Heliyon 8 (2022) e10704

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Exploring the frontiers of sustainable livelihoods research within grassland ecosystem: A scientometric analysis

Tong Li [a,b], Lizhen Cui [c], Wencong Lv [d], Xiufang Song [e], Xiaoyong Cui [c,f,**], Li Tang [a,b,*]

[a] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China
[b] Centre for Planetary Health and Food Security, School of Environment and Science, Griffith University, Nathan, Brisbane QLD 4111, Australia
[c] College of Life Sciences, University of Chinese Academy of Sciences, Beijing 100049, China
[d] Sino-Danish College, Sino-Danish Center for Education and Research, University of Chinese Academy of Sciences, Beijing 100049, China
[e] National Science Library, Chinese Academy of Sciences, Beijing 100190, China
[f] Beijing Yanshan Earth Critical Zone National Research Station, University of Chinese Academy of Sciences, Beijing 101408, China

ARTICLE INFO

Keywords:
Sustainable livelihoods
Grassland degradation
Scientometric
Sustainability management

ABSTRACT

Grassland degradation has become a global social–ecological problem, which seriously limits the sustainability of indigenous people's livelihoods. Bibliometrics, a type of analysis based on the Science Citation Index—Expanded (SCI-E), was therefore performed to explore the research trends and focus areas of studies on sustainable livelihoods (SLs). We conducted an in-depth analysis of 489 research publications and their 25,144 references from 1991 to 2020. The results show that only few papers have been published, but the number of countries and research institutions involved shows an overall imbalance. We identified eight main clusters based on keyword co-occurrence, these being studies the content of which is an important representation of current research directions in this topic. The document co-citation analysis revealed 10 research clusters, representing the frontiers of research. Clusters included the following topics: NPP (Net Primary Productivity) dynamics, global change, ecological restoration, risk indicators, livelihood strategies, smallholder systems, drought relief, sustainable land management and common pool resources. We reviewed and interpreted these clusters in depth with a view to provide an up-to-date account of the dynamics of this research. As the first scientometric evaluation of research on sustainable livelihoods in grassland ecosystems, this study provides several theoretical and practical implications for global poverty eradication research, which are of great scientific value for global sustainable development.

1. Introduction

Grassland ecosystems are the largest terrestrial ecosystems on Earth, covering approximately 40% of the Earth's land surface (Cingolani et al., 2005; Li et al., 2021a; Milchunas and Lauenroth, 1993). They play an essential and unique role in climate regulation, water conservation (Chen et al., 2021), the supply of livestock products, biodiversity conservation (Cao et al., 2013) and socio-ecological security (Bengtsson et al., 2019; Blair et al., 2014), and also sustain the livelihood of approximately 800 million people (Archibold, 1995). As one of the most important resources for human survival, grasslands with fragile habitat, a large population, and a large livestock population, as well as the typical characteristics of shared use and management by pastoralists (Reid et al., 2014). However, with the advent of the ***Anthropocene***, grasslands have experienced increasingly severe global climate change and high-intensity human activities, and grassland degradation has become one of the most global ecological problems (Zhang et al., 2020a), severely limiting international economic development and restricting the livelihoods of local residents (Li et al., 2022a).

Approximately 50% of the grasslands in the world have experienced different degrees of degradation, of which nearly 5% have reached the level of severe degradation (Li et al., 2022b). Degradation can influence the physicochemical properties of the soil (Lin et al., 2010b; Wu et al., 2010, 2014b), types of grassland vegetation and species patterns (Bi et al., 2020; Li et al., 2008; Lin et al., 2010a; Su et al., 2015; Yan and Lu, 2015), and grassland ecosystem structure and function (Dong et al., 2020; Zhang et al., 2020b). Grassland degradation is a complex social–ecological problem (Li et al., 2022b; Li et al., 2021a). On the one hand, local herders must rely on the grassland to maintain their livelihood needs, and need the grassland ecosystem to provide rich and diverse

* Corresponding author.
** Corresponding author.
E-mail addresses: cuixy@ucas.ac.cn (X. Cui), tangli@ucas.ac.cn (L. Tang).

https://doi.org/10.1016/j.heliyon.2022.e10704
Received 21 January 2022; Received in revised form 6 July 2022; Accepted 14 September 2022

products (such as, milk, meat, and fur) and services (grassland culture, and the ecological landscape) (Li et al., 2022a). The production model of herders is a natural choice under resource constraints and is the result of long-term cultural adaptation to the grassland ecosystem. On the other hand, a decline in the quality of grassland (including plants and soils) to varying degrees and a reduction in productivity, economic potential, and service functions (Tschopp et al., 2010; Zhang et al., 2020b). These factors can decrease the productivity of grassland when directly compared with non-degraded grassland. Therefore, the productive capacity needed to maintain the original livelihood level of pastoralists is reduced, and to some extent their ability to cope with external risks and disasters is weakened, and the potential threat of unattainable regional development increased.

To maintain the original quality of their livelihood, pastoralists need to engage in larger and more intensive grazing activities on the current low-quality grasslands. This process forms a vicious circle of "grassland degradation—livelihood needs—expansion of production scale/intensity—grassland degradation again", leading to a new "grassland degradation" trap for pastoralist. Grassland degradation poses a major threat to global ecosystem functions and regional ecological security (Harris, 2010; Lu et al., 2015; Wu et al., 2014a). At the same time, it serious constraints on global social–ecological development and the effective achievement of the 2030 sustainable development goals (Zhang et al., 2020b). Livelihoods reflect the choice and utilization of resources by humans (Jampel, 2016). With pastoralism, livelihoods comprise a range of pastoral activities combined with non-pastoral activities. These activities provide strategies for resource acquisition and constitute pastoral livelihood systems (Li et al., 2021b). Sustainable livelihoods (SLs), as an important tool for achieving sustainable development and poverty eradication, have been extensively studied in many rural areas around the world. Therefore, the study of SLs in pastoral areas has become particularly important in this context.

SLs refer to the ability to combine environmental and economic resources to recover from these traumas and to enhance and maintain long-term survival when people's survival is subject to external shocks and stress (Li et al., 2021b; Chambers, R.a.C., G.R, 1992; Scoones, 2009). SLs are closely related to specific environment, societies and cultures, and are often used as a starting point for understanding resource utilization and potential welfare. Differences in natural geographical environment and social–ecological conditions in different regions lead to significant differences in people's value orientation, resource utilization methods and levels, resulting in different livelihood tools (Su et al., 2021; Yan et al., 2010). The spatial differentiation of livelihoods is not only reflected in livelihood assets but also in livelihood mode, livelihood risk, livelihood security and livelihood vulnerability. Livelihood is an integrated combination of the means of earning a living based on capabilities, assets (including reserves, resources, requirements and entitlements) and activities (Borowy, 2013). As the core of livelihood, capital can be divided into natural capital, human capital, financial capital, physical capital and social capital (Scoones, 1998, 2009).

Scientometric analysis is a classic and popular method to analyze the focus and trends of a specific research field. This method has been applied to land degradation livelihoods (Aleixandre-Benavent et al., 2018; Guan et al., 2019; Romanelli et al., 2018; Xie et al., 2020), environment management livelihoods (Escadafal et al., 2015; Wu et al., 2018), and global sustainable livelihoods (Zhang et al., 2019). There are few studies on SLs in grassland ecosystems. More importantly, earlier studies were limited to a specific location and did not allow for an integrated and comprehensive analysis of global studies. Therefore, based on the above research gap, we use the co-citation and co-occurrence method to analyze the SLs within grassland ecosystems. The main research of this study is (1) the basic development status of SLs; (2) the current research directions of SLs, and the main areas of focus; (3) the frontiers of SLs within the grassland ecosystem.

2. Materials and methods

2.1. Database

The studies chosen were based on the SCIE database of Clarivate Analytics, USA. We obtained the final search criteria by consulting relevant literature and consulting experts to repeatedly test keywords. The final choice was TS = (sustain* and livelihood*) AND TS = (grassland* or meadow* or meadowland* or steppe or rangeland or grazing or herdman or livestock* or pasture or prairie or campo grassland* or pampas grassland or savanna) for retrieval (Li et al., 2021b). The database selected SCI-EXTENDED, SSCI in the core collection. The retrieval time was from 1990 to 2020. The database was updated on October 26, 2020, and the language selected was English. A total of 587 studies were obtained, and 489 studies were finally selected as the research literature collection after eliminating the irrelevant research subjects.

2.2. Methods of data analysis

2.2.1. Keywords co-occurrence analysis

Co-occurrence analysis uses word pairs or noun phrases that co-occur in a collection to determine the relationship between the topics represented by the collection (Li et al., 2021b). By counting the frequency of subject words appearing in the same document, a co-word network consisting of pairs of these words can be formed (Li et al., 2021b; van Eck and Waltman, 2010). High-frequency keywords can indicate the research hotspots and research topics in a certain period (Li et al., 2021b). Through the automatic algorithm of VOSviewer software, the co-occurrence analysis of these keywords was carried out, and clusters formed, representing the current research field (Li et al., 2021b; van Eck and Waltman, 2010). These clusters can denote the directions that are currently of the most interest among the related researchers (Li et al., 2021b).

2.2.2. Document Co-citation analysis (DCA)

DCA uses CiteSpace reference analysis, according to the co-citation and strength of the establishment of network links, to carry out an efficient review of the knowledge base and knowledge structure in a field. This analysis allows researchers to quickly grasp the historical context of the field. It is usually visualized in the form of a network clustering diagram and timeline diagram. The timeline graph can effectively review the heat and activity of some key studies over time and can form cluster labels. The cluster tags generally represent the topics of common research in this group. Professor Chen Chaomei generally recommends the log likelihood ratio (LLR) function within CiteSpace (Chen, 2004, 2017; Chen et al., 2010). To further improve the accuracy of tags, we extracted not only specific tags from the title of the publication, but also suggested keywords and phrases in articles and abstracts (Aryadoust, 2020). We explored and tabulated the content of each category of mainstream publications, while revising imprecise titles for major clusters. The appearance of word senses can increase the attention of certain works in the literature, referring to a sudden increase in a certain publication over a certain period of time. This is a form of visual representation that is valued by scholars in the field of study.

