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Research Progress on Soil Security Assessment in Farmlands and Grasslands Based on Bibliometrics over the Last Four Decades

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Abstract: Soil security assessments are an important part of the green development of agriculture and animal husbandry. To explore the research progress and development trends in the field of farmlands and grasslands soil security assessments, a bibliometric study was conducted using VOSviewer software to visually analyze 3618 papers from the Web of Science Core database on the topic of "soil security assessment" published from 1979 to 2023. The results revealed the following: (1) Research started in 1979; the number of papers can be divided based on germination, start-up, and rapid development stages. China published the most articles, the Chinese Academy of Sciences had the highest number of publications, and Science of the Total Environment issued the most publications (247). (2) Based on keywords, the research frontier can be divided into a distinct time sequence: the initial exploratory period (1979–2008), wherein relevant research focused on resource development and management; the rapid development period (2009–2015), wherein research focused on sustainable development and efficient farmland use; and the comprehensive development period (2016–2023), wherein research focused on the assessment, measurement, and evolution of cultivated land. (3) Related researches at home and abroad focus on land development and utilization, highlighting the rational development and efficient use of land; the security of industrial and supply chains, underlining risk assessment and promotion strategies; ecological security, emphasizing the ecological security assessments of agricultural production and the water environment; and ecosystem service value, underscoring spatiotemporal evolution and driving factors, evolution mechanisms, value prediction, and compensation strategy. Currently, there is an urgent need to develop soil security assessment models based on regional development, soil biology, spatial metrology, and other parameters, to establish an index system, and to analyze the evolution rules of soil security at different scales and investigate the scale effect of soil quality evaluations.

Keywords: soil security; farmland and grassland; evaluation system; ecosystem; sustainability

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1. Introduction

Soil plays an important role in the transfer and transformation of substances and energy in Earth's surface systems [1]. It represents an important part of Earth's critical zone, thus providing a basic guarantee for maintaining agricultural production, plant growth, animal habitats, biodiversity, and environmental quality. It is a core element linking the entire natural ecosystem [2]. Research on soil quality began in the 1970s [3], and the conceptual definition indicates that soil maintains biological productivity and

environmental quality to promote the health of animals, plants, and humans within the scope of ecosystems and land use. Soil health is a derivative of soil quality. In 2015, the Food and Agriculture Organization of the United Nations (FAO) proposed the "healthy soil brings healthy life" concept during the International Year of Soils and pointed out that only healthy soil can produce healthy food and foster healthy people and a healthy society. Thirteen of the 17 sustainable development goals set by the United Nations are directly or indirectly related to soil [4]. The Chinese government has always attached great importance to soil health and indicated its adherence to the principle of "protection in use and utilization in protection"; thus, it has established the strictest protection system of cultivated land, introduced the soil health status concept into the "Quality Grade of Cultivated Land" (GB/T 33469-2016), and clarified the continuous ability of soil to maintain its function as a dynamic living system. Simultaneously, a comprehensive monitoring and evaluation system has been established. Over the past 40 years, with the rapid development of economies, rapid transformation of high-intensity land use, and increasing intensification of agriculture and forestry, countries worldwide have faced varying challenges, such as tightened resource constraints, serious environmental pollution, fragile ecosystems, frequent extreme weather, and degraded soil functions and quality. Farmland and grassland are the largest land use types on Earth and represent an important part of the "community of mountain, river, forest, field, lake and grassland", accounting for 12% and 26% of ice-free land on Earth, respectively. Therefore, the soil security of farmlands and grasslands is of immense importance for maintaining the health of the entire natural ecosystem and realizing sustainable development.

In recent years, scholars worldwide have conducted numerous studies on soil security in farmland and grassland. These studies primarily include medium- and small-scale spatial research under a specific land use mode or agricultural farmland condition; however, limited research has focused on multi-spatial scales and multifunctional dimensions. Soil security assessments represent a systematic project, and the measurement methods of each evaluation index differ based on the different soil types and management methods. Currently, the most widely used assessment method employs the soil health index (SHI) to assess the health status of farmlands and grasslands by constructing a minimum dataset. With the development of digitization and information technology, the soil health assessment method, which combines hierarchical analysis and big data, has improved early SHI construction methods [5]. Maharjan et al. considered the soil properties of natural agricultural and pastoral lands that were not disturbed by human activities as the benchmark and judged changes in soil health and soil degradation degree by observing differences in property indexes between changed soil under human activities and baseline soil, which was called the "soil health gap" method [6]. In China, an evaluation system for cultivated land resources has been established, and it takes the county as a project unit and the field as an evaluation unit and summarizes provincial and national achievements step by step [7,8]. However, because of scale hybridity, the scale situation above the county level is difficult to describe accurately and quickly. Moreover, soil function and environmental status have not been sufficiently considered and the evaluation results are singular, making it difficult to meet the multi-objective requirements of soil health management and protection.

Several methods are available to conduct soil security assessments in farmlands and grasslands, and the procedures can be summarized into three steps: index selection, index grading, and system integration [9]. Owing to the lack of theoretical research and incomplete practical programs, the establishment of multi-scale soil security evaluation theories and methods for farmlands and grasslands has become a bottleneck in the field of land resource management. This study has three objectives: (1) it has theoretical and practical significance, summarizing research hotspots and exploring future research trends in the field of soil security assessment of farmlands and grasslands; (2) it intends to systematically analyze the changes in the number of papers published in the field of soil security assessment of farmlands and grasslands, as well as the changing trends and themes of research hotspots; (3) it proposes future research prospects following the systematic

analysis of the research results of soil security assessments of farmlands and grasslands, that is, to establish a scientific soil security evaluation model, index system, and analysis scale, in order to provide a reference for the quantitative analysis of soil security effects in farmlands and grasslands.

2. Materials and Methods

2.1. Data Collection

To analyze soil security assessment research in its broadest scope, collective publications in the field of soil security assessments were considered, and their full bibliometric information was exported and analyzed. In composing the search query, all subjects that were indexed by the Web of Science (WOS) core database as "soil security assessment" were considered, and their total indexation included 5354 valid data points. The filtering process identified the time range (1979–2023) and document type (primarily papers and literature reviews). The search was conducted on 4 September 2023, and the query string resulted in N = 3618 research items. The full bibliometric data for this set of documents were exported as text files for analysis. These include the title, date of publication, author names and affiliations, citation count, list of keywords, abstract text, and list of references.

2.2. Analytical Methods

Bibliometrics was applied to describe, evaluate, and predict the status quo and development trends of a specialty subject using mathematical and statistical methods based on various characteristics, as described in the literature [10–13]. Scientific knowledge mapping is a visual tool that illustrates the development process of a scientific knowledge system and its mutual structural relationships [14,15]. VOSviewer 1.6.17 is a knowledge mapping software that can effectively analyze core authors, research institutions, journal types, keyword co-occurrence, research content evolution paths, research hotspots, and research field development frontiers [14,16–18]. To statistically analyze the bibliometric data, the structure and composition of the field were analyzed using the Visualization of Similarities (VOS) method developed by Eck and Waltman [19], whereas temporal trends in keywords associated with soil security assessment research were identified using the document co-citation analysis methodology.

3. Results and Discussion

3.1. Overview of Soil Security

3.1.1. Publication Trends

The number of published papers is an important index for measuring the degree of scholarly attention focused on a specific research field [20]. By searching the WOS core database, research on soil security in farmlands and grasslands could be traced back to 1979. From 1979 to 2023, the changing trend of the annual published papers on farmland and grassland soil security research increased slightly in the early period and increased sharply in recent years (Figure 1). In 1979, soil security-related papers appeared in the WOS core database, and a slow growth rate was observed until 2000, when the number of papers began to increase slightly. From 2001 to 2010, the number of publications on soil security-related research increased significantly. From 2011 to 2022, soil security-related research grew rapidly, with the number of publications increasing from 101 in 2011 to 615 in 2022, which indicates that, with rapid economic development, problems such as resource shortages and environmental pollution intensification have become more evident. Researchers have tended to focus on soil security and environmental protection.

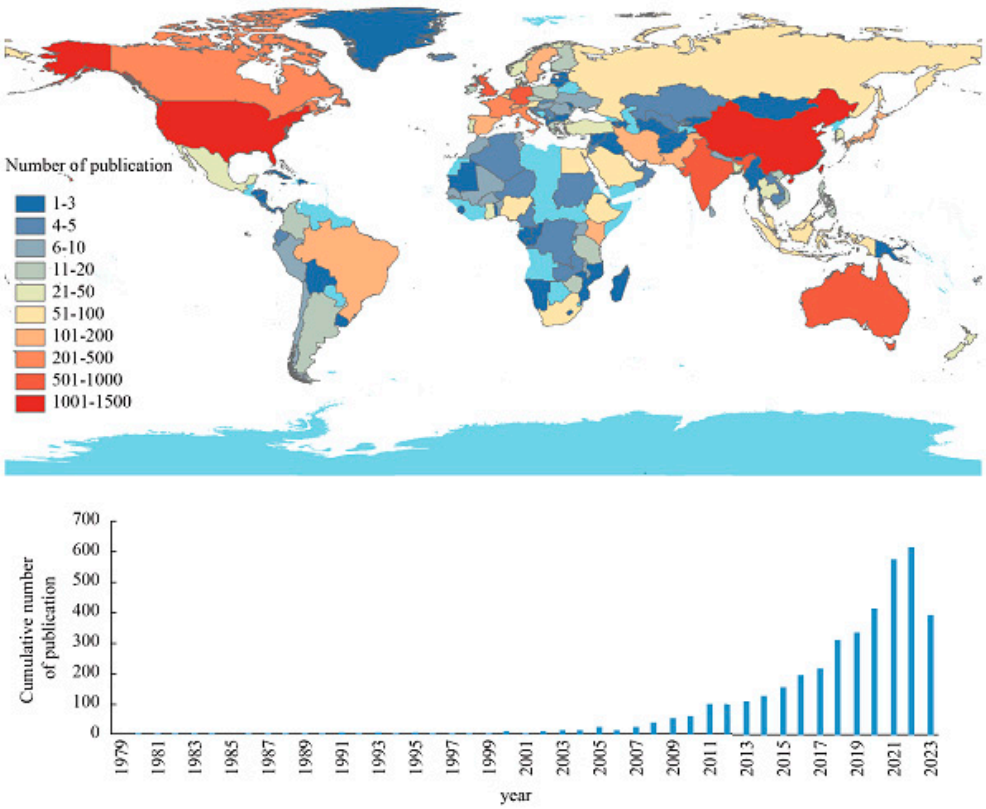

Figure 1. Number of publications by region and year.

