Knowledge Mapping of Research on Land Use Change and Food Security: A Visual Analysis Using CiteSpace and VOSviewer

Peng Cheng 1, Houtian Tang 2, Yue Dong 1, Ke Liu 3, Ping Jiang 1,4, * and Yaolin Liu 1,4

Abstract: Many scholars have conducted in-depth research on the theme of land use change and food security, and formed fruitful research results, but there is a lack of quantitative analysis and comprehensive evaluation of research achievements. Therefore, based on the relevant literature on the theme of land use change and food security in the core collection of the Web of Science (WOS) database, this paper takes the advantage of CiteSpace and VOSviewer bibliometric software to draw the cooperative network and keyword cooccurrence map to analyze the research progress and frontier. The results reveal that: (1) The research started in 1999 and can be divided into three stages: initial research, rapid development, and a stable in-depth stage. This topic has increasingly become a research hotspot in the academic community. (2) The distribution of research institutions is concentrated and forms a small cluster, and the research networks between developed and developing countries have been established, and developed countries are in the core position, but the cooperation network is not prominent. (3) The research content is becoming increasingly organized and systematic, and the research hot topics are divided into seven aspects. (4) The research area of the subject covers multiple levels, such as global, national, and specific natural geographical regions, and has formed a research system of geographic information technology and satellite remote sensing technology. It also presents the trend of cross integration with economics, land management and soil science. In the future, theoretical innovation still needs to be strengthened, and we should strengthen the research on the impact of agricultural chemical fertilizers on food security and study the impact of urban expansion on land use change.

Keywords: land use change; food security; visual analysis; CiteSpace; VOSviewer; progress and frontier

1. Introduction

Land use change and its impact on food security have become one of the frontiers and hot topics studied by scholars worldwide [1–4]. With the development of human society, the structure, depth and intensity of land use are constantly changing, which not only affects biodiversity but also has a great impact on human food security [5]. The issue of “food security” was first put forward by the United Nations International Food and Agriculture Organization at the First World Food Summit in November 1974. The definition of food security is to ensure that anyone can obtain enough food for survival and health at any time, including food supply, food access, food stability and food utilization [6,7]. Over the years, food security has been a major issue related to the overall political and economic situation of a country or region. In particular, regional food production and food security have become hot issues of concern to governments and scholars [8–10]. According to the prediction of the United Nations [11], the global population will exceed...
9.8 billion in 2050, food demand will increase by more than 50%, and food problems will be extremely serious [12]. However, there are many factors affecting grain production, including institutional and policy innovation, scientific and technological progress, material and labor investment, climate change, but cultivated land resources in land resources are the most important factor in grain production [13,14]. Cultivated land resources are the most basic natural condition of agricultural production. Food security is closely related to changes in cultivated land. The change in the quantity and quality of cultivated land directly affects grain output and then affects the effective supply of grain and the level of food security [15,16].

In recent years, research related to the theme of land use change and food security has emerged in the academic community, mainly combined with issues of climate change, carbon emissions, agricultural intensification [5,17,18]. For example, Galeana-Pizaña et al. [1] used a GIS-based food environmental efficiency (FEE) index to evaluate the trend of land use change and regional food security, and the FEE index proved useful assessment of land use policies. Moore et al. [19] used the regional climate model to compare the impacts of projected future greenhouse gases and future land use change on spatial variability of grain yields in East Africa. These show that this theme is an evolving knowledge field, but there is a lack of systematic review of research results. Accurately understanding the research progress and academic trends of land use change and food security is of great significance for carrying out follow-up research. Therefore, based on the core collection of the Web of Science (WOS) database, this paper comprehensively uses the advantages of CiteSpace and VOSviewer software to conduct bibliometric analysis, systematically and visually analyze and summarize the literature in the fields of land use change and food security, and explore the status of research. This research field objectively reveals the trends, accurately evaluates the research progress on land use change and food security and provides a reference for combining the research framework and expanding new ideas and methods in this field.

2. Data Collection and Research Methods

2.1. Data Collection

The data on the relevant literature used in this paper come from the core collection of the WOS database (http://apps.webofknowledge.com, accessed on 6 September 2021) and adopt the method of group retrieval. The WOS Citation database is an information retrieval platform developed by Thomson Reuters of the United States. With the Science Citation Index, Social Science Citation Index, and Arts and Humanities Citation Index as the core, it contains more than 9000 world authoritative and influential academic journals, and the documents in the database have high authority in the academic community [20,21]. The search prerequisites of this research are set as follows: (TS = “land use change” and “grain security”) OR (TS = “land use change” and “food security”), TS is the theme, time spans are unlimited, the language is “English”, and the literature types are “article” and “review”. There were 628 literature records related to the subject that were retrieved. To avoid duplicate literature, CiteSpace’s deduplication function was used for inspection, and no duplicate publications were found.

2.2. Research Methods

As an auxiliary procedure of bibliometrics, science mapping provides a spatial representation of network structures. Science mapping involves the interdisciplinary fields of applied mathematics, information science and computer science. It is a new development of scientometrics and information metrology. In recent years, with the rapid development of computer science, many scholars have used various science mapping tools to analyze the potential dynamic mechanism of discipline evolution [22–24]. CiteSpace and VOSviewer software are two powerful and complementary science mapping analysis tools. CiteSpace (https://sourceforge.net/projects/citespace, accessed on 6 September 2021) is a Java-based application software proposed by Professor Chen of Drexel University in 2004. It is based on the co-citation analysis theory and pathfinder, minimum spanning trees
algorithm to make a quantitative analysis of the literature in specific fields, which is used to analyze and visualize the emerging trends and patterns in the knowledge field of scientific publications [25,26]. It has unique advantages in literature keyword analysis, cluster analysis, subject words, author information. VOSviewer (https://www.vosviewer.com, accessed on 6 September 2021) is also a literature analysis and knowledge visualization software tool developed by van Eck and Waltman of the Centre for Science and Technology Studies at Leiden University [27]. It can realize the construction and visualization of the keyword cooccurrence network in various fields. Compared with other visualization software, VOSviewer software has advantages in processing big data and drawing images, which can more clearly show the hot spots and topics in the research field [28].

3. Results

3.1. Trend Analysis of Literature Publication

The annual distribution of the number of published articles can reflect the research level and degree of development of a certain discipline [29]. The number of published articles on land use change and food security is shown in Figure 1. From 1999 to 6 September 2021, the number of published studies on land use change and food security showed a stable growth trend on the whole, which experienced three stages, i.e., initial research, rapid development, and a stable in-depth stage.

![Figure 1. Number of articles published annually on the theme of land use change and food security.](image)

The initial stage of the research (1999–2008): At this stage, the number of relevant research studies was relatively small, the research topic was relatively limited, and the number of research scholars in this field was also small, mainly because there was not much research on land use change and food security. Before this stage, scholars studied the theme of land use change or food security separately. In 1999, Sporton et al. first studied the theme of land use change and food security [30]. Subsequently, Murdiyarso and Verburg et al. paid more attention to this research topic [31,32].

The rapid development stage of the research (2009–2017): During this stage, scholars showed great interest in the research topic, the number of published articles continued to increase, the research questions and perspectives were further expanded, and several leading studies emerged, such as Alexander and Verburg et al. [33,34]. In 2009, famous scholars such as Khan, Garnett, Mertz and Yan et al. [35–38] published a series of high-level papers, meanwhile, the number of people suffering from hunger in the world will reach 1.02 billion in 2009 announced by the United Nations, reversing the continuous decline of hungry people, which made the research on land use change and food security widely
concerned in the academic community. With the intensification of global land use change and food security, scholars researched climate change, biodiversity, policy development, agriculture, greenhouse gas emissions, and the research contents and methods were further enriched [19,39].

Stable in-depth stage of the research (2018-present): During this stage, the literature publication trend was relatively smooth, and the research content and perspective gradually increased in depth. The research perspective has focused on both macro and micro issues, including population growth, land systems, rural development, soil organic carbon, and life cycle assessment, in the research agenda of land use change and food security, and the overall research has continued to deepen [40,41].

3.2. Network Analysis of Author Cooperation, Institutional Cooperation and National Cooperation

3.2.1. Analysis of Author Cooperation Network

By analyzing the author’s cooperation network [42], we can determine the strength of representative scholars and core research teams in the field of land use change and food security. VOSviewer software was used to overlay and visualize the author collaborative networks with more than 5 published articles. Through the color gradient, it can intuitively reflect the cooperation of various scholars in recent years (Figure 2) and present the author information with the number of published articles for the top 20 publications (Table 1). We found that the authors with a large number of published articles showed obvious network characteristics, mainly including the cooperative network of Verburg, Smith, Havlik and Popp. This indicates that these are core authors who have developed a high-yield author research team in the field of land use change and food security that has initially formed a scale. According to the Price Law [43], the formula for calculating the minimum number of published articles of core authors in a field is \( m = 0.749 \times \sqrt{n_{\text{max}}} = 2.996 \) (where \( n_{\text{max}} \) is the number of published articles of the top 1 author). Therefore, authors with more than three published articles are regarded as the core authors in this field. The top three scholars in the number of published articles are Verburg (16 articles), Smith (13 articles) and Havlik (10 articles). According to the data, there are 43 core authors and 206 articles, accounting for 32.8% of the total articles published in this field, which is less than the standard of 50% of the Price Law. This shows that after more than 20 years of development, the core author group in the field of land use change and food security has initially formed, but still needs further development.