3. Results

3.1. Descriptive statistics

We conducted an analysis of basic data information in the literature to determine the number of papers published each year, the names of the journals in which these papers were published, and the names of the most productive authors, universities/institutions, and countries/regions in which the authors resided at the time of publication, as well as the disciplinary categories of these papers. Overall, research on SLs in grassland ecosystems has shown an exponential growth trend since 1991

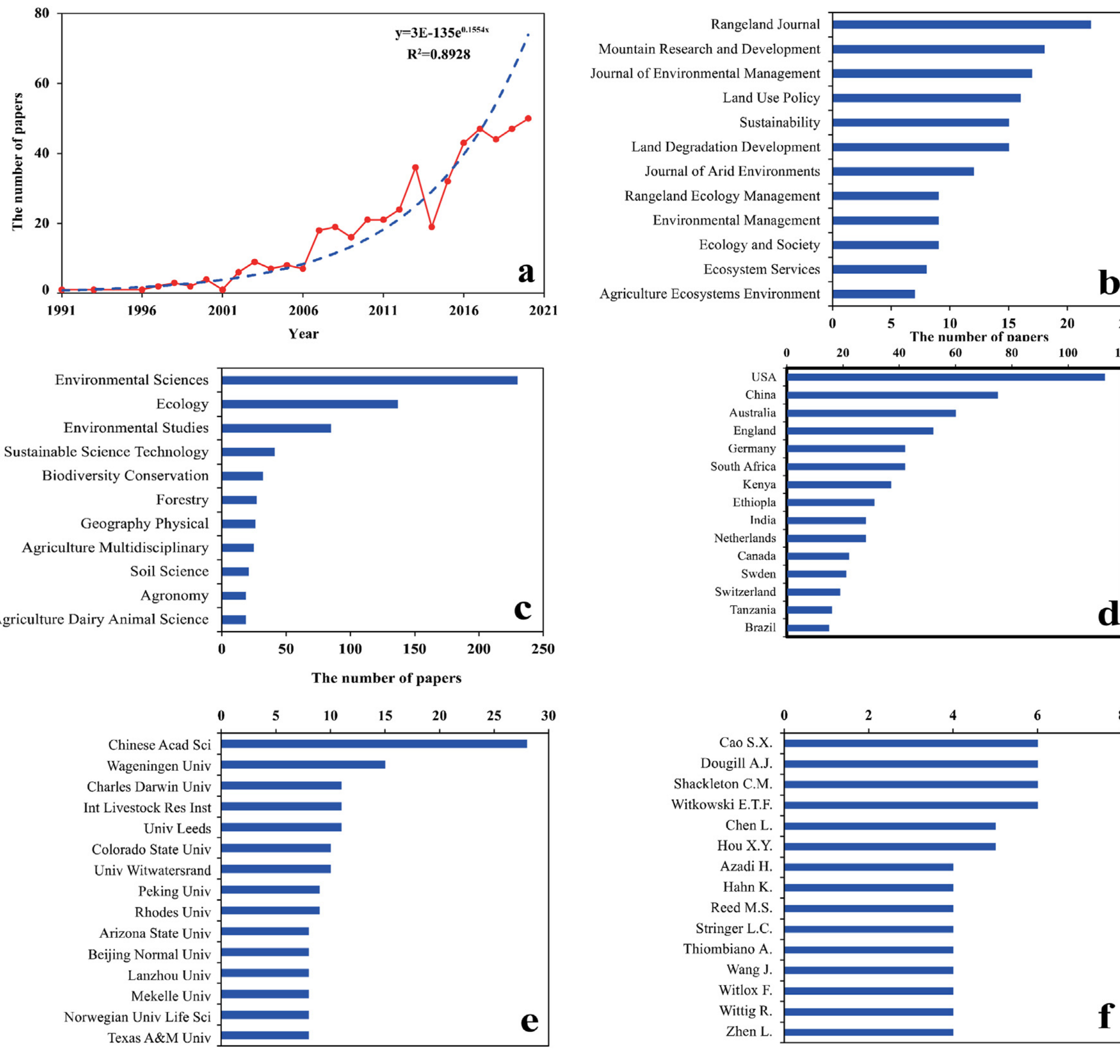

Figure 1. Frequency analysis of the 489 publications on these filed studies.

(Figure 1a). Figure 1b displays the top 12 publishing journals, with the largest number of articles being published in *Rangeland Journal* (22), *Mountain Research and Development* (18), and *Journal of Environmental Management* (17). Figure 1c and 1d highlight the trends over the last 10 years in the subject categories of SLs in grassland ecosystems research, and the top five subject categories, mainly in ecology and environmental science research. In terms of participating universities and institutions, the Chinese Academy of Sciences topped the list with 28 papers, while Wageningen University (15 papers) was second, and Charles Darwin University, International Livestock Research Institute, and University Leeds all tied for third place with 11 papers each (Figure 1e). Figure 1f highlights the most prolific authors, with Cao S.X., Dougill A.J., Shackleton C.M., and Witkowski Etf topping the list of published papers (six papers each), followed by Chen L., and Hou X.Y. (five papers). All other authors published fewer than five papers.

3.2. Keywords co-occurrence analysis

A total of 22,224 keywords were detected in 489 papers on SLs from 1991 to 2020. These keywords were analyzed using co-occurrence (Figure 2) and clustering techniques. The eight seminal keyword categories that provide the basis for SLs research in pastoral areas are as follows: management, livelihoods, conservation, sustainability, climate change, degradation, biodiversity, and climate. In addition to these, the following themes stand out: adaptation, dynamics, land use, rangeland, vegetation, and pastoralism. In this sense, the different periods studied by SLs make up an elegant collection. That may also contribute to validate the eight research themes identified in the research activities, representing the eight clusters. Table 1 shows the eight clusters that were examined. These are labeled with the most frequent keywords and are ordered by the percentage of keywords they contain, as follows: cluster 1, red, climate change; cluster 2, green, management; cluster 3, deep blue, degradation; cluster 4, yellow, sustainability; cluster 5, purple, biodiversity; cluster 6, light blue, ecosystem services; cluster 7, orange, livestock; cluster 8, brown, grassland. The link weight and total link strength contributed by each representative keyword are included and the ten most important keywords are provided. These key clusters are an important form of visualization for many studies and are important for understanding current research (Figure 2).

3.3. Document co-citation analysis

The DCA identified 10 clusters, of which 7 significant clusters contained one or more bursts (Figure 3). The timeline visualization of the DCA network, as illustrated in Figure 4, provides an overview of the development of research on SLs in pastoral areas (modularity Q = 0.9433; mean silhouette score = 0.9723). The longest cluster shown in the visualization is cluster 0, which is automatically labeled "NPP dynamics" (Here, NPP is Net Primary Productivity). The cluster 0 was active from 2002 to 2011.

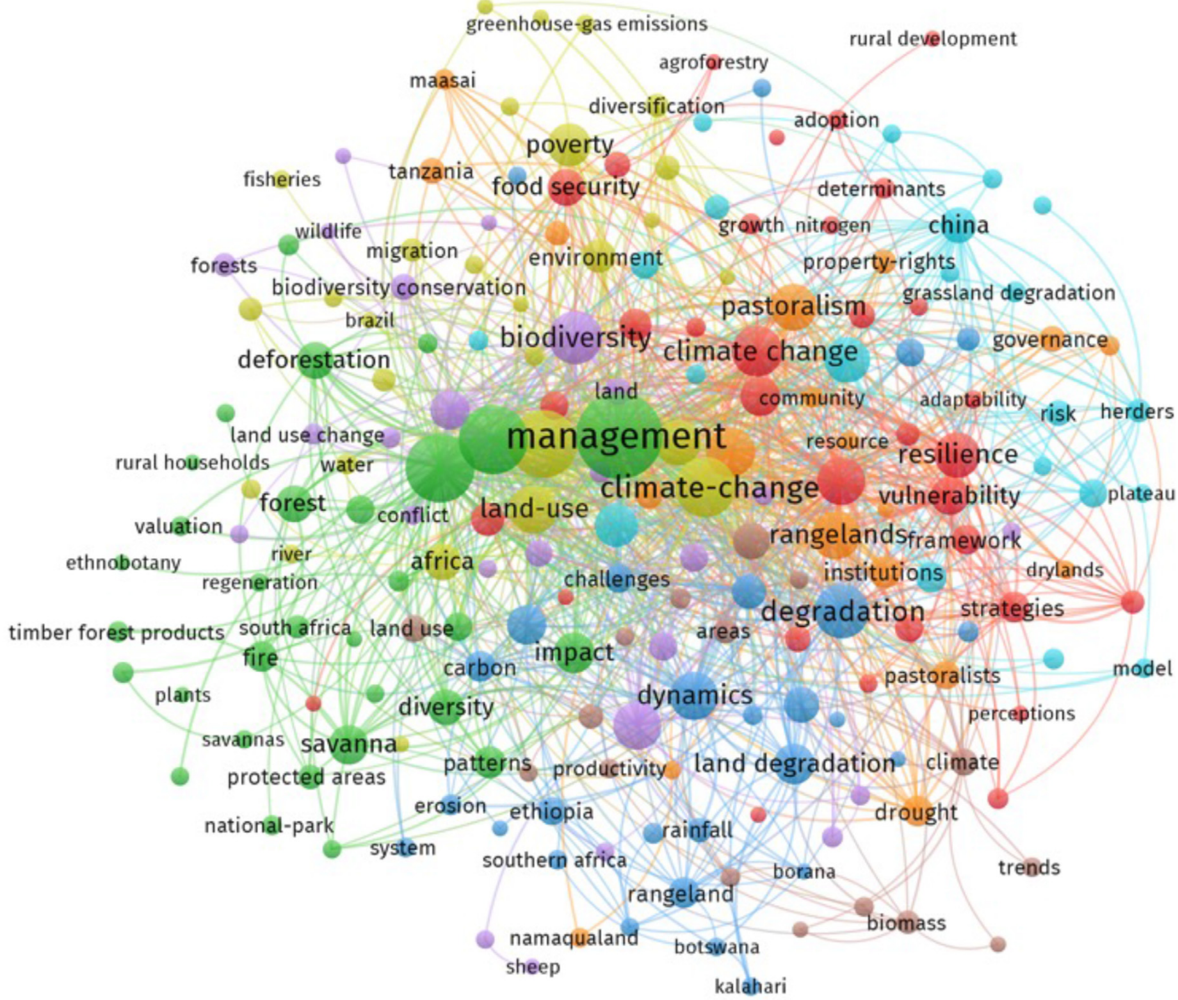

Figure 2. Network of keywords based on the co-occurrence method on SLs research from 1991 to 2020.