3.1.2. Nation Distribution

The VOSviewer software was used to analyze the countries' publication contributions corresponding to papers on soil security assessment (Figure 2). The results showed that China published the largest number of papers, followed by the USA, India, Germany, England, and Australia. China published 1395 papers, accounting for 20.53% of the total; the USA published 823 papers, accounting for 12.11%; and India published 315 papers, accounting for 4.64% of the total, which was much lower than that of China and the USA (Table 1). According to the number of published papers, among the top 10 countries, except China and India, the remaining eight are powerful agricultural countries [21], indicating that the level of agricultural development has played a significant role in promoting soil security research. The co-occurrence analysis of soil security assessments of farmlands and grasslands indicated the existence of close co-operative relationships among different countries (Figure 2). There was more co-operation in China with 896 total link strength, the USA with 1083 total link strength, and Germany with 661 total link strength, and other countries.

Table 1. Top 10 national statistics in soil security assessment field from 1979 to 2023.

Ranking	Country	Published Paper	Percentage
1	China	1395	20.53%
2	USA	823	12.11%
3	India	315	4.64%
4	Germany	275	4.05%
5	England	271	3.99%
6	Australia	254	3.74%
7	The Netherlands	195	2.87%
8	Italy	186	2.74%
9	Canada	153	2.25%
10	France	145	2.13%

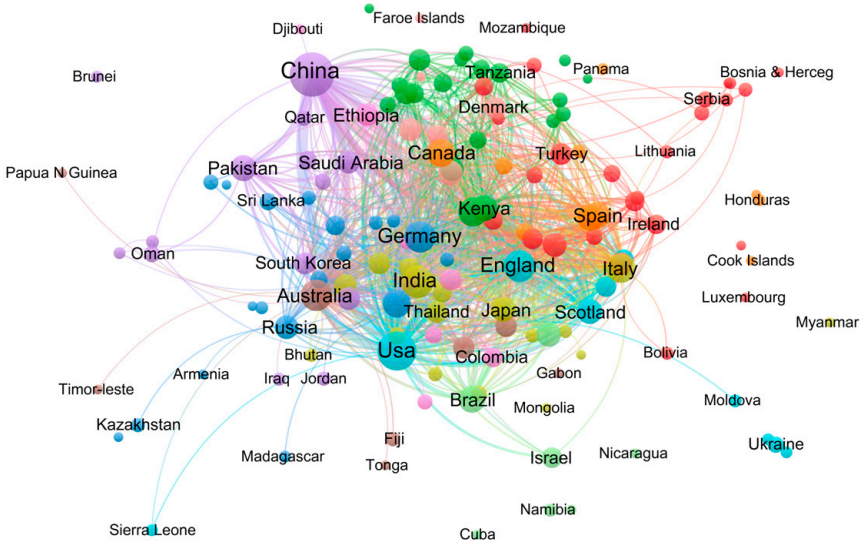

Figure 2. Co-occurrence network of countries that published papers in soil security assessment research from 1979 to 2023.

3.1.3. Research Institution

The co-occurrence analysis of soil security in farmland and grassland data published by scientific research institutions was carried out (Figure 3). There were strong links and co-operations among different agencies institutions, especially the Chinese Academy of Sciences, University of Chinese Academy of Sciences, China Agricultural University, and Chinese Academy of Agricultural Sciences, with total link strength 678, 265, 262, and 225, respectively. From the distribution of publication institutions, a total of 1381 scientific research institutions participated in research related to soil security in farmlands and grasslands, among which 541 institutions published two papers on soil security, 446 institutions publish 3–5 papers, 251 institutions published 6–10 papers, and 143 institutions published more than 10 papers. According to the statistics of the top 10 research institutions (Table 2), the Chinese Academy of Sciences published the most papers (306), the University of the Chinese Academy of Sciences published 108 papers, the China Agricultural University published 88 papers, and the Chinese Academy of Agricultural Sciences published 80 papers.

Table 2. Top 10 institutions researching soil security assessment from 1979 to 2023.

Ranking	Research Institution	Article Number
1	Chinese Academy of Sciences	306
2	University of Chinese Academy of Sciences	108
3	China Agricultural University	88
4	Chinese Academy of Agricultural Sciences	80
5	Beijing Normal University	72
6	Zhejiang University	65
7	Northwest A&F University	54
8	Nanjing Agricultural University	53
9	Wageningen University	51
10	China University of Geosciences	42

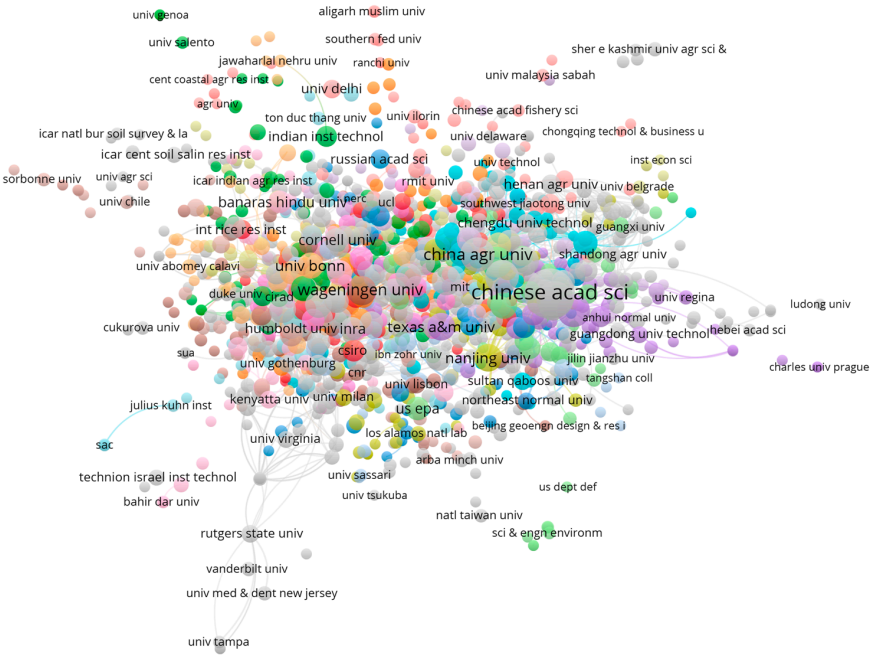

Figure 3. Co-occurrence network of institutions that published papers in soil security assessment research from 1979 to 2023.

3.1.4. Journal Source

High-impact publications are important carriers for scholars to present their academic research results [3]. To analyze the distribution of publications related to soil security research, this study counted the top 10 journals on soil security in farmlands and grasslands since 1979 (Table 3). Science of the Total Environment had the largest number of publications at 247, Environmental Science and Pollution Research had the second largest number at 158, and Environmental Pollution and Journal of Environmental Management had the third largest number at 86. Other leading publications included Sustainability and Chemosphere. From the perspective of co-occurrence and research direction (Figure 4), different journals were mutually related. The studies primarily focused on agricultural ecology, environmental science, and soil science. Science of the Total Environment showed the strongest performing links (33,264) with other journals, followed by Environmental Science and Pollution Research, which had the second largest total link strength at 14,024, followed by Environmental Pollution (9551) and Journal of Environmental Management (8660). From the perspective of journal level, eight journals were located in the Q1 region, among which the Journal of Hazardous Materials had the highest impact factor of 13.6.

Table 3. Top 10 journals publishing on soil security assessment from 1979 to 2023.

Ranking	Journal	Number of Papers	Impact Factor (2023)	Journal Citation Reports
1	Science of The Total Environment	247	9.8	Q1
2	Environmental Science and Pollution Research	158	5.8	Q1
3	Environmental Pollution	86	8.9	Q1
4	Journal of Environmental Management	86	8.7	Q1
5	Sustainability	71	3.9	Q2
6	Chemosphere	66	8.8	Q1
7	Environmental Science & Technology	65	11.4	Q1
8	Journal of Hazardous Materials	53	13.6	Q1
9	Agricultural Systems	50	6.6	Q1
10	Environmental Monitoring and Assessment	48	3	Q3

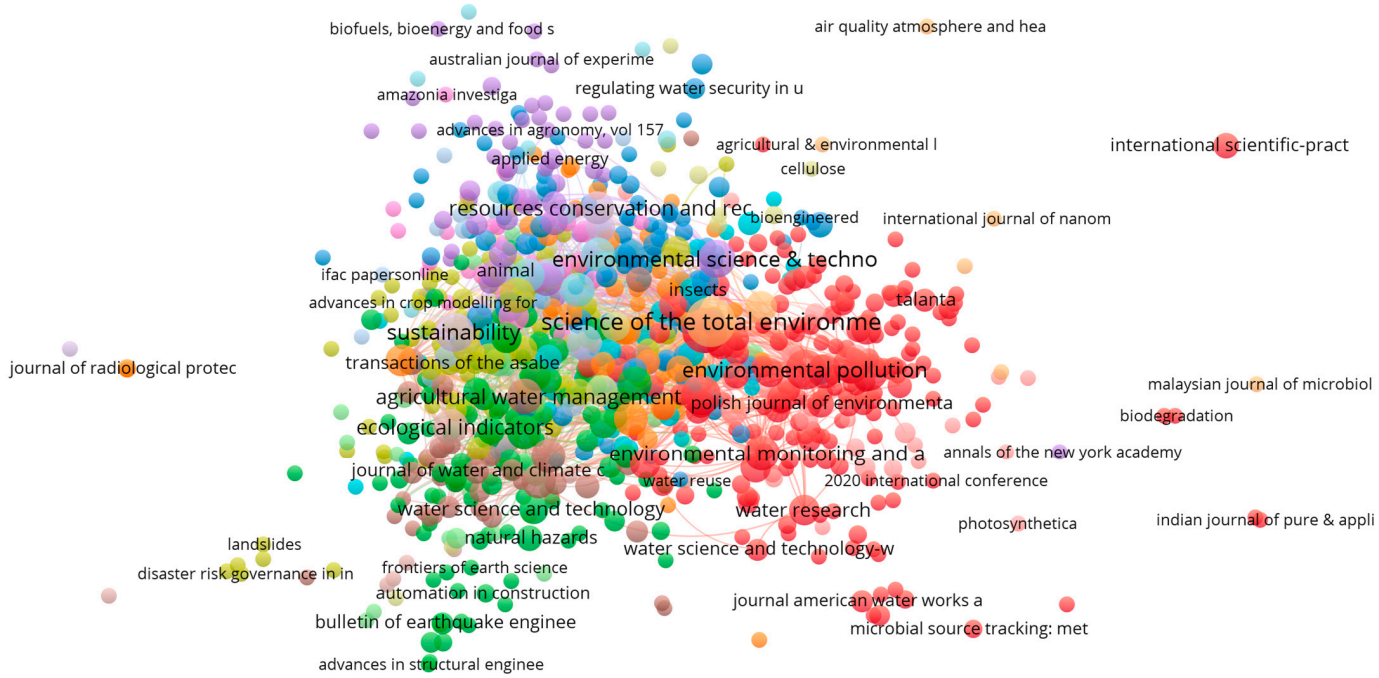

Figure 4. Co-occurrence network of journal sources that published papers in soil security assessment research from 1979 to 2023.

