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Grassland Ecosystem Progress: A Review and Bibliometric Analysis Based on Research Publication over the Last Three Decades

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Abstract: Understanding the grassland ecosystem is crucial for improving grassland ecosystem functions and services such as climate regulation, water and soil conservation, carbon sequestration, and biodiversity and gene pool maintenance. However, a systematic and comprehensive review of the relevant literature is still unclear and lacking. The VOSviewer software and cluster analysis were used to visually analyze and perform dimension reduction classification on the 27,778 studies related to grassland ecosystem research based on the Web of Science database. The number of publications targeting grassland ecosystem increased rapidly from 2006 to 2021. Ecology, agronomy, and environmental science were the most popular research categories, and the top journal sources were *Remote Sensing*, *Journal of Ecology*, and *Ecology and Evolution*. The leading publishing countries were the United States, China, and Germany. The top three institutions were the Chinese Academy of Sciences, the University of Chinese Academy of Sciences, and Colorado State University. Cooperation between different countries and institutions had increased. Keyword co-occurrence network analysis showed that Biodiversity, Vegetation and Conservation were the most popular study areas, grassland management, climate change, land use pattern, and ecosystem impact were the hot research topics. All studies could be divided into three categories by cluster analysis: grassland ecological characteristics including basic physicochemical properties, vegetation community characteristics, aboveground and belowground biomass, and soil structural quality of grassland; driving mechanisms that demonstrated effects of human activities and climate change on grassland ecosystem function; and grassland ecosystem services that focused the influences of different grassland management strategies on ecological services, animal welfare and human well-being. The three topic categories of reviewed studies were interrelated and consistent with each other, and the performances were progressive. This paper reviewed the trend evolution through keyword hotspots and analyzed the future research directions to provide an important reference for scientists to better respond to the balance of herbage and sustainable utilization of grassland and maintenance of ecological security.

Keywords: VOSviewer; grassland ecosystem; ecological characteristics; driving mechanism; ecosystem service; sustainable development

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1. Introduction

Grassland is the largest and most widely distributed terrestrial ecosystem type in the world sustaining the major animal husbandry production and maintaining multiple

ecosystem services [1–3], thus allowing it to retain biodiversity, conserve water and soil, preserve wind, and fix sand [4]. A grassland ecosystem refers to a terrestrial ecosystem where perennial herbaceous plants are the main producers, which is the general term for the perennial drought-tolerant, low-temperature tolerant and grass-dominated plant community [5,6]. Grassland ecosystem service includes the grassland's natural environmental conditions and utilities formed by the ecosystem to maintain the survival of human beings, or all benefits directly or indirectly obtained by human beings from the fine ecological environment provided by the grassland ecosystem [5].

As important assessment criteria of the grassland ecological quality, grassland ecosystem services and carrying capacity play important roles in analyzing the utilization status of grassland resources and the existing problems and promoting the optimal utilization of grassland resources [7–9]. Many scholars have carried out research on grassland ecosystem services and have made important progress [10–12]. For instance, research revealed that climate change [6], grazing [5,13–15], and mineral overexploitation [14,16] have all resulted in severe detrimental changes across grassland ecosystems [17]. However, there are still some deficiencies in the research related to grassland ecosystems, such as unclear concepts and a lack of integrated evaluation models and methods considering multiple factors.

In recent years, climate change, overgrazing and other factors have led to environmental issues in grassland ecosystems including the degradation of grassland ecosystem function, the reduction of biodiversity, and the stability of the ecosystem has been affected to a certain extent [14,18,19] with a particular focus on patterns of biodiversity conservation [20], community stability of vegetation [1,21], soil structural quality and soil textures [22–24], ecosystem value and services [25,26], animal welfare, and human well-being [2,27,28]. Most studies have concentrated on the effects of natural and social coupling on grassland ecosystems, including warming and wetting climate changes and nitrogen deposition [29], overgrazing [30,31], and urbanization [32]. In addition, Heavy involvement of policies and government-led programs in grassland environmental restoration and mitigation are also noteworthy, including the Grain for Green Project [33], the forage production-based grazing and settlement [34–36], and Grassland Ecological Compensation Policy [37,38], especially after 2000. Although some programs have caused adverse environmental outcomes, the overall effect, such as promoting grazing exclusion, is quite positive. the environmental degradation of many grasslands has slowed down and ecosystem functions have been restored [2,39]. Important summaries and analyses targeting research scales for grassland ecosystems have also been conducted by researchers [19,24,40]. Previous studies on grassland ecosystems mainly focused on the soil or vegetation of a certain type of grassland such as alpine meadow and alpine steppe [41–43], or typical regions such as Inner Mongolia [44,45], Qinghai-Tibetan Plateau [46] and Eurasia [47], lacking the estimation and analysis of the distribution characteristics of the whole grassland ecosystem. The region has been studied at a variety of scales from the national scale [48–50] to the regional level [51,52] and the individual household level [53,54].

The concept of sustainable development and ecological capacity of grassland was mainly used to deal with grassland degradation [54], global climate change [55,56], and excessive intervention of human activities [57]. Liao (2019) argued that the grassland ecosystem was entangled and complex, due to a multitude of factors and their interactions. Sustainability research was needed to propose a sustainability science framework, which promoted the integration between natural and social sciences [58,59]. With sustainability science emerging as a new paradigm relevant to many disciplines, more multifactorial studies were needed to fully understand the sustainability of grassland ecosystems [57,60]. However, a systematic and comprehensive bibliometric-based review targeting grassland ecosystem-related research problems was still unclear and lacking. Therefore, applying a bibliometric analysis, the trends and research themes in grassland ecosystems were explored based on related studies published in the last three decades. This study was intended to: (1) describe and evaluate the current research status of the grassland ecosystem;

(2) identify critical research topics and key knowledge gaps that need to be addressed to maintain the grassland ecosystem's capacity and sustainability.