Since 2012, new developments have been observed in visualization. For example, cluster 2 is marked as ecological restoration, cluster 3 is labeled as "risk indicator", cluster 8 is marked as "drought relief", and cluster 14 is marked as "common pool resource". These clustering tags form the knowledge base and structure of a new research direction. From 2015 to 2016, there were large nodes and red tree circles in the cluster, indicating that publications in the cluster were highly cited during this period. The timeline visualization also provides chronological information about the duration of each cluster activity. We can see the activity and the duration of the topic in the research direction of the references. At present, the active clusters are 2, 3, 8, and 14, and cluster 4, labeled "livelihoods strategies", is relatively active.

The temporal characteristics, as well as the duration of all clusters, are shown in Table 2, and the results show that cluster 0 has the longest duration, but also started the earliest, from 2003 to 2012. Cluster 14 has the shortest duration, but started later, from 2016, and the whole cluster can be judged based on the temporal characteristics heat and activity. The results show that cluster 3 has the highest activity, and the latest study, in 2020, reflects that cluster 3 is marked as a risk indicator.

3.3.1. Literature co-citation analysis: clustering characteristics

Table 2 shows the published representative articles that cover the most citations in each cluster. The coverage index refers to the number of articles in the listed literature that cite the articles in the cluster as references. The degree of coverage represents the contribution of the article to the formation of the cluster labels; the higher the coverage, the more integrated and representative it is in the whole cluster. For example, two articles in cluster 5 have high coverage for references in the cluster, reaching 0.59 and 0.55, respectively. Phelps and Kelly (2019) has a high coverage index for articles in cluster 8, indicating that this article cites 57% of the literature in this group. These articles are useful for determining the overall sub-research direction. Suggested cluster label names are also given for the articles with high coverage index. In the "Discussion" section, the content and scope of each cluster are further discussed, and the latest articles and keywords are used to interpret the research hotspots and frontier areas.

3.3.2. Document co-citation analysis: burst detection

The publications and authors with the top 10 greatest burst intensities are displayed in Figure 3. Moreover, this article presents the sudden high value from 2019, and the article of Reid et al. (2014) is also a recent emergent reference, indicating that the two are of common concern to many scholars, which implies the basis of knowledge for a potential new research direction. Among these references, the longest duration of emergence was found in Reynolds et al. (2007), which reached 5 years. After the introduction of the 2030 sustainable development goals, Foley et al. (2011) emerged as a prominent reference, with a duration of only 2 years. Reid et al. (2014), Harris (2010), Li and Huntsinger (2011) other articles were all emergent studies in the literature that appeared one year after publication; Vetter (2013) was the most prominent article of that year. It took an average of three to four years for other articles to break out. These emergent articles played an important role in the evolution of

Table 1. Identified clusters of keywords on SLs research from 1991 to 2020.

ID	M	C	Name	O	L	TLS	Top 10 Keywords
1	33	red	climate change	38	101	215	Adaptation; resilience; systems Vulnerability; food security; knowledge cattle; strategies framework
2	31	green	management	101	173	602	Livelihoods; conservation; impact; savanna; deforestation; forest; diversity; patterns; indigenous knowledge
3	28	deep blue	degradation	402	678	29,40	Systems, dynamics, land degradation, desertification, communities, carbon Rangeland, challenges, Ethiopia, restoration
4	28	yellow	sustainability	65	145	371	land-use, impacts, poverty, Africa, environment carbon sequestration, cover, diversification ecology
5	25	purple	biodiversity	65	145	371	Vegetation, agriculture, landscape, sustainable livelihoods, grazing, land, biodiversity conservation, forests, Bhutan
6	21	light blue	ecosystem services	32	102	185	Policy, China, grasslands, inner-Mongolia Soil, risk, intensification, herders grassland degradation
7	19	orange	livestock	37	112	238	Rangelands, pastoralism, institutions Drought, pastoralists, commons, governance, Tanzania, Kenya, property-rights
8	16	brown	grassland	21	67	107	Climate, land use, areas, classification, Biomass, GIS, ecosystem, productivity, remote sensing

Abbreviations, ID: cluster ID; M: cluster members; C: color in Figure 2; O: Occurrences; L: Weight Links; TLS: Weight Total Link Strength.

the knowledge structure of SLs in pastoral areas. It is necessary to further analyze these knowledge bases in the discussion.

4. Discussion

In this study, keyword co-occurrence scores were applied to showcase popular keywords and research clusters of current research. These clusters represent current research directions, with a total of eight research directions that play an overarching role in the in-depth understanding of SLs in pastoral areas. Most importantly, DCA was applied as a co-citation analysis to mine 489 publications on SLs in pastoral areas from Web of Science. We identified 10 research clusters. The following section focuses on the key features of each cluster in DCA, their contribution to research on SLs in pastoral areas, and the implications of these findings.

The following sections highlight the main characteristics of each cluster in DCA, its contribution to pastoral SL research, and the implications of these findings.

- Cluster 0: NPP dynamic

This cluster brings together 37 references and is the largest cluster but has a relatively low level of reference activity. The main focus of these articles is on the primary productivity of grasslands to sustain livestock production and the maintenance of pastoralist livelihoods. The size of the primary productivity of grasslands is the basis of pastoralist livelihoods, and understanding the drivers and mechanisms of grassland productivity dynamics is a prerequisite for research into effective resource regimes and policies for the sustainable management of grassland resources (Wang et al., 2013). However, grassland degradation and desertification on a global scale (Reynolds et al., 2007) lead to severe ecological problems (e.g., sandstorms) (Adeel and Safriel, 2008) and stimulate the frequency of natural disasters (Ulambayar and Fernández-Giménez, 2019). This has had a significant impact on social–ecological development. To maintain grassland ecosystems such that they are able to provide sound ecosystem services and better sustain the livelihoods of pastoralists. The research has identified two main areas of national policy macro-regulation and alternative livelihood strategies to better promote SLs. For example, the Grain to Green Program (GTGP), implemented by the Chinese government, has been cited by many scholars as a means of converting arable land into forests and grasslands by providing food and cash subsidies to farmers (Liu et al., 2008), to achieve the goal of curbing grassland degradation and improving local livelihoods in the western rangeland (Zhou et al., 2009). Alternative livelihood strategies are designed to reduce the social pressure on grassland ecosystems. For example, chicken farming in the Hunshundake sand of northern China has reduced pressure on grasslands while increasing vegetation cover and primary productivity. Thus, it provides a guarantee to effectively curb the socio-ecological problems caused by grassland degradation, such as declining primary productivity and livelihood vulnerability, and can be a powerful tool to overcome and reverse grassland degradation and maintain SLs (Adeel and Safriel, 2008; Laflamme, 2011; Reynolds et al., 2007).

- Cluster 1: global change

The main research theme of this cluster is the identification of drivers for the development of SLs in pastoral areas in the context of global climate change and economic uncertainty. Under the impact of global climate change and irrational grazing practices, grassland socio-ecological systems are facing a range of eco-economic problems, such as overgrazing, rodent damage (Harris, 2010), repeated drought, erosion processes, changes in forest and landscape patterns. For example, forest to grassland (Fraser et al., 2011; Sendzimir et al., 2011), the invasion of woody plants in grassland (Maestre et al., 2016), and population growth. Additionally, the impact of government land policies has invariably exacerbated social pressures to maintain SLs. However, drivers of grassland degradation are currently unclear and need to be further identified (Harris, 2010).

