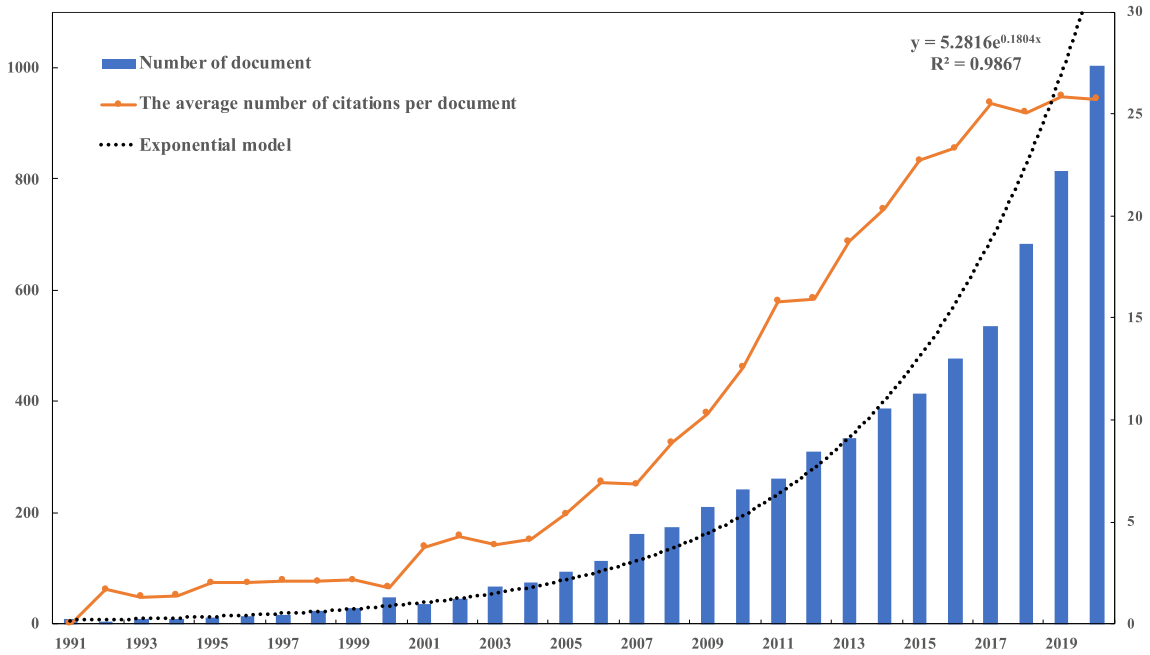


Fig. 2 Temporal evolution of documents on sustainable livelihoods research (1991 to 2020)

(1991–2000) marked the beginning of SL research with a steady low publication rate. In the development stage (2001–2010), a marked increase in the number of publications highlighted an amplified interest in SL research. Finally, the booming stage (2011–2022) has been characterized by a surge in SL research, with annual publications exceeding 100 from 2006 and 500 from 2017. This surge was particularly prominent from 2016. The overall annual growth rate has been striking, growing from 9 documents in 1991 to 1004 in 2020, marking an annual growth rate of 331.2%. These segmented stages of growth provide a comprehensive perspective on the evolution and exponential growth of SL research over the past thirty years.

Web of Science subject categories

Results indicated that the areas of SL research have increased from seven fields in 1991 to 142 by 2020. These were concentrated mainly in environmental science (2020), environmental studies (1539), green sustainable science technology (827), ecology (808), development studies (423), and water resources (423). The main two research areas, including environmental science and environmental studies, represented 3559 of the 6441 documents, making up approximately 55.0% of the total (Fig. 3). This revealed that the SL studies have been primarily focused on environmental problems, although they also covered a wide range of other research areas, such as soil science, water resources, fisheries, and plant sciences. Therefore, disciplinary characteristics of SL research showed a trend of interdisciplinary integration which is a strength to unpack different components and their dynamics crucial in shaping SL (Scoones 2009).

Trends in research countries, institutions on sustainable livelihood research

The results showed that 135 countries had been engaged in SL research. Out of these, the top five with the largest number of documents on SL research were the United States (1426), England (968), Australia (725), India (690), and China (564) (Fig. 4). This followed a similar trend as reported in Zhang et al. (2019). In addition, the centrality of domestic cooperation was also used as one of the indicators to measure a country's research strength. It resulted to know that in the top 15 countries, India has the highest percentage (63.48%) of single corresponding authored articles followed by China (46.28%), South Africa (43.113%), UK (37.71%), USA (36.89%), and Australia (32.28%), respectively (Fig. S1). The country with the highest percentage of non-corresponding author articles included Indonesia (73%) followed by France (64.7%). The countries with the ratio of the corresponding author to non-corresponding author articles close to 1:1 were Italy (57.97%), Switzerland (55.61%), Brazil (54.80%), Belgium (52.48%), Sweden (52.31%), Ethiopia (52.28%), and Bangladesh (51.51%). The

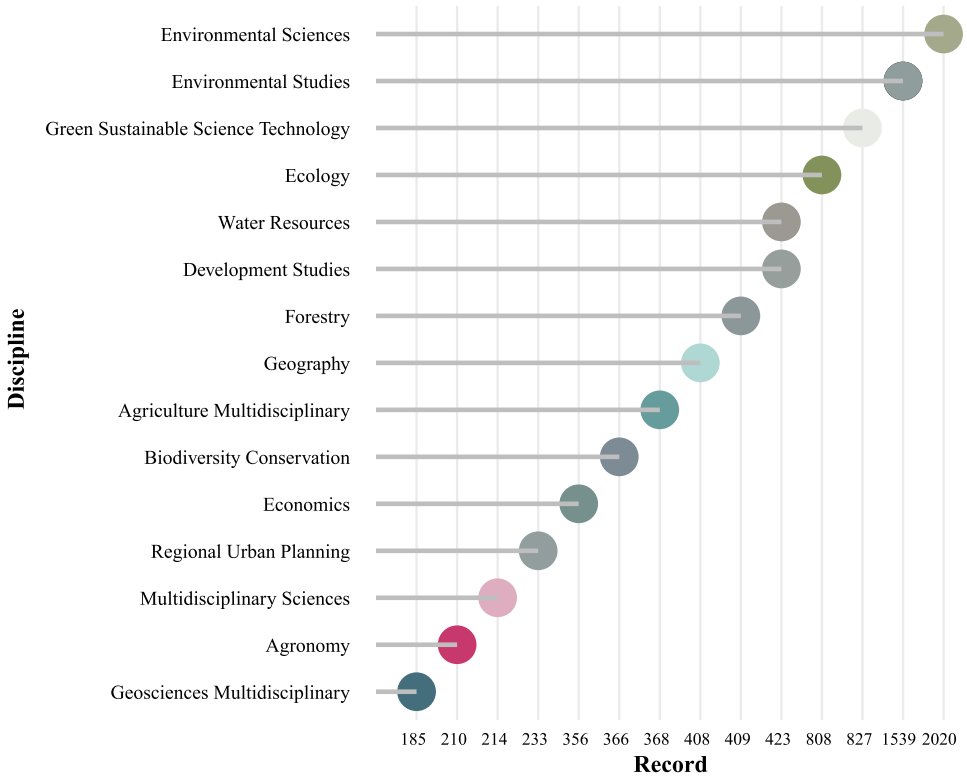


Fig. 3 Top 15 main research discipline categories in Web of Science on sustainable livelihood research studies from 1991 to 2020