Figure 2. Author cooperation network map.
### Table 1. Author information table of the top 20 published articles.

| Ranker | Count | Centrality | Year | Authors                        | Ranker | Count | Centrality | Year | Authors                        |
|--------|-------|------------|------|--------------------------------|--------|-------|------------|------|--------------------------------|
| 1      | 16    | 0          | 2016 | Peter H Verburg               | 11     | 5     | 0          | 2018 | Wenbin Wu                      |
| 2      | 13    | 0.03       | 2008 | Pete Smith                    | 12     | 5     | 0          | 2015 | Isabelle Weindl                |
| 3      | 10    | 0.01       | 2014 | Petr Havlik                   | 13     | 5     | 0          | 2013 | Alexander V Prishchepestov    |
| 4      | 9     | 0.03       | 2014 | Alexander Popp                | 14     | 5     | 0          | 2017 | K Butterbachbahl               |
| 5      | 7     | 0          | 2014 | Hermann Lotzecampen           | 15     | 5     | 0          | 2014 | Hans Van Meijl                 |
| 6      | 6     | 0          | 2014 | Tomoko Hasegawa               | 16     | 5     | 0          | 2017 | M C Rufino                     |
| 7      | 6     | 0          | 2009 | Jiyuan Liu                    | 17     | 5     | 0          | 2017 | Jasper Van Vliet               |
| 8      | 6     | 0          | 2014 | Hugo Valin                    | 18     | 4     | 0          | 2016 | Almut Arnet                    |
| 9      | 5     | 0          | 2014 | Shinichiro Fujimori           | 19     | 4     | 0          | 2017 | Kamini Yadav                   |
| 10     | 5     | 0          | 2014 | Christoph Schmitz             | 20     | 4     | 0          | 2014 | Andrzej Tabeau                 |

Note: The centrality indicator measures the importance of network nodes [44]. The larger the value of centrality, the more articles published by the author in cooperation with other authors.

#### 3.2.2. Analysis of Institutional Cooperation Network

Taking the research institution as the node for visual analysis, we can obtain the cooperation network map of the research institution (Figure 3) and show the network with connections. According to the information of the top 20 major research institutions (Table 2), the Chinese Academy of Sciences has the highest number of published articles (52), followed by Vrije University Amsterdam (26) and Wageningen University (22), and a research network has been formed of these three research institutions as the core. This shows that these institutions have strong scientific research and influence in the field, and there are cooperative relations and large-scale collaborations between the different institutions. It is worth noting that the reason for the highest number of documents issued by the Chinese Academy of Sciences may be related to China’s national conditions. The main reasons include the following points: (1) In terms of policy, the Chinese Government has put forward the “red line of 1.8 billion mu of cultivated land” and other cultivated land protection policies to control land use changes and ensure food security. (2) In terms of economics, the Chinese Government has adjusted agricultural protection policies, increased investment in agricultural science and technology, and continuously improved the rate of grain self-sufficiency. (3) In terms of society, China is a populous country in the world, it is required to ensure food supply and firmly put its rice bowl in its own hands. (4) In terms of the environment, the deterioration of land and other production factors had a great impact on food security. To ensure food security, the Government has always taken measures to prevent land resource degradation and improve the ecological environment.

In Figure 3, the research institutions are in a local aggregation state, indicating that the distribution of research institutions is relatively concentrated and that a small aggregation cluster is formed; that is, there are some cooperative relations among institutions. Generally, there are a large number of research institutions related to the theme of land use change and food security, but a large cross-national institutional cooperation group has not yet formed.
3.2.3. Analysis of Country Cooperation Network

According to Figure 4 and Table 3, there are more than 100 articles published in the USA, China, and Germany, which is significantly higher than that in other countries. The number of articles published in these three countries accounted for 31.84%, 19.9% and 18.15% of the total number of articles published in this field, respectively. It can be seen from the connectivity in Figure 4 that the connections between nodes are dense and complex, indicating that there are many cooperative relations between different countries. In Figure 4, purple appears at the edge of some nodes, indicating that the centrality is $\geq 0.1$, which also indicates that the node is in an important position within the network structure. Among them, the centrality values of the USA (0.58), Germany (0.13), England (0.11) and France (0.11) are higher than 0.1, indicating that these countries are in a relatively core area
in the research field of land use change and food security and that the relevant research studies have a significant impact on this field.

![Figure 4. Country cooperation network map.](image)

**Table 3.** Information table of the top 20 major research countries with published articles.

| Ranker | Count | Centrality | Year | Countries    | Ranker | Count | Centrality | Year | Countries    |
|--------|-------|------------|------|--------------|--------|-------|------------|------|--------------|
| 1      | 200   | 0.58       | 2003 | USA          | 11     | 30    | 0.11       | 2010 | France       |
| 2      | 125   | 0.10       | 2009 | China        | 12     | 26    | 0.01       | 2007 | Italy        |
| 3      | 114   | 0.13       | 2009 | Germany      | 13     | 25    | 0.06       | 2013 | Switzerland  |
| 4      | 93    | 0.11       | 2009 | England      | 14     | 23    | 0.01       | 2011 | Indonesia    |
| 5      | 92    | 0.10       | 2008 | The Netherlands | 15 | 22 | 0.02 | 2008 | Belgium |
| 6      | 56    | 0.04       | 2009 | Australia    | 16     | 22    | 0.03       | 2008 | Canada       |
| 7      | 47    | 0.04       | 2010 | Scotland     | 17     | 20    | 0.09       | 2009 | Denmark      |
| 8      | 36    | 0.02       | 2007 | Austria      | 18     | 20    | 0.01       | 2009 | Sweden       |
| 9      | 35    | 0.03       | 2008 | Kenya        | 19     | 19    | 0.01       | 2015 | Colombia     |
| 10     | 33    | 0.00       | 2009 | Brazil       | 20     | 18    | 0.01       | 2012 | India        |

### 3.3. Analysis of Hot Research Topics and Frontiers Trending

#### 3.3.1. Analysis of Hot Research Topics

Keywords capture the core idea of the article. Through the research on keywords in a field, we can quickly grasp the hot topics in the field [44]. In this study, VOSviewer software was used to visualize keywords. Nodes in the knowledge map represent keywords. The larger the node is, the higher the frequency, and the lines between nodes represent the cooccurrence of particular keywords. In addition, in the VOSviewer knowledge map, different colors represent different clusters, and the same color represents the same cluster.

By analyzing the keyword cooccurrence knowledge map (Figure 5), we find that the whole keyword knowledge map takes “food security”, “land use change” and “climate change” as the core, producing a radial shape. Considering that high-frequency keywords can be clearly displayed, a total of 279 high-frequency keywords are obtained with the threshold of five of each keyword. The cooccurrence map of keywords is relatively clear, and the top 20 high-frequency keywords are shown in Table 4. As seen from Figure 5 and Table 4, “land use change” (185), “food security” (141), “climate change” (119), “impact” (102) and
other high-frequency keywords constitute representative terms in this field. In terms of layout, these high-frequency keywords are also key hub nodes. Other nodes around them have together formed the hot cutting-edge research topics in this field in recent years.

Figure 5. Keyword cooccurrence network map.

Table 4. Information table of top 20 keywords with cooccurrence.

| Ranker | Count | Centrality | Year | Keywords          | Ranker | Count | Centrality | Year | Keywords          |
|--------|-------|------------|------|-------------------|--------|-------|------------|------|-------------------|
| 1      | 185   | 0.29       | 2000 | Land use change   | 11     | 42    | 0.08       | 2009 | Biodiversity      |
| 2      | 141   | 0.21       | 2006 | Food security     | 12     | 41    | 0.07       | 2006 | Deforestation     |
| 3      | 119   | 0.13       | 2006 | Climate change    | 13     | 37    | 0.05       | 2010 | Land use          |
| 4      | 102   | 0.08       | 1999 | Impact            | 14     | 34    | 0.05       | 2000 | Policy            |
| 5      | 62    | 0.14       | 2003 | Agriculture       | 15     | 33    | 0.06       | 2008 | Conservation      |
| 6      | 45    | 0.08       | 2009 | Management        | 16     | 32    | 0.02       | 2014 | Ecosystem service |
| 7      | 45    | 0.04       | 2011 | System            | 17     | 31    | 0.04       | 2012 | Greenhouse gas    |
| 8      | 45    | 0.02       | 2000 | Model             | 18     | 30    | 0.02       | 2006 | Cover change      |
| 9      | 43    | 0.05       | 2006 | Dynamics          | 19     | 30    | 0.08       | 2005 | Carbon            |
| 10     | 43    | 0.06       | 2000 | Pattern           | 20     | 27    | 0.02       | 2012 | Expansion         |

To refine the research topics more intuitively and effectively in this field, we use the unique clustering density map function of VOSviewer software to visualize the keyword cooccurrence clustering results (Figure 6). In the cluster density map, the density of an element depends on the number and weight of its surrounding elements. From the cold tone to the warm tone, the representative clustering density gradually increases; that is, the frequency of keyword cooccurrence increases, and the heat of related research topics increases [45]. According to the clustering results in Figure 6, combined with professional
knowledge, we can extract seven frontier hot topics in the current research field of land use change and food security (Table 5) and further analyze and discuss the research contents and important achievements of each frontier hot topic.