- Cluster 2: ecological restoration

Most grasslands are located in underdeveloped areas, and people face poverty and grassland degradation (mainly physical degradation and erosion), which interact to form a "poverty trap" (Cao et al., 2017a). The aim of the co-evolution of environmental management research and policy approaches is to mitigate land degradation in drylands (Stringer et al., 2012). In order to achieve SLs in pastoral areas, grassland degradation can be reversed through active measures (e.g., mixed species planting and framework species) and passive measures (e.g., area isolation, assisted natural regeneration, rotational grazing, grazing bans and ecological migration) (Yirdaw et al., 2017). However, the process of ecological restoration should

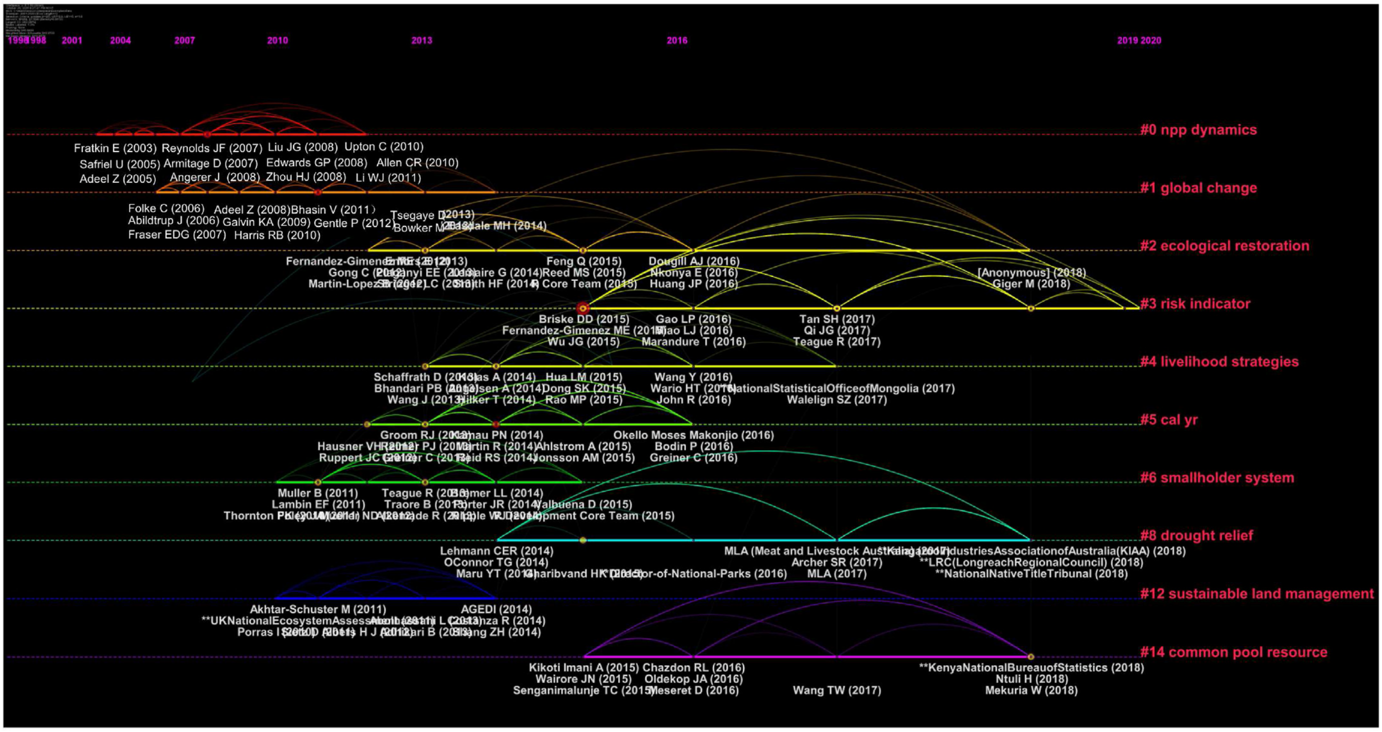

Figure 3. Top 10 References with the strongest citation bursts (the red bars indicate some keywords cited frequently; the green bars indicate keywords cited infrequently).

References	Year	Strength	Begin	End	2001 - 2020
Wu JG, 2015, LANDSCAPE ECOL, V30, P1579, DOI	2015	**3.17**	2019	2020	
Reynolds JF, 2007, SCIENCE, V316, P847, DOI	2007	**2.96**	2008	2012	
Angerer J, 2008, RANGELANDS, V30, P46, DOI	2008	**2.96**	2012	2013	
Harris RB, 2010, J ARID ENVIRON, V74, P1, DOI	2010	**2.74**	2011	2015	
Dong SK, 2011, ECOL SOC, V16, P0	2011	**2.65**	2014	2016	
Reid RS, 2014, ANNU REV ENV RESOUR, V39, P217, DOI	2014	**2.62**	2018	2020	
Vetter S, 2013, AFR J RANGE FOR SCI, V30, P1, DOI	2013	**2.54**	2013	2013	
Xu JT, 2006, ECOL ECON, V57, P595, DOI	2006	**2.52**	2009	2010	
Foley JA, 2011, NATURE, V478, P337, DOI	2011	**2.26**	2015	2016	
Li WJ, 2011, ECOL SOC, V16, P0	2011	**2.22**	2012	2014	

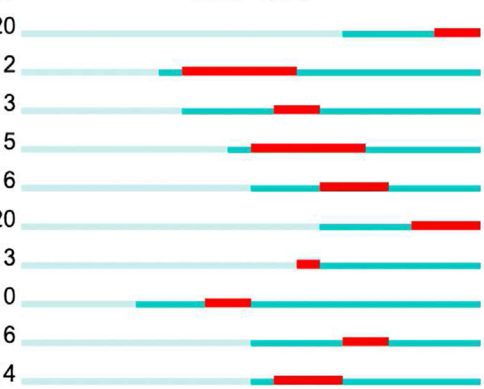

Figure 4. Visualization of clusters of the published research emerging from 1991 to 2020 using Document Co-citation Analysis (Modularity Q = 0.9433; Mean silhouette score = 0.9723). This figure was generated using CiteSpace computer package, version 5.7R2. All the clustering information can be detailed in the Appendix.

not be focused on restoration effects and environmental improvements to the exclusion of the livelihoods of local people (Cao et al., 2010, 2017b, 2017c). It has been shown that long-term improvements in livelihoods and poverty alleviation have a significant positive effect on reducing grassland degradation (Cao et al., 2017b). The collaborative management of settlement planning, combining soil conservation and livestock management strategies (such as controlled grazing levels and rotational grazing), can improve the quality of land in rangeland areas (Orchard et al., 2016). Urbanization dynamics will be a major influence on the future use of grassland resources (Allington et al., 2018; Reed et al., 2015).

- Cluster 3: risk indicator

The risk indicators presented in these articles mainly refer to the risk indicators that affect the access of pastoralists to SLs, and a review of the literature shows that these risk indicators fall into two main categories: risk indicators of irrational grazing by pastoralists (high stock carrying rates) and risk indicators of climate change (Jimoh et al., 2020). Both directly or indirectly affect the state of grassland utilization to some extent. Risk indicators that affect pastoralist stock carrying rates are mainly in the five dimensions of livelihood capital, such as natural capital (area of grassland owned) (Jimoh et al., 2020), human capital (level of education and ecological awareness), social capital (pastoralist cooperation, policy factors, and joint household management) (Li et al., 2018a), physical capital (transport), and financial capital (availability of finance). The risk indicators of climate change are mainly related to climate extremes, differences in annual seasonal precipitation, the length of the dry season (Pachzelt et al., 2015), winter weather disasters, and the invasion of exotic species (Fernández-Giménez et al., 2015). Some findings suggest that in addressing these risk indicators, pastoralists have stronger adaptive strategies and adaptive capacity in communities with, rather than without, formal community-based natural resource management

Table 2. Temporal properties of major clusters.

ID*	Size	Si*	F*	To	D*	M*	Su*	A*	Label
0	37	0.997	2003	2012	10	2007		Inactive	NPP dynamic
1	32	0.963	2006	2014	9	2009		Inactive	global change
2	32	1	2012	2018	7	2014	+++	Active	ecological restoration
3	32	0.936	2015	2020	6	2017	++++	Active	risk indicator
4	23	0.912	2013	2017	5	2014	++	Inactive	livelihood strategies
5	22	0.991	2012	2016	5	2014		Inactive	cal yr
6	21	0.963	2011	2015	5	2012		Inactive	smallholder system
8	20	1	2014	2018	5	2016	+++	Active	drought relief
12	11	0.98	2011	2014	4	2012		Inactive	sustainable land management
14	10	0.994	2016	2018	3	2016	+++	Active	common pool resource

Abbreviations: ID* = Cluster ID; Si* = Silhouette value; F* = From; D* = Duration; M = Mean (Year); Su* = Sustainability; A* = Activeness.

(CBNRM), as CBNRM communities have better knowledge exchange, information access, social capital linkages, and positive behaviors (Fernandez-Gimenez et al., 2014). Meanwhile, Liao et al. (2020) found that the reduced mobility of pastoralists can increase grassland degradation (Briske et al., 2015), because sedentary pastoralists use rangelands more frequently. The prevailing strategy for addressing grassland degradation emphasizes strengthening livestock production systems to sustain pastoralist livelihoods and large livestock numbers. However, this strategy is unsustainable as maximizing livestock income brings with it high supplementary fodder costs, marginalizing net household income and promoting larger flock sizes, thus creating a positive feedback loop that drives grassland degradation (Briske et al., 2015). This is the same pattern as in the pastoralist areas of China, where the pastoralist model of joint-household grazing (Cao et al., 2011, 2013, 2018) can be found. Associated with declining mobility are livelihood intensification and diversification, but this livelihood shift can bring with it both social–ecological and environmental risks. Thus, addressing risk indicators and achieving SLs must start with improving pastoral livelihood capital, encouraging livelihood diversification strategies, increasing pastoralist community-based operations, taking into account local ecological conditions and pastoralist perspectives in policy design, and providing ongoing education for pastoralists (Jimoh et al., 2020).

- Cluster 4: livelihood strategies

This cluster brings together a total of 22 references cited in studies on SLs in grasslands, where pastoralists' livelihood strategies are based on flexible pasture management practices. These practices are actively or passively selected based on changes in livelihood capital stocks and social–ecological dynamics (Lu, 2018). The aim is to create a collection of programs that can achieve the objectives, specific dynamics, relevance and spatial and temporal heterogeneity (Lu, 2018) that are largely influenced by livelihood capital. This is a functional response of livelihood capital, which acts as a buffer mechanism when shocks occur (Ding et al., 2018).