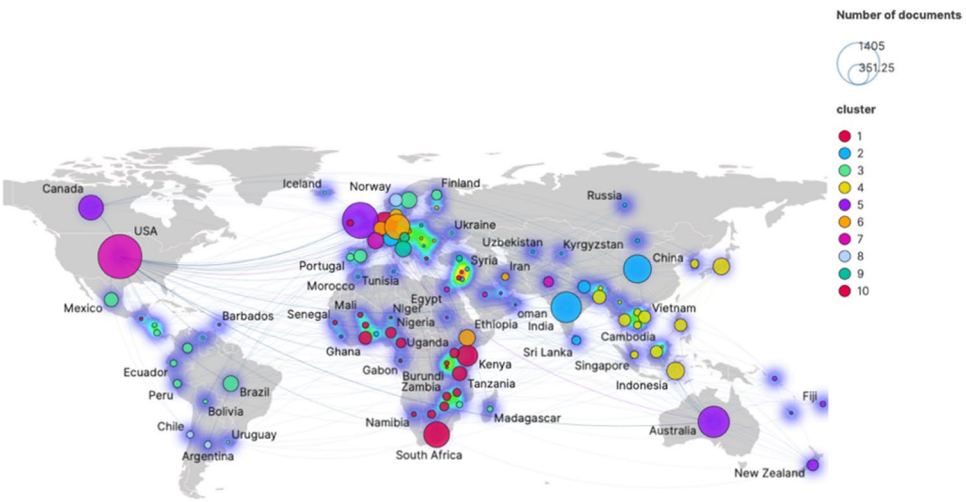


Fig. 4 The distribution and cooperation density visualization between countries in sustainable livelihood research field

top five countries in terms of centrality were found to be the USA, Germany, China, Canada, and Australia. The USA has cooperation with more than 20 countries, including China, Brazil, and Australia, while South Africa and China cooperate with Germany, Canada, Australia, and Japan (Fig. 4). The differential pattern of corresponding authorship across the nations might be governed by the nature of interdisciplinary team working and publishing on SL, resources, and nature of collaborations among them, and academic culture (Kwiek and Kurkiewicz 2012; Kwiek 2015). In addition, sharing the authorship roles (specially the correspondence) and associated outcomes and soldering the responsibilities on research claims made on SL might also be affected by the individual motivation governed by performance-based promotion of carrier and perceived self-prestige of authors (Kwiek 2015, 2017).

We observed a total of 2341 institutions globally who were engaged in SL research. The five most influential research institutions represented 833 articles, including cooperation achievements for each institution. The number of papers in one institution was significantly higher than that of other institutions. This indicated that the research documents of the five most influential institutions were asymmetrical in publication distribution. In terms of institutions, the Consortium of International Agricultural Research Center (CGIAR) ranked first with the largest number of papers (512), followed by both Wageningen University and Research (216) and the Chinese Academy of Sciences (216) received second rank (Table 1). The variations among different institutions (Asia and Europe) in terms of producing SL publications might be on account of follow-up action on addressing multiple stresses (climatic, ecological, socio-economic, and political) under SDG targets set-up by different nations (Sianes et al. 2022). Additionally, more dependence of local communities in developing nations on agriculture and natural resources and attention of international donors and multilateral agencies supporting projects to reinvigorate livelihoods of such communities (in view of SDGs) by the identical institutions (either alone or in network mode) while managing livelihood risks (Filho et al. 2018) might have also proportionally increase the SL publications.

Table 1 Top 10 productive institutions on SL research from 1991 to 2020

Institution	TA	Location
CGIAR	512	France
Wageningen University and Research	216	Netherlands
Chinese Academy of Sciences	187	China
Indian Council of Agricultural Research	164	India
University of California System	137	USA
Center for International Forestry Research	131	Indonesia
University of London	115	UK
University of Queensland	107	Australia
CSIRO	100	Australia
University of British Columbia	93	Canada
University of Oxford	91	UK
State University System of Florida	87	USA
CIRAD	86	France
James Cook University	83	Australia
ICRAF	80	Kenya

Abbreviations: *TA*, total number of articles; *CGIAR*, Consortium of International Agricultural Research Center; *CSIRO*, Commonwealth Scientific and Industrial Research Organization; *CIRAD*, French Agricultural Research Center for International Development; *ICRAF*, International Center for Research in Agroforestry

Trends in influential journals covering sustainable livelihood research

The SL studies have appeared in 1108 journals, and the average number of journals per year increased from 4 to 108 since

1991 (Table S1). The top 30 (2.7%) journals published 2207 (34.26%) of the total number of publications. On the contrary, 960 journals (86.64%) published less than ten papers, while 527 journals (47.56%) published only one paper (data table not shown). The top three journals with the largest number of papers published were Sustainability (201), Land Use Policy (185), and Ecology and Society (147). According to Bradford's law (Li et al. 2021), the SL research documents were highly dispersed with a large portion being published in ten journals as shown in Table 2 (marked with *). This indicated that these journals were the core sources in SL research and played an essential role in understanding the progress in SL research. In addition to the specialized journals, SL research also made a significant presence in internationally recognized journals of general interest, such as Nature (7), Science (4), and Proceedings of the National Academy of Sciences (31). The journals including World Development, Global Environmental Change-human and Policy Dimensions, Ecological Economics, Ecology and Society, Journal of Environmental Management, and Current Opinion in Environmental Sustainability appeared to be ranked in the top five in terms of citations there. This trend indicated a substantial contribution of document quantity published in a journal to its total local citation score (TLCS) value (Table 2), and showed that these journals not only have more documents but also influenced the SL research. Adding SL research into the aim and scope of these high impact journals would have also impacted the evolution of research-based SL knowledge and its sharing among the multi-stakeholders influencing policy and practices on sustainable development (Kerkhoff and Lebel 2006).

Core authors and academic community on sustainable livelihood research

The analysis of authors can identify those who are more energetic, productive, or cited in SL research, and the researcher networks' contribution to SL studies. We observed that the top five authors, with the largest number of articles, were Singh RK (28), Shackleton CM (26), Chirwa PW (22), Stringer LC (21), and Milner-Guland EJ (20) (Table 3). Dougill AJ was ranked first in terms of the highest average number of citations (54 per article), which was 16 times higher than that of the second-ranked author. Shackleton CM, Stringer LC, and Dougill AJ were the top three authors in terms of the H index in the dataset relating to SL research (Table 3). According to Price's law (Li et al. 2021), authors who publish more than four papers on SL research are identified as the core authors, and therefore, a total of 393 such authors were identified working on SL research.