3.2. Temporal Evolution

Keywords can highly condense research content, and high-frequency collinear analysis can help understand the hotspots and trends of research in specific fields. Based on the number of publications, trend analysis, and significant content, China launched the second national soil survey in 1979, perfected the soil classification in 2009, and issued the "Soil Pollution Prevention and Control Action Plan" in 2016 (by the State Council). This study divided soil security research into three stages using VOSviewer visualization of research hotspots to analyze the research evolution trends in each stage.

3.2.1. Initial Exploratory Period (1979–2008)

The period 1979–2009 was the initial exploration stage of soil security research in farmlands and grasslands, and few studies were published. The high-frequency keywords at this stage (Figure 5) were agriculture (13 times, centrality = 2.43), food security (12 times, centrality = 2.12), management (11 times, centrality = 1.31), model (9 times, centrality = 2.01), water (8 times, centrality = 0.54), climate change (7 times, centrality = 3.31), and the environment (7 times, centrality = 1.38). This reflects the fact that research on soil security focused on resource development and management in the early stages. The content was primarily regional distribution, problems, and the supply and demand situation of agricultural development [22–24], as well as policy measure impact on agricultural production [25] and environmental impact on agricultural production [26]. Next, strategic objectives, concrete measures, and development ideas were proposed for sustainable utilization of agricultural resources in China.

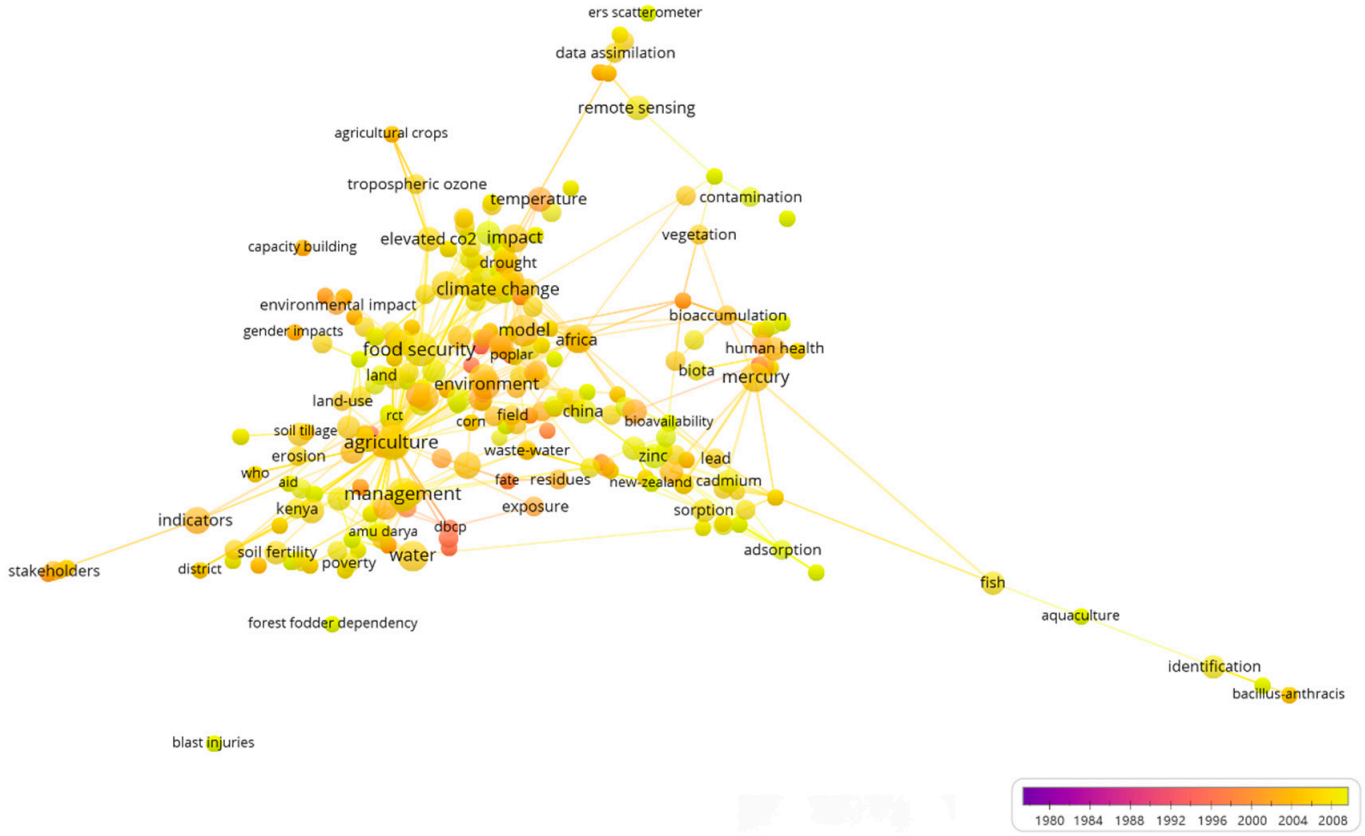

Figure 5. Co-keyword network in soil security assessment research from 1979 to 2008. The size of node rings in the figure indicates the frequency of keywords. The larger the ring area, the higher the frequency of keywords and the hotter the research hotspot. The same conditions apply below.

3.2.2. Rapid Development Period (2009–2015)

At this stage, high-frequency keywords increased sharply, the relationships between words became more complex, and research on soil security in farmlands and grasslands entered a stage of rapid development (Figure 6). The high-frequency keywords at this stage were food security (133 times, centrality = 1.77), management (74 times, centrality = 2.22), climate change (54 times, centrality = 1.28), soil (48 times, centrality = 1.01), water (46 times, centrality = 0.81), and agriculture (45 times, centrality = 1.87). Thus, with an emphasis on farmland and grassland resources, the research content in soil security was gradually enriched, excluding the development and utilization of farmland and grassland soil [27,28]. Research was performed on development situations [29], strategic countermeasures [30,31], index measurements, and empirical assessments [32,33]. Leroy et al. [34] identified nine indicators and grouped them into three broad categories to assess food access at the household and individual levels. Norse et al. [35] noted that distorted policies designed to boost food self-sufficiency damaged the environment. Brulle et al. [36] used the Stimson method to construct aggregate opinion measures and applied data from 74 separate surveys over a 9-year period to construct quarterly measures of public concern over global climate change. Meanwhile, studies on sustainability development and land use-based energy yield also appeared in this stage, which indicated that researchers began to pay attention to sustainable development [37,38], the efficient use of farmland [39–41], and basic research on soil security.

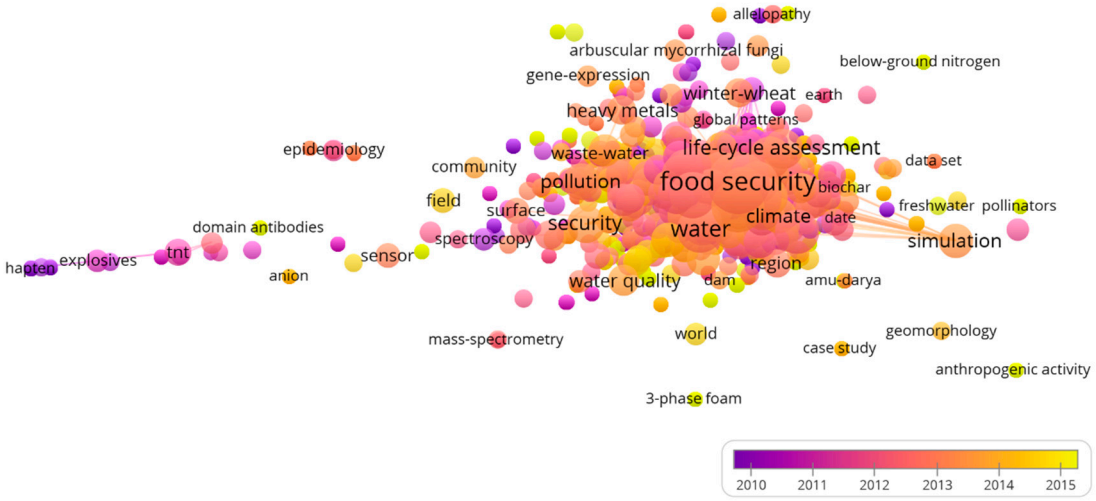

Figure 6. Co-keyword network in soil security assessment research from 2009 to 2015.

3.2.3. Comprehensive Development Period (2016–2023)

From 2016 to 2023, the relevant research direction on soil security in farmlands and grasslands was more diversified and the research content was more focused (Figure 7). The high-frequency keywords in this stage were food security (473 times, centrality = 0.96), management (282 times, centrality = 0.78), soil (254 times, centrality = 0.86), and climate change (244 times, centrality = 1.03). These results showed that, although soil security research in farmland and grassland represented an extension of the previous two stages, the research topics were more prominent in monitoring method, the evolution law of cultivated land, and factors that influence cultivated land quality [42,43]. Wu et al. [44] proposed a method for monitoring cropland retirement using Landsat images and time series sub-sequences of cropland probabilities. Wang et al. [45] presented a newly developed distributed land use change prediction model for the high-precision prediction of land use change based on a comprehensive depiction of future cropland N_2O emissions on a national scale, which provided an opportunity to elucidate how the changes in cropland area affected the magnitude and spatial distribution of N_2O emissions from China's croplands from 2020 to 2070. Li et al. [46] applied a linear regression method to analyze the inter-annual variation trend of soil water content in the source region of the Yangtze River from 2011 to 2021 and used the *t*-test to analyze the correlation between the changes in average temperature and precipitation and the changes of soil water content in the source region of the Yangtze River from 2011 to 2021.