As the natural capital of herdsmen, arid grassland is an important part of pastoralists' livelihood. The precipitation is the climatic factor that has the greatest impact on the functioning of grassland ecosystems (Wang et al., 2013). The spatial heterogeneity of climate highlights the differences in livelihood capital from local-scale studies (Hu et al., 2018). Pastoralists having more natural capital leads them to choose livelihood strategies without pastoral production, and when pastoralists have more physical and financial capital, they tend to choose livelihood strategies that involve livestock production (Ding et al., 2018). There is a need for income diversification strategies to enhance total livelihood capital (Soltani et al., 2012), such as capacity building and business education (Ding et al., 2018).

The enhancement of human capital contributes to the provision of sustainable fodder resources for maintaining livestock systems and slowing down the degradation of grasslands (Altmann et al., 2018). Some scholars have shown that local governments and market institutions play an important role in developing and promoting livelihood strategies for pastoralists. It's mainly reflected in enriching the social capital of local pastoralists through mobility and community cooperation. The acquisition and storage of pastures has become an important adaptation strategy for pastoralists. While livestock management strategies, household financial capital, environmental (i.e., precipitation and vegetation growth) variability and grassland degradation are important factors influencing pastoralists adaptation strategies (Wang et al., 2013).

- Cluster 5: cal yr

The proposed label for this cluster is landscape heterogeneity. Global grassland ecosystems are facing two major pressures, climate change (annual inter-seasonal variation in rainfall and spatial variation) and the spatial and temporal heterogeneity of habitats (habitat fragmentation due to grassland grazing) (Marchant et al., 2018; Reid et al., 2014). The amount of rainfall will directly determine grazing intensity (Collins et al., 2012), and the use of grazing in turn affects the efficiency of rainwater use (Ruppert et al., 2012). Due to the specificity and fragility of grassland ecosystems, livestock farming as the main form of land use varies with precipitation and grassland quality, leading to different livelihood strategies (Marchant et al., 2018). Differences in grassland use directly determine the level of grassland productivity and pastoralist livelihoods, so the sustainability of pastoral livelihoods lies in how to effectively enhance the use of landscape heterogeneity.

Innovative grassland management using landscape-scale variability is an effective way to improve pastoralist SLs (Greiner et al., 2013; Reid et al., 2014; Wu, 2005, 2013). For example, the family contract responsibility system for grassland in China fails to fully recognize the heterogeneity of grassland resources, resulting in the fragmentation and degradation of the grassland landscape and the reduced ability of individual herders to cope with natural disasters (Reid et al., 2014). This system increases the mobility of livestock and reduces the number of livestock per unit area and per unit time, thus effectively increasing the level of pasture productivity and grazing income, improving the livelihood structure, and promoting the sustainable development of the livelihoods of grassland pastoralists. This management approach can effectively increase the mobility of natural resources and social factors (Martin et al., 2016), and helps pastoralists to approach the market, protect external resources, and improve their ability to cope with external environmental pressures (Marchant et al., 2018; Martin et al., 2016; Reid et al., 2014). Martin et al. (2016) noted that the adoption of strategies to "increase mobility" and "diversify incomes to cope with income risks from livestock farming" have increased risk resilience to some extent, thereby contributing to the maintenance of SLs in pastoral areas.

- Cluster 6: smallholder system

The research area of smallholder systems is mainly focused in the arid and semi-arid grassland regions of Africa. Smallholder systems are characterized by high rates of greenhouse gas emissions and the vulnerability of livestock to climate change (Traore et al., 2013; Foley et al., 2011). Local pastoralists require constant adaptation of dynamic environment and extensive use for grasslands to maintain the basic productivity and livelihoods of local people (Descheemaeker et al., 2016). However, the high level of exploitation and conversion of rangelands to agricultural land is based on the need for food and a lack of awareness of the loss of biodiversity, resulting in the incompleteness of ecosystems. These processes are constrained by a number of factors, including small farm size, herd structure, lack of market access and related knowledge, insecurity of land tenure, and the common property status of most grazing resources, all of which contribute to simplistic levels of livelihoods and crude land management (Descheemaeker et al., 2016). Therefore, the management of smallholder systems is critical to livelihoods and land sustainability.

Sustained agricultural intensification policies, improved forage mix production systems, and effective forage sustainability (genetic intensification—the development and use of superior forage and legume varieties to improve livestock productivity; ecological intensification—the development and application of improved agricultural and natural resource management practices; and social–ecological intensification) can reduce pressure on rangeland biodiversity and increase productivity and ecosystem services. Improving local and national institutions and policies to enable improved technologies and support their sustainable use. Some researcher indicated this can reduce pressure on rangeland biodiversity and increase productivity and ecosystem services, via approaches such as improving soil quality, reducing erosion, minimizing sedimentation and greenhouse gas emissions, and halting biodiversity loss altogether (Alkemade et al., 2013; Foley et al., 2011; Rao et al., 2015).

- Cluster 8: drought relief

Drought and climate change are important ecological issues facing grassland ecosystems globally (Phelps and Kelly, 2019). For example, rising atmospheric carbon dioxide concentrations could lead to the invasion of grasslands by woody plants (Yamba et al., 2017). The increase in drought triggers the incidence of grassland fire (Lehmann and Parr, 2016; O'Connor and Page, 2014) and the degradation of grasslands (Bardgett et al., 2021; Lehmann and Parr, 2016). Grassland degradation and livelihood vulnerability are two major challenges facing pastoralists, rangeland managers, and policy makers in arid and semi-arid areas (Gharibvand et al., 2015), particularly in rangelands that may lack sound social–ecological systems (Phelps and Kelly, 2019). For example, the Central West Queensland (CWQ) region of Australia has officially been in drought since 2013 with well below average rainfall, and remained in drought as of 2019, which has resulted in a 20% reduction in livelihood losses and out-migration. To protect grasslands and sustain livelihoods, mitigation (eg. livelihoods diversification), adaptation (eg., adapting to climate-related stressors) and transformation (eg., new technologies) livelihood strategies are mostly used in an attempt to create and promote an appropriate set of livelihood alternatives (Foran et al., 2019; Lamb et al., 2019) and keep them sustainable, focusing capacity building on communities that have accumulated knowledge over time based on rangeland demographics (Foran et al., 2019). Rather than being limited to supporting 'vulnerable livelihoods', SLs and sustainable rangeland management can be achieved (Gharibvand et al., 2015).

- Cluster 12: sustainable land management

Reed et al. (2015) proposed new ways to move from land degradation to sustainable land management using economic mechanisms, combining insights from the ecosystem services framework with SLs analysis (Reed et al., 2013, 2015) to identify economic opportunities arising from the ecosystem services provided by sustainable land management. Bush invasion described globally as "the most prevalent problem on dryland rangelands" (Afzali et al., 2021). Bush invasion reduces forage production while increasing the number of invasive species that livestock do not like, thus reducing the availability and heterogeneity of forage resources (Perkins and Thomas, 1993; Scoones, 1998). This land degradation can therefore lead to a reduction in the economic output of cattle-based livelihood systems (Scholes et al., 2013). By exploring the extent to which sustainable land management enhances the provision of ecosystem services, it is possible to systematically consider some of the costs, benefits and trade-offs associated with different approaches to addressing land degradation (Bunting et al., 2013).

In the case of the China Pastoral Study, for example, many scholars have conducted more in-depth studies on the causes, processes, influencing factors and restoration measures of grassland degradation (Kemp et al., 2020; Li et al., 2013, 2018b; Liu et al., 2019). Many research results have shown that overgrazing and other irrational human resource use pattern (eg., mining exploitation; unreasonable use of chemical fertilizers) is the main cause of grassland degradation (Li et al., 2022a, Li et al., 2022c). To curb grassland degradation effectively, the Chinese government has adopted many grassland management policies (such as, the grassland contract responsibility system and the grassland ecological protection subsidy and incentive mechanism), however the results have not been satisfactory (Zhu et al., 2022). Numerous studies have shown that the above grassland management policies have, to a certain extent, improved the degradation of grassland caused by overgrazing, increased herders' income, and improved the quality of grassland (Li et al., 2022a; MacDougall et al., 2013). However, due to numerous factors, such as poor resource conditions in pastoral areas, high habitat vulnerability, high population pressure, a single grassland industrial structure, the increased costs of fixed grazing production, low ecological incentive standards, the hidden imbalance of resources caused by contracting pasture to households, and the "fencing effect" brought about by the construction of a large number of fences, coupled with the phenomenon of the "de-grazing of pastoralists" in pastoral areas, overgrazing still exists to a large degree, leading to the situation of continuous degradation in some areas.

The root cause of this is the lack of in-depth research into the effects of grassland management policies and the internal causes of grassland degradation, which has led to measures to combat grassland degradation being based on the simple logic of "increasing grass and reducing livestock" and on the idea of "correcting herders' behavior". As a result, policies aimed at protecting the ecology have had little effect, and in some places the ecology of grasslands has even deteriorated further. It is the diversity and complexity of stakeholders in grassland ecosystems that exacerbates the uncertainty in managing grassland degradation, and it is this uncertainty that makes it so difficult to address the problem. Although a great deal of research has been carried out in the past on the effects of grassland management policies, there is still a lack of systematic analysis and reporting on the mechanisms of sustainable management models for pastoralists, which remains a priority for future research.