2. Materials and Methods

2.1. Literature Search Strategy

Bibliometrics analysis based on VOSviewer software, which visually revealed the development trends of themes in the specific domain [61–66]. In this study, bibliometric analysis utilized advanced search capabilities in the Web of Science (https://www.webofscience.com/, accessed on 22 September to 12 October 2022) where the retrieval period was from 1990 to 2021, and the literature analysis was conducted by fuzzy searching the vocabulary or keywords 'grasslands ecosystem' that were published before 12 October 2022. The non-academic literature that was not related to the research topic was filtered and screened one by one and 27,778 English articles were obtained. The documents were exported in plain text (with full records and cited references) and RIS (without references) file formats, respectively, as samples of analysis data.

2.2. Descriptive Analysis

The keywords extracted from the cited literature (literature co-cited clustering naming) were considered to be the research frontier to build the science map targeting the dynamic development of grassland ecosystems. In this study, country keywords, organization keywords, journal keywords, high-frequency keywords and the relationship between keywords were selected for the co-word analysis. In addition, descriptive statistics and clustering analysis for data dimension reduction were combined to analyze the sampled literature.

3. Results

3.1. General Situation of Grassland Ecosystem Research in the Last Three Decades

Based on the Web of Science database, the number of publications in the field of grassland ecosystems was fairly constant from 1990 to 2006, but then showed an exponential growth pattern from 2007 to 2021 and the year 2006 as the change point with the annual publication growth rate was 20.09% (Figure 1), which showed that grassland ecosystem research had received increasing attention from scholars after the year 2006. The discipline distribution of publications in the Web of Science database was 40.87% in ecology, 26.20% in agronomy, 17.60% in environmental science, and 10.50% in plant science with the remaining in other categories (Figure 2). The top three popular journals (Figure 3) were *Remote Sensing* (427 publications), *Journal of Ecology* (424 publications), and *Ecology and Evolution* (365 publications), which confirmed the academic status of the above journals in the grassland ecosystem field.

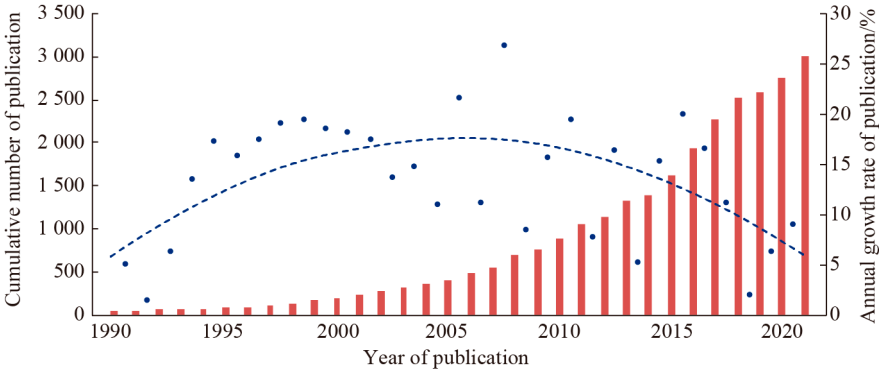


Figure 1. Cumulative number and annual growth rate of publications in the grassland ecosystem field from the Web of Science database (1990–2021).

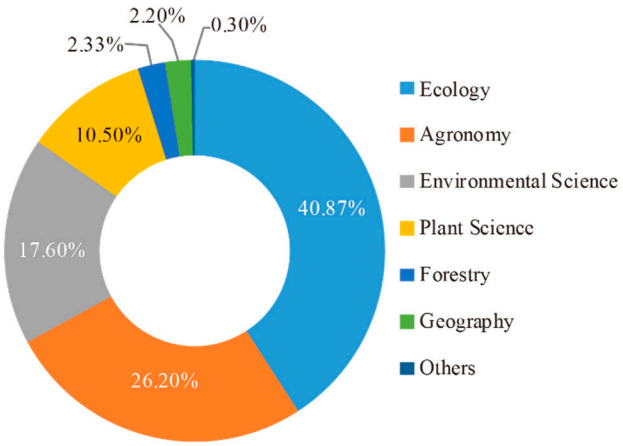


Figure 2. Discipline distribution of publications in the grassland ecosystem field.

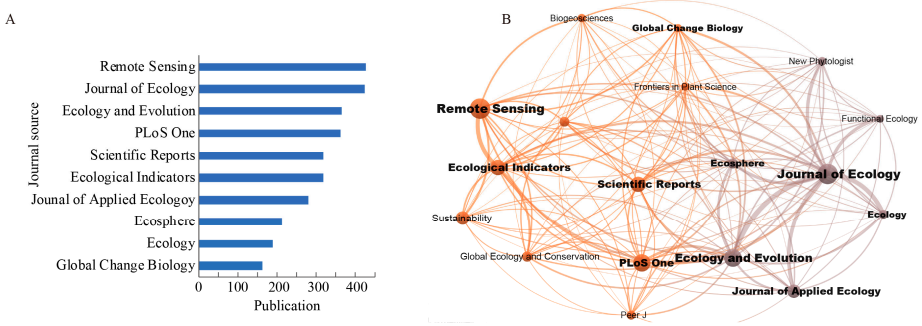


Figure 3. Ranking of journal sources by the number of publications. Subfigure (**A**) demonstrated the ranking of journal sources by the number of publications; Subfigure (**B**) showed top journal sources occurrences by the number of publications.