3.3. Keyword Co-Occurrence Network and Topic Mining

Excel software 2020 was used to calculate the frequency of keywords in publications related to soil security assessments in farmlands and grasslands from 1979 to 2023. The top 30 high-frequency keywords were summarized (Table 4), and they represent the research hotspots.

Based on the keyword frequency statistics, keyword collinear graphs (Figure 8), and cluster analysis, thematic relationships among research hotspots were analyzed. By combining the synonyms of the graph and screening the information, the popular topics in the field of soil security assessments of farmlands and grasslands were summarized, and they included land development and utilization, security of industrial and supply chains, ecological security, and ecosystem service value. The keywords changed over time. For example, from 1979 to 2008, they focused on the environment and mercury; from 2009 to 2015, they focused on energy and emissions; and, from 2009 to 2013, they focused on heavy metals and ecosystem services.

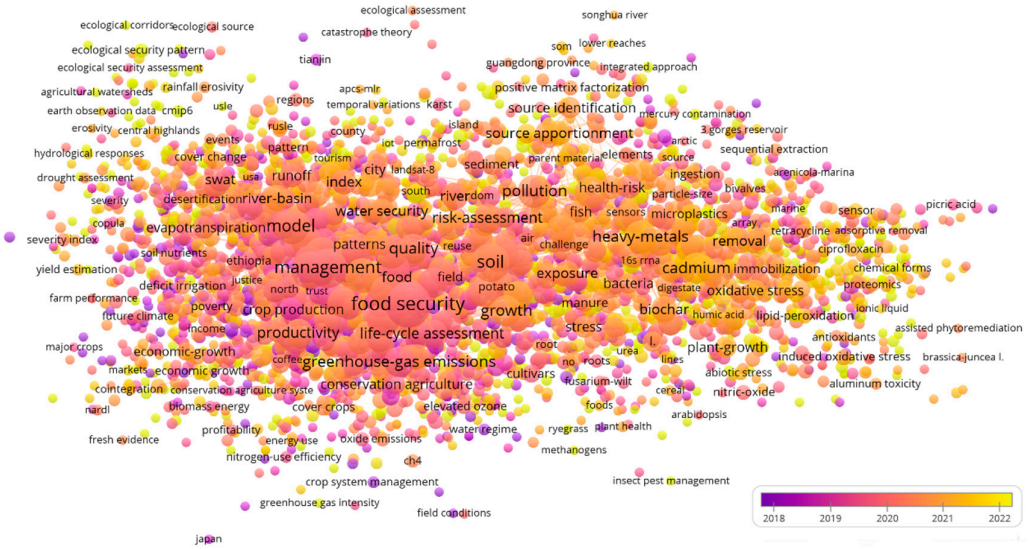

Figure 7. Co-keyword network in soil security assessment research from 2016 to 2023.

Table 4. Statistics on the high-frequency keywords in soil security assessment research.

Ranking	Keyword	Frequency	Ranking	Keyword	Frequency
1	food security	618	16	systems	146
2	climate change	534	17	land-use	144
3	impact	427	18	ecosystem services	135
4	management	367	19	growth	135
5	soil	308	20	quality	133
6	agriculture	267	21	nitrogen	131
7	water	260	22	cadmium	128
8	model	218	23	greenhouse-gas emissions	127
9	yield	188	24	accumulation	124
10	China	180	25	life-cycle assessment	122
11	pollution	176	26	rice	117
12	security	176	27	maize	112
13	heavy metals	165	28	irrigation	111
14	sustainability	165	29	productivity	111
15	contamination	152	30	wheat	109

3.3.1. Land Development and Utilization

The high-frequency keywords (frequency) in this section primarily included soil (308), land use (144), agriculture (267), and irrigation (111). This indicates that the research hotspots for soil security assessments of farmlands and grasslands were concentrated on land development and utilization. Such research investigated land resource development practices under different resource conditions at home and abroad [47–49], spatiotemporal characteristics, green development, ecological risk analysis [50–52], and utilization efficiency and cost-benefit analyses [53–55]. He et al. [56] conducted a spatiotemporal analysis of land development and utilization intensity in the Tampa Bay watershed from 1985 to 2015. Huang et al. [57] discussed the feasibility of achieving carbon neutrality in China by 2060 and the carbon sink distribution carried by different land use modes based on the prediction of anthropogenic carbon emissions and terrestrial ecosystem carbon sinks by the intelligent prediction and association tool model. Yanbo et al. [58] pointed out that territorial spatial planning mediation for potential land utilization conflicts represented a scientific choice to achieve high-quality regional development and was of great significance in guiding the national space utilization mode. Zheng et al. [59] explored the interactions between economic development and land-intensive utilization using dynamic econometrics based on measuring the degree of economic development and land-intensive

utilization; they found that both economic development and land-intensive utilization were integrated of one order. The response of land-intensive utilization to the economic development impulse was remarkable, and the economic development impulse explained 85% of land-intensive utilization changes.

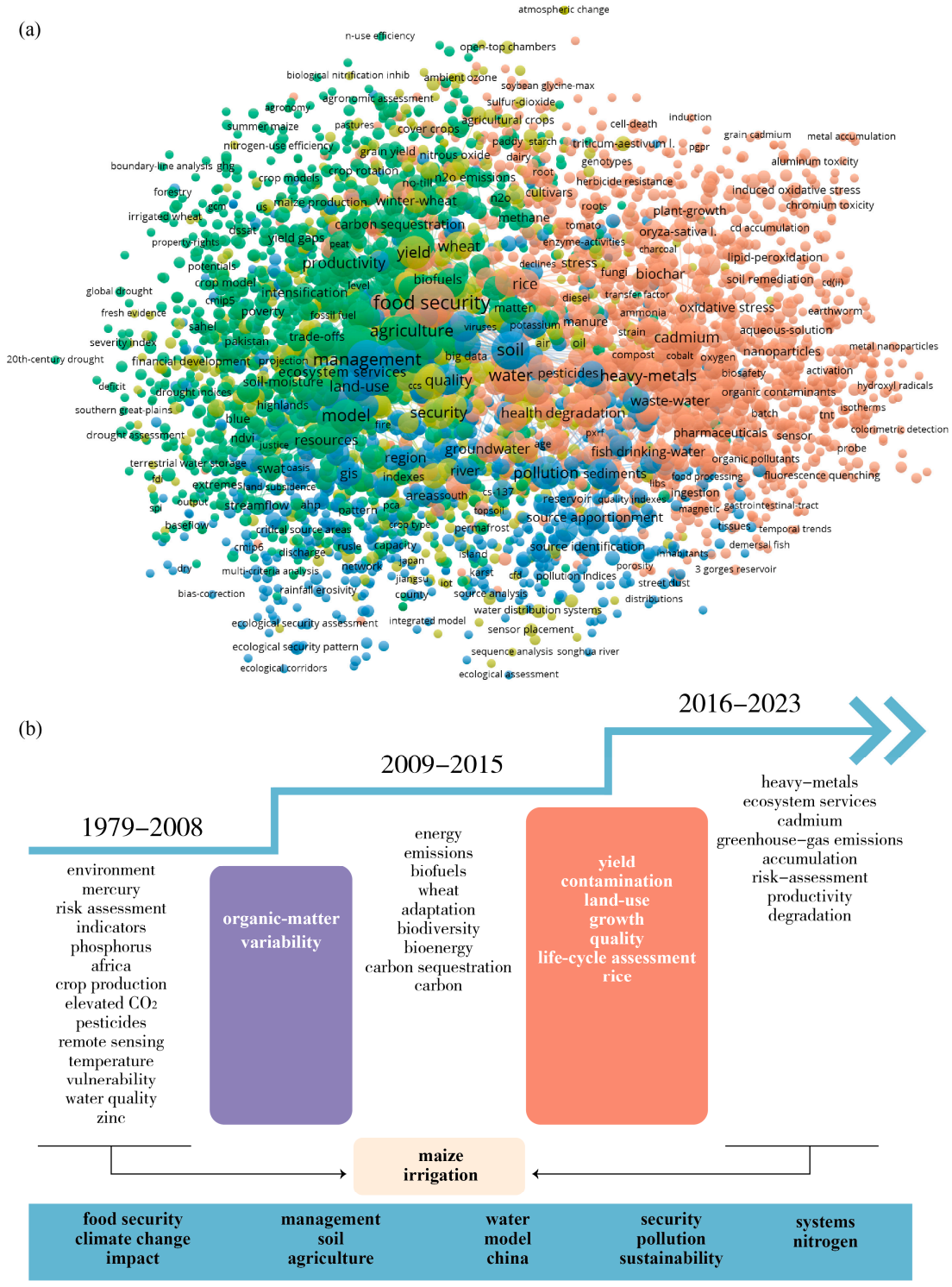

Figure 8. (**a**) Co-keyword network of soil security assessment research from 1979 to 2023; and (**b**) keyword change map from 1979 to 2023. The green cluster represents land development and utilization, the yellow cluster represents security of industrial and supply chains, the brown cluster represents ecological security, and the blue cluster represents ecosystem service value.