- Cluster 14: common pool resource

Grasslands are known as a worldwide common pool resource, not only because they are a major source of food, but also because they provide powerful ecological and environmental services that play an important role in supporting the livelihoods of local people (Addison and Brown, 2014). Existing research on grassland degradation has focused mainly on technical solutions, with little attention being paid to the institutional and policy drivers of pastoralist behavior and the resulting environmental impacts. This may explain why, despite significant efforts by governments to control grassland degradation, the area of degraded grassland continues to expand at a rapid rate (Assefa and Hans-Rudolf, 2017; Wang et al., 2019; Zhang et al., 2020a). Additionally, studies have shown that effective management systems can balance the vested interests and responsibilities between property owners and responsibilities. In managing grasslands with the aim of reducing degradation, government funding for the construction of fences and sheds, for example, is necessary for micro-grassland users (Assefa and Hans-Rudolf, 2017; Banks et al., 2003; Wang et al., 2019; Zhang et al., 2020c). At the same time, policies should be developed to improve the educational level of pastoralists and to make it more likely that they will participate in non-farm employment opportunities. Reducing the number of people in pastoral areas and reducing population pressure is undoubtedly an effective measure to reduce the degradation of grasslands. It is also an important basis for achieving SLs for local people.

5. Conclusion

In conclusion, the scientometric approach used in this study provides evidence of the dynamic nature of SLs in grassland ecosystem research in the first time. In this study, the results show that popular keywords and clusters of current research by keywords co-occurrence, which a total of eight current research directions, and plays an important role in gaining an in-depth understanding of SLs in pastoral areas. Most importantly, the DCA results identify ten research clusters that form an important basis for past, current, and future research. Moreover, the use of visualization and co-citation techniques allowed us to map out the frontiers of the profession, emphasizing the interconnections between all publications and research trends. These studies have important implications for a deeper understanding of the role of SLs in grassland ecosystems globally and are instructive for addressing issues in sustainable development, with the goal of poverty eradication.

6. Limitations

This study also has several limitations. Firstly, the scope of the study literature is limited to the core collection of Web of Science. As a result, a broader scope of data analysis, such as a comparison with Google Scholar, is lacking. While a "competitive" analysis that does not consider external influences is valid, a comprehensive competitive judgment of an organization, journal, or author would require broader supporting data than just internal data from a closed-ended reexamination. Secondly, the number of literature searches underpins all results and discussions, and a comparison of the number of studies on sustainable livelihoods in grasslands with other well-established research topics reveals that the literature is relatively small. In addition, the literature co-citation analysis is also limited because the results rely on clusters calculated by the software's internal algorithm, rather than the results of a manual exact analysis, and lack of comparative analysis. Although this analysis can predict frontiers in a short period of time, it cannot predict the value of individual studies in a short period of time, so this approach is not conducive to evaluating the most recently published studies. Consideration of the above issues should be considered in future studies. Therefore, the results of these studies can be used as an important basis for future research, and it is worth considering the research directions and priorities for in-depth interpretation and discernment of SLs in grassland ecosystem.

Declarations

Author contribution statement

Tong Li: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Xiaoyong Cui; Li Tang: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Lizhen Cui: Analyzed and interpreted the data; Performed the experiments.

Xiufang Song; Wencong Lv: Performed the experiments.

Funding statement

Li Tang was supported by the Fundamental Research Funds for the Central Universities [E1E40514].

Xiaoyong Cui was supported by the Chinese Academy of Sciences (CAS) Strategic Priority Research Program [XDA20050103].

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e10704.

Acknowledgements

Thanks to Chen Chaomei for the computing support with the CiteSpace software, and to Li Jie for answering questions related to his blog. Comments and suggestions from anonymous reviewers, the Academic Editor, and the Editor are greatly appreciated.

References

Addison, J., Brown, C., 2014. A multi-scaled analysis of the effect of climate, commodity prices and risk on the livelihoods of Mongolian pastoralists. J. Arid Environ. 109, 54–64.
Adeel, Z., Safriel, U., 2008. Achieving sustainability by introducing alternative livelihoods. Sustain. Sci. 3 (1), 125–133.
Afzali, S.F., Khanamani, A., Maskooni, E.K., Berndtsson, R., 2021. Quantitative assessment of environmental sensitivity to desertification using the modified MEDALUS model in a semiarid area. Sustainability 13 (14), 7817.
Aleixandre-Benavent, R., Aleixandre-Tudó, J.L., Castelló-Cogollos, L., Aleixandre, J.L., 2018. Trends in global research in deforestation. A bibliometric analysis. Land Use Pol. 72, 293–302.
Alkemade, R., Reid, R.S., van den Berg, M., de Leeuw, J., Jeuken, M., 2013. Assessing the impacts of livestock production on biodiversity in rangeland ecosystems. Proc. Natl. Acad. Sci. USA 110 (52), 20900.
Allington, G., Fernandez-Gimenez, M., Chen, J., Brown, D., 2018. Combining participatory scenario planning and systems modeling to identify drivers of future sustainability on the Mongolian Plateau. Ecol. Soc. 23 (2), 9.
Altmann, B.A., Jordan, G., Schlecht, E., 2018. Participatory mapping as an approach to identify grazing pressure in the Altay Mountains, Mongolia. Sustainability 10 (6), 1960.
Archibold, O.W., 1995. Ecology of World Vegetation. Chapman & Hall, London.
Aryadoust, V., 2020. A review of comprehension subskills: a scientometrics perspective. System 88, 102180.
Assefa, E., Hans-Rudolf, B., 2017. Indigenous resource management practices in the Gamo Highland of Ethiopia: challenges and prospects for sustainable resource management. Sustain. Sci. 12 (5), 695–709.
Banks, T., Richard, C., Li, P., Yan, Z.L., 2003. Community-based grassland management in Western China-Rationale, pilot project experience, and policy implications. Mt. Res. Dev. 23 (2), 132–140.
Bardgett, R., Bullock, J., Lavorel, S., Manning, P., Schaffner, U., Ostle, N., et al., 2021. Combatting global grassland degradation. Nat. Rev. Earth Environ. 2 (10), 720–735.
Bengtsson, J., Bullock, J.M., Egoh, B., Everson, C., Everson, T., O'Connor, T., et al., 2019. Grasslands-more important for ecosystem services than you might think. Ecosphere 10 (2), e02582.
Bi, X., Li, B., Xu, X., Zhang, L., 2020. Response of vegetation and soil characteristics to grazing disturbance in mountain Meadows and temperate typical steppe in the Arid Regions of Central Asian, Xinjiang. Int. J. Environ. Res. Publ. Health 17 (12), 4572.
Blair, J., Nippert, J., Briggs, J., 2014. Grassland ecology. In: Ecology and the Environment, pp. 389–423.
Borowy, I., 2013. Defining Sustainable Development for Our Common Future: a History of the World Commission on Environment and Development (Brundtland Commission). Taylor & Francis.
Briske, D.D., Zhao, M.L., Han, G.D., Xiu, C.B., Kemp, D.R., Willms, W., et al., 2015. Strategies to alleviate poverty and grassland degradation in Inner Mongolia: intensification vs production efficiency of livestock systems. J. Environ. Manag. 152, 177–182.
Bunting, E., Steele, J., Keys, E., Muyengwa, S., Child, B., Southworth, J., 2013. Local perception of risk to livelihoods in the semi-arid landscape of Southern Africa. Land 2, 225–251.
Cao, S.X., Tian, T., Chen, L., Dong, X.B., Yu, X.X., Wang, G.S., 2010. Damage caused to the environment by reforestation policies in arid and semi-arid areas of China. Ambio 39 (4), 279–283.

Cao, J.J., Xiong, Y.C., Sun, J., Xiong, W.F., Du, G.Z., 2011. Differential benefits of multi- and single-household grassland management patterns in the Qinghai-Tibetan plateau of China. Hum. Ecol. 39 (2), 217–227.

Cao, J.J., Yeh, E.T., Holden, N.M., Yang, Y.Y., Du, G.Z., 2013. The effects of enclosures and land-use contracts on rangeland degradation on the Qinghai-Tibetan plateau. J. Arid Environ. 97, 3–8.

Cao, S., Zheng, X., Chen, L., Ma, H., Xia, J., 2017a. Using the green purchase method to help farmers escape the poverty trap in semiarid China. Agron. Sustain. Dev. 37 (2), 1–8.

Cao, S.X., Shang, D., Yue, H., Ma, H., 2017b. A win-win strategy for ecological restoration and biodiversity conservation in Southern China. Environ. Res. Lett. 12 (4), 044004.

Cao, S.X., Zheng, X.Y., Chen, L., Ma, H., Xia, J.Z., 2017c. Using the green purchase method to help farmers escape the poverty trap in semiarid China. Agron. Sustain. Dev. 37 (2), 1–8.

Cao, J.J., Li, M.T., Deo, R.C., Adamowski, J.F., Cerda, A., Feng, Q., et al., 2018. Comparison of social-ecological resilience between two grassland management patterns driven by grassland land contract policy in the Maqu, Qinghai-Tibetan Plateau. Land Use Pol. 74, 88–96.

Chambers, R.a.C., G.R, 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century.

Chen, C., 2004. Searching for intellectual turning points: progressive knowledge domain visualization. Proc. Natl. Acad. Sci. U. S. A. 101 (Suppl_1), 5303–5310.

Chen, C., 2017. Science mapping: a systematic review of the literature. J. Data Inf. Sci. 2 (2), 1–40.

Chen, C., Ibekwe-SanJuan, F., Hou, J., 2010. The structure and dynamics of cocitation clusters: a multiple-perspective cocitation analysis. J. Am. Soc. Inf. Sci. Technol. 61 (7), 1386–1409.

Chen, M., Li, C., Spencer, R.G.M., Maie, N., Hur, J., McKenna, A.M., et al., 2021. Climatic, land cover, and anthropogenic controls on dissolved organic matter quantity and quality from major alpine rivers across the Himalayan-Tibetan Plateau. Sci. Total Environ. 754, 142411.

Cingolani, A.M., Noy-Meir, I., Diaz, S., 2005. Grazing effects on rangeland diversity: a synthesis of contemporary models. Ecol. Appl. 15, 757–773.