In the retrieved articles, the leading countries in grassland ecosystem research (Figure 4A,B) were the United States (5062 publications), China (3161 publications), Germany (1722 publications), England (1651 publications) and France (1077 publications), which indicated that these countries showed strong scientific research strength and output in this field, accompanied by more investment in scientific research funds. At the same time, the cooperative publication of papers by multiple countries had also become an important trend in grassland ecosystem research. China, the United States, Germany, and England cooperated closely and published a large number of papers, among which China and the United States have published the most papers (Figure 4A). In addition, top scientific research institutions (Figure 4C,D) came from the Chinese Academy of Sciences (1343 publications), the University of Chinese Academy of Sciences (615 publications), Colorado State University (250 publications) being the top three, which showed that Chinese scientific research institutions were taking the lead in grassland ecosystem field.

3.2. Temporal Evolution of Keyword Frequencies

As shown in Figure 5, during the 1995 to 2005 period, ranking by keyword occurrence weight, vegetation, grassland, diversity, dynamics, growth, competition, patterns, biodiversity, nitrogen, and communities were the most frequent keywords (Figure 4) with the average occurrence weight was 229.0, and these keywords were concentrated around 2002. The ground-based investigations for plant community composition and manipulation experiments about grassland biodiversity and vegetation were studied [67–69], effects of grass vegetation and biodiversity communities [70,71] were important during this period. Diversity, biodiversity, vegetation, grassland, dynamics, conservation, patterns, responses, management, and species richness were the primary keywords with an average occur-

rence weight of 871.2 during the second decade (2006–2015), and these keywords were concentrated around 2011. The trend showed in the relative contributions of different managements and patterns to grassland dynamic change [27,72]. In the last five years (2016–2021), diversity, biodiversity, vegetation, grassland, climate change, conservation, dynamics, management, responses, and patterns where the most frequently occurring keywords had an average occurrence weight of 1512.3. These keywords were concentrated around 2019. These research hotspots suggested that scientists showed strong interest in the role of grassland management in ecosystems grassland ecosystem sustainability [73,74], grassland services [14,75], and animal welfare and human well-being [36].

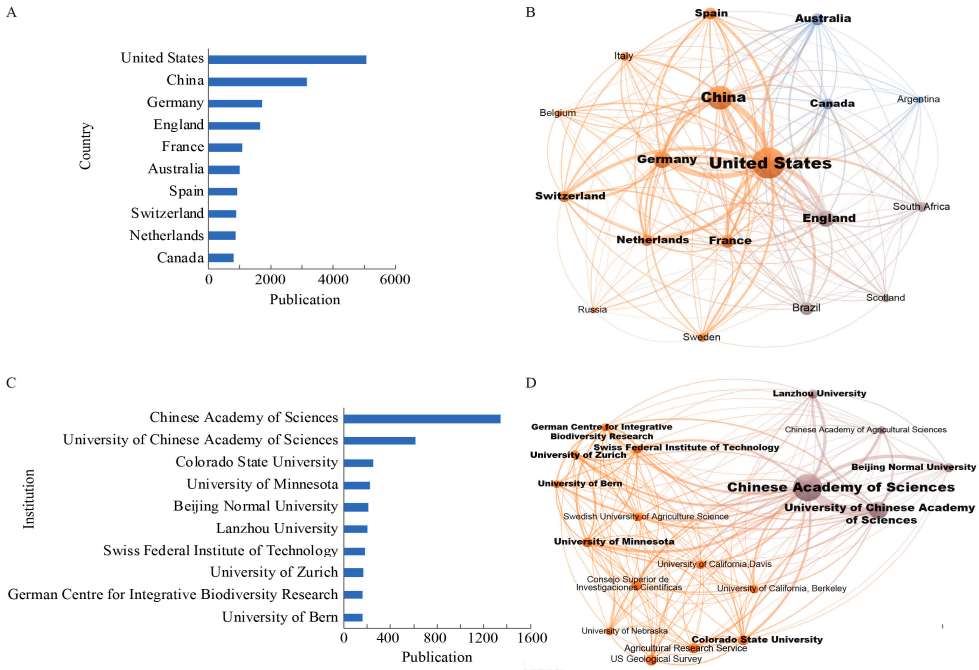


Figure 4. Ranking of countries and institutions by publishing articles. Subfigure (**A**,**B**) demonstrated the ranking of countries by the number of publications; Subfigure (**C**,**D**) demonstrated the ranking of institutions by the number of publications.