Figure 6. Keyword cooccurrence clustering density map produced by VOSviewer software.

Climate Change and Carbon Emissions

With excessive carbon emissions produced in the process of human production and consumption, global warming and abnormal climate events frequently occur, which have a direct impact on land use, especially on changes in cultivated land area, threatening global food security [46–48]. At present, with the continuous intensification of abnormal climate change, the geographical distribution of food-deficient areas will further expand. At the same time, grain production areas have been chronically affected by energy crops, feed crops, forestry and other economic crops, as well as the continuous expansion of vegetation areas caused by climate warming, which forces people to reduce the land allocated to grain production, thus, causing a global food supply crisis [49–51]. Hasegawa et al. built a comprehensive assessment model of the impact of climate change mitigation policies on food security [52]. The research found that if mitigation policies to address climate change are strictly implemented, they will have a huge negative impact on global food production and consumption, especially in low-income countries in Africa and South Asia. Moreover, Nobre and Beltrán-Tolosa et al. found that the development of traditional agriculture and animal husbandry will inevitably reduce the area of vegetation coverage, resulting in
environmental problems such as soil and water loss and soil erosion, leading to drought with climate change, thus affecting the production of the main food crops [53–55]. Relevant studies show that by the end of this century, due to the impact of climate change, grain prices may rise by 110% or more over the prices in the baseline year. Similarly, Hasegawa and Popp et al. also confirmed that food prices in parts of Asia and Africa will be more affected, increasing the potential risk of a food crisis [49,56]. Therefore, the impact of climate change and carbon emissions on land use change and food security will still be one of the key topics that scholars continue to pay attention to in the future [57,58].

Table 5. Keyword cooccurrence clustering induction.

| Cluster-ID | Research Topics                     | Main Keywords Included                                           |
|------------|-------------------------------------|------------------------------------------------------------------|
| 1          | Climate change and carbon emissions | Climate change, global change, climate change mitigation, change impacts, greenhouse gas emissions, carbon sequestration, carbon stocks, greenhouse gas emissions, soil carbon sequestration, soil organic carbon |
| 2          | Sustainable land management policy   | Land management, policy, protection policies, cropland protection, farmland abandonment, rapid urbanization, transformation, urban expansion, urban sprawl, urbanization |
| 3          | Agricultural intensive development   | Agricultural intensification, sustainable intensification, agricultural productivity, ecosystem, environmental change, food security, biodiversity conservation, impacts, risk |
| 4          | Land degradation                    | Cropping systems, land use change, degradation, desertification, land degradation, pollution, soil erosion, water resources, croplands, climate change impacts, rice, river basin |
| 5          | Renewable bioenergy                 | Carbon, carbon footprint, water footprint, bioenergy, biofuel, energy, environmental impact, farming systems, life cycle assessment, production systems, renewable energy, soil erosion, sustainable agriculture |
| 6          | Food production                     | Crop productivity, crop yield, efficiency, food production, human appropriation, impact assessment, yield gap, use efficiency, net primary production, irrigation, maize, wheat |
| 7          | Agricultural benefits               | Agriculture, benefits, biodiversity, certification, costs, crop, food demand, integrated assessment, intensification, plantations, policies, scenarios, validation, yields |

Sustainable Land Management Policy

A sustainable land management policy can help mitigate climate change, protect the land from soil erosion and ensure food security. Its core is to emphasize the resilience of management methods, that is, to seek maximum synergy through the combination of different land management policies [59,60]. Russo and Pavone believe that the mitigation potential of multiple land management policies that work together on the same land is generally greater than that of a single policy [61]. Moreover, Dax et al. also confirm that the combination of multiple land management policies can save resources, enhance social resilience and promote ecological restoration to better mitigate and adapt to climate change, prevent desertification and land degradation, and strengthen food security [62]. For example, (1) strengthening the combination of fire management and afforestation can increase land carbon sequestration, enhance the potential to mitigate climate change and land degradation, reduce management costs and ensure food production areas [63]. (2) Reducing food waste and a carnivorous diet will help to reduce carbon emissions, achieve sustainable land use management, and ensure food security and low carbon emissions [64]. (3) The construction of urban green infrastructure is also a solution to mitigate climate change. Through measures such as vertical greening, roof gardens, suburban agriculture and vertical agriculture, it can not only meet some food needs of urban residents but may also reduce the pressure of rural land food production and land degradation [65,66]. (4) In addition, improving land market management policies, ensuring land ownership and integrating environmental costs into food security and ecological compensation will help
to achieve sustainable land management and eliminate poverty to achieve food security with stable food production [67,68]. A successful sustainable land management policy requires the participation of more stakeholders, especially local stakeholders such as local farmers and community residents who are easy to ignore, which can fully mobilize their enthusiasm to understand and practice land management policies [69,70]. However, there are great differences in the actual situation in diverse regions. Therefore, in future research, scholars should realistically build sustainable land management policies suitable for each region to achieve the stable production of food crops and ensure food security.

Agricultural Intensive Development

In the face of the food security crisis, although the development of marginal ecological land can improve food output in the short term, this process is mostly irreversible, and the opportunity for agricultural land expansion is limited [71]. Excessive exploitation of natural resources can easily lead to land degradation and reduction of ecological land area, resulting in greater social and ecological costs [12]. Therefore, the intensive development of land use is considered to be the fundamental approach to not only ensure the needs of human land products and functions but also to effectively reduce marginal land development and protect the ecological environment [72,73]. Compared with the traditional intensification realized by changing management practices and decisions, sustainable land use intensification has been widely discussed and explored as a necessary way to improve global food security and reduce ecological vulnerability and environmental pollution. Moreover, Charles and Struik et al. sustainable intensification can balance the competing demands for land use, improve ecosystem services and maintain biodiversity while increasing production to achieve common growth [74,75].

Research on agricultural intensification can be traced back to 1990. Vlek took sub-Saharan Africa as an example to explore the role of alternative soil fertility and other measures in agricultural production [76]. There are relatively many studies on sustainable intensification, focusing on the sustainable intensification of agricultural land, farms and agricultural production; the specific research contents include the conceptual connotation, empirical evaluation, impact mechanism, biodiversity, and improvement of soil organic matter [72,77]. For example, Wezel et al. [78] distinguished between the concepts of “ecological intensification”, “sustainable intensification” and “agricultural ecological intensification” and analyzed the subtle differences of the three concepts. Mulwa et al. [79] used the dynamic random effect probit model and the control function method to evaluate the vitality of adopting sustainable agricultural inputs and the effect of large grain traders strengthening the adoption of these sustainable agricultural inputs at the farm level. However, with the in-depth development of agricultural intensification, ecological and environmental problems have gradually appeared. How to stabilize food production under the condition of coordinating land use types and protecting the ecological environment still needs further research.

Land Degradation

Climate change has changed the process of surface change and terrestrial ecosystems and their composition, structure and function [80], triggered changes in land use, accelerated the process of desertification and land degradation in many areas, reduced agricultural output and agricultural income, and deeply affected the security of world food production. According to the relevant data released by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) of the United Nations, human intervention has degraded the ecological function of approximately 80% of the world’s agricultural land, 10–20% of pasture land and 87% of wetlands, which brings economic losses ranging from 450 billion to 10.6 trillion US dollars to the global ecological service system every year; it also directly or indirectly affects the well-being of approximately 3.2 billion people around the world [81,82].
Land degradation seriously affects food production and distribution through soil erosion, the decline of land fertility and salinization [83]. Paoloni and Onorati found that it also directly threatens the well-being of the rural population, children and women and affects food security worldwide [84]. At present, a large number of studies have analyzed the factors of land degradation by exploring the driving force of land use change to analyze its impact on food security, especially from the aspects of geographical conditions, population characteristics, economic growth, road traffic, meteorological factors, Government policies, and technological evolution [75,85–87]. Among them, Prokop [86] analyzed the degree and type of land degradation of the Meghalaya Plateau through remote sensing data and found that the impact of different land degradation types and degrees on grain yield showed differentiated trends. In the face of land degradation, in response to the increase in food demand, Ranasinghe and Piyadasa [87] argue that we should integrate the main environmental, natural and socioeconomic factors in a region to build a productive land management system and explore an optimal mode of land production use to ensure the stable production of food. Land degradation is closely related to food production. Adopting sustainable land management policies not only effectively curbs the trend of land degradation and optimizes land use structure but also gives full play to the overall efficiency of different land types.