Table 2 Top 20 journals ranked by the total local citation score (TLCS) in SL research from 1991 to 2020

Journal	TLCS	ND	H_i	AC	PY_s	IF
World Development*	4053	79	30	51	1995	6.67
Global Environmental Change-human and Policy Dimensions*	3622	58	33	62	2001	11.16
Proceedings of the National Academy of Sciences of the United States of America*	2798	31	21	90	2007	12.78
Science	2360	4	4	590	2007	63.84
Ecological Economics*	2330	73	27	32	1997	6.53
Ecology and Society*	2308	110	25	21	2006	5.27
Nature	2208	7	7	315	2003	69.5
Journal of Environmental Management*	2101	74	24	28	1998	8.91
Current Opinion in Environmental Sustainability*	2096	46	22	46	2009	7.96
Biodiversity and Conservation*	2084	41	23	51	1996	4.41
Marine Policy*	2078	95	21	22	2001	4.31
Land Use Policy*	2030	127	24	16	1998	6.18
Progress in Human Geography	1946	5	5	389	2000	9.04
PLOS One*	1941	72	20	27	2009	3.75
Conservation Biology*	1925	38	20	51	2003	7.56
Ecosystem Services*	1877	49	19	38	2012	6.91
Sustainability*	1850	302	20	6	2011	3.88
Forest Policy and Economics*	1746	76	21	23	2002	4.25
Agriculture Ecosystems and Environment*	1702	36	20	47	2000	6.57
Environmental Science and Policy*	1638	38	19	43	2008	6.42

Abbreviations: *X**, the journal is the core resource of SL research; *TLCS*, total local citation score; *ND*, number of documents; *H_i*, H index; *PY_s*, published year started; *AC*, average citation; *IF*, impact factor (in 2021)

Table 3 Top 10 research authors' local impact ranked by total documents

Author	TD	TLCS	AC	H_i	PY_start	Institution	Country
Singh RK	28	159	6	7	2008	College of Horticulture and Forestry, Central Agricultural University an ICAR-Central Soil Salinity Research Institute	India
Shackleton CM	26	975	38	15	2002	Department of Environmental Science, Rhodes University	South Africa
Chirwa PW	22	261	12	8	2008	Department of Plant and Soil Sciences, Faculty of Natural and Agricultural Sciences, University of Pretoria	South Africa
Stringer LC	21	505	24	14	2007	Sustainability Research Institute, School of Earth and Environment, University of Leeds	UK
Milner-Guland EJ	20	570	29	12	2008	Interdisciplinary Center for Conservation Science, Department of Zoology, University of Oxford	UK
Kumar S	18	190	11	7	2012	ICAR-Central Soil Salinity Research Institute	India
Dougill AJ	16	866	54	12	2001	School of Earth and Environment, University of Leeds	UK
Azadi H	16	154	10	7	2015	Hossein Azadi Department of Geography, Ghent University Faculty of Environmental Sciences, Czech University of Life Sciences Prague	Belgium Czech
Maikhuri RK	15	350	23	10	2000	Department of Environmental Science, HNB Garhwal University	India
Hickey GM	15	149	10	8	2012	Department of Natural Resource Sciences, Faculty of Agricultural and Environmental Sciences, McGill University	Canada

Abbreviations: *TD*, total number of documents; *TLCS*, total local citation score; *AC*, average citation score; *H_i*, H index; *TLCS*, this refers to the citation in the data set; *PY_s*, published year started

The 6441 documents involved 19,082 authors, and a total of 939 independent authors published 100 studies. On average, the remaining documents have 4.8 co-authors per document. The cooperation index of authors in these documents was 3.17. Overall, on average, each author contributed 0.338 documents and each document had an average of 2.96 authors. This also indicated that SL research has been typically a multi-authored cooperative field (Fig. 5), and may be due to the need of diverse discipline and expertise needed in unpacking the issues on sustainability. It should be pointed out that we did not distinguish between the order of authors in their list of names, the calculated document, and the citation; rather, we recorded a name if it was on the list of authors.

Current research themes

A total of 22,224 keywords were detected from 6,441 papers on SL research from 1991 to 2020. The keywords were analyzed using co-occurrence and clustering techniques (Fig. 6). The six major groups of pioneering keywords that have established the basis of the SL studies included livelihoods, deforestation, adaptation, impacts, resilience, and governance. These were in addition to the following prominent topics: climate change, biodiversity, conservation, fisheries, land-use, ecosystem services, systems, adaptive capacity, and community reliance. Recently, Zhang et al. (2019) have also identified ecosystem conservation, poverty reduction,

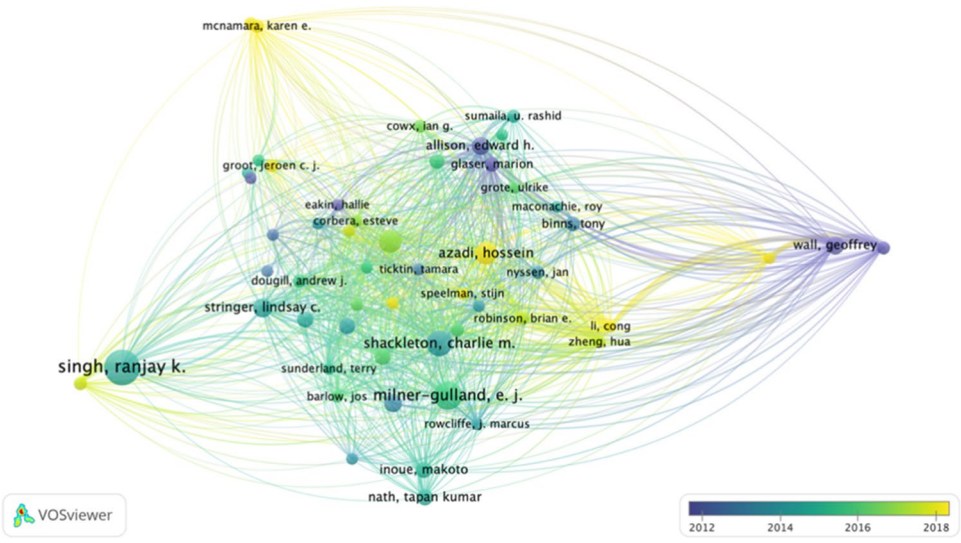


Fig. 5 Evolution of authors' network based on the co-occurrence method on sustainable livelihood research (1991 to 2020)