Over the past 30 years, as the number of articles increased, the research content involved became more and more extensive. However, according to the frequency of keywords retrieved, research on grassland ecosystems had undergone some changes (Figure 6). Through the comparison of the database keyword maps from three time periods, 1990 to 2005, 2006 to 2015, and 2016 to 2021, it could be seen that vegetation, biodiversity/diversity, biomass, community structure, soil, species richness, climate change, grazing, impact, landscape, plant, productivity, responses, restoration, and conservation, were still the main content of grassland ecosystem research. At the same time, the frequency of key phrases such as climate change, grazing, land use, response, restoration, and conservation increased, which further indicated that the research was more focused on the causes of grassland dynamic change (such as climate change, land use, etc.) and its impact on biodiversity and ecosystem in the past five years. In addition, the increasing frequency of keywords in the past five years, such as decomposition [21,60], functional diversity [4,5], degradation [3,16,43,55], agriculture [19,29,32,72], forests [24,33–35,74], remote sensing [8,69] also showed the importance of studying grassland degradation and intercropping study of agriculture and animal husbandry combined with forest and grass.

3.3. Keyword Co-Occurrence Network of Grassland Ecosystem Research

The keywords network, after excluding the minimum number of occurrences of less than 170 used keywords, was mapped (Figure 7). There were 238 network nodes,

22,996 connecting lines, and the most influential and important keywords within the network were biodiversity, vegetation and conservation, which demonstrated that most researchers have focused on ecological compositions and interaction mechanisms targeting grassland ecosystems. In addition, our results showed that terms such as grassland management, climate change, land use pattern, and ecosystem impact were among many other keywords, both from the perspective of their use and their importance within the network.

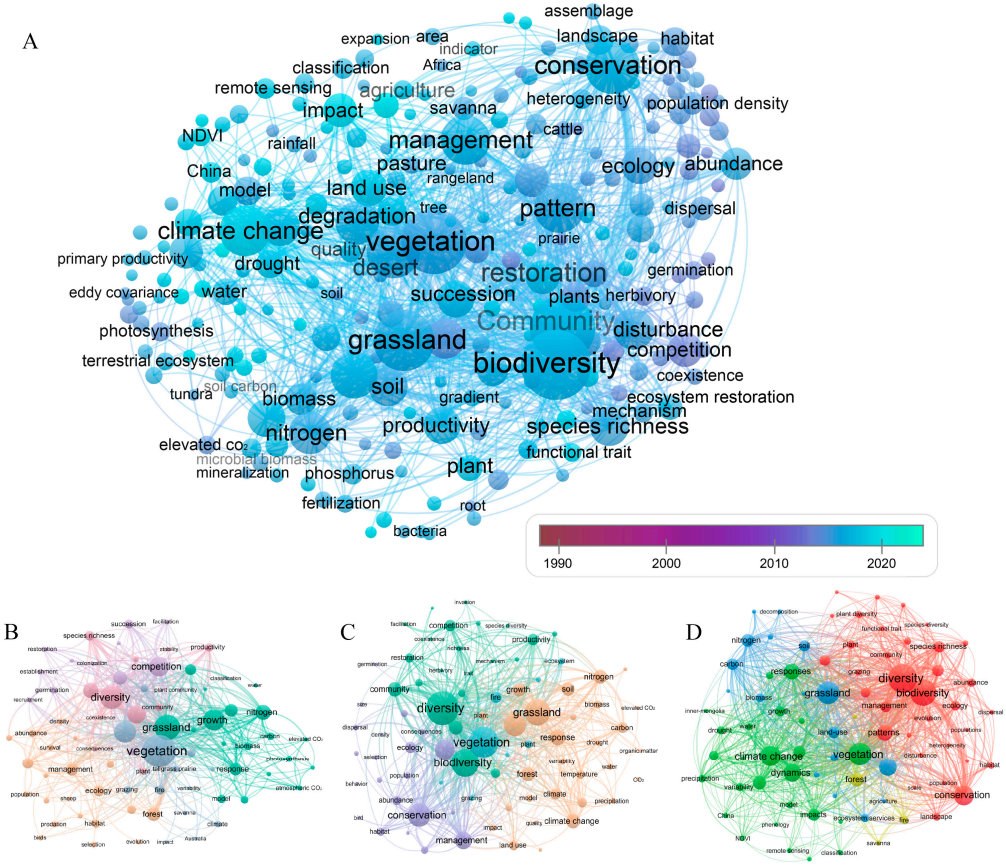


Figure 5. Keyword hotspot evolution of grassland ecosystems. Subfigure (**A**) showed keywords occurrences from 1990 to 2021; Subfigure (**B**) showed keywords occurrences from 1990 to 2005; Subfigure (**C**) showed keywords occurrences from 2006 to 2015; Subfigure (**D**) showed keywords occurrences from 2016 to 2021. (Every node in the network represented a keyword, the size of nodes by occurrences, and the link between the nodes represented the keywords co-occurrence. Only keywords that met the threshold that minimum number of occurrences > 170 were included in the study).

According to Figure 7, keywords in the first cluster included nitrogen, biomass, soil, productivity, phosphorus, plant community, gradient, fertilization, and mineralization, and the top items were nitrogen with 1834 weights of occurrences, and biomass with 1196 weights of occurrences. Keywords in the second cluster mainly contained vegetation, conservation, pattern, management, ecology, heterogeneity, abundance, and population density, which the top items were vegetation with 3371 weights of occurrences, conservation with 2386 weights of occurrences, and pattern with 2023 weights of occurrences. Keywords in the third cluster included climate change, land use, degradation, drought, water, terrestrial ecosystem, primary productivity, NDVI, rainfall, remote sensing classification, expansion, and impact, from which the top items were climate change with 3391 weights of occurrences, and land use with 1194 weights of occurrences. Keywords in the fourth cluster were closely related to keyword such as biodiversity, species, community, productivity, restoration, disturbance, succession, mechanism, functional traits, coexistence, competition, and ecosystem restoration, from which the top items were biodiversity with

6838 weights of occurrences, community with 1453 weights of occurrences, species with 2075 weights of occurrences.