Renewable Bioenergy

With increasing attention given to energy security and ecological security, governments worldwide are pursuing multiple goals of energy security, reducing greenhouse gas emissions, and developing rural economies. Tian and Renzaho et al. found that the government have invested much money or established tax incentive mechanisms to develop renewable bioenergy represented by fuel ethanol and biodiesel to replace nonrenewable fossil fuels (coal, oil and natural gas) [88,89]. While the world vigorously advocates for the development of bioenergy to ensure energy security, the demand for land for bioenergy production is also increasing [90]. With the sharp rise of global food prices, whether bioenergy threatens food security is not only the focus of major international organizations and governments but also the main topic of debate within the academic community [46,91]. Although the use of bioenergy instead of fossil fuels can effectively reduce greenhouse gas emissions to a certain extent, the large-scale increase in bioenergy demand may also cause forest degradation and reduce food production [56,92]. Moreover, a large number of agricultural products are used to produce bioenergy, which greatly reduces the food supply in the international market and will inevitably lead to an increase in food prices [93], threatening global food security, especially the basic living needs of people in low-income countries with food shortages [94,95]. However, at present, there is no systematic research on how much-cultivated land is occupied by the development of bioenergy, what impact it has on land use change, how energy crops compete with other crop types at the household scale, and how to stabilize food production, which are worthy of further exploration by scholars in the future.

Food Production

Food security is a multidimensional security goal and is affected by many factors, among which food production is the most critical link in the food security system [96–98]. Land use change affects regional food production through changes in area and spatial location among different land use types, and temporal and spatial changes in cultivated land are one of the main forms of land use change [99], which affects the global food security supply [100]. At present, the research focus of most scholars is on quantifying the impact of cultivated land change on food security. However, due to the differences in research methods, regions and periods, the research results are also quite different [100]. For example, Wang et al. constructed the evaluation framework of “land food water” to quantify the impact of temporal and spatial changes in cultivated land on food production
and water resource consumption and proposed the sustainable development policy of cultivated land and the optimal management policy of water resources [101].

In addition, the research results of some scholars show that grain production is affected by a variety of natural and socioeconomic factors, among which regional factors, family size, farming system, land use intensity, land tenure, climate change and environmental cost have a great influence on grain productivity. The actual grain yield is affected by the quantity and quality of cultivated land, climate, agricultural technology, and planting methods [13,102,103]. However, on the whole, although the current research helps to alleviate the contradiction between cultivated land change and food production, there are still some aspects to be optimized. For example, (1) the relevant research in this field is carried out at the national or a natural area level, which makes it difficult to guide practical work at the provincial level, and (2) weak supervision of newly reclaimed cultivated land and insufficient reserve resources of cultivated land easily leads to potential questions of food security production.

Agricultural Benefits

Global land use change is affected not only by climate change, land degradation and other factors but also by economic factors such as agricultural benefits [104]. The former is an irresistible natural factor, while the latter is the spontaneous change of land use types by farmers in pursuit of better comprehensive benefits [105]. In the environment of the market economy, farmers, as “rational economic people”, their subjective will and choice of land production mode are the main influencing factors of cultivated land resource utilization and management and grain production capacity. Moreover, Wang and Tian et al. found that the price of agricultural products directly affects the type of cultivated land utilization and the result of grain production [106]. At present, there is a realistic situation that is not optimistic; that is, the economic benefits of food production are generally lower than those of other economic crops. Therefore, when there is no government subsidy or it is too low, farmers’ willingness to plant food will continue to decrease and then switch to other economic crops [107]. In recent years, scholars have recognized that the change of land use types poses a greater threat to world food security than the small reduction of cultivated land area, and called on the Government to take effective measures to curb the drastic change of modes of man-made land use, which will help to stabilize the production area of cultivated food [108].

In addition, facing the problems of land fragmentation, higher agricultural production costs, lower agricultural productivity and lower grain output, most countries in the world have generally used effective measures, promoting moderately intensive land and large-scale production and management to transform and upgrade the agricultural system, to reduce agricultural production costs and to improve agricultural benefits [109]. Moreover, with the deepening of people’s understanding of environmental pollution and biodiversity [110], scholars’ attention to agricultural benefits has increased social and ecological benefits from a single economic benefit to emphasis more on the comprehensive benefits of agricultural production [111]. In this way, improving agricultural benefits not only protects the ecological environment but also stabilizes food production and ensures global food security.

3.3.2. Analysis of Frontier Trending Topics

Although the keyword clustering density map of the VOSviewer software can intuitively show the hot research topics in the field, the time factor is not considered. The time zone map of the CiteSpace software arranges keywords according to time series, which can more intuitively show the distribution of hot topics in each period [112]. Therefore, this paper combines the time zone map with the burst word detection function of CiteSpace software, which vividly shows the evolution of the research topic over time. We selected keywords with a frequency of more than five every one year (slice length = 1) from 1999 to
6 September 2021, to build a keyword cooccurrence network map (Figure 7). Furthermore, three burst words were detected (Table 6).

![Time zone map for studying the evolution path produced by CiteSpace software.](image)

**Table 6.** Top three burst keywords detection with the CiteSpace software.

| Keywords            | Year | Strength | Begin | End   | 1999–2021               |
|---------------------|------|----------|-------|-------|-------------------------|
| Area                | 1999 | 3.56     | 2015  | 2016  |                         |
| Consumption         | 1999 | 3.21     | 2015  | 2017  |                         |
| Ecosystem service   | 1999 | 3.4      | 2019  | 2021  |                         |

Combined with Figure 7 and Table 6, according to the time distribution of key nodes, we summarize the development trend in the research field of land use change and food security as follows: (1) The research in the field of land use change and food security started from the field of land use change and then combined the research with food security. (2) From 2009 to 2017, there were a large number of key nodes related to the theme of land use change and food security, including agriculture, land use, forest, rice, food demand and yield. During this period, research on land use change and food security was in a stage of rapid development, which once again shows that research on this topic has attracted the continuous attention of scholars. (3) In addition, scholars generally pay attention to key nodes, including climate change, carbon, urban expansion, and environmental impact, which suggests that scholars prefer to further analyze the impact of land use change on food security by researching the current situation and influencing factors of land use change. (4) Since 2017, scholars have paid more attention to global research on land use change and food security, raised the issue of food security to the field of risk research, and advocated the formulation and implementation of agricultural protection policies to ensure food security.

The burst detection algorithm was proposed by Kleinberg to explore the research frontier trend in a field by studying the strength and duration of keyword bursts [113]. The research on land use change and food security includes three top burst keywords: “area”, “consumption” and “ecosystem service” (Table 6). In 2015, the keywords “area” and...
“consumption” were the research hotspots, focusing on “differences in different research regions” and “energy and food consumption”, but the duration was short. In 2019, the keyword “ecosystem service” has become a new research hotspot and continues until now. It focuses on agricultural intensive development, grain production and environmental protection, which shows that ecosystem service will become a hotspot and trend in future research. As a whole, there are few burst words in this research field, indicating that the research concentration in this field is poor, and further research is needed.

4. Discussion

To ensure food security, countries all over the world have generally adopted strict land use restriction measures, such as China’s cultivated arable land minimum policy, Japan’s land classification management system and the United States’ land fallow policy. They hope to strictly restrict land use change through administrative control methods to stabilize food production and limit food risk within a controllable range [114–116]. At the same time, the academic research results on the theme of land use change and food security have increased significantly in the past two decades, and these results show a significant positive development trend.

4.1. Research Process

The results of this paper show that the first research article on the theme of land use change and food security was published in 1999. Since then, the number of published articles has shown a slow-growth trend. To deeply analyze the evolution of the research field of land use change and food security, this paper divides these research studies into three stages according to the number of articles published annually and the category and frequency of keywords. The first stage is the initial stage of research (1999–2008), during which the number of published articles was small, the research theme concentrated on a single topic, and overall research progress went slowly. Related research mainly focuses on conceptual and technical analysis, as well as direct analysis of the impact of land use change on food security. The second stage is the rapid development stage (2009–2017), during which basic research knowledge increased to a certain extent. The research focused on the influencing factors of land use change, including climate change, carbon emissions, and sustainable land management, climate change and sustainability would continue to be focused on in the future. During this stage, scholars also paid more attention to improving the ability to deal with land use change and food security risks, and to explore countermeasures and governance schemes at multiple levels, such as technology and policy. The number of articles published on the theme of land use change and food security did not increase significantly until 2009, which may attribute to the theme of World Food Day in that year, which was described as “coping with the crisis and achieving food security”, and emphasized the serious plight of malnutrition of 1.02 billion people in the world, as well as the need to help solve the problem of hungry people under conditions of economic crisis. The third stage is the stable deepening stage (2018–present). In this stage, as the global food security problem becomes increasingly serious, scholars pay more attention to global land use change and food security, and they raise the issue of food security to a risk problem.