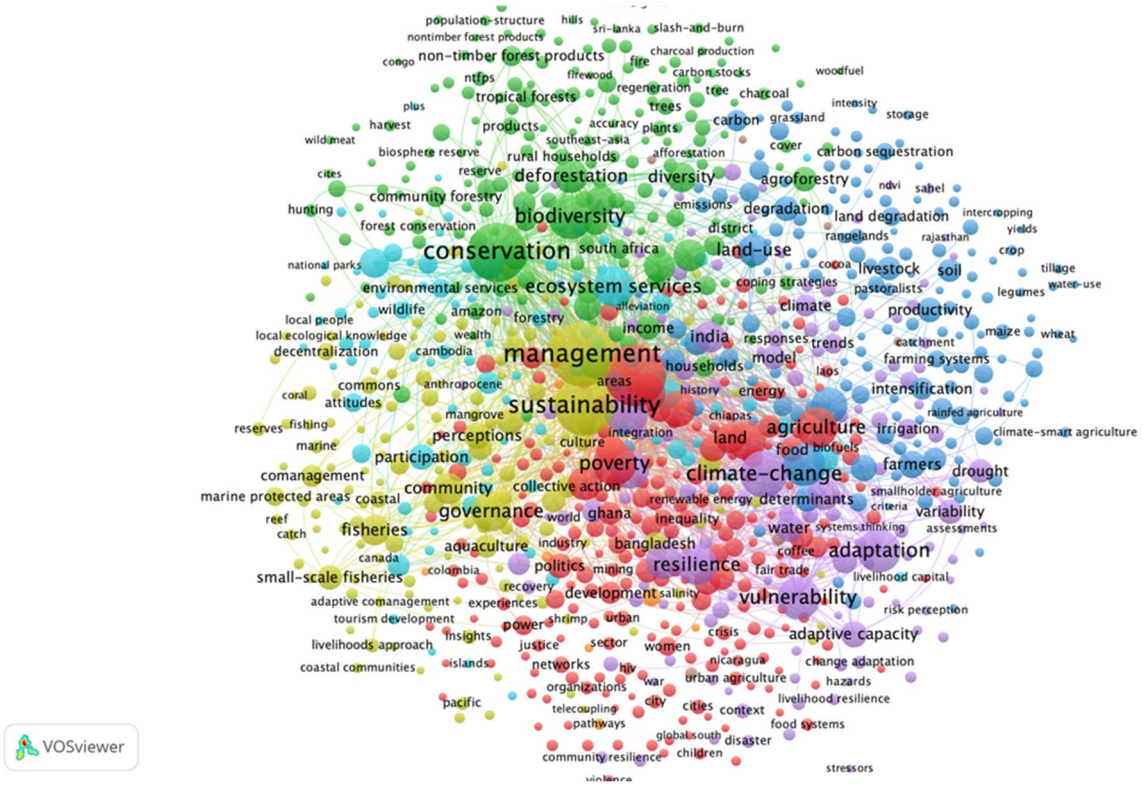


Fig. 6 Network of keywords based on the co-occurrence method on sustainable livelihood research (1991 to 2020)

and sustainable livelihoods in special poverty-stricken areas, impact of climate change on livelihoods and sustainable livelihoods-related policies, and institutional change as the current key themes in SL research. In this sense, the different periods in which SL studies have been conducted are an elegant collection and may also help to validate the six research themes identified in the research activities, those represented six clusters (Fig. S2). These were labeled using the keyword with the most occurrences and ranked by the percentage of keywords. They included as cluster 1, red: livelihoods; cluster 2, green: conservation; cluster 3, deep blue: food security; cluster 4, yellow: management; cluster 5, purple: climate-change; and cluster 6, light blue: ecosystem services (Table 4). Based on the cluster analysis, the significant key research areas are discussed below in details.

Livelihoods

This term livelihood focuses on practical analysis of its required components using SLF. After entering the twenty-first century, the theory of sustainable livelihoods has been minimally enriched; however, it is being replicated using the DFID's SLA framework (Liu et al. 2020; Yang et al. 2019). These progresses have been led by the evaluation indicator system to improve rural livelihoods and cover areas, such as policy, structure, livelihood capital, social equity, and vulnerability environment (Lyu and Xu 2020; Wang et al. 2015). These are primarily theoretical studies which suggest effective and rational livelihood adaptation strategies. It is widely acknowledged that establishing an effective and innovative indicator system and monitoring program are critical to the success of reducing global poverty (UN 2008).

Conservation

The relationship between human livelihoods and the ecological environment has been one of the core scientific propositions of sustainable development to date (Liu et al. 2020; Mathew et al. 2018). In many developing countries, the livelihood choices of farmers, especially poor ones, are often strongly dependent on the natural environment. Such environmental resources provide them with various ecological services and opportunities for exploitation to enhance income and means of livelihood (Birge et al. 2016). However, livelihood activities that are overly dependent on environmental resources can adversely impact and compromise conservation and sustainability of natural resources (Syampungani et al. 2009), and overall food and nutritional

Table 4 Identified clusters of keywords on SL research from 1991 to 2020

ID	M	C	Name	O	L	TLS	Top 10 keywords
1	233	Red	Livelihoods	968	908	7193	Poverty, agriculture, Africa, policy, impact sustainable livelihoods, land, challenges, gender, migration
2	186	Green	Conservation	905	865	6825	Biodiversity, deforestation, dynamics, rural livelihoods, forest, diversity, knowledge, resources agroforestry, poverty alleviation, patterns
3	166	Deep blue	Food security	402	678	2940	Systems, land-use, farmers, sub-Saharan Africa, growth, degradation, productivity, determinants, Tanzania, livestock
4	152	Yellow	Management	1083	913	7906	Sustainability, governance, community, fisheries, institutions, perceptions, small-scale fisheries, lessons, social-ecological systems
5	135	Purple	Climate-change	522	728	3967	Adaptation, impacts, vulnerability, resilience, sustainable development framework, strategies, India, water, adaptive capacity, variability
6	96	Light blue	Ecosystem services	368	700	2944	Biodiversity conservation, China, protected areas, diversification, participation, benefits, tourism, trade-offs areas, payments, environmental services, national park

ID, cluster ID; *M*, cluster members; *C*, color in Fig. 7; *O*, occurrences; *L*, weight links; *TLS*, weight total link strength

security can be compromised (Estrada-Carmona et al. 2020). As a result, this may trap farmers in a poverty–environment loop and even trigger environmental migration. Sustainable livelihoods depend on natural ecosystems and the rationalization of biological resource allocation (Scoones 2009). Therefore, balancing ecological and productive benefits is also an important element in achieving sustainable development. This includes conservation of biodiversity, application of indigenous knowledge, best management practices (Kemp et al. 2020; Laflamme 2011), and optimal development models (Kerkhoff and Lebel 2006).

Food security

Food security is the most fundamental aspect of livelihoods, from land-use practices to productivity improvements and reproduction processes that directly determine the sustainability of farmers' livelihoods (Schumann et al. 2010; 2011). To ensure and maintain basic livelihoods, farmers often increase utilization, leading to a new round of land degradation, and therefore, food security may become a key concern for livelihoods (UN 2008). Due to severe poverty and widespread livelihood difficulties, regions such as Africa and a few Asian countries have become the focus of international research on sustainable livelihoods (Birkmann et al. 2022). These regions are key for securing basic livelihoods and achieving global "food security" (Ellis and Freeman 2004; Mwacharo and Drucker 2005).