3.3.2. Security of the Industrial and Supply Chains

The security of industrial and supply chains is assessed based on the use of an optimization analysis of the supply chain to investigate the entire industrial chain. The high-frequency keywords (frequency) in this section primarily included food security (618), management (367), security (176), pollution (176), and quality (133). With the current high-quality development of agriculture and animal husbandry, the requirement for soil security assessments of farmlands and grasslands is increasing. Coupled with the changing world pattern and the tightening constraints on domestic soil and water resources, the soil security situation is grim, and the robustness of the supply chain system requires urgent improvement. Associated research focuses on current risk analyses, promotion strategies [60], and development effects [61]. Among research focused on status quo risk and judgment, Rossetto et al. [62] analyzed sustainability in the sugarcane supply chain in Brazil and pointed out issues and methods for advancement. In addition, Romeiko and Bianchi et al. [63,64] analyzed the spatially and temporally explicit life cycle environmental impacts of soybean production and performed a life cycle comparison of environmental analyses along the supply chains of dark, milk, and white chocolate, respectively. Among research investigating advancement strategies, Gordillo et al. [65] proposed an agricultural solution for a product supply chain using blockchain. In addition, Pastorelli et al. [66] noted that the digestate from biogas production can be recycled into the soil as a conditioner or fertilizer, which can improve the environmental sustainability of the energy supply chain. Pelletier et al. [67] highlighted the complex relationships among energy use in food systems, food system productivity, and energy resource constraints and revealed the key drivers and trends in food system energy use along with opportunities and constraints on improved efficiency. Among research on development effectiveness, Nuhu et al. [68] used fixed effects and instrumental variable estimators to address the endogeneity of smallholder crop sale decisions and estimated the smallholder welfare effects of non-formal contract midstream activities in Zambia's soybean value chain, and the results suggested that the recent expansion of the soybean industry in Zambia benefited smallholder farmers but was not necessarily sufficient to move the smallest of these farmers out of poverty. Fu et al. [69] proposed and empirically examined a model using survey data from 78 agricultural companies and 321 peasant households in China and showed that different types of power have different effects on contract farming. In particular, non-economic power significantly and positively affected supply chain integration, and the impact on process co-ordination was greater than that on information sharing. Sharma et al. [70] examined the direct effects of Industry 4.0 technology capabilities (I4TCs) and supply chain integration (SCI) on sustainable agricultural supply chain performance (SASCP) based on data collected from 262 food processing organizations in India. Their findings highlight the noteworthy impact of I4TC on SASCP and verify the presence of SCI as a partially mediating variable.

3.3.3. Ecological Security

Ecological security reflects the health and integrity of an ecosystem and guarantees the protection of human production and life from ecological damage and environmental pollution. Protecting the integrity of ecosystem functions and providing ecological benefits are of great significance [71]. Ecological security assessments are performed to support ecological protection and analyze the development level and existing problems of ecological security by constructing qualitative and quantitative models. The high-frequency keywords (frequency) in this section primarily include impact (427), model (218), systems (146), and life cycle assessment (122). Existing research primarily focuses on agricultural production, water environment [72–75], and ecological landscape. The analysis methods include the structural equation method, improved analytic hierarchy process [76], energy analysis [77], and entropy weight fuzzy comprehensive evaluation [78]. Zhang et al. [79] used a structural equation model to empirically study the action law of each influencing factor and the mechanisms underlying the associated interest linkage based on 358 research data samples from participants in the green supply chain of grassland livestock products in the Inner

Mongolia Autonomous Region. Ouyang et al. [80] estimated the nutrient delivery ratio and habit quality of the Naoli River in 2000, 2006, and 2014 based on the SWAT model and the integrated valuation of ecosystem services and tradeoffs (InVEST) model and obtained the response of N and P loads and habit quality to spatial and temporal variation. Song et al. [81] constructed an evaluation index system of landscape ecological security to analyze the landscape ecological security level and its spatiotemporal distribution pattern in Beijing City from 1988 to 2004, and the results showed that the landscape ecological security index was at a moderate level, with the above parameters presenting average values of 0.410 and 0.403, respectively. Wang et al. [82] investigated the mechanisms and methodologies for regional ecological security assessments from the perspective of disasters based on the pressure-state-response (P-S-R) mechanism. Wang [83] and Wang et al. [84] developed ecological security assessment models to evaluate the ecological security of the Huaihe River in Anhui Province and the Daling River watershed in West Liaoning Province, respectively.

3.3.4. Ecosystem Service Value

Ecosystem service value is a quantitative estimation of ecosystem service capacity, and it plays an important role in spatial planning, ecological regulation, and ecological restoration [85]. Presently, ecosystem services are primarily measured by material quality and value quantity. Material quality refers to the flow of materials generated by ecosystem processes or functions that can improve human welfare, and value quantity refers to the monetary value of an ecosystem. The high-frequency keywords (frequency) in this section primarily included climate change (534), China (180), greenhouse gas emissions (127), and accumulation (124). Previous studies on ecosystem service value have primarily focused on spatiotemporal evolution [86,87], driving factors [88,89], evolution mechanism [90], value prediction, and compensation strategies [91]. Deng et al. [92] used the ecological service value equivalent factor method, grid method, and exploratory spatial data analysis to discuss the spatial distribution and evolution of the ecosystem service value before and after the implementation of the Grain for Green Project (GGP) and determine the impacts of the GGP on the ecosystem service value based on land use data for northern Shaanxi from 1990, 2000, and 2015. Jiang et al. [93] evaluated the ecosystem service value of 24 towns in Anxi County from 1999 to 2019 using the adjustment coefficients of biomass factors and socioeconomic factors to modify the traditional ecosystem service valuation model. Li et al. [94] explored the tradeoffs and synergies between ecosystem services using Pearson's correlation and spatial autocorrelation analyses for multiple scenarios in 2025, and the results showed that the pattern of land use changed significantly. In addition, Ding et al. [95] analyzed land use change situations and introduced assessment and scoring theories to study dynamic changes in ecosystem services.

3.4. Current Methods for Soil Security Assessment

Soil security is an important basis for the development of green and low-carbon agriculture and animal husbandry, and scientific and systematic evaluations of soil health levels must be performed to promote the high-quality development of agriculture. This study presents an index system and evaluation model for soil security to provide a reference for further research on soil security evaluation.

3.4.1. Index System

For evaluation indicators related to the soil security of farmlands and grasslands, the selected indicators and their application ranges differ from study to study, and most are related to a specific spatial scale [96] or land use mode. Different spatial scales or evaluation objects have different evaluation criteria, and their evaluation methods differ significantly. In general, an indicator reflects the spatial conditions and changes in soil security in farmland and grassland at national and provincial scales. Areas in which cultivated soil health is limited or vulnerable are characterized, and optimization and

conservation strategies are studied. At the county scale, the overall status and spatial variation of cultivated soil security under different planting systems and intensity levels have been discussed, and soil security management and protection strategies for farmland and grassland have been proposed [86]. At the field scale, the factors limiting soil security have been identified according to different land management situations, and a management model for maintaining soil security in farmlands and grasslands has been established [92].

In terms of evaluation indicators, the index type primarily includes soil survey data and distributed sampling tests. Considering the low availability of soil quantity data at large spatial scales and the minimal dataset indicator filtering, the number of indicators selected in the empirical study ranged from 1 to 12 [97–100], more than half of which had fewer than seven index types. Therefore, 6–12 indexes can achieve a comprehensive evaluation of soil security at different scales, and certain commonalities are observed among the core evaluation indexes. The associated data were obtained from a soil database and a soil map.

3.4.2. Evaluation Model

The connotations of soil quality are complicated, and existing evaluation models primarily provide comprehensive evaluations of factors such as accumulation, accumulation and multiplication, and empirical function types. The cumulative method is the most widely used and refers to the average summation of relatively independent evaluation index data or weighted summation after weighting various approaches, such as the Delphi method, analytic hierarchy process, and principal component analysis, to obtain comprehensive evaluation results. In the continuous multiplication method, a relatively independent index value is continuously multiplied, and the final result is considered the result of the comprehensive evaluation. This method is suitable for situations with fewer evaluation indicators, and the evaluation results show a distinct differentiation. The accumulative and multiplicative methods divide the evaluation indicators into several groups using the accumulative type within the group and the continuous multiplicative type between the groups to obtain comprehensive evaluation results. This method is suitable for situations in which the evaluation objectives are relatively complex. The empirical function method has been utilized to obtain comprehensive evaluation results using the validated evaluation index mapping function and input index values. This method is suitable for a single evaluation target, and the evaluation results are more reliable.

Typical studies on soil security assessments in farmlands and grasslands and the different analytical dimensions are listed in Table 5.

Table 5. Canonical research on soil security assessments.

Nation	Area	Goal	Indicator	Model	Reference
Germany, Russia, China	Soil of cultivated and grassland	Crop potential	Basic index, soil matrix, topsoil structure, biological activity, and so on. Risk indicators, rock depth, coarse particulate matter content, drought, and so on	Type of synthesis: accumulation multiplicative	[101]
Italy	Soil for all land use types	Characterization of resistance to desertification and drought	Soil layer thickness, texture, parent material, slope	Type of synthesis: tandem	[99]
Rahul Valley, northwest Himalaya	Soil for all land use types	Evaluation of agricultural application value of night soil compost	Fertility and heavy metal parameters determine fertility and cleanliness indicators	-	[102]

Table 5. *Cont.*

Nation	Area	Goal	Indicator	Model	Reference
China	Plowland	Investigation of the distribution characteristics of As content in dry soil and maize seed in Guizhou Province	Content and basic physicochemical properties of As	Single factor pollution index method	[103]
China	Garden, woodland, etc.	Soil safety evaluation	Cadmium, mercury, arsenic (metal-like), lead, chromium, and other heavy metals	Nemerow pollution index method	[104]
Ukraine	Agricultural activities and arable land	Soil organic carbon loss and soil degradation	Land productivity, soil organic matter content, land use type	Geographic information model	[105]
China	Dry land, paddy fields, vegetable fields, tea gardens, orchards, Chinese medicine fields and tobacco fields	Spatial distribution of mercury (Hg) concentration in agricultural soil and its food safety risk assessment	Mercury concentration	-	[106]
China	Facility agricultural land	Environmental quality of soil heavy metals	Cd, Hg, As, Pb, Cr, Cu, Ni, and Zn contents	Single factor pollution index method and Nemerow index method	[107]
China	Dry red soil	Responses of different soil health to long-term inorganic and organic fertilization management	Twenty soil physical, chemical and biological indicators, with copper, zinc, cadmium, lead as four heavy metal indicators	-	[108]
China	Facility agricultural land	Assessing the risk of heavy metals in soil and vegetables in plastic sheds	Cd, Cr, Cu, Zn, Ni, Pb, and As contents	DTPA extraction and DGT extraction	[109]
China	Ferrallitic soil	Soil fertility	Organic matter, total nitrogen, total phosphorus, available phosphorus, pH, cation exchange capacity, clay content, etc.	Synthesis: accumulation multiplicative type	[110]
China	Cultivated soil	Ecological health status of high-yield farmland	Bulk density, water retention, texture, aggregate, microorganisms, soil layer thickness, REDOX potential, total nitrogen, etc.	-	[111]

4. Conclusions

In the present study, we analyzed 3618 Chinese and foreign periodical studies with "soil security" as the research object from the WOS core database. Using VOSviewer software, a bibliometric method was used to analyze publication number, publication institutions, keywords, topic clustering, and research hotspots in the field of "soil security assessment". The main findings were as follows:

(1) Research on the soil security assessment of farmlands and grasslands started in 1979, and the number of papers presented three stages: germination, start-up, and rapid development. The countries with the largest number of published papers were China and India, and the remaining eight in the top 10 were powerful agricultural countries, indicating that the level of agricultural development plays a significant role in promoting soil security research. A total of 1381 research institutions performed soil security assessments of farmlands and grasslands. The Chinese Academy of Sciences, University of Chinese Academy of Sciences, and China Agricultural University were the top three institutions, with 306, 108, and 88 publications, respectively. Science of The total Environment was the journal with the highest number of publications at 247.