4.2. The Impact of Land Use Changes on Food Security

We found that the research in this field mainly explores the impact on food security from four land use change factors: environmental change, land quality, crop planting type and agricultural production mode. First, environmental change involves climate change and carbon emissions. Excessive carbon emissions will lead to global warming and extreme climate events, resulting in changes in production factors such as moisture, heat, humidity, and temperature, which will lead to changes in land use patterns to varying degrees, eventually affecting the cultivated land area of food production and endangering food security. Second, land quality is related to land degradation. Due to
the unreasonable use of land and changes in the natural environment, part of land in the world has experienced serious degradation (soil erosion), which leads to a decline in land productivity and has a serious impact on food production. Third, crop planting types involve renewable bioenergy and food production. Compared with the economic benefits of food crops, the economic benefits of other cash crops are higher, especially with the rapid development of clean energy (bioenergy), which leads to the conversion of some cultivated land originally planted with food crops to other cash crops. The reduction in the planting area of food crops will inevitably lead to a decline in total food production, then threatening global food security. Fourth, the agricultural production model involves sustainable land management policy, agricultural intensive development, food production and agricultural benefits. Facing practical problems such as land degradation, reduction of ecological land, land pollution and decline of soil fertility, people urgently need to change the extensive agricultural production model to the production model with higher overall efficiency. For example, the intensive agricultural model pays more attention to the stability of grain production and the protection of the ecological environment, which can give full play to the economic, social and ecological effects of agricultural production [117].

4.3. Research Hotspots

At present, the research topic in this field is mainly aimed at the complex practical problems of global land use change and food security, and the research content is becoming increasingly organized and systematic. According to the clustering results, we can extract seven frontier hot topics in this field: climate change and carbon emissions, sustainable land management policy, agricultural intensive development, land degradation, renewable bioenergy, food production and agricultural benefits. These results present the trend of cross integration with economics, land management, soil science, public policy, politics, geography, and other disciplines, and indicate that the research in this field continues to expand. Meanwhile, it is worth noting that although the theme of land use change and food security has become very popular in recent years, scholars’ research perspective is not limited to the direct analysis of the impact of land use change on food security but also considers climate change, carbon emissions, renewable bioenergy, agricultural intensive development models and other relevant aspects [7,8,54]. In terms of research methods, this field has formed a research system of geographic information technology, satellite remote sensing technology, theoretical models, investigations and interviews and other methods. Besides, through the analysis and summary of recent relevant literature, we found that scholars mainly focus on the hot issues including the utilization efficiency of chemical fertilizer (active nitrogen, etc.), urbanization expansion, greenhouse effects, and pay more attention to the combination of economic, social and ecological benefits of agricultural production to reduce the threat of land use change to food security [118–121].

4.4. Research Deficiency

This paper also has some research limitations that can be improved in the future. Firstly, because we only selected the WOS database as the data source for the bibliometric analysis of this study, and did not choose other databases (such as China National Knowledge Infrastructure, Scopus, et al.), the data used in our study cannot include all literature. However, as one of the most comprehensive databases in the world, the WOS database contains high-quality documents, it can represent the research hotspot and frontier in this field. Secondly, we can fully analyze the most influential publications in the database in the future, which will help to understand the real impact of the most important research in the scientific community.

5. Conclusions

This paper comprehensively used CiteSpace and VOSviewer software for bibliometric analysis and performed a visual analysis of the knowledge map of the literature with the theme of land use change and food security in the WOS database, and explored the research
status, knowledge structure and evolution context. Since 1999, the number of annual published articles in the field of land use change and food security has shown an overall upward trend, which can be divided into three stages: initial research, rapid development, and a stable in-depth stage. Although a core author group was initially formed, the overall cooperation network is still relatively scattered. The distribution of research institutions is concentrated and forms a small cluster, which shows that there are only a few cooperative relationships among research institutions, and large institutional collaborative groups have not been formed across countries or regions. In national cooperation networks, developed countries are in the core position, but the cooperation network is not prominent. Meanwhile, keywords such as food security, land use change and climate change are taken as the core issues, they exhibit a radial shape and form seven frontier hot topics in this field. Moreover, due to the complexity of the research theme of land use change and food security, the research methods in this field are in-depth and diverse, and multidisciplinary development is constantly integrated. In addition, with the emergence of factors or problems such as climate change, carbon emission limitations, the application of new land use models and technologies, and the imbalance between food production and demand, there are new opportunities and challenges to the research on land use change and food security.

The research field of land use change and food security can be strengthened in the following aspects in the future. (1) Theoretical innovation still needs to be strengthened. At present, the research in this field is carried out through technology and mathematical models, which lack theoretical construction and innovation. The research perspective can also be innovated from the dimensions of land property rights systems and land management systems. (2) We should strengthen the research on the impact of agricultural chemical fertilizers on food security. Agricultural chemical fertilizer plays an important role in slowing down land use change and ensuring the sufficiency of food production, especially synthetic nitrogen fertilizer. However, the loss of active nitrogen will not only affect grain yields but also pollute the ecological environment. (3) Further research can focus on the impact of urban expansion on land use change. Due to the urbanization process of countries worldwide, a large amount of high-quality cultivated land around cities is occupied, which seriously threatens food security, especially in developing countries.

Author Contributions: Conceptualization, P.C. and P.J.; methodology, P.C., Y.D. and H.T.; software, P.C. and H.T.; formal analysis, P.C. and H.T.; data curation, P.C. and K.L.; writing—original draft preparation, P.C. and H.T.; writing—review and editing, P.C., H.T., Y.D., K.L. and P.J.; visualization, P.C.; supervision, P.J. and Y.L.; project administration, P.J. and Y.L.; funding acquisition, P.J. and Y.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Major Projects of National Social Science Foundation (20ZDA086).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available in the Web of Science core database.

Conflicts of Interest: The authors declare no conflict of interest.

References
1. Galeana-Pizaña, J.M.; Couturier, S.; Monsivais-Huertaero, A. Assessing food security and environmental protection in Mexico with a GIS-based Food Environmental Efficiency index. Land Use Policy 2018, 76, 442–454. [CrossRef]
2. Daioglou, V.; Doelman, J.C.; Wicke, B.; Faaij, A.; van Vuuren, D.P. Integrated assessment of biomass supply and demand in climate change mitigation scenarios. Glob. Environ. Chang. 2019, 54, 88–101. [CrossRef]
3. Chigbu, U.E.; Ntihinyurwa, P.D.; de Vries, W.T.; Ngenzi, E.I. Why tenure responsive land-use planning matters: Insights for land use consolidation for food security in rwanda. Int. J. Environ. Res. Public Health 2019, 16, 1354. [CrossRef] [PubMed]
4. Long, H.; Ge, D.; Zhang, Y.; Tu, S.; Qu, Y.; Ma, L. Changing man-land interrelations in China’s farming area under urbanization and its implications for food security. J. Environ. Manag. 2018, 209, 440–451. [CrossRef] [PubMed]
5. Chen, C.; Yu, L.; Choguill, C.L. “Dipiao”, Chinese approach to transfer of land development rights: The experiences of Chongqing. *Land Use Policy* **2020**, *99*, 104870. [CrossRef]

6. Ericksen, P.J. Conceptualizing food systems for global environmental change research. *Glob. Environ. Chang.* **2008**, *18*, 234–245. [CrossRef]

7. Verbong, P.H.; Mertz, O.; Erb, K.H.; Haberl, H.; Wu, W. Land system change and food security: Towards multi-scale land system solutions. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 494–502. [CrossRef] [PubMed]

8. Guo, Y.; Fu, Y.; Hao, F.; Zhang, X.; Wu, W.; Jin, X.; Robin Bryant, C.; Senthilnath, J. Integrated phenology and climate in rice yields prediction using machine learning methods. *Ecol. Indic.* **2021**, *120*, 106935. [CrossRef]

9. Ge, D.; Long, H.; Zhang, Y.; Ma, L.; Li, T. Farmland transition and its influences on grain production in China. *Land Use Policy* **2018**, *70*, 94–105. [CrossRef]

10. Wang, J.; Zhang, Z.; Liu, Y. Spatial shifts in grain production increases in China and implications for food security. *Land Use Policy* **2018**, *74*, 204–213. [CrossRef]

11. UNDESA. *World Family Planning*; United Nations, Department of Economic and Social Affairs: New York, NY, USA, 2020; ISBN 9789211484382.