Management

Management is the key in ensuring policy implementation to sustain livelihoods. Different management models and governance mechanisms can directly affect the sustainability of livelihoods and the stability of social-ecological systems (Singh et al. 2021b; Wang et al. 2019). Therefore, the impact of institutions on sustainable livelihoods is crucial (Oduor 2020), and government policies (at all levels), implemented by these institutions, impact the livelihoods in multifarious ways (Singh et al. 2021b). The management of resources, emanated through policies, such as ecological conservation and compensation, managing desertification led by various stressors, and restoration, has been a significant part of international sustainable livelihoods research over the past two decades (Dong et al. 2009; Ojima et al. 2020). Global desertification studies have shown that government policies, such as grazing bans and reforestation, significantly impact communities' livelihoods (Du et al. 2016). At the same time, the health of community members is also affected in the process of environmental management (Bai et al. 2012). At the macro level, relevant policies on SL research have direct or indirect impacts on communities' livelihoods depending on the management and coherence of different programs (Du et al. 2016; Li et al. 2020; Singh et al. 2022).

Climate change

Climate change is one of the most serious stresses to humanity in the twenty-first century (Hayes et al. 2018), and has particularly adverse implications on less-developed regions and ecologically fragile ecosystems, where a majority of people are materially resource-poor (Barbier 2010; Singh et al. 2021a). These resource-poor farmers are more severely affected by climate change (Descheemaeker et al. 2016; Scialabba and Muller-Lindenlauf 2010). This has become a compounding stress to rural poverty, limiting the ability of the economically poor people to access the livelihood capitals (Makate et al. 2017; Singh et al. 2020) and thus reducing their livelihood options. As a result, this has posed serious

challenges to resource degradation, food security (Singh et al. 2020), and social inequality in rural communities (Barbier 2010). Simultaneously, climate change has also caused increased vulnerability of ecosystems to some extent, strengthening the frequency of livelihood risks (especially food security), water security, and the emergence of new pests and diseases that have bearing impacts on sustainable livelihoods of farmers (Barbier 2010; Singh et al. 2020). This trend could result the interest in the recent past on how to enhance the ability of a population to cope with risks and optimize livelihood strategies (Githumbi et al. 2018; Wang et al. 2014).

Ecosystem services

The trade-off between livelihoods and ecological resources has been a concern for researchers (Meyfroidt 2017; Mora et al. 2016). The improvement of livelihoods without depleting ecosystem services to ensure resource sustainability has been a shared interest among multi-stakeholders (Reyes et al. 2020). With the degradation of global ecosystems and the loss, and reduction in ecosystem services, ecological compensation has received widespread attention from both developing and developed countries as an effective policy tool to address environmental issues (Farley et al. 2011; Wang et al. 2020). As a major provider of ecosystem services, the impact of ecological compensation on farmers' livelihoods influences sustainability and social equity (Zhou et al. 2018). However, rural tourism, as an external force entering rural communities, inevitably has adverse effects on economic and social-ecological systems (Biddulph 2015; Nautiyal and Kaechele 2009). Therefore, it has multiple impacts and may cause risks to farmers' livelihoods. However, further research is needed to determine whether it can fully replace or efficiently complement local livelihoods (Stabile et al. 2020).

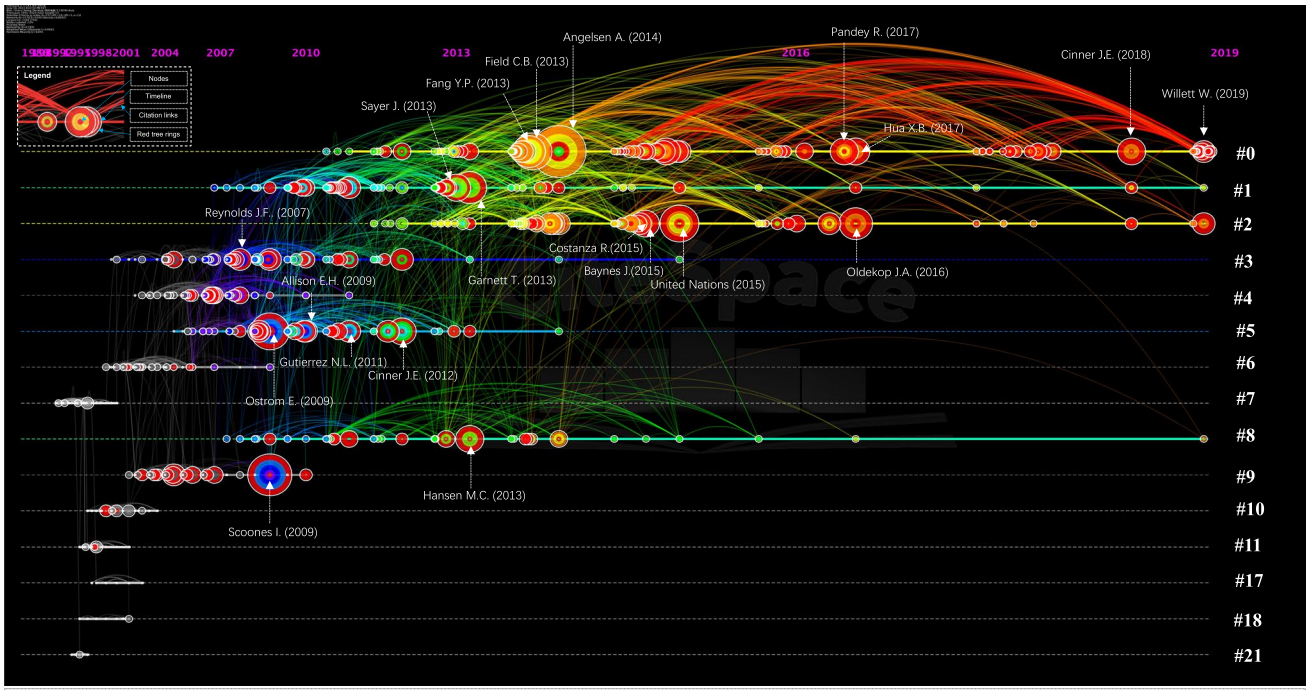
The key results on ecological resources (soil, water, and biodiversity) find a broad spectrum of research clusters in SL that are intricately linked to the United Nations Sustainable Development Goals (SDGs), particularly climate change (SDG 13) and life on land (SDG 15). In addition, the impact of management policies and the relationship between the resources required for SL these resonate with several of the 17 SDGs. Prominent clusters like rural household, agricultural intensification, cultural intensification, and conservation intervention represent the evolving discipline of sustainable livelihoods. These clusters are projected to remain active, vital for future developments, and pivotal to achieving SDGs such as No Poverty (SDG 1), Zero Hunger (SDG 2), and Sustainable Cities and Communities (SDG 11).