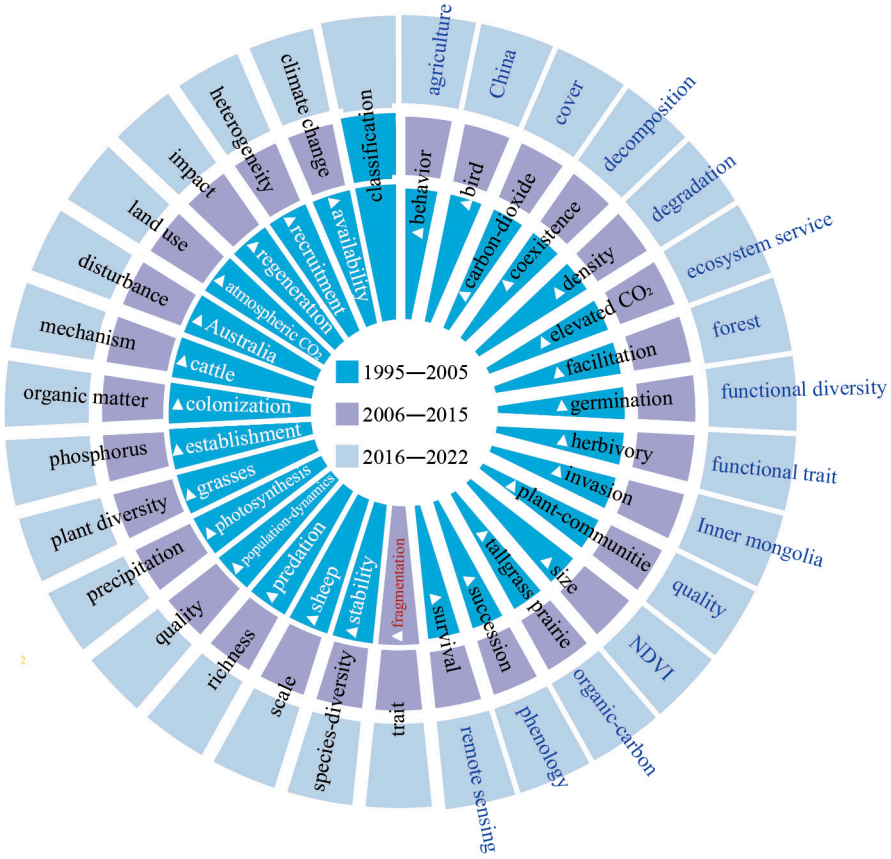


Figure 6. The keywords evolution and change of grassland ecosystem from 1990 to 2005, 2006 to 2015, and 2016 to 2021 (blue text indicated keywords that appeared only from 2016 to 2021; red text indicated keywords that appear only from 2006 to 2015; white text indicated keywords that appeared only from 1995 to 2005; white text marked with a triangle represented the disappearance of keywords; black text indicated the keywords that appeared in two time periods simultaneously, and the location indicates the covering time period).

3.4. Keyword Cluster Analysis and Theme Mining of Grassland Ecosystem Research

All studies can be divided into three categories that reveal the evolution of keywords through the thematic map (Figure 8): grassland ecological characteristics including basic physicochemical properties, vegetation community characteristics, aboveground and belowground biomass, and soil structural quality of grassland; a driving mechanism that effects human activities and climate change on grassland ecosystem function; the influences of different grassland management strategies on ecological services, and animal welfare and human well-being. The three topic categories of reviewed studies were interrelated and consistent with each other, and the performances were progressive.

From the results of the keyword temporal evolution (Figures 5 and 6) and keyword co-occurrence network analysis (Figure 7), grassland ecological characteristics, driving mechanism and impacting factors, efficient resource use and grassland ecosystem services have been paid increasing attention to in-depth study. Thematic composition derived from keywords was inconsistent and discrepant due to the different types and structures of articles (Figures 6 and 7). The first cluster articles were mainly centered on basic physicochemical properties, vegetation community characteristics, aboveground and belowground biomass, and soil structural quality of grassland and the grassland ecosystem, which has become one of the primary research themes in recent years [20,76–78]. The second

theme discussed the driving mechanism of human activities and climate change on grassland ecosystem function, which had been increasingly reported by scholars [32,39,79,80]. Therefore, strengthening the research on the coupling relationship among anthropogenic activities including grazing and land use, grassland community involving community structure, ecosystem function in aboveground vegetation, greenhouse gas emissions, and natural factors could become a popular research direction for researchers in the next few years. In addition, with the proposal and promotion of carbon neutrality and carbon peaking, the interaction between the carbon cycle and climate change in grassland ecosystems had become a hot issue [81–83], which had been further studied by scholars [84–86], which also directly promotes the further development of grassland ecosystems and related research areas [87]. The third theme focused on the effects of different grassland management strategies on ecological services, animal welfare and human well-being. How to maintain sustainable development of grassland ecosystem and improve the grass resource use efficiency has become a popular research direction for scientists, and it was estimated that the theme of grassland ecosystem sustainability would still be favored by scientists in the coming years [18,88].