12. Schiefer, J.; Lair, G.J.; Blum, W.E.H. Potential and limits of land and soil for sustainable intensification of European agriculture. *Agric. Ecosyst. Environ.* **2016**, *230*, 283–293. [CrossRef]

13. Singirankabo, U.A.; Ertsen, M.W. Relations between land tenure security and agricultural productivity: Exploring the effect of land registration. *Land* **2020**, *9*, 138. [CrossRef]

14. Lu, D.; Wang, Y.; Yang, Q.; He, H.; Su, K. Exploring a moderate fallow scale of cultivated land in China from the perspective of food security. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4329. [CrossRef] [PubMed]

15. Zhou, Y.; Li, Y.; Xu, C. Land consolidation and rural revitalization in China: Mechanisms and paths. *Land Use Policy* **2020**, *91*, 104379. [CrossRef]

16. Li, Q.; Yan, J. Assessing the health of agricultural land with emergy analysis and fuzzy logic in the major grain-producing region. *Catena* **2012**, *99*, 9–17. [CrossRef]

17. Qi, X.; Si, Z.; Zhong, T.; Huang, X.; Crush, J. Spatial determinants of urban wet market vendor profit in Nanjing, China. *Habitat Int.* **2019**, *94*, 102064. [CrossRef]

18. Zhong, T.; Si, Z.; Scott, S.; Crush, J.; Yang, K.; Huang, X. Comprehensive Food System Planning for Urban Food Security in Nanjing, China. *Land* **2021**, *10*, 1090. [CrossRef]

19. Moore, N.; Alagarswamy, G.; Pijanowski, B.; Thornton, P.; Lofgren, B.; Olson, J.; Andresen, J.; Yanda, P.; Qi, J. East African food security as influenced by future climate change and land use change at local to regional scales. *Clim. Chang.* **2012**, *110*, 823–844. [CrossRef]

20. Liao, H.; Tang, M.; Luo, L.; Li, C.; Chiclana, F.; Zeng, X.J. A bibliometric analysis and visualization of medical big data research. *Sustainability* **2018**, *10*, 166. [CrossRef]

21. Abati, R.; Sampaio, A.R.; Maciel, R.M.A.; Colombo, F.C.; Libardoni, G.; Battisti, L.; Lozano, E.R.; de Castilhos Ghisi, N.; Costa-Maia, F.M.; Potrich, M. Bees and pesticides: The research impact and scientometrics relations. *Environ. Sci. Pollut. Res.* **2021**, *28*, 32282–32298. [CrossRef]

22. Chen, C.; Chen, Y.; Horowitz, M.; Hou, H.; Liu, Z.; Pellegrino, D. Towards an explanatory and computational theory of scientific discovery. *J. Informetr.* **2009**, *3*, 191–209. [CrossRef]

23. Ali, M.; Prakash, K.; Hossain, M.A.; Pota, H.R. Intelligent energy management: Evolving developments, current challenges, and research directions for sustainable future. *J. Clean. Prod.* **2021**, *314*, 127904. [CrossRef] [PubMed]

24. Ji, B.; Zhao, Y.; Vymazal, J.; Mander, U.; Lust, R.; Tang, C. Mapping the field of constructed wetland-microbial fuel cell: A review and bibliometric analysis. *Chemosphere* **2021**, *262*, 128366. [CrossRef] [PubMed]

25. Chen, C.; Song, I.Y.; Yuan, X.; Zhang, J. The thematic and citation landscape of Data and Knowledge Engineering (1985–2007). *Data Knowl. Eng.* **2008**, *67*, 234–259. [CrossRef]

26. Fan, J.; Gao, Y.; Zhao, N.; Dai, R.; Zhang, H.; Feng, X.; Shi, G.; Tian, J.; Chen, C.; Hambly, B.D.; et al. Bibliometric Analysis on COVID-19: A Comparison of Research Between English and Chinese Studies. *Front. Public Health* **2020**, *8*, 477. [CrossRef] [PubMed]

27. van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef]

28. Donthu, N.; Kumar, S.; Pattanaik, D. Forty-five years of Journal of Business Research: A bibliometric analysis. *J. Bus. Res.* **2020**, *109*, 39. [CrossRef]

29. Long, H.; Zhang, Y.; Ma, L.; Tu, S. Land use transitions: Progress, challenges and prospects. *Land* **2021**, *10*, 903. [CrossRef]

30. Sporton, D.; Thomas, D.S.G.; Morrison, J. Outcomes of social and environmental change in the Kalahari of Botswana: The role of migration. *J. S. Afr. Afr. Stud.* **1999**, *25*, 441–459. [CrossRef]

31. Murdiyarso, D. Adaptation to climatic variability and change: Asian perspectives on agriculture and food security. *Environ. Monit. Assess.* **2000**, *61*, 123–131. [CrossRef]

32. Verborg, P.H.; Chen, Y.; Veldkamp, T.A. Spatial explorations of land use change and grain production in China. *Agric. Ecosyst. Environ.* **2000**, *82*, 333–354. [CrossRef]
33. Alexander, P.; Rounsevell, M.D.A.; Dislich, C.; Dodson, J.R.; Engström, K.; Moran, D. Drivers for global agricultural land use change: The nexus of diet, population, yield and bioenergy. *Glob. Environ. Chang.* 2015, 35, 138–147. [CrossRef]

34. Verburg, P.H.; Ritsema van Eck, J.R.; de Nijs, T.C.M.; Dijst, M.J.; Schot, F. Determinants of land-use change patterns in the Netherlands. *Environ. Plan. B. Des.* 2004, 31, 125–150. [CrossRef]

35. Khan, S.; Hanjra, M.A.; Mu, J. Water management and crop production for food security in China: A review. *Agric. Water Manag.* 2009, 96, 349–360. [CrossRef]

36. Mertz, O.; Mbow, C.; Reenberg, A.; Diouf, A. Farmers’ perceptions of climate change and agricultural adaptation strategies in rural Senegal. *Environ. Manag.* 2009, 43, 804–816. [CrossRef]

37. Garnett, T. Livestock-related greenhouse gas emissions: Impacts and options for policy makers. *Environ. Sci. Policy* 2009, 12, 491–503. [CrossRef]

38. Yan, H.; Liu, J.; Huang, H.Q.; Tao, B.; Cao, M. Assessing the consequence of land use change on agricultural productivity in China. *Glob. Planet. Chang.* 2009, 67, 13–19. [CrossRef]

39. Song, X.; Ouyang, Z.; Li, Y.; Li, F. Cultivated land use change in China, 1999-2007: Policy development perspectives. *J. Geogr. Sci.* 2012, 22, 1061–1078. [CrossRef]

40. Ziem Bonye, S.; Yenglier Yiridomoh, G.; Derbile, E.K. Urban expansion and agricultural land use change in Ghana: Implications for peri-urban farmer household food security in Wa Municipality. *Int. J. Urban Sustain. Dev.* 2021, 13, 383–399. [CrossRef]

41. Wang, C.; Siriwardana, M.; Meng, S. Effects of the Chinese arable land fallow system and land-use change on agricultural production and on the economy. *Econ. Model.* 2019, 79, 186–197. [CrossRef]

42. Jiang, Y.; Ritchie, B.W.; Benckendorff, P. Bibliometric visualisation: An application in tourism crisis and disaster management research. *Curr. Issues Tour.* 2019, 22, 1925–1957. [CrossRef]

43. de Price, D.J.S. *Little Science, Big Science*; Columbia University Press: New York, NY, USA, 1963; ISBN 023188575X.

44. Chen, C.; Ibekwe-Sanjuan, F.; Hou, J. The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis. *J. Am. Soc. Inf. Sci. Technol.* 2010, 61, 1386–1409. [CrossRef]

45. Colares, G.S.; Dell’Osbel, N.; Wiesel, P.G.; Oliveira, G.A.; Lemos, P.H.Z.; da Silva, F.P.; Lutterbeck, C.A.; Kist, L.T.; Machado, É.L. Floating treatment wetlands: A review and bibliometric analysis. *Sci. Total Environ.* 2020, 714, 136776. [CrossRef] [PubMed]

46. Zimmermann, A.; Benda, J.; Webber, H.; Jafari, Y. The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis. *Technol. Forecast. Soc. Chang.* 2010, 77, 1055–1074. [CrossRef]

47. Yawson, D.O.; Mulholland, B.J.; Ball, T.; Adu, M.O.; Mohan, S.; White, P.J. Estimating virtual land use under future conditions: Application of a food balance approach using the UK. *Land Use Policy* 2021, 101, 105132. [CrossRef]

48. Yawson, D.O.; Mulholland, B.J.; Ball, T.; Adu, M.O.; Mohan, S.; White, P.J. Effect of climate and agricultural land use changes on UK feed barley production and food security to the 2050s. *Land Use Policy* 2017, 64, 74. [CrossRef]

49. Hasegawa, T.; Fujimori, S.; Shin, Y.; Tanaka, A.; Takahashi, K.; Masui, T. Consequence of Climate Mitigation on the Risk of Hunger. *Environ. Sci. Technol.* 2015, 49, 7245–7253. [CrossRef]

50. Krishnamurthy, P.K.; Lewis, K.; Choularton, R.J. A methodological framework for rapidly assessing the impacts of climate risk on national-level food security through a vulnerability index. *Glob. Environ. Chang.* 2014, 25, 121–132. [CrossRef]

51. Jabbar, A.; Wu, Q.; Peng, J.; Sher, A.; Imran, A.; Wang, K. Mitigating catastrophic risks and food security threats: Effects of land ownership in Southern Punjab, Pakistan. *Int. J. Environ. Res. Public Health* 2020, 17, 9258. [CrossRef]

52. Hasegawa, T.; Fujimori, S.; Hlavik, P.; Valin, H.; Bodirsky, B.L.; Doelman, J.C.; Fellmann, T.; Kyle, P.; Koopman, J.F.L.; Lotze-Campen, H.; et al. Risk of increased food insecurity under stringent global climate change mitigation policy. *Nat. Clim. Chang.* 2018, 8, 699–703. [CrossRef]