(2) According to the time sequence of the keywords, the research frontier of soil security assessments in farmlands and grasslands can be divided into three stages. During the initial exploratory period (1979–2008), the keywords were agriculture, food security, and management, and the relevant research focused on resource development and management. During the rapid development period (2009–2015), the keywords were climate change, soil, water, and sustainability, and the relevant research focused on sustainable development and the efficient use of farmland. During the comprehensive development period (2016–2023), the keywords included impact and model, and the relevant research focused on the assessment, measurement, and evolution of cultivated land.

(3) Research on soil security assessments of farmlands and grasslands at home and abroad primarily focused on four aspects: land development and utilization, security of industrial and supply chains, ecological security, and ecosystem service value. The keywords in the field of land development and utilization were soil, land use, and agriculture, and the research focused on the rational development and efficient use of land. The keywords in the field of industrial and supply chain security were food security, management, and security, and the research focused on risk assessment and promotion strategies. The keywords in the field of ecological security were impact, model, and systems, and the research focused on ecological security assessments of agricultural production and the water environment. The keywords in the field of ecosystem service value were climate change, China, and greenhouse gas emissions, and the research focused on spatiotemporal evolution and driving factors, evolution mechanisms, value predictions, and compensation strategies. At present, there is an urgent need to conduct soil security assessment models based on regional development, soil biology, spatial metrology, and other parameters, to establish an index system, and to analyze the evolution rules of soil security at different scales and investigate the scale effect of soil quality evaluations.

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References

1. Zhao, F.K.; Yang, L.; Chen, L.D.; Li, G.; Sun, L.; Li, S.J. Soil security in peri-urban ecosystems: Problems and challenges. *Acta Ecol. Sin.* **2018**, *12*, 4109–4120.
2. Si, S.C.; Wu, Y.C.; Li, Y.; Tu, C.; Fu, C.C.; Luo, Y.M. The current research progress and prospects of cultivated and grassland soil health: A Review. *Acta Pedol. Sin.* **2022**, *3*, 625–642.
3. Mausel, P.W. Soil quality in illinois-an example of a soils geography resource analysis. *Prof. Geogr.* **1971**, *2*, 127–136. [CrossRef]
4. Zhang, D.D.; Sheng, H.; Xiao, H.C.; Yin, Z.R.; He, Y.R.; Zhou, P. Assessment methods of soil health and their applications. *Soils Crops* **2023**, *1*, 109–116.
5. Kahl, J.; Baars, T.; Bügel, S.; Busscher, N.; Huber, M.; Kusche, D.; Rembiałkowska, E.; Schmid, O.; Seidel, K.; Taupier-Letage, B.; et al. Organic food quality: A framework for concept, definition and evaluation from the European perspective. *J. Sci. Food Agric.* **2012**, *14*, 2760–2765. [CrossRef]
6. Maharjan, B.; Das, S.; Acharya, B.S. Soil Health Gap: A concept to establish a benchmark for soil health management. *Glob. Ecol. Conserv.* **2020**, *23*, e01116. [CrossRef]
7. Wu, K.N.; Yang, Q.J.; Zhao, R. A discussion on soil health assessment of arable land in China. *Acta Pedol. Sin.* **2021**, *3*, 537–544.
8. Peng, X. China's demographic history and future challenges. *Science* **2011**, *6042*, 581–587. [CrossRef]
9. Xue, R.; Wang, C.; Liu, M.; Zhang, D.; Li, K.; Li, N. A new method for soil health assessment based on analytic hierarchy process and meta-analysis. *Sci. Total Environ.* **2019**, *2*, 2771–2777. [CrossRef]
10. Stephan, P.; Veugelers, R.; Wang, J. Blinkered by bibliometrics. *Nature* **2017**, *7651*, 411. [CrossRef]
11. Hicks, D.; Wouters, P.; Waltman, L.; de Rijcke, S.; Rafols, I. Bibliometrics: The leiden manifesto for research metrics. *Nature* **2015**, *7548*, 429–431. [CrossRef] [PubMed]
12. Bhatt, Y.; Ghuman, K.; Dhir, A. Sustainable manufacturing. Bibliometrics and content analysis. *J. Clean. Prod.* **2020**, *260*, 120988. [CrossRef]
13. Haunschild, R.; Bornmann, L.; Marx, W. Climate change research in view of bibliometrics. *PLoS ONE* **2016**, *7*, e0160393. [CrossRef] [PubMed]
14. Ding, X.; Yang, Z. Knowledge mapping of platform research: A visual analysis using VOSviewer and CiteSpace. *Electron. Commer. Res. Appl.* **2022**, *3*, 787–809. [CrossRef]
15. Qi, S.; Hua, F.; Xu, S.; Zhou, Z.; Liu, F. Trends of global health literacy research (1995–2020): Analysis of mapping knowledge domains based on citation data mining. *PLoS ONE* **2021**, *8*, e0254988. [CrossRef] [PubMed]
16. van Eck, N.J.; Waltman, L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics* **2017**, *2*, 1053–1070. [CrossRef]
17. Kuzior, A.; Sira, M. A bibliometric analysis of blockchain technology research using VOSviewer. *Sustainability* **2022**, *13*, 8206. [CrossRef]
18. Li, B.; Hu, K.; Lysenko, V.; Khan, K.Y.; Wang, Y.; Jiang, Y.; Guo, Y. A scientometric analysis of agricultural pollution by using bibliometric software VoSViewer and histcite. *Environ. Sci. Pollut. Res.* **2022**, *25*, 37882–37893. [CrossRef]
19. van Eck, N.J.; Waltman, L. VOS: A new method for visualizing similarities between objects. In *Advances in Data Analysis: Proceedings of the 30th Annual Conference of the Gesellschaft für Klassifikation eV, Freie Universität Berlin, 8–10 March 2006*; Springer: Berlin/Heidelberg, Germany, 2006; pp. 299–306.
20. Jing, X.D.; Tian, G.L.; Ban, Q.Q.; Hu, H.; Zhang, Y.N. Research status and development trend of ecosystem services in China since the 21st century based on bibliometrics. *Acta Ecol. Sin.* **2023**, *17*, 7341–7351.
21. Wei, H.K.; Cui, K. The connotation characteristics, construction foundation and promotion strategy of agricultural power. *Reform* **2022**, *12*, 1–11.
22. Okazaki, S.I.; Okuda, M.; Sakurai, T. Evaluation of weed species as Tomato spotted wilt virus (Bunyaviridae: Tospovirus) acquisition sources for *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Jpn. J. Appl. Entomol. Zool.* **2009**, *4*, 181–184. [CrossRef]
23. Rounsevell, M.D.A.; Annetts, J.E.; Audsley, E.; Mayr, T.; Reginster, I. Modelling the spatial distribution of agricultural land use at the regional scale. *Agric. Ecosyst. Environ.* **2003**, *2*, 465–479. [CrossRef]
24. Lotze-Campen, H.; Müller, C.; Bondeau, A.; Rost, S.; Popp, A.; Lucht, W. Global food demand, productivity growth, and the scarcity of land and water resources: A spatially explicit mathematical programming approach. *Agric. Econ.* **2008**, *3*, 325–338. [CrossRef]
25. Marsden, T.; Sonnino, R. Rural development and the regional state: Denying multifunctional agriculture in the UK. *J. Rural Stud.* **2008**, *4*, 422–431. [CrossRef]
26. Fiala, N. Meeting the demand: An estimation of potential future greenhouse gas emissions from meat production. *Ecol. Econ.* **2008**, *3*, 412–419. [CrossRef]
27. Day, L. Proteins from land plants: Potential resources for human nutrition and food security. *Trends Food Sci. Technol.* **2013**, *1*, 25–42. [CrossRef]
28. Rumpel, C.; Kögel-Knabner, I. Deep soil organic matter: A key but poorly understood component of terrestrial C cycle. *Plant Soil* **2011**, *1/2*, 143–158. [CrossRef]
29. Nordhaus, W. Climate change: The ultimate challenge for economics. *Am. Econ. Rev.* **2019**, *6*, 1991–2014. [CrossRef]