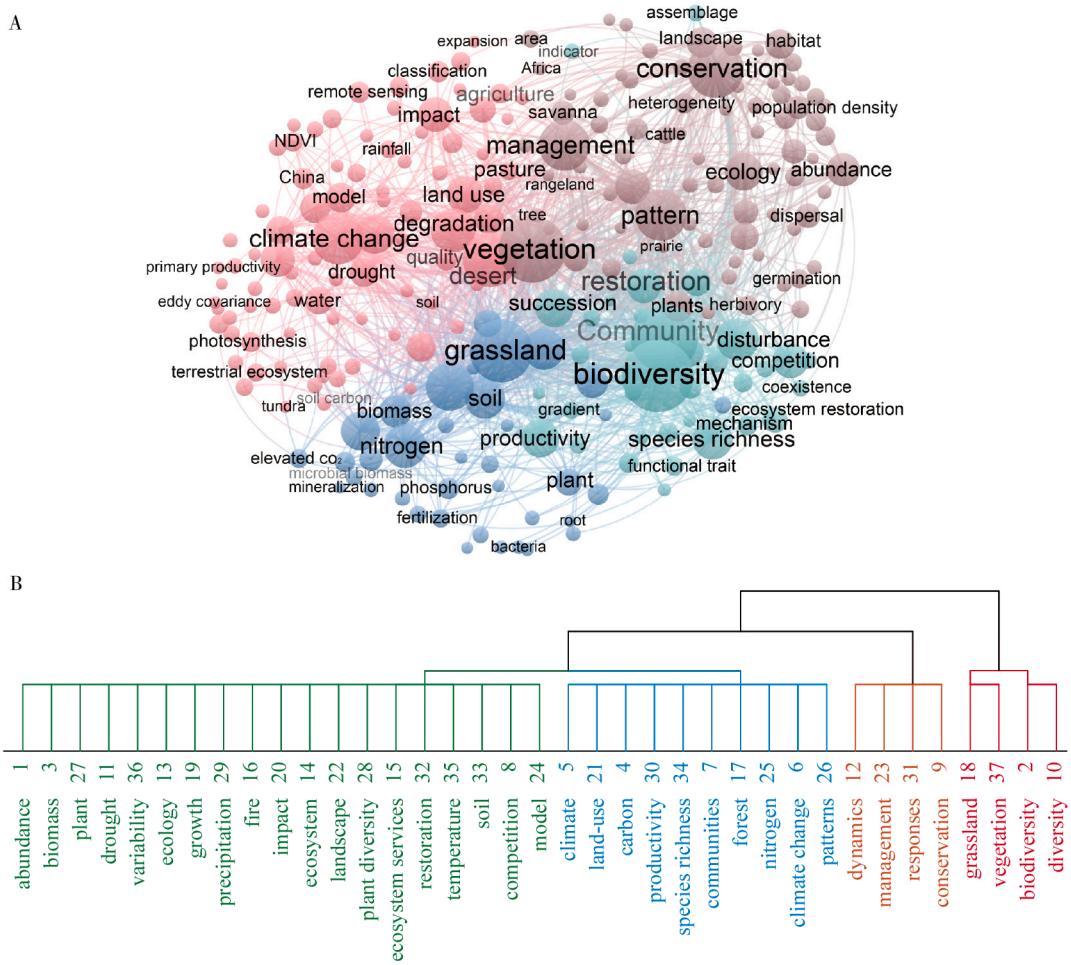


Figure 7. Keyword co-occurrence network (**A**) and cluster analysis (**B**) of grassland ecosystem (Every node in the network represented a keyword, size of nodes by occurrences, the link between the nodes means the keywords co-occurrence. Only keywords that met the threshold of a minimum number of occurrences > 170 were included in the study. Green and red part of the cluster indicated grassland ecological characteristics, blue part of the cluster indicated driving mechanisms, orange part of the cluster indicated grassland ecosystem services).

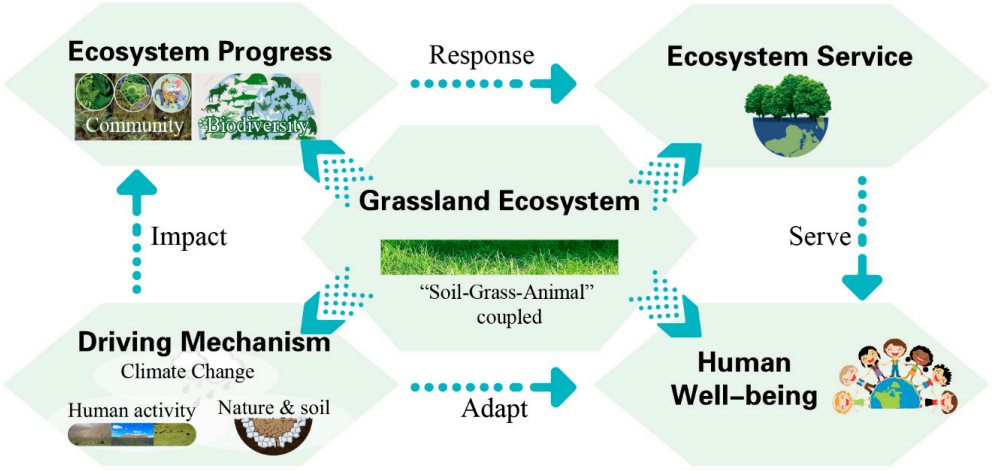


Figure 8. Thematic map of a grassland ecosystem.