Collins, S.L., Koerner, S.E., Plaut, J.A., Okie, J.G., Brese, D., Calabrese, L.B., et al., 2012. Stability of tallgrass prairie during a 19-year increase in growing season precipitation. Funct. Ecol. 26 (6), 1450–1459.

Descheemaeker, K., Oosting, S.J., Tui, S.H.K., Masikati, P., Falconnier, G.N., Giller, K.E., 2016. Climate change adaptation and mitigation in smallholder crop-livestock systems in sub-Saharan Africa: a call for integrated impact assessments. Reg. Environ. Change 16 (8), 2331–2343.

Ding, W.Q., Jimoh, S.O., Hou, Y.L., Hou, X.Y., Zhang, W.G., 2018. Influence of livelihood capitals on livelihood strategies of herdsmen in Inner Mongolia, China. Sustainability 10 (9), 3325.

Dong, S., Shang, Z., Gao, J., Boone, R.B., 2020. Enhancing sustainability of grassland ecosystems through ecological restoration and grazing management in an era of climate change on Qinghai-Tibetan Plateau. Agric. Ecosyst. Environ. 287, 106684.

Escadafal, R., Barbero-Sierra, C., Exbrayat, W., Marques, M.J., Akhtar-Schuster, M., El Haddadi, A., et al., 2015. First appraisal of the current structure of research on land and soil degradation as evidenced by bibliometric analysis of publications on desertification. Land Degrad. Dev. 26 (5), 413–422.

Fernandez-Gimenez, M., Ballard, H., Sturtevant, V., 2014. Adaptive Management and social learning in collaborative and community-based monitoring: a study of five community-based forestry organizations in the western USA. Ecol. Soc. 13 (2), 4.

Fernández-Giménez, M.E., Batkhishig, B., Batbuyan, B., Ulambayar, T., 2015. Lessons from the dzud: community-based rangeland management increases the adaptive capacity of Mongolian herders to winter disasters. World Dev. 68, 48–65.

Foley, J., Ramankutty, N., Brauman, K., Cassidy, E., Gerber, J., Johnston, M., et al., 2011. Solutions for a cultivated planet. Nature 478 (7369), 337–342.

Foran, B., Smith, M.S., Burnside, D., Andrew, M., Blesing, D., Forrest, K., et al., 2019. Australian rangeland futures: time now for systemic responses to interconnected challenges. Rangel. J. 41 (3), 271–292.

Fraser, E.D.G., Dougill, A.J., Hubacek, K., Quinn, C.H., Sendzimir, J., Termansen, M., 2011. Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. Ecol. Soc. 16 (3), 3.

Gharibvand, H.K., Azadi, H., Witlox, F., 2015. Exploring appropriate livelihood alternatives for sustainable rangeland management. Rangel. J. 37 (4), 345–356.

Greiner, C., Alvarez, M., Becker, M., 2013. From cattle to corn: attributes of emerging farming systems of former pastoral nomads in East Pokot, Kenya. Soc. Nat. Resour. 26 (12), 1478–1490.

Guan, Y., Kang, R., Liu, J., 2019. Evolution of the field of ecological restoration over the last three decades: a bibliometric analysis. Restor. Ecol. 27 (3), 647–660.

Harris, R.B., 2010. Rangeland degradation on the Qinghai-Tibetan plateau: a review of the evidence of its magnitude and causes. J. Arid Environ. 74 (1), 1–12.

Hu, G.Z., Davies, J., Gao, Q.Z., Liang, C.Z., 2018. Response of ecosystem functions to climate change and implications for sustainable development on the Inner Mongolian Plateau. Rangel. J. 40 (2), 191–203.

Jampel, C., 2016. Cattle-based livelihoods, changes in the taskscape, and humaé bear conflict in the Ecuadorian Andes. Geoforum 69, 84–93.

Jimoh, S., Feng, X., li, P., Hou, Y., Hou, X., 2020. Risk-overgrazing relationship model: an empirical analysis of grassland farms in northern China. Rangel. Ecol. Manag. 73 (4), 463–472.

Kemp, D.R., Behrendt, K., Badgery, W.B., Han, G.D.D., Li, P., Zhang, Y.J., et al., 2020. Chinese degraded grasslands-pathways for sustainability. Rangel. J. 42 (5), 339–346.

Laflamme, M., 2011. A framework for sustainable rangeland livelihoods. Rangel. J. 33 (4), 339–351.

Lamb, V., Marschke, M., Rigg, J., 2019. Trading sand, undermining lives: omitted livelihoods in the global trade in sand. Ann. Assoc. Am. Geogr. 109 (5), 1511–1528.

Lehmann, C., Parr, C., 2016. Tropical grassy biomes: linking ecology, human use and conservation. Phil. Trans. R. Soc. B: Biol. Sci. 371 (1703), 20160329.

Li, F.R., Zhao, W.Z., Liu, J.L., Huang, Z.G., 2008. Degraded vegetation and wind erosion influence soil carbon, nitrogen and phosphorus accumulation in sandy grasslands. Plant Soil 317 (1-2), 79–92.

Li, Y., Dong, S., Wen, L., Wang, X., Wu, Y., 2013. Assessing the soil quality of alpine grasslands in the Qinghai-Tibetan Plateau using a modified soil quality index. Environ. Monit. Assess. 185 (10), 8011–8022.

Li, A., Wu, J., Cheung, H., Xue, J., Liu, Z., Han, X.G., et al., 2018a. China's new rural "separating three property rights" land reform results in grassland degradation: evidence from Inner Mongolia. Land Use Pol. 71, 170–182.

Li, L., Zhang, Y., Liu, L., Wu, J., Li, S., Zhang, H., et al., 2018b. Current challenges in distinguishing climatic and anthropogenic contributions to alpine grassland variation on the Tibetan Plateau. Ecol. Evol. 8 (11), 5949–5963.

Li, T., Cui, L., Xu, Z., Hu, R., Joshi, P.K., Song, X., et al., 2021a. Quantitative analysis of the research trends and areas in grassland remote sensing: a scientometrics analysis of web of science from 1980 to 2020. Rem. Sens. 13 (7), 1279.

Li, W., Huntsinger, L., 2011. China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks. EEcol. Soc. 16 (2).

Li, T., Jia, Y., Fava, F., Xu, Z., Zhu, J., Yang, Y., et al., 2021b. A geographic identification of sustainable development obstacles and countermeasures in drylands: a case study in Inner Mongolia, China. Ecol. Indicat. 132, 108257.

Li, T., Cui, L., Liu, L., Wang, H., Dong, J., Wang, F., et al., 2022c. Characteristics of nitrogen deposition research within grassland ecosystems globally and its insight from grassland microbial community changes in China. Front. Plant Sci. 13, 947279.

Li, T., Cai, S., Singh, R.K., Cui, L., Fava, F., Tang, L., et al., 2022a. Livelihood resilience in pastoral communities: methodological and field insights from Qinghai-Tibetan Plateau. Sci. Total Environ. 838, 155960.

Li, T., Cui, L., Scotton, M., Dong, J., Xu, Z., Che, R., et al., 2022b. Characteristics and trends of grassland degradation research. J. Soils Sediments 22 (7), 1901–1912.

Liao, C., Agrawal, A., Clark, P.E., Levin, S.A., Rubenstein, D.I., 2020. Landscape sustainability science in the drylands: mobility, rangelands and livelihoods. Landscape Ecol 35 (11), 2433–2447.

Lin, Y., Han, G., Zhao, M., Chang, S.X., 2010a. Spatial vegetation patterns as early signs of desertification: a case study of a desert steppe in Inner Mongolia, China. Landsc. Ecol. 25 (10), 1519–1527.

Lin, Y., Hong, M., Han, G., Zhao, M., Bai, Y., Chang, S.X., 2010b. Grazing intensity affected spatial patterns of vegetation and soil fertility in a desert steppe. Agric. Ecosyst. Environ. 138 (3-4), 282–292.

Liu, J., Li, S., Ouyang, Z., Tam, C., Chen, X., 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. Proc. Natl. Acad. Sci. U. S. A 105 (28), 9477–9482.

Liu, Y., Zhang, Z., Tong, L., Khalifa, M., Wang, Q., Gang, C., et al., 2019. Assessing the effects of climate variation and human activities on grassland degradation and restoration across the globe. Ecol. Indicat. 106, 105504.

Lu, T.C., 2018. Impacts of changes in rangeland management laws and policies on grazing flexibility and pastoral livelihoods in Inner Mongolia, China. Int. J. Sustain. Dev. World Ecol. 25 (2), 166–175.

Lu, X., Yan, Y., Sun, J., Zhang, X., Chen, Y., Wang, X., et al., 2015. Short-term grazing exclusion has no impact on soil properties and nutrients of degraded alpine grassland in Tibet, China. Solid Earth 6 (4), 1195–1205.

MacDougall, A., McCann, K., Gellner, G., Turkington, R., 2013. Diversity loss with persistent human disturbance increases vulnerability to ecosystem collapse. Nature 494 (7435), 86–89.

Maestre, F.T., Eldridge, D.J., Soliveres, S., Kefi, S., Delgado-Baquerizo, M., Bowker, M.A., et al., 2016. Structure and functioning of dryland ecosystems in a changing world. In: Futuyma, D.J. (Ed.), Annual Review of Ecology, Evolution, and Systematics, 47, pp. 215–237.

Marchant, R., Richer, S., Boles, O., Capitani, C., Courtney-Mustaphi, C.J., Lane, P., et al., 2018. Drivers and trajectories of land cover change in East Africa: human and environmental interactions from 6000 years ago to present. Earth Sci. Rev. 178, 322–378.

Martin, R., Linstädter, A., Frank, K., Müller, B., 2016. Livelihood security in face of drought-Assessing the vulnerability of pastoral households. Environ. Model. Software 75, 414–423.