30. Di Falco, S.; Veronesi, M.; Yesuf, M. Does adaptation to climate change provide food security? A micro: Perspective from ethiopia. *Am. J. Agric. Econ.* **2011**, *3*, 829–846.
31. Martin, K.S.; Rong, W.U.; Wolff, M.; Colantonio, A.G.; Grady, J. A novel food pantry program: Food security, self-sufficiency, and diet-quality outcomes. *Am. J. Prev. Med.* **2013**, *5*, 569–575. [CrossRef]
32. Reth, S.; Reichstein, M.; Falge, E. effect of soil water content, soil temperature, soil pH-value and the root mass on soil CO_2 efflux: A modified model. *Plant Soil* **2005**, *1–2*, 21–33. [CrossRef]
33. Knox, S.H.; Sturtevant, C.; Matthes, J.H.; Koteen, L.; Verfaillie, J.; Baldocchi, D. Agricultural peatland restoration: Effects of land-use change on greenhouse gas (CO_2 and CH_4) fluxes in the sacramento: San joaquin delta. *Glob. Chang. Biol.* **2015**, *2*, 750–765. [CrossRef] [PubMed]
34. Leroy, J.L.; Ruel, M.; Frongillo, E.A.; Harris, J.; Ballard, T.J. Measuring the food access dimension of food security: A critical review and mapping of indicators. *Food Nutr. Bull.* **2015**, *2*, 167–195. [CrossRef] [PubMed]
35. Norse, D.; Ju, X. Environmental costs of China's food security. *Agric. Ecosyst. Environ.* **2015**, *209*, 5–14. [CrossRef]
36. Brulle, R.J.; Carmichael, J.; Jenkins, J.C. Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the U.S., 2002–2010. *Clim. Chang.* **2012**, *2*, 169–188.
37. Don, A.; Schumacher, J.; Freibauer, A. Impact of tropical land-use change on soil organic carbon stocks: A meta-analysis. *Glob. Chang. Biol.* **2011**, *4*, 1658–1670. [CrossRef]
38. Meneses, B.M.; Reis, R.; Vale, M.J.; Saraiva, R. Land use and land cover changes in Zêzere watershed (Portugal): Water quality implications. *Sci. Total Environ.* **2015**, *527*, 439–447. [CrossRef] [PubMed]
39. Hurtt, G.C.; Chini, L.P.; Frolking, S.; Betts, R.A.; Feddema, J.; Fischer, G.; Fisk, J.P.; Hibbard, K.; Houghton, R.A.; Janetos, A.; et al. Harmonization of land-use scenarios for the period 1500–2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands. *Clim. Chang.* **2011**, *1–2*, 117–161. [CrossRef]
40. Hurtt, G.C.; Frolking, S.; Fearon, M.G.; Moore, B.; Shevliakova, E.; Malyshev, S.; Pacala, S.W.; Houghton, R.A. The underpinnings of land-use history: Three centuries of global gridded land-use transitions, wood-harvest activity, and resulting secondary lands. *Glob. Chang. Biol.* **2006**, *7*, 1208–1229. [CrossRef]
41. Schmitz, C.; van Meijl, H.; Kyle, P.; Nelson, G.C.; Fujimori, S.; Gurgel, A.; Havlik, P.; Heyhoe, E.; Mason d'Croz, D.; Popp, A.; et al. Land-use change trajectories up to 2050: Insights from a global agro-economic model comparison. *Agric. Econ.* **2014**, *1*, 69–84. [CrossRef]
42. Li, H.; Dai, M.; Dai, S.; Dong, X. Current status and environment impact of direct straw return in China's cropland: A review. *Ecotoxicol. Environ. Saf.* **2018**, *15*, 293–300. [CrossRef] [PubMed]
43. Hao, J.Y.; Wan, Y.; Yao, X.H.; Zhao, W.G.; Hu, R.Z.; Chen, C.; Li, L.; Zhang, D.-Y.; Wu, G.-H. Effect of different planting areas on the chemical compositions and hypoglycemic and antioxidant activities of mulberry leaf extracts in Southern China. *PLoS ONE* **2018**, *6*, e0198072. [CrossRef] [PubMed]
44. Wu, W.; Li, P. A method for monitoring cropland retirement using landsat images and time series subsequence of cropland probability. *Peking Univ.* **2022**, *2*, 271–281.
45. Wang, Q.; Liu, R.; Zhou, F.; Huang, J.; Jiao, L.; Li, L.; Wang, Y.; Cao, L.; Xia, X. A Declining trend in China's future cropland-N_2O emissions due to reduced cropland area. *Environ. Sci. Technol.* **2021**, *21*, 14546–14555. [CrossRef] [PubMed]
46. Li, J.M.; Shanren, Q.; Yang, Y.; Qi, X.J.; Ha, Y.J.; Wang, Y.X.; He, Y.; Li, Y.J.; Lu, S.J. Effects of climate change on soil moisture in the source region of the Yangtze River. *J. Yunnan Univ.* **2022**, *44*, 775–784.
47. Wang, X.; Peng, L.; Su, C.; Xu, D.; Chen, T. Development and utilization of low-slope hilly land resources based on a landscape security pattern theory: A case study in Luxian County, Sichuan Province. *Acta Ecol. Sin.* **2016**, *12*, 3646–3654.
48. Jiang, W.; Zeng, Z.; Zhang, Z.; Zhao, Y. Regulation and optimization of urban water and land resources utilization for low carbon development: A case study of Tianjin, China. *Sustainability* **2022**, *5*, 2760. [CrossRef]
49. Marthen Pasang, S.; Edwen Donald, W.; Andriko Noto, S. Land suitability and proposed land utilization of Selaru Island, West Southeast Moluccas Regency for development food crops. *J. Tanah Trop. Dan Kualitas Lingkung.* **2016**, *3*, 187–196.
50. Wei, F.; Liu, J.; Xia, L.; Long, X.; Xu, Z. Landscape ecological risk assessment in Weibei dryland region of Shaanxi Province based on LUCC. *China Environ. Sci.* **2022**, *4*, 1963.
51. Yang, B.; Wang, Z.; Zou, L.; Zou, L.; Zhang, H. Exploring the eco-efficiency of cultivated land utilization and its influencing factors in China's Yangtze River Economic Belt, 2001–2018. *J. Environ. Manag.* **2021**, *294*, 112939. [CrossRef]
52. Zhang, Y.; Dai, Y.; Chen, Y.; Ke, X. Coupling coordination development of new-type urbanization and cultivated land low-carbon utilization in the Yangtze River Delta, China. *Land* **2022**, *6*, 919. [CrossRef]
53. He, P. Multi-index cost-benefit model to assess land development costs. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *3*, 32018. [CrossRef]
54. Liu, J.; Jin, X.; Xu, W.; Fan, Y.; Ren, J.; Zhang, X.; Zhou, Y. Spatial coupling differentiation and development zoning trade-off of land space utilization efficiency in eastern China. *Land Use Policy* **2019**, *85*, 310–327. [CrossRef]
55. Miao, J.; Lu, Q. An empirical study on the potential of land resources utilization in urban agglomeration development zones based on combination analysis. *Earth Sci. Res. J.* **2020**, *4*, 439–447. [CrossRef]
56. He, G.; Li, J.; Liu, Y.; Shi, X.; Ma, J.; Pu, R.; Guo, Q.; Feng, B.; Huang, R. Spatio-temporal analysis of land development and utilization intensity in Tampa Bay watershed from 1985 to 2015. *J. Nat. Resour.* **2019**, *1*, 66. [CrossRef]
57. Huang, X.J.; Zhang, X.Y.; Lu, X.H.; Wang, P.Y.; Qin, J.Y.; Jiang, Y.C.; Liu, Z.M.; Wang, Z.; Zhu, A.X. Land development and utilization for carbon neutralization. *Nat. Resour.* **2021**, *12*, 2995. [CrossRef]

58. Qu, Y.; Wang, S.; Tian, Y.; Jiang, G.; Zhou, T.; Meng, L. Territorial spatial planning for regional high-quality development: An analytical framework for the identification, mediation and transmission of potential land utilization conflicts in the Yellow River Delta. *Land Use Policy* **2023**, *125*, 106462. [CrossRef]
59. Zheng, H.W.; Zhang, R.; Zhang, J.F.; Liu, Y.Z. Dynamic econometric analysis of the relationship between land intensive utilization and economic development in jiangsu province. *Resour. Environ. Yangtze Basin* **2012**, *4*, 412–418.
60. Yu, L.; Sun, J.; Liu, W.; Zhang, W.; Sun, L.; Wu, J. Policy analysis of biomass recycling supply chain considering carbon and pollution emission reduction—Taking China's straw subsidy policy for example. *Systems* **2023**, *7*, 343. [CrossRef]
61. Shirzadi, S.; Ghezavati, V.; Tavakkoli-Moghaddam, R.; Ebrahimnejad, S. Developing a green and bipolar fuzzy inventory-routing model in agri-food reverse logistics with postharvest behavior. *Environ. Sci. Pollut. Res.* **2021**, *30*, 41071–41088. [CrossRef]
62. Rossetto, R.; Ramos, N.P.; de Matos Pires, R.C.; Xavier, M.A.; Cantarella, H.; Guimarães de Andrade Landell, M. Sustainability in sugarcane supply Chain in Brazil: Issues and way forward. *Sugar Tech* **2022**, *3*, 941–966. [CrossRef]
63. Romeiko, X.X.; Lee, E.K.; Sorunmu, Y.; Zhang, X. Spatially and temporally explicit life cycle environmental impacts of soybean production in the U.S. midwest. *Environ. Sci. Technol.* **2020**, *8*, 4758–4768. [CrossRef] [PubMed]
64. Bianchi, F.R.; Moreschi, L.; Gallo, M.; Vesce, E.; Del Borghi, A. Environmental analysis along the supply chain of dark, milk and white chocolate: A life cycle comparison. *Int. J. Life Cycle Assess* **2021**, *4*, 807–821. [CrossRef]
65. Kevin Gordillo, O.; Paulo Alonso, G.-G.; Carlos Enrique Montenegro, M. Towards an agriculture solution for product supply chain using blockchain: Case study Agro-chain with BigchainDB. *Acta Agric. Scand. Sect. B Soil Plant Sci.* **2021**, *1*, 1–16.
66. Pastorelli, R.; Valboa, G.; Lagomarsino, A.; Fabiani, A.; Simoncini, S.; Zaghi, M.; Vignozzi, N. Recycling biogas digestate from energy crops: Effects on soil properties and crop productivity. *Appl. Sci.* **2021**, *2*, 750. [CrossRef]
67. Pelletier, N.; Audsley, E.; Brodt, S.; Garnett, T.; Henriksson, P.; Kendall, A.; Kramer, K.J.; Murphy, D.; Nemecek, T.; Troell, M. Energy intensity of agriculture and food systems. *Annu. Rev. Environ. Resour.* **2011**, *1*, 223–246. [CrossRef]
68. Nuhu, A.S.; Liverpool-Tasie, L.S.O.; Awokuse, T.; Kabwe, S. Do benefits of expanded midstream activities in crop value chains accrue to smallholder farmers? Evidence from Zambia. *World Dev.* **2021**, *143*, 105469. [CrossRef]
69. Fu, S.; Zhan, Y.; Ouyang, J.; Ding, Y.; Tan, K.H.; Fu, L. Power, supply chain integration and quality performance of agricultural products: Evidence from contract farming in China. *Prod. Plan. Control* **2021**, *13*, 1119–1135. [CrossRef]
70. Sharma, R.; Kamble, S.; Mani, V.; Belhadi, A. An empirical investigation of the influence of industry 4.0 technology capabilities on agriculture supply Chain integration and sustainable performance. *IEEE Trans. Eng. Manag.* **2022**, 1–21. [CrossRef]
71. Ye, X.; Zou, C.X.; Liu, G.H.; Lin, N.F.; Xu, M.J. Main research contents and advances in the ecological security pattern. *Acta Ecol. Sin.* **2018**, *10*, 3382–3392.
72. Li, Y.; Yu, J.; Wang, F.; Shen, K. Ecological security assessment of Qiandao Lake based on catastrophe theory. *J. Zhejiang Univ. (Sci. Ed.)* **2014**, *6*, 689–724.
73. Feng, N.; Mao, F.; Li, X.Y.; Zhang, A.D. Research on ecological security assessment of Dianchi Lake. *Environ. Sci.* **2010**, *2*, 282–286.
74. Jin, X.; Wang, S.; Xi, H. Lake ecological security and assessment methodology framework. *Res. Environ. Sci.* **2012**, *4*, 357–362.
75. Wang, L.; Zheng, B. Method for ecological security assessment of reservoirs (I): IROW framework. *J. Lake Sci.* **2010**, *2*, 169–175.
76. Li, Y.; Zhu, C.; Zhang, L.; Wang, Y.; Wu, Z.; Niu, X. Ecological security assessment and countermeasures of water environment based on improved analytic hierarchy process: A case study of Xingtai City. *J. Peking Univ.* **2019**, *2*, 310–316.
77. Cao, M.L.; Li, Y.D. Ecological security assessment of Tangshan City based on emergy analysis. *Chin. J. Appl. Ecol.* **2009**, *9*, 2214–2218.
78. Gao, C.; Chen, X.; Wei, C.; Peng, X. Application of entropy weight and fuzzy synthetic evaluation in urban ecological security assessment. *Chin. J. Appl. Ecol.* **2006**, *10*, 1923–1927.
79. Zhang, J.; Wang, Y.; Zhang, X. Influence mechanism of green supply chain interest linkage of grassland livestock products: A study from the perspective of pastoral modernization. *Sustainability* **2023**, *15*, 11830. [CrossRef]
80. Ouyang, W.; Ju, X.Y.; Gao, X.; Hao, F.H.; Gao, B. Ecological security assessment of agricultural development watershed considering non-point source pollution. *China Environ. Sci.* **2018**, *3*, 1194.
81. Song, Y.; Cao, M. Landscape ecological security assessment of Beijing City based on RS and GIS. *Chin. J. Appl. Ecol.* **2010**, *11*, 2889–2895.
82. Wang, G.; Gao, X.; Gao, H.; Ding, X.; Wang, L. The mechanism and methodology investigation of regional ecological security assessment from a perspective on disaster: A case study of Liaohe River watershed. *Acta Ecol. Sin.* **2010**, *13*, 3511–3525.
83. Wang, Z.; Zhu, X.; Shi, L.; Li, Y.; Wang, J.; Jia, L. Ecological security assessment model and corresponding indicator system of the regions along Huaihe River in Anhui Province. *Chin. J. Appl. Ecol.* **2006**, *12*, 2431–2435.
84. Wang, H.; Wei, J.; Jiang, P.; Wu, G. Ecological security assessment of Daling River watershed in West Liaoning Province. *Chin. J. Appl. Ecol.* **2006**, *12*, 2426–2430.
85. Liu, Z.T.; Wang, S.J.; Fang, C.L. Spatiotemporal evolution and influencing mechanism of ecosystem service value in the Guangdong-Hong Kong-Macao Greater Bay Area. *J. Geogr. Sci.* **2021**, *11*, 2797–2813. [CrossRef]
86. Zhao, H.; Mo, H. Spatial-temporal change of ecosystem service value in Changsha-Zhuzhou-Xiangtan urban agglomeration. *Sci. Surv. Mapp.* **2022**, *12*, 206.
87. Li, T.; Gan, D.X.; Yang, Z.J.; Wang, K.; Qi, Z.X.; Li, H.; Chen, X. Spatial-temporal evolvement of ecosystem service value of Dongting Lake area influenced by changes of land use. *Chin. J. Appl. Ecol.* **2016**, *12*, 3787–3796.