4. Discussion

4.1. Three Perspectives in the Grassland Ecosystem

The grassland ecological characteristics were comprehensively and systematically reviewed [89,90], which would provide an important reference for the scientific management and utilization of grassland ecosystems and the restoration and management of grassland dynamic change. Current studies on grassland ecological characteristics (Table 1) based on bibliometrics mainly included species composition and diversity [91], vegetation community characteristics [92,93], aboveground and belowground biomass [94,95], and soil structural quality and soil carbon and nitrogen cycle of grassland [48,96]. At the vegetation level, the ecological characteristics of grassland were shown as productivity [97], quality and coverage [98], dominant species [99], diversity and ecosystem stability [4]. In terms of soil structure and physical and chemical properties, it mainly included nutrient content, soil erosion, desertification and salinization, and microbial community [6,26,48]. Grassland ecological degradation included plant coverage and biodiversity decreases [78,100,101], soil characteristics, soil community [102] and land changes [16,103], productivity and nutrient declines [38], and ecosystem function reduction [88].

Grassland degradation was a negative ecological characteristics formalization of grassland and was an ongoing process [3]. Most grasslands in the world had different degrees of degradation and desertification, and grasslands with different degrees of degradation behave differently [104]. In the slightly degraded grassland, the individual vegetation was greatly affected, and the height, coverage and yield were reduced. In the moderately degraded grassland, the soil's physical structure and physical and chemical properties changed and the vegetation composition showed variation. In the severely degraded grassland, the soil has been eroded, vegetation and soil conditions had deteriorated significantly, and large areas of grassland had become desertification. There were differences in vegetation composition and soil properties among different types of grassland, and the response of plant and animal communities to environmental factors on different types of grassland should be paid more attention in the research on the degradation performance [105,106], to help us take more reasonable and effective measures to prevent grassland degradation and protect grassland ecosystem. Through systematic summary, species composition and structure had changed, biodiversity showed significant variation, aboveground and underground biomass were affected, and soil carbon and nitrogen cycling processes appeared imbalanced in the process of grassland degradation [107,108]. Curbing grassland degradation and strengthening grassland management and ecological restoration had become major challenges that need to be solved globally in the near future.

The driving mechanism of human activities and climate change on the grassland ecosystem (Table 1) was manifested by affecting the material cycle and energy flow of the grassland ecosystem, leading to the decrease of vegetation growth, soil nutrient content and biodiver-

sity [109,110]. Human activities in grassland mainly included grazing, grassland reclamation and mineral exploitation. Grazing affected grassland vegetation, soil physical and chemical properties, and soil microorganisms, and further influenced the grassland ecosystem [111,112]. Previous studies had shown that grazing had no significant effect on plant diversity, soil bacterial abundance, actinomyces abundance and total microbial abundance, but significantly reduced grassland productivity and soil carbon, nitrogen and phosphorus nutrients, and significantly increased soil bulk density, pH, and soil fungi abundance [113]. The response of the grassland ecosystem to grazing was affected by the grazing intensity and annual average precipitation. Moderate grazing was beneficial to maintain the growth of the underground part of plants, while light grazing was beneficial to maintain soil moisture and nutrients. In arid areas with low annual average precipitation (<300 mm), plants might have better resistance to grazing disturbance, and the destabilization of grazing on soil nutrients was not serious. In humid areas with high average annual precipitation (>400 mm), grazing was more likely to alter soil microbial community composition [114–116].

Unreasonable overgrazing was the main human activity leading to grassland degradation. The selective feeding of livestock changed the original species composition of the grassland, the community type became single, the community structure tended to be simplified, the stability of the ecosystem became worse, and the ecosystem was more susceptible to external interference [117]. Excessive feeding activities and random excretion behavior of livestock interfered with the normal circulation of soil nutrients, trampling behavior destroyed the soil surface structure, and the soil conservation ability decreased [118]. Domestic and foreign scholars had carried out research on the value evaluation of the effects of different grassland management strategies on ecological services, animal welfare and human well-being (Table 1) at different scales and different ecosystems [119,120], which had built a bridge for the ecosystem service function from theoretical research to practical decision-making.

Table 1. Three categories and corresponding parameters targeting grassland ecosystems.

Category	Content	Parameter	Reference
Grassland ecological characteristics	basic physicochemical property, vegetation community characteristics, soil structural quality of grassland	Vegetation index, Leaf Area Index (LAI), Normalized differential vegetation index (NDVI), Enhanced vegetation index (EVI), Soil regulates vegetation index (SAVI), Modified soil adjusted vegetation index (MSAVI), Productivity, Net primary productivity (NPP), Net ecosystem productivity (NEP), aboveground biomass (AGB), Nitrogen nutrient index (NI), Soil texture, Soil carbon, Nitrogen cycle of grassland, Vegetation coverage	[6,26,29,48,54,91–99,109,112]
Driving mechanism	effects of human activities (grazing, grassland reclamation and mineral exploitation) and climate change on grassland ecosystem function	Population (Population density, Urbanization rate); Economic (GDP, Primary, secondary, and tertiary industries, Distance to town center); Climate (Precipitation, Temperature, Relative humidity, Solar radiation, Air pressure, Wind speed)	[5,6,13–15,53–57]
Grassland ecosystem service	the influences of different grassland management strategies on ecological services, animal welfare, and human well-being	Organic matter production, Nutrient conservation, Soil conservation, Carbon fixation and oxygen release, Water conservation	[2,14,25–28,36,75,91–99]