Diversifying literature and key reference

Using the LLR algorithm, a total of 15 visual clusters were observed, with each representing a direction evolution according to their activeness (Fig. 7; additional details in Table S2). The more active the current cluster was, the more it could represent the research frontiers. The color curves represent the co-citation links added in the corresponding color year. Larger nodes or nodes with red-tree rings were particularly worth exploring, because they were either highly referenced, and had cited emergencies, or even both. Based on their size, the clusters were numbered, with cluster #0 being the most massive cluster placed at the top of the graph (Fig. 7). The different clusters' timelines had different colors. As the timeline overview showed, the persistence of research content clusters was different. Some clusters lasted more than 15 years, while others had a relatively short-life span. Some clusters have stayed active until 2019, the latest year for which references have been cited in this study.

The most frequently cited paper in the co-cited literature was found to be the "Sustainable Rural Livelihoods" (Table S3). As emphasized by Scoones (1998), the sustainable livelihoods should include the five dimensions of work-time creation: poverty reduction, well-being and capability, adaptability, vulnerability and resilience, and natural resources sustainability. The connotations, such as employment, poverty reduction, and sustainability, can be successfully used to understand the sustainable dimensions of livelihoods (Chambers and Conway 1991; Scoones 1998). Later, emphasis has been given to effectively integrate macro and micro levels of perspectives in a new livelihood, as some current livelihood frameworks failed to link to the process of economic globalization or were too localized (Scoones 2009). They also lacked in linking the practical challenges of environmental sustainability and political economy analysis (Scoones 2009).

In terms of time series, the earliest knowledge network of sustainable livelihoods research can be traced back to Ostrom's book of 1990 on "Governing the commons": the evolution of institutions for collective action. Ostrom's work focuses on the issue of small-scale public pond resources and proposed an institutional theory of autonomous organization and governance of public affairs using a fairly large number of empirical studies on livelihood issues. Another classic work on practical dimensions of sustainable livelihoods was laid by Chambers and Conway (1991) who provided the future direction (Table S3). These previous scholars portrayed diversity of solutions available through local and autonomous institutions and knowledge network for different problems in diverse setting, beyond the market and government institutions. Even in current context of environmental change also, such institutions



clusters' label: **#0**, rural household; **#1**, agricultural intensification; **#2**, conservation intervention; **#3**, environmental service; **#4**, social research; **#5**, small-scale fisheries; **#6**, adaptive co-manager; #7, ecological economics; **#8**, livelihood vulnerability; **#9**, south Africa; **#10**, less-favoured area; **#11**, market processes; **#17**, ameliorative policy option; **#18**, linking livelihood; **#21**, health ecology.

Fig. 7 Visualization of clusters in terms of timeline view of the document co-citation analysis (DCA) in sustainable livelihood research from 1991 to 2020. The horizontal axis represents the year, each node represents a popular cited reference, and the size of each node is proportional to its cited frequency, red tree rings represent the burst. The line between each node represents the temporal evolution of the cited reference, and the line thickness represents the co-citation strength; these lines reflect the relationship between transfer and inheritance among cited references

often help communities to minimize livelihood vulnerability at local level together with sustaining the social-ecological systems (Singh et al. 2021b, 2022). The potential of such knowledge and institutions can be leveraged to enhance livelihood sustainability while implementing market and policy led initiatives, provided power balance among the stakeholders is maintained (Singh et al. 2022).

Frontier areas of sustainable livelihood research

Studying the frontier areas and hotpot in SL research has emerged one of the core areas in which scholars track changes in the keywords over time as one of the indicators to generate the knowledge map (Liang et al. 2022). Some studies, for example of Li et al. (2022b), stressed that productivity, global change, ecological restoration, risk indicators, livelihood strategies, and differential production systems management of private and common pool resources could be the frontiers of SL research. Similarly, we also observed the top 10 citing documents that have indicated priority (ranked by times) of future potential SL research (Table S4). Further, the top 12 terms of SL research, based on the score relevance attribute calculated by VOSviewer (see Section "Scientometrics analysis methods"), have allowed us to identify 11 future lines of research with more importance (Fig. 8) discussed below.

Mass tourism

In order to better promote the economic development in less developed areas, in the recent past, the mass tourism, as it received rank 1st (highest score 53.78), has become an important developmental component for poverty alleviation (Jeyacheya and Hampton 2020). There has been a growing dynamic trend on tourist flows into less-developed regions influencing livelihoods (Khan et al. 2020). The hypothesis of pro-poor tourism and its antecedents is that stronger linkages with the local economy can increase the proportion of tourism expenditures flowing to the poor, thus may also help in reducing their direct dependence on natural resources and eliminating poverty (Patwary et al. 2023). However, most of the recent studies have focused on the static effect analysis of tourism impact on the livelihoods of farmers (Chen et al. 2018; Zhao 2017) (Fig. 8). Such studies should have

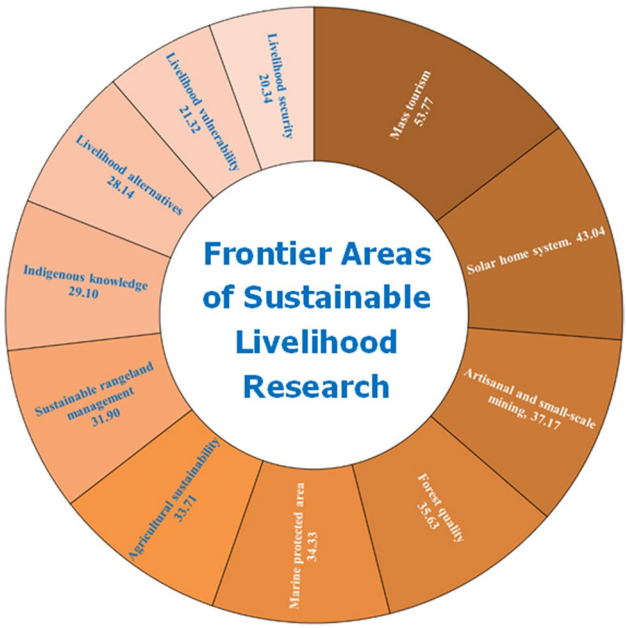


Fig. 8 Sunburst diagram indicating frontier areas of sustainable livelihood research

paid more attention to understanding the dynamic process of tourism impacting farmers' livelihoods (Richardson 2021).

Solar home system

Solar home system (SHS) was found to be another frontier area (ranked 2nd with score 43.04) of future SL research (Fig. 8). The SHS is an autonomous photovoltaic system that provides a cost-effective lighting and electrical supporting power supply mode for off-grid homes in remote regions (Akinsipe et al. 2021). In rural areas that are not connected with the grid, SHS can be used to meet household energy needs. Battery charging electrification can improve people's lifestyles by providing power for light and other appliances (Abubakar 2017; Riva et al. 2018). The availability and affordability of such energy services can also reduce the size of the rural–urban divide, and thereby reduce migration (Cherni and Hill 2009; Neffati et al. 2021). This energy mix requires only a one-time investment or government-subsidized payment by the consumer, who overcomes the high-cost barrier. This model is applicable to the households who live in scattered ways and to those who need solar heating.

