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A Bibliometric and Visualization Review Analysis of Agricultural Ecosystem Services Research

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Abstract

As environmental pollution problems caused by agricultural production attract more and more attention, agricultural ecosystem services gradually become a hot topic of academic research. This study utilized CiteSpace to perform a bibliometric and visualization review of relating literature. Specifically, the countries and institutions with the greatest number of publications were identified. By analyzing references, the most influential authors and publications were located. Furthermore, an in-depth analysis of research emphasis derived from keyword visualization was conducted, suggesting that existing research can be grouped into three theme clusters. Finally, research trends were summarized and future trending topics were deduced.

Keywords

Bibliometric, Visualization, Agriculture, Ecosystem Services

1. Introduction

As the most vital industry satisfying basic requirements for the survival of human beings, agricultural production has long been a highly relevant topic in the field of academic research. While the initial focus was on the efficiency of agricultural production, scholars gradually started to notice the environmental pollution it imposed on the environment and began to devote themselves to figuring out ways to balance socio-economic development and the natural environment.

Based on that idea, ecosystem services surfaced and grew to be a widely discussed subject. Ecosystem services refer to the direct and indirect benefits human obtain from ecosystems (Daily, 1997, Ma et al., 2012). There are various services provided by ecosystems including providing, regulating, cultural, and

supporting services. Agricultural ecosystem services (AES) need to be investigated in order to achieve sustainable development that equally benefits human society and the nature. Other than food providing services, the agricultural ecosystem also contributes to biodiversity, water filtration, flood defense, carbon sequestration, soil retention, nutrient cycling, and so on (Barbier et al., 2011; Jones et al., 2011; Olsen et al., 2011; Burden et al., 2013; Beaumont et al., 2014). However, a great portion of services or benefits provided by ecosystems is overlooked and not calculated economically. Therefore, in the real-life market, owners of natural resources or ecosystems often do not get compensated fairly, while the users always get free rides. Consequently, owners lack motivation in protecting the ecosystem and its service-providing capacity, which hinders the welfare of humans as a whole. In order to tackle the above issue, payment for ecosystem services was suggested by scholars in the hope of incentivizing both parties in protecting the ecosystems. Numbers of researchers have looked into payment for agroecosystem services, such as payment for farmland, grassland, ranches, organic production practices, and so on (Jaeck & Lifran, 2014; Accatino et al., 2019; Borghesi et al., 2022).

Even though studies on agricultural ecosystem services are flourishing, currently there is no bibliometric review in this domain of research. Bibliometrics is a widely adopted method to analyze academic publications, with the purpose of revealing the traces of development on a certain topic, as well as to address future trends. In this paper, we performed bibliometric and visual analysis on journals, countries/regions, authors, institutions, references, and keywords in the field of agricultural ecosystem services. This paper makes two innovative contributions. First, we described the current status of agricultural ecosystem service study objectively through revealing the most highly cited journals, institutions, publications and authors. Second, by implementing bibliometric review of literature, this paper can serve scholars in the following ways: provide insights for researchers to find gaps in current research, identify future trends, and locate institutions or researchers for potential collaborations.

2. Data Collection and Methodology

In order to perform bibliometric analysis, a dataset of relevant publications was retrieved from Web of Science (WoS) core collection. TheWoS is considered to be one of the most prestigious academic databases (Van Leeuwen, 2006). The literature was downloaded in January 2022. The complete process for literature retrieving is composed of the following steps (Shown in **Figure 1**). First, the topic was set as "ecosystem service*" and "agricultur*" or "agroecosystem*"[1]. Second, to acquire more relevant articles, restrictions were applied. Language was refined to English, the timeframe was set from January 2011 to January 2022, since the topic has only been recently developed in the last decade. Then,

[1]Note that adding a * sign when searching for literature means that we are performing a fuzzy search, which allows for more flexibility of a string. For example, by inputting "agricultur*", results containing "agriculture" and "agricultural" will be included in the search results.

to accurately acquire the most relevant articles, the field of research was restricted to "economics" or "agricultural economics policy". At this point, we had a total of 198 papersas presented in Figure 2. Finally, we screened the results by carefully reading the titles and abstracts of all 198 of them, and 24 were excluded for being largely irrelevant. In the end, we have a dataset of 174 highly relevant and influential papers to perform the analysis with.

For data analysis, the software of CiteSpace 5.8.R3 was utilized. CiteSpace is a bibliometric analysis and visualization tool created in 2004 by scholar Chaomei Chen (Chen, 2004). It is widely used to analyze network maps of author co-citation references with scaling algorithms, as well as to outline the development trend in a certain field of research (He et al., 2018; Liu et al., 2017; Li & Nan, 2017). Compared to the traditional literature review, bibliometric literature analysis can minimize the influence of subjectivity, and identify the frontier of research more reliably and objectively (Li et al., 2017).

3. Visualization Results and Analysis

3.1. Visualization of Research Journals

For researchers, it is important to learn about the top journals in the field of research. Co-citation counts are one of the most important indicators in terms of a journal's academic influence (Koondhar et al., 2021). Selecting "cited journal" as the node type in CiteSpace 5.8.R3, a visualization of research journals based on co-citation was retrieved, as shown in Figure 3.

The most cited journals in the AES domain (refer to Table 1) are Ecological Economics, Science, Proceedings of the National Academy of Sciences of the United States of America, Agriculture Ecosystem & Environment, Land Use Policy, American Journal of Agricultural Economics, Nature, Environmental & Resource Economics and Bioscience. Most of these journals are in the environmental science field. Among the top journals, 3 of them are published by Elsevier and 2 of them by Springer Nature. Ecological Economics is the most-cited journal, with a cluster frequency of 155. Science ranks second with citation counts of 104. Proceedings of the National Academy of Sciences of the United States of America is the third-ranking journal with a citation count of 88.

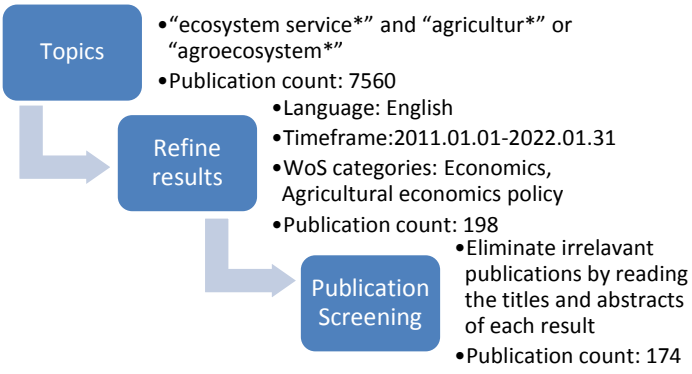

Figure 1. Processes of literature search.