4.2. Future Research Themes for the Grassland Ecosystem

Although there were some differences in the understanding of the relationship between grassland ecological characteristics and ecosystem services, the mainstream view was that grassland ecological attributes included all natural resources and ecological environments that can provide services and welfare for human beings, and were the combination and unity of the value of natural resources and ecosystem services. From the literature research of 30 years, the previous research focused on the natural attributes of grassland, while future research should pay attention to the socio-economic attributes that depend on grassland, reconstruct the close relationship between ecology and economy of grassland, and avoid the cost internalization of external uneconomic behaviors (Figure 9). From the perspective of natural ecosystems supporting the sustainable development of human society, future studies should introspect the limitations of the past dualistic development model of economy and environment in grassland, deal with the relationship between humans and nature scientifically, seek methods to solve the coupling and coordinated development of grassland ecology and social economy and form the connotation and framework of grassland ecosystem based on the coupling relationship between humans and earth. With the excessive consumption of grassland resources in social and economic development, the coordinated and unified ecological economic mechanism between humans and nature is destroyed [121]. After long-term accumulation, once the consumption of grassland resources exceeds the threshold value of stock, the imbalance of resources, environment, ecology, and the social economy will be triggered [122]. The social attribute of grassland assets was ignored, and a situation of zero natural capital and zero human welfare would be formed [123,124].

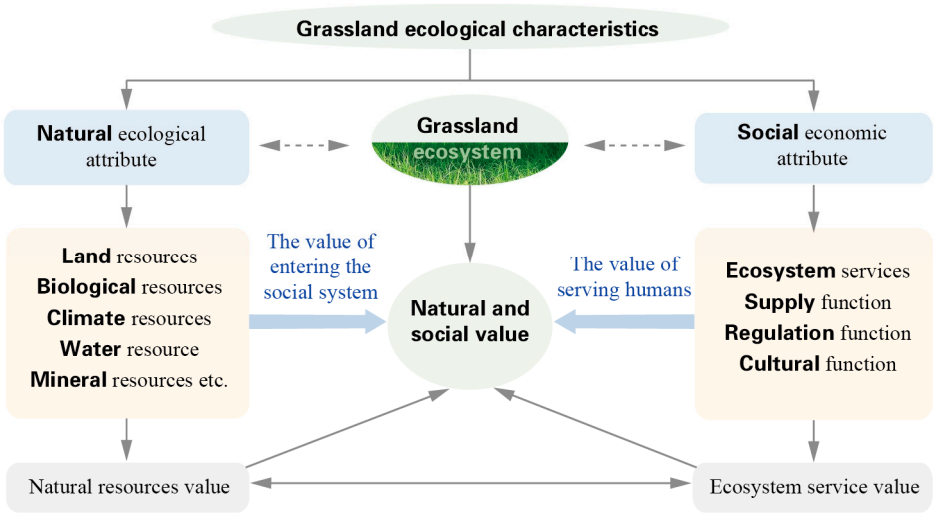


Figure 9. Future research themes and directions of grassland ecosystems.

Although the research on grassland ecological attributes and ecosystem services at home and abroad has made many achievements in theory and practice [125], the concept of grassland ecological attributes and ecosystem services was still unclear, and the accounting and evaluation system was not perfect. Therefore, to accurately define the concepts and characteristics of grassland ecological attributes and ecosystem services is the premise to ensure the rationality, accuracy and effectiveness of grassland ecological accounting and ecosystem service value assessment (Figure 9). Improving grassland ecosystem service-ability and seeking ways to realize grassland ecological value should be important issues of academic and social attention in the near future. Future studies should focus on the concepts, evaluation indexes and methods of grassland ecosystem services and carrying capacity. The key problems to be solved in the study of grassland ecosystem services and carrying capacity were put forward from the aspects of theoretical basis, technical method, and early warning mechanism, to provide a scientific basis for further study of grassland ecosystem stability, grassland carrying process and carrying mechanism, and

ecological security of ecologically fragile areas, to promote sustainable utilization and healthy development of grassland ecosystem.

5. Conclusions

This study reviewed the grassland ecosystem research progress, including the keywords, themes, and key research contents of grassland ecosystems in the past 30 years with bibliometrics. Although interest in grassland ecosystems received increased attention from the scientific community, its development accelerated after 2006. Grassland ecosystem research mainly involved ecology, agronomy, environmental science, plant science and other disciplines, and the cooperation between different countries and regions showed an increasing trend. The keywords analysis indicated that grassland ecology characteristics and services were the most popular study areas. The previous studies identified three types based on the bibliometric review, the first category included grassland ecological characteristics, which focused on basic physicochemical properties, vegetation community characteristics, aboveground and belowground biomass, and soil structural quality of grassland. The second type was centered on the impact of the driving mechanism of social and natural factors on grassland ecosystems. The last type was the effects of different grassland management strategies on ecological services, animal welfare and human well-being, which was crucial to maintain the sustainability and ecological carrying capacity of grassland ecosystems, but it had not received enough attention. The bias in current research priorities indicated a gap between our knowledge and the changing grassland ecosystem, especially in studies related to grassland ecosystem planning and management. In the future, research on grassland ecosystems should consider the cross-integration of multi-disciplines, emphasize the systematic and holistic correlation of different dimensions and multi-trophic levels, attach importance to the coupling of social and natural systems to coordinate the development of ecological restoration, regional economy and livelihood improvement, and strike a balance between ecosystem services and functions, ecosystem integrity and cultural value.

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