Milchunas, D.G., Lauenroth, W.K., 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecol. Monogr. 63 (4), 327–366.

O'Connor, T., Page, B., 2014. Simplification of the composition, diversity and structure of woody vegetation in a semi-arid African savanna reserve following the re-introduction of elephants. Biol. Conserv. 180, 122–133.

Orchard, S.E., Stringer, L.C., Quinn, C.H., 2016. Mangrove system dynamics in Southeast Asia: linking livelihoods and ecosystem services in Vietnam. Reg. Environ. Change 16 (3), 865–879.

Pachzelt, A., Forrest, M., Rammig, A., Higgins, S., Hickler, T., 2015. Potential impact of large ungulate grazers on African vegetation, carbon storage and fire regimes: Grazer impacts on African savannas. Global Ecol. Biogeogr. 24 (9), 991–1002.

Perkins, J.S., Thomas, D.S.G., 1993. Spreading deserts or spatially confined environmental impacts? land degradation and cattle ranching in the kalahari desert of Botswana. Land Degrad. Dev. 4 (3), 179–194.

Phelps, D., Kelly, D., 2019. Overcoming drought vulnerability in rangeland communities: lessons from central-western Queensland. Rangel. J. 41 (3), 251–270.

Rao, I., Peters, M., Castro, A., Schultze-Kraft, R., White, D., Fisher, M., et al., 2015. LivestockPlus-The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics. Trop. Grassl. Forrajes Trop. 3 (2), 59–82.

Reed, M.S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., et al., 2013. Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. Ecol. Econ. 94, 66–77.

Reed, M.S., Stringer, L.C., Dougill, A.J., Perkins, J.S., Atlhopheng, J.R., Mulale, K., et al., 2015. Reorienting land degradation towards sustainable land management: linking sustainable livelihoods with ecosystem services in rangeland systems. J. Environ. Manag. 151, 472–485.

Reid, R.S., Fernandez-Gimenez, M.E., Galvin, K.A., 2014. Dynamics and resilience of rangelands and pastoral peoples around the globe. In: Gadgil, A., Liverman, D.M. (Eds.), Annual Review of Environment and Resources, Annual Reviews. Palo Alto, 39, pp. 217–242.

Reynolds, J.F., Smith, D.M.S., Lambin, E.F., Turner, B.L., Mortimore, M., Simon, P.J.B., et al., 2007. Global desertification: building a science for dryland development. Science 316 (5826), 847–851.

Romanelli, J.P., Fujimoto, J.T., Ferreira, M.D., Milanez, D.H., 2018. Assessing ecological restoration as a research topic using bibliometric indicators. Ecol. Eng. 120, 311–320.

Ruppert, J.C., Holm, A., Miehe, S., Muldavin, E., Snyman, H.A., Wesche, K., et al., 2012. Meta-analysis of ANPP and rain-use efficiency confirms indicative value for degradation and supports non-linear response along precipitation gradients in drylands. J. Veg. Sci. 23 (6), 1035–1050.

Scholes, R., Reyers, B., Biggs, R., Spierenburg, M., Duriappah, A., 2013. Multi-scale and cross-scale assessments of social-ecological systems and their ecosystem services. Curr. Opin. Environ. Sustain. 5 (1), 16–25.

Scoones, I., 1998. Sustainable Rural Livelihoods: A Framework for Analysis. In: IDS Working Paper No, 72.

Scoones, I., 2009. Livelihoods perspectives and rural development. J. Peasant Stud. 36 (1), 171–196.

Sendzimir, J., Reij, C., Magnuszewski, P., 2011. Rebuilding resilience in the sahel: regreening in the maradi and zinder regions of Niger. Ecol. Soc. 16 (3), 1.

Soltani, A., Angelsen, A., Eid, T., Naieni, M.S.N., Shamekhi, T., 2012. Poverty, sustainability, and household livelihood strategies in Zagros, Iran. Ecol. Econ. 79, 60–70.

Stringer, L., Dougill, A., Thomas, A., Spracklen, D., Chesterman, S., Ifejika Speranza, C., et al., 2012. Challenges and opportunities in linking carbon sequestration, livelihoods and ecosystem service provision in drylands. Environ. Sci. Pol. 19, 121–135.

Su, X.K., Wu, Y., Dong, S.K., Wen, L., Li, Y.Y., Wang, X.X., 2015. Effects of grassland degradation and re-vegetation on carbon and nitrogen storage in the soils of the Headwater Area Nature Reserve on the Qinghai-Tibetan Plateau, China. J. Mt. Sci. 12 (3), 582–591.

Su, F., Chang, J., Shang, H., 2021. Coupling coordination analysis of livelihood efficiency and land use for households in poverty-alleviated mountainous areas. Land 10 (11), 1115.

Traore, B., Corbeels, M., Van Wijk, M., Rufino, M., Giller, K., 2013. Effects of climate variability and climate change on crop production in southern Mali. Eur. J. Agron. 49, 115–125.

Tschopp, R., Aseffa, A., Schelling, E., Zinsstag, J., 2010. Farmers' perceptions of livestock, agriculture, and natural resources in the rural ethiopian highlands. Mt. Res. Dev. 30 (4), 381–390.

Ulambayar, T., Fernández-Giménez, M.E., 2019. How community-based rangeland management achieves positive social outcomes in Mongolia: a moderated mediation analysis. Land Use Pol. 82, 93–104.

van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84 (2), 523–538.

Vetter, S., 2013. Development and sustainable management of rangeland commons–aligning policy with the realities of South Africa's rural landscape. Afr J Range Forage Sci 30 (1), 1–9.

Wang, J., Brown, D.G., Agrawal, A., 2013. Climate adaptation, local institutions, and rural livelihoods: a comparative study of herder communities in Mongolia and Inner Mongolia, China. Global Environ. Change 23 (6), 1673–1683.

Wang, W.W., Zhou, L.H., Yang, G.J., Sun, Y., Chen, Y., 2019. Prohibited grazing policy satisfaction and life satisfaction in rural northwest China-a case study in Yanchi County, Ningxia Hui Autonomous Region. Int. J. Environ. Res. Publ. Health 16 (22), 4374.

Wu, J., 2005. Effects of land-use change on ecosystems. Ecology 86, 3420–3421.

Wu, J., 2013. Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landsc. Ecol. 28 (6), 999–1023.

Wu, G.L., Liu, Z.H., Zhang, L., Chen, J.M., Hu, T.M., 2010. Long-term fencing improved soil properties and soil organic carbon storage in an alpine swamp meadow of western China. Plant Soil 332 (1), 331–337.

Wu, G.L., Ren, G.H., Dong, Q.M., Shi, J.J., Wang, Y.L., 2014a. Above- and belowground response along degradation gradient in an alpine grassland of the Qinghai-Tibetan Plateau. Clean: Soil, Air, Water 42 (3), 319–323.

Wu, X., Li, Z., Fu, B., Lu, F., Wang, D., Liu, H., et al., 2014b. Effects of grazing exclusion on soil carbon and nitrogen storage in semi-arid grassland in Inner Mongolia, China. Chin. Geogr. Sci. 24 (4), 479–487.

Wu, F., Geng, Y., Tian, X., Zhong, S., Wu, W., Yu, S., et al., 2018. Responding climate change: a bibliometric review on urban environmental governance. J. Clean. Prod. 204, 344–354.

Xie, H.L., Zhang, Y.W., Wu, Z.L., Lv, T.G., 2020. A bibliometric analysis on land degradation: current status, development, and future directions. Land 9 (1), 28.

Yamba, S., Appiah, D., Siaw, L., Asante, F., 2017. Smallholder farmers' livelihood security options amidst climate variability and change in rural Ghana. Sci. Tech. Rep. 2017, 1–10.

Yan, Y., Lu, X., 2015. Is grazing exclusion effective in restoring vegetation in degraded alpine grasslands in Tibet, China? PeerJ 3, e1020.

Yan, J.Z., Wu, Y.Y., Zhang, Y.L., Zhou, S.B., 2010. Livelihood diversification of farmers and nomads of eastern transect in Tibetan Plateau. J. Geogr. Sci. 20 (5), 757–770.

Yirdaw, E., Tigabu, M., Monge, A., 2017. Rehabilitation of degraded dryland ecosystems-review. Silva Fenn. 51 (1B), 1673.

Zhang, C., Fang, Y., Chen, X., Congshan, T., 2019. Bibliometric analysis of trends in global sustainable livelihood research. Sustainability 11 (4), 1150.

Zhang, J., Cui, X.Y., Wang, Y.F., Gongbuzeren, Zhuang, M.H., Ji, B.M., 2020a. Ecological consequence of nomad settlement policy in the pasture area of Qinghai-Tibetan Plateau: from plant and soil perspectives. J. Environ. Manag. 260, 110114.

Zhang, Q., Buyantuev, A., Fang, X., Han, P., Li, A., Li, F.Y., et al., 2020b. Ecology and sustainability of the Inner Mongolian grassland: looking back and moving forward. Landsc. Ecol. 35 (11), 2413–2432.

Zhang, Y., Wang, Q., Wang, Z., Yang, Y., Li, J., 2020c. Impact of human activities and climate change on the grassland dynamics under different regime policies in the Mongolian Plateau. Sci. Total Environ. 698, 134304.

Zhou, H., Van Rompaey, A., Wang, J.A., 2009. Detecting the impact of the "Grain for Green" program on the mean annual vegetation cover in the Shaanxi province, China using SPOT-VGT NDVI data. Land Use Pol. 26 (4), 954–960.

Zhu, J.P., Xu, X.L., Li, T., Liu, Y.L., Yang, Y.Q., Cui, X.Y., 2022. Fundamental strategic shift required by the expensive ecological policy in Chinese grasslands. J. Resour. Ecol. 13 (6), 1–10.