53. Nobre, C.A.; Sampao, G.; Borma, L.S.; Castillo-Rubio, J.C.; Silva, J.S.; Cardoso, M. Land-use and climate change risks in the amazon and the need of a novel sustainable development paradigm. *Proc. Natl. Acad. Sci. USA* 2016, 113, 10759–10768. [CrossRef] [PubMed]

54. Beltrán-Tolosa, L.M.; Navarro-Racines, C.; Pradhan, P.; Cruz-Garcia, G.S.; Solis, R.; Quintero, M. Action needed for staple crops in the Andean-Amazon foothills because of climate change. *Mitig. Adapt. Strateg. Glob. Chang.* 2018, 23, 699–703. [CrossRef]

55. Liu, X.; Liu, Y.; Liu, Z.; Chen, Z. Impacts of climatic warming on cropping system borders of China and potential adaptation strategies for regional agriculture development. *Sci. Total Environ.* 2021, 755, 142415. [CrossRef]

56. Popp, A.; Calvin, K.; Fujimori, S.; Hlavik, P.; Humpenöder, F.; Stehfest, E.; Bodirsky, B.L.; Dietrich, J.P.; Doelman, J.C.; Gusti, M.; et al. Land-use futures in the shared socio-economic pathways. *Glob. Environ. Chang.* 2017, 42, 331–345. [CrossRef]

57. Ranjan, R. Land use decisions under REDD+ incentives when warming temperatures affect crop productivity and forest biomass growth rates. *Land Use Policy* 2021, 108, 105595. [CrossRef]

58. Wilts, R.; Latka, C.; Britz, W. Who is most vulnerable to climate change induced yield changes? A dynamic long run household analysis in lower income countries. *Clim. Risk Manag.* 2021, 33, 100330. [CrossRef]

59. Dunning, R.J.; Moore, T.; Watkins, C. The use of public land for house building in England: Understanding the challenges and policy implications. *Land Use Policy* 2021, 105, 105434. [CrossRef]

60. Wang, L.; Zheng, W.; Tang, L.; Zhang, S.; Liu, Y.; Ke, X. Spatial optimization of urban land and cropland based on land production capacity to balance cropland protection and ecological conservation. *J. Environ. Manag.* 2021, 285, 112054. [CrossRef] [PubMed]

61. Russo, M.; Pavone, P. Evidence-based portfolios of innovation policy mixes: A cross-country analysis. *Technol. Forecast. Soc. Chang.* 2021, 168, 120708. [CrossRef]
62. Dax, T.; Schroll, K.; Machold, I.; Derszniak-Noirjean, M.; Schuh, B.; Gaupp-Berghausen, M. Land abandonment in mountain areas of the EU: An inevitable side effect of farming modernization and neglected threat to sustainable land use. *Land* 2021, 10, 591. [CrossRef]

63. Le Page, Y.; Hurtt, G.; Thomson, A.M.; Bond-Lamberty, B.; Patel, P.; Wise, M.; Calvin, K.; Kyle, P.; Clarke, L.; Edmonds, J.; et al. Sensitivity of climate mitigation strategies to natural disturbances. *Environ. Res. Lett.* 2013, 8, 15018. [CrossRef]

64. Shabanali Fami, H.; Aramyan, L.H.; Sijtsema, S.J.; Alambagi, A. The relationship between household food waste and food security in Tehran city: The role of urban women in household management. *Ind. Mark. Manag.* 2021, 97, 71–83. [CrossRef]

65. Edmondson, J.L.; Davies, Z.G.; Gaston, K.J.; Leake, J.R. Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. *J. Appl. Ecol.* 2014, 51, 880–889. [CrossRef] [PubMed]

66. Wilhelm, J.A.; Smith, R.G. Ecosystem services and land sparing potential of urban and peri-urban agriculture: A review. *Renew. Agric. Food Syst.* 2018, 33, 481–494. [CrossRef]

67. Mwambo, F.M.; Fürst, C.; Nyarko, B.K.; Borgemeister, C.; Martius, C. Maize production and environmental costs: Resource evaluation and strategic land use planning for food security in northern Ghana by means of coupled emergy and data envelopment analysis. *Land Use Policy* 2020, 95, 104490. [CrossRef]

68. Zhou, Y.; Li, X.; Liu, Y. Rural land system reforms in China: History, issues, measures and prospects. *Land Use Policy* 2020, 91, 104330. [CrossRef]

69. Therville, C.; Antona, M.; de Foresta, H. The poliscapes of agroforestry within Mediterranean protected landscapes in France. *Sustain. Sci.* 2020, 15, 1435–1448. [CrossRef]

70. Domingo, A.; Charles, K.A.; Jacobs, M.; Brooker, D.; Hanning, R.M. Indigenous community perspectives of sustainable food security, sustainable food systems and strategies to enhance access to local and traditional healthy food for partnering williams treaties first nations (Ontario, Canada). *Int. J. Environ. Res. Public Health* 2021, 18, 4404. [CrossRef]

71. Liu, Y.; Song, W.; Deng, X. Understanding the spatiotemporal variation of urban land expansion in oasis cities by integrating remote sensing and multi-dimensional DPSIR-based indicators. *Ecol. Indic.* 2019, 96, 23–37. [CrossRef]

72. Djurfeldt, A.A.; Hall, O.; Isinika, A.; Msuya, E.; Yengoh, G.T. Sustainable agricultural intensification in four Tanzanian villages—A view from the ground and the sky. *Sustainability* 2020, 12, 8304. [CrossRef]

73. Kyalo Willy, D.; Muyanga, M.; Jayne, T. Can economic and environmental benefits associated with agricultural intensification be sustained at high population densities? A farm level empirical analysis. *Land Use Policy* 2019, 81, 100–110. [CrossRef] [PubMed]

74. Charles, H.; Godfray, H.; Garnett, T. Sustainable agricultural intensification in four Tanzanian villages—A view from the ground and the sky. *Sustainability* 2020, 12, 8304. [CrossRef]

75. Struik, P.C.; Kuyper, T.W. Sustainable intensification in agriculture: The richer shade of green. A review. *Agron. Sustain. Dev.* 2017, 37, 39. [CrossRef]

76. Vlek, P.L.G. The role of fertilizers in sustaining agriculture in sub-Saharan Africa. *Fertil. Res.* 2019, 126, 327–339. [CrossRef]

77. Fischer, G.; Darkwah, A.; Kamoto, J.; Kampanje-Phiri, J.; Grabowski, P.; Djenontin, I. Sustainable agricultural intensification and gender-biased land tenure systems: An exploration and conceptualization of interactions. *Int. J. Agric. Sustain.* 2020, 19, 403–422. [CrossRef]

78. Wezel, A.; Antona, M.; de Foresta, H. The poliscapes of agroforestry within Mediterranean protected landscapes in France. *Sustain. Sci.* 2020, 15, 1435–1448. [CrossRef]

79. Mulwa, C.K.; Muyanga, M.; Visser, M. The role of large traders in driving sustainable agricultural intensification in smallholder farms: Evidence from Kenya. *Agric. Econ.* 2021, 52, 329–341. [CrossRef]

80. Seddon, A.W.R.; Macias-Fauria, M.; Long, P.R.; Benz, D.; Willis, K.J. Sensitivity of global terrestrial ecosystems to climate variability. *Nature* 2016, 531, 229–232. [CrossRef] [PubMed]

81. Zhang, B.; Pan, Y.; Xu, J.; Tian, Y. IPBES thematic assessment on land degradation and restoration and its potential impact. *Biodivers. Sci.* 2018, 26, 1243–1248. [CrossRef]

82. Gonzalez-Roglich, M.; Zvoleff, A.; Noorn, M.; Liniger, H.; Fleiner, R.; Harari, N.; Garcia, C. Synergizing global tools to monitor progress towards land degradation neutrality: Trends and the World Overview of Conservation Approaches and Technologies sustainable land management database. *Environ. Sci. Policy* 2019, 93, 34–42. [CrossRef]

83. Práválie, R.; Patriche, C.; Borrelli, P.; Panagos, P.; Rosca, B.; Dumitrașcu, M.; Nita, I.A.; Săvulescu, I.; Birsan, M.V.; Bandoc, G. Arable lands under the pressure of multiple land degradation processes. A global perspective. *Environ. Res.* 2021, 194, 110697. [CrossRef]

84. Paoloni, L.; Onorati, A. Regulations of large-scale acquisitions of land: The case of the voluntary guidelines on the responsible governance of land, fisheries and forests. *Law Dev. Rev.* 2014, 7, 369–400. [CrossRef]

85. Ren, Y.; Li, Y.; Fu, B.; Comber, A.; Li, T.; Hu, J. Driving factors of land change in china’s loess plateau: Quantification using geographical weighted regression and management implications. *Remote Sens.* 2020, 12, 453. [CrossRef]

86. Prokop, P. Remote sensing of severely degraded land: Detection of long-term land-use changes using high-resolution satellite images on the Meghalaya Plateau, northeast India. *Remote Sens. Appl. Soc. Environ.* 2020, 20, 100432. [CrossRef]