Artisanal and small-scale mining

Artisanal and small-scale mining (ranked 3rd) could be another area of the future SL research (Fig. 8). Artisanal mining was first described as a "poverty-driven activity" employing others who do not have jobs (Baffour-Kyei et al. 2021). In recent decades, this activity, characterized as "low-skilled, labor-intensive mineral extraction and processing," has grown exponentially in the developing world (Baffour-Kyei et al. 2021; Warra and Prasad 2018). This has attracted tens of millions of direct participants and created hundreds of millions of income-generating opportunities in a range of upstream and downstream industries. Such industries have now taken root in sub-Saharan Africa, Asia, and Latin America in countless rural and peri-urban areas (Cohen 2004; Ofosu 2022). Consequentially, this has played an important role in sustaining the livelihoods of people in poor areas (Ofosu 2022). Nevertheless, the livelihood issues and impacts of artisanal mining on rural communities remained relatively less studied subject; therefore, more research is needed to underpin the benefits of the trade-offs.

Forest quality

As the world faces the challenges of climate change, food shortages, and improving the livelihoods of people, forests have a pivotal role to play (Ali et al. 2023). The forest quality would decide the use and dependence pattern by a group of people, and we found it as one of the potential future areas (ranked 4th) for SL research (Fig. 8). By the 2050, the world will need to provide shelter, food, clothing, and livelihoods for an additional 2 billion people (FAO 2017). For centuries, forests have served as a natural safety net for communities in times of famine or other climatic and ecological uncertainties affecting agriculture and food production (Singh 2013; Singh et al. 2021a). They provide diversified products and services (Singh et al. 2018a). Forests support people and the animals they may depend on for trade or diet in times of crop failure (Steel et al. 2022). Many of the world's remaining forests are under increasing threat due to human activities and climate change (Abbass et al. 2022; Kettle 2012). Although the rate of deforestation has slowed in some areas (Aleixandre-Benavent et al. 2018; Azevedo et al. 2020), some 14.5 million hectares of the world's forests are being lost each year (Svensson et al. 2020). Therefore, the future focus on SL realization must be based on a greater emphasis on forest ecosystem conservation and capacity enhancement.

Marine protected areas

The marine protected areas (MPAs) were recorded to be another frontier area (ranked 5th with score 34.33) for SL research (Fig. 8). Globally, MPAs have been recognized to be a unique ecosystem for protecting marine habitats and conserving biodiversity (Charles et al. 2016; Pham 2020). While there has been some success, they have also disrupted the livelihoods of coastal village communities, causing severe economic shock and triggering local conflicts (Pham 2020). It has been emphasized that the protection of MPAs can contribute to achieving SDGs 14 and 15 (Dudley et al.

2017). In the last two years, the COVID-19 outbreak has increased the risk to MPAs, and due to this risk, coastal ports and harbors were put on lockdown for periods ranging from 2–3 months and thus suspended all maritime activities (McGinlay et al. 2020). A closure period to stop the spread of coronavirus was an opportunity to benefit the marine biodiversity (Zari et al. 2019). However, this has had a considerable negative impact on the livelihoods of coastal communities that depend on tourism and other marine activities (Varea et al. 2022). Without concerted efforts to promote new forms of livelihoods, it seems difficult to prevent populations from returning to the ocean, which poses a threat to marine biodiversity (Charles et al. 2016). Therefore, it is more important than ever to promote mitigation solutions to maintain the fragile relationships that MPAs maintain between local populations and the ocean.

Agricultural sustainability

Our study revealed agricultural sustainability as also one of the other frontier areas (ranked 6th) of future SL research (Fig. 8). It has been claimed that through sustainable agricultural practices, farming communities are provided supports for food production that are economically viable, ecologically sound, and socially and culturally justifiable (Makate et al. 2017). Through such practices, small-scale farmers in marginal and ecologically fragile areas learn how low-cost resource conservation techniques may help to conserve biodiversity, regenerate soil fertility, manage water, and increase crop yields, while simultaneously reducing their dependence on external resources to sustain livelihoods (Kremen et al. 2012). Increasingly, rural people have been integrating their agricultural activities with diverse allied strategies to enhance their subsistence (Rana and Bisht 2023; Sneddon 2000). Therefore, food, water, and land security remain important concerns for future SL research, which can be strengthened by sustainable agricultural practices.

Sustainable rangeland management

We found that sustainable rangeland management could be a candidate frontier area (ranked 7th on relevance score) for future SL research (Fig. 8). Grasslands are the largest type of ecosystem on the earth which account for about 40% of the earth's land surface (Cingolani et al. 2005). They provide essential and unique ecosystem services such as raw materials, products, and other values for human beings (Bengtsson et al. 2019; Blair et al. 2014) and simultaneously help sustain the livelihoods of ~ 800 million people (Li et al. 2022b). However, as grassland ecosystems experience increasing global climate change and high-intensity anthropogenic activities in the Anthropocene, potential grassland degradation has become a considerable global ecological problem (Hu et al. 2018; Miehe et al. 2019). As a result, this limits international economic development and constrains the livelihoods of local inhabitants (Xu et al. 2018). About 49.2% of the world's grasslands have experienced different degrees of degradation, with nearly 5% of the grassland reaching severe degradation (Gang et al. 2014). Therefore, achieving management of grasslands is not only important for maintaining sustainable livelihoods (Singh et al. 2018b) but also necessary for achieving sustainability of grassland ecosystems (LaFlamme 2011; Shackleton and Campbell 2003).

Indigenous knowledge

In many parts of the world, indigenous knowledge has played a pivotal role in sustaining local livelihoods (Singh et al. 2010; World Bank 2004). In this study, indigenous knowledge has emerged as one of the core areas of future SL research (ranked 8th; Fig. 8). Numerous studies have focused often on the effects of the policies and programs on the livelihoods of rural communities (Cao et al. 2018; Nelson et al. 2023); however, such studies lacked in highlighting the importance of local people's indigenous knowledge. This knowledge system has evolved through accumulation from local resource use and long-term management practices and is a blind spot for multiple stakeholders of concern (Dong et al. 2009; Wu et al. 2015). For example, the practical experience of grasslands management showed that in the past, the design of pastoral policies was mostly based on the assumption that herders are indifferent to the pasture they depend on for their livelihoods (Cao et al. 2019). However, the emergence of the multi-household rangeland management model has shown that herders have rich ecological knowledge, which allows them to develop strategies to reduce the risks posed by the natural environment (Cao et al. 2019; Singh et al. 2018b). These strategies include transhumance and livestock breed diversification (Soh and Omar 2012; Singh et al. 2018b). Therefore, community-based adaptive grazing practices and local agroecological knowledge can be incorporated into the development of new grassland management policies (Fernández-Giménez et al. 2015; Kiffner et al. 2020). Further, the construction of a case base of indigenous knowledge can be established to provide the practical support for better scientific decision making (Singh et al. 2021a, 2022).