88. Chen, F.; Liu, Y.; Zhang, Q.; Yan, B.; Feng, Y.; Niu, J. Study on the Spatio-temporal Change of Ecosystem Service Value in Henan Province. *J. Xinyang Norm. Univ.* **2023**, *2*, 173.
89. Chen, R.; Yang, C.; Yang, Y.; Dong, X.Z. Spatial-temporal evolution and drivers of ecosystem service value in the Dongting Lake Eco-economic Zone, China. *Chin. J. Appl. Ecol.* **2022**, *1*, 169–179.
90. Li, Z.; Chen, J.; Zhang, W.; Lei, L.; Sha, Z. Analysis of evolution and influencing factors of ecosystem service value in Hubei Province. *Sci. Surv. Mapp.* **2023**, *1*, 245.
91. Deng, Y.J.; Hou, M.Y.; Jia, L.; Wang, Y.Q.; Zhang, X.; Yao, S.B. Ecological compensation strategy of the old revolutionary base areas along the route of Long March based on ecosystem service value evaluation. *Chin. J. Appl. Ecol.* **2022**, *1*, 159–168.
92. Deng, Y.; Hou, M.; Xie, Y.; Gao, Q.; Yao, S.; Gong, Z.; Lu, Y.; Jia, L.; Li, Y. Impact of the Grain for Green Project on the temporal and spatial evolution of ecosystem service value in northern Shaanxi. *Acta Ecol. Sin.* **2020**, *18*, 6597.
93. Jiang, W.J.; Lin, M.H.; Weng, P.Y.; Wei, D.Z.; Lin, W.X.; Su, K. Evolution mechanism of ecosystem service value at the township-scale in Anxi County of Fujian Province, China. *Chin. J. Appl. Ecol.* **2021**, *12*, 4457–4466.
94. Li, L.; Wu, D.; Wang, F.; Liu, Y.; Liu, Y.; Qian, L. Prediction and tradeoff analysis of ecosystem service value in the rapidly urbanizing Foshan City of China: A case study. *Acta Ecol. Sin.* **2020**, *24*, 9023.
95. Ding, M.; Pei, F.; Hu, Y.; Dong, S.; Zhang, Z.; Liu, Z. Spatial and temporal changes of ecosystem service value in Jiangsu Province based on LUCC. *Acta Ecol. Sin.* **2020**, *19*, 6801.
96. Yang, Q.J.; Wu, K.N.; Feng, Z.; Zhao, R.; Zhang, X.D.; Li, X.L. Soil quality assessment on large spatial scales:advancement and revelation. *Acta Pedol. Sin.* **2020**, *3*, 565–578.
97. Kibblewhite, M.G. Definition of priority areas for soil protection at a continental scale. *Soil Use Manag.* **2012**, *1*, 128–133. [CrossRef]
98. Stone, D.; Costa, D.; Daniell, T.J.; Mitchell, S.M.; Topp, C.F.E.; Griffiths, B.S. Using nematode communities to test a European scale soil biological monitoring programme for policy development. *Appl. Soil Ecol. A Sect. Agric. Ecosyst. Environ.* **2016**, *97*, 78–85. [CrossRef]
99. Salvati, L.; Ferrara, C.; Corona, P. Indirect validation of the Environmental Sensitive Area Index using soil degradation indicators: A country-scale approach. *Ecol. Indic.* **2015**, *57*, 360–365. [CrossRef]
100. Liu, Z.; Zhou, W.; Shen, J.; Li, S.; Ai, C. Soil quality assessment of yellow clayey paddy soils with different productivity. *Biol Fertil Soils* **2014**, *3*, 537–548. [CrossRef]
101. Mueller, L.; Schindler, U.; Shepherd, T.G.; Ball, B.C.; Smolentseva, E.; Hu, C.; Hennings, V.; Schad, P.; Rogasik, J.; Zeitz, J.; et al. A framework for assessing agricultural soil quality on a global scale. *Arch. Acker-Pflanzenbau Bodenkd.* **2012**, *58*, S76–S82. [CrossRef]
102. Borker, S.S.; Thakur, A.; Khatri, A.; Kumar, R. Quality assessment, safety evaluation, and microbiome analysis of night-soil compost from Lahaul valley of northwestern Himalaya. *Waste Manag.* **2022**, *149*, 42–52. [CrossRef] [PubMed]
103. Huang, F.Y.; Zhou, L.; Song, B.; Pang, R.; Wu, Y.; Wang, F.P.; Zhang, Y.X. Characteristics and planting safety assessment of as content in dryland soil and maize in Guizhou province. *Environ. Sci.* **2023**, *1*, 415–425.
104. Zeng, Q.G.; Ma, X.J.; Peng, P.H.; Feng, S.X. Assessment of soils safety and early warning plan in the original producing area for siraitia grosvenorii. *J. Guangxi Norm. Univ.* **2012**, *2*, 138–142.
105. Bogdanets, V.; Nosenko, V. Indicators of sustainable development of safety land use and assessment of degradation processes development of soil cover using gis models. *Zemleustrìj Kadastr Ì Monìtorìng Zemel'* **2022**, *3*. [CrossRef]
106. Wang, S.; Zhong, T.; Chen, D.; Zhang, X. Spatial Distribution of Mercury (Hg) Concentration in Agricultural Soil and Its Risk Assessment on Food Safety in China. *Sustainability* **2016**, *8*, 795. [CrossRef]
107. Zhang, J.; Xue, Q.; Chen, Q.F.; Zhao, C.S.; Liu, W.; Li, Q. Heavy metal pollution characteristics and assessment of environmental quality and safety of facility agriculture soil in Shouguang. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *1*, 12019. [CrossRef]
108. Si, S.; Wu, Y.; Li, Y.; Yang, S.; Peng, X.; Luo, Y. Divergent soil health responses to long-term inorganic and organic fertilization management on subtropical upland red soil in China. *Ecol. Indic.* **2023**, *154*, 110486. [CrossRef]
109. Meng, M.; Yang, L.; Wei, B.; Cao, Z.; Yu, J.; Liao, X. Plastic shed production systems: The migration of heavy metals from soil to vegetables and human health risk assessment. *Ecotoxicol. Environ. Saf.* **2021**, *215*, 112106. [CrossRef]
110. Sun, B.; Zhang, T.L.; Zhao, Q.G. Comprehensive evaluation of soil fertility in the hilly and mountainous region of southeastern China. *Acta Pedol. Sin.* **1995**, *4*, 362–369.
111. Gao, W.S.; Chen, Y.Q.; Shi, Y.Q.; Yang, B. Constructing an index system for ecological health evaluation of cropping system in China main food production areas. *Chin. Agric. Sci. Bull.* **2007**, *10*, 131–137.