87. Ranasinghe, T.K.G.P.; Piyadasa, R.U.K. Optimising usage of salinized lands in the lower part of the river basin for the coastal community in Bentota, Sri Lanka. *J. Natl. Sci. Found. Sri Lanka* 2020, 48, 379–396. [CrossRef]
89. Renzaho, A.M.N.; Kamara, J.K.; Toole, M. Biofuel production and its impact on food security in low and middle income countries: Implications for the post-2015 sustainable development goals. Renew. Sustain. Energy Rev. 2017, 78, 503–516. [CrossRef]

90. Wicker, R.J.; Kumar, G.; Khan, E.; Bhatnagar, A. Emergent green technologies for cost-effective valorization of microalgal biomass to renewable fuel products under a biorefinery scheme. Chem. Eng. J. 2021, 415, 128932. [CrossRef]

91. Benites Lazaro, L.L.; Giatti, L.L.; Puppim de Oliveira, J.A. Water-energy-food nexus approach at the core of businesses—How businesses in the bioenergy sector in Brazil are responding to integrated challenges? J. Clean. Prod. 2021, 303, 127102. [CrossRef]

92. Harris, E.; Ladreiter-Knauss, T.; Butterbach-Bahl, K.; Wolf, B.; Bahn, M. Land-use and abandonment alters methane and nitrous oxide fluxes in mountain grasslands. Sci. Total Environ. 2018, 628–629, 997–1008. [CrossRef]

93. Hasegawa, T.; Sands, R.D.; Bruneille, T.; Cui, Y.; Frank, S.; Fujimori, S.; Popp, A. Food security under high bioenergy demand toward long-term climate goals. Clim. Chang. 2020, 163, 1587–1601. [CrossRef]

94. Carrino, L.; Visconti, D.; Fiorentino, N.; Fagnano, M. Biofuel production with castor bean: A win-win strategy for marginal land. Agronomy 2020, 10, 1690. [CrossRef]

95. Brinkman, M.; Levin-Koopman, J.; Wicke, B.; Shutes, L.; Kuiper, M.; Fafij, A.; van der Hilst, F. The distribution of food security impacts of biofuels, a Ghana case study. Biomass Bioenergy 2020, 141, 105695. [CrossRef]

96. Jiang, L.; Wu, S.; Liu, Y.; Yang, C. Grain security assessment in Bangladesh based on supply-demand balance analysis. PLoS ONE 2021, 16, e0252187. [CrossRef]

97. Serra-Majem, L.; Tomaino, L.; Demini, S.; Berry, E.M.; Lairon, D.; de la Cruz, J.N.; Bach-Faig, A.; Donini, L.M.; Medina, F.X.; Belahsen, R.; et al. Updating the Mediterranean diet pyramid towards sustainability: Focus on environmental concerns. Int. J. Environ. Res. Public Health 2020, 17, 8758. [CrossRef]

98. He, J.; Liu, Y.; Yu, Y.; Tang, W.; Xiang, W.; Liu, D. A counterfactual scenario simulation approach for assessing the impact of farmland preservation policies on urban sprawl and food security in a major grain-producing area of China. Appl. Geogr. 2013, 37, 127–138. [CrossRef]

99. Cheng, C.; Liu, Y.; Liu, Y.; Yang, R.; Hong, Y.; Lu, Y.; Pan, J.; Chen, Y. Cropland use sustainability in Cheng-Yu Urban Agglomeration, China: Evaluation framework, driving factors and development paths. J. Clean. Prod. 2020, 256, 120692. [CrossRef]

100. Li, Y.; Li, X.; Tan, M.; Wang, X.; Xin, L. The impact of cultivated land spatial shift on food crop production in China, 1990–2010. Land Degrad. Dev. 2018, 29, 1652–1659. [CrossRef]

101. Wang, X.; Xin, L.; Tan, M.; Li, X.; Wang, J. Impact of spatiotemporal change of cultivated land on food-water relations in China during 1990–2015. Sci. Total Environ. 2020, 716, 137119. [CrossRef] [PubMed]

102. Pan, T.; Du, G.; Dong, J.; Kuang, W.; De Maeyer, P.; Kurban, A. Divergent changes in cropping patterns and their effects on grain production under different agro-ecosystems over high latitudes in China. Sci. Total Environ. 2019, 659, 314–325. [CrossRef] [PubMed]

103. Saddique, Q.; Liu, D.L.; Wang, B.; Feng, P.; He, J.; Ajaz, A.; Ji, J.; Xu, J.; Zhang, C.; Cai, H. Modelling future climate change impacts on winter wheat yield and water use: A case study in Guanzhong Plain, northwestern China. Eur. J. Agron. 2020, 119, 126113. [CrossRef]

104. Jalilov, S.M.; Keskinen, M.; Varis, O.; Ameer, S.; Ward, F.A. Managing the water-energy-food nexus: Gains and losses from new water development in Amu Darya River Basin. J. Hydrol. 2016, 539, 648–661. [CrossRef]

105. Santisteban, J.I.; Celis, A.; Mediavilla, R.; Gil-García, M.J.; Ruiz-Zapata, B.; Castaño, S. The transition from climate-driven to human-driven agriculture during the Little Ice Age in Central Spain: Documentary and fluvial records evidence. Palaeogeogr. Palaeoclimatol. Palaeoecol. 2021, 562, 110153. [CrossRef]

106. Wang, S.; Tian, Y.; Liu, X.; Foley, M. How farmers make investment decisions: Evidence from a farmer survey in China. Sustainability 2020, 12, 247. [CrossRef]

107. Qiu, T.; Boris Choy, S.T.; Li, S.; He, Q.; Luo, B. Does land renting-in reduce grain production? Evidence from rural China. Land Use Policy 2020, 90, 104311. [CrossRef]

108. Schindwein, S.L.; Feitosa de Vasconcelos, A.C.; Bonatti, M.; Sieber, S.; Strapasson, A.; Lana, M. Agricultural land use dynamics in the Brazilian part of the Plata Basin: From driving forces to societal responses. Land Use Policy 2021, 107, 105519. [CrossRef]

109. Gao, X.; Li, B.; Jiang, S.; Nie, Y. Can increasing scale efficiency curb agricultural nonpoint source pollution? Int. J. Environ. Res. Public Health 2021, 18, 8798. [CrossRef] [PubMed]

110. Kong, X.; Zhou, Z.; Jiao, L. Hotspots of land-use change in global biodiversity hotspots. Resour. Conserv. Recycl. 2021, 174, 105770. [CrossRef]

111. Al Masud, M.M.; Gain, A.K.; Azad, A.K. Tidal river management for sustainable agriculture in the Ganges-Brahmaputra delta: Implication for land use policy. Land Use Policy 2020, 92, 104443. [CrossRef]

112. Chen, C.; Hu, Z.; Liu, S.; Tseng, H. Emerging trends in regenerative medicine: A scientometric analysis in CiteSpace. Expert Opin. Biol. Ther. 2012, 12, 593–608. [CrossRef] [PubMed]

113. Kleinberg, J. Bursty and hierarchical structure in streams. Data Min. Knowl. Discov. 2003, 7, 373–397. [CrossRef]

114. Liu, Y.; Zhou, Y. Reflections on China’s food security and land use policy under rapid urbanization. Land Use Policy 2021, 109, 105699. [CrossRef]

115. Huang, W.; Hashimoto, S.; Yoshida, T.; Saito, O.; Taki, K. A nature-based approach to mitigate flood risk and improve ecosystem services in Shiga, Japan. Ecosyst. Serv. 2021, 50, 101309. [CrossRef]
116. Mutiibwa, D.; Fleisher, D.H.; Resop, J.P.; Timlin, D.; Reddy, V.R. Regional food production and land redistribution as adaptation to climate change in the U.S. Northeast Seaboard. *Comput. Electron. Agric.* **2018**, *154*, 54–70. [CrossRef]

117. Ickowitz, A.; Powell, B.; Rowland, D.; Jones, A.; Sunderland, T. Agricultural intensification, dietary diversity, and markets in the global food security narrative. *Glob. Food Sec.* **2019**, *20*, 9–16. [CrossRef]

118. Chang, J.; Havlík, P.; Leclère, D.; de Vries, W.; Valin, H.; Deppermann, A.; Hasegawa, T.; Obersteiner, M. Reconciling regional nitrogen boundaries with global food security. *Nat. Food* **2021**, *2*, 700–711. [CrossRef]

119. Wang, X.; Liu, F. Effects of elevated CO2 and heat on wheat grain quality. *Plants* **2021**, *10*, 1027. [CrossRef]

120. Youssef, A.; Sewilam, H.; Khadr, Z. Impact of Urban Sprawl on Agriculture Lands in Greater Cairo. *J. Urban Plan. Dev.* **2020**, *146*, 05020027. [CrossRef]

121. Zhang, Y.; Wang, H.; Xie, P.; Rao, Y.; He, Q. Revisiting Spatiotemporal Changes in Global Urban Expansion during 1995 to 2015. *Complexity* **2020**, *2020*, 6139158. [CrossRef]