Livelihood alternatives

The current research has mainly focused on poor and ecologically fragile areas, and it has emerged that alternative livelihoods (ranked 9th) could be another focal area of future SL research (Fig. 8). The basic purpose of livelihoods research has been to find the causes of poverty and provide multiple solutions (Fahad et al. 2023). However, due to the differential

adaptive capacity of rural communities and their resource endowments, livelihoods have obvious regional characteristics, threats, challenges, and opportunities to build sustainable livelihoods which vary across regions (Khedrigharibvand et al. 2019). Therefore, livelihood research should not be limited only to poor areas, ecologically fragile areas, or farmers, but should be broadened to include a wide range of regions and research subjects (Gharibvand et al. 2015) to make livelihood sustainability research more representative. Meanwhile, more research is needed in the assessment of alternative ecology, the selection of alternative strategies, and the process and mechanism that shape the varieties of alternatives to traditional livelihoods.

Livelihood vulnerability

The vulnerability to livelihood was observed to be one of the most important future areas (ranked 10th) for SL research (Fig. 8). Livelihood vulnerability is an important characteristic of poverty and is characterized as the degree to which exposure to shock, stresses, and hazards exhibits insufficient resistance, insecurity, and vulnerability to disaster (Chambers and Conway 1991; Ellis and Bahiigwa 2003). Broadly, farmers' livelihood vulnerability studies have focused on its possible risks, adaptation strategies, and resilience level to varying risks (Sujakhu et al. 2018). The increasing vulnerability and sensitivity of social-ecological systems caused by climate change and the increased intensity of human activities might be further compounded by the impact of the novel COVID-19 global pandemic (Adu et al. 2018). Therefore, finding the most suitable livelihood development model in an uncertain, changing, and complex vulnerability environment might be the focus of future research in shaping sustainable livelihood.

Livelihood security

With rank 11th, the livelihood security was recorded to be another focal area for SL research (Fig. 8). Study on SL security index (Singh and Hiremath 2010) indicated capturing the broad dimensions of SL of rural communities. This index has three broad aspects covering ecological security, economic efficiency, and social equity. Such an approach of studying sustainable livelihoods can effectively balance the common concerns of economists, environmentalists, and egalitarians and can provide a reference for achieving sustainable development (Ferrol-Schulte et al. 2013).

The future frontier areas of SL research align with several SDGs. This includes, for example, the solar home systems with Affordable and Clean Energy (SDG 7), artisanal and small scale mining with Decent Work and Economic Growth (SDG 8), and forest quality, agricultural sustainability, and rangeland management with Life on Land (SDG 14 and 15). This diverse range of frontier areas emphasizes the increasing complexity and interdisciplinary nature of sustainable livelihoods research. It reflects the multifaceted challenges facing livelihood sustainability worldwide, reiterating the essence of the SDGs—to ensure a sustainable and resilient future for all.

Conclusion and perspectives on sustainable livelihoods

Our analysis reveals an exponential growth in SL research over the past three decades, which is the leading contribution from countries like the United States, Australia, UK, and China. Notably, the Consortium of International Agricultural Research Centers stands out as a significant institutional contributor. The key journals in this field include World Development, Global Environmental Change-Human and Policy Dimensions, Ecological Economics, and Ecology and Society. Work of certain authors, notably Singh RK, Shackleton CM, Chirwa PW, Stringer LC, and Milner-Guland EJ, has greatly influenced the direction of SL research. This trend toward collaboration highlights the importance of multi-disciplinary efforts in addressing the complex challenges of livelihood sustainability.

The grounded theory of SL, the impact of management policies, and the relationship between SL and ecological resources, climate change, and food security have emerged as broad research clusters within the field. Noteworthy clusters such as rural household, agricultural intensification, cultural intensification, and conservation intervention represent the evolving discipline of sustainable livelihoods and are expected to remain active and significant for the Sustainable Development Goals (SDGs). The identified future frontier areas of SL, including mass tourism, forest quality, marine-protected areas, agricultural sustainability, sustainable rangeland management, and indigenous knowledge, will play a vital role in SL and have an impact on SDGs, especially in developing nations. Therefore, it is crucial to appropriately integrate these frontier areas into plans and policies related to sustainable livelihoods to mitigate risks faced by communities due to various stresses while ensuring the sustainability of social-ecological systems. Furthermore, the evolution of SL research over time and its trends highlights the importance of interdisciplinary collaboration among different stakeholders to understand and address the complexities involved in sustainable livelihoods. The key findings of this study provide valuable guidance for deepening our understanding of SL and offer potential directions for future research aimed at enhancing livelihood sustainability in both practice and policy realms.

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Data availability Please contact the listed corresponding author for requesting the raw data used in the paper.

Declarations

Ethical approval Not applicable.

Consent to participate All participated in the design of this manuscript and consented for submission.

Consent for publication All authors have given their explicit approval to publish this manuscript.

Competing interests The authors declare no competing interests.

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Authors and Affiliations

Tong Li[1,2,3,4] · Ranjay K. Singh[5,6] · Lizhen Cui[2,4] · Zhihong Xu[3] · Hongdou Liu[3] · Francesco Fava[7] · Shalander Kumar[8] · Xiufang Song[9] · Li Tang[1,2,3,4] · Yanfen Wang[1,4,10] · Yanbin Hao[2,4] · Xiaoyong Cui[2,4]

✉ Xiaoyong Cui
cuixy@ucas.ac.cn

Tong Li
tong.li7@griffithuni.edu.au

Ranjay K. Singh
ranjaysingh_jbp@rediffmail.com

Lizhen Cui
cuilizhen18@mails.ucas.ac.cn

Zhihong Xu
zhihong.xu@griffith.edu.au

Hongdou Liu
hongdou.liu@griffith.edu.au

Francesco Fava
francesco.fava@unimi.it

Shalander Kumar
K.Shalander@cgiar.org

Xiufang Song
songxf@mail.las.ac.cn

Li Tang
tangli@ucas.ac.cn

Yanfen Wang
yfwang@ucas.ac.cn

Yanbin Hao
ybhao@ucas.ac.cn

[1] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

[2] College of Life Sciences, University of Chinese Academy of Sciences, Beijing 100049, China

[3] School of Environment and Science, Centre for Planetary Health and Food Security, Griffith University, Nathan, Brisbane, QLD 4111, Australia

[4] Beijing Yanshan Earth Critical Zone National Research Station, University of Chinese Academy of Sciences, Beijing 101408, China

[5] College of Horticulture and Forestry, Central Agricultural University, Arunachal Pradesh, Pasighat 791102, India

[6] ICAR-Central Soil Salinity Research Institute, Karnal, Haryana, India

[7] Department of Environmental Science and Policy, Università Degli Studi Di Milano, Festa del Perdono Milano, Milano 720122, Italy

[8] International Crop Research Institute for the Semi-Arid Tropics, Patancheru 502324, India

[9] National Science Library, Chinese Academy of Sciences, Beijing 100190, China

[10] State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources, Chinese Academy of Sciences, Beijing 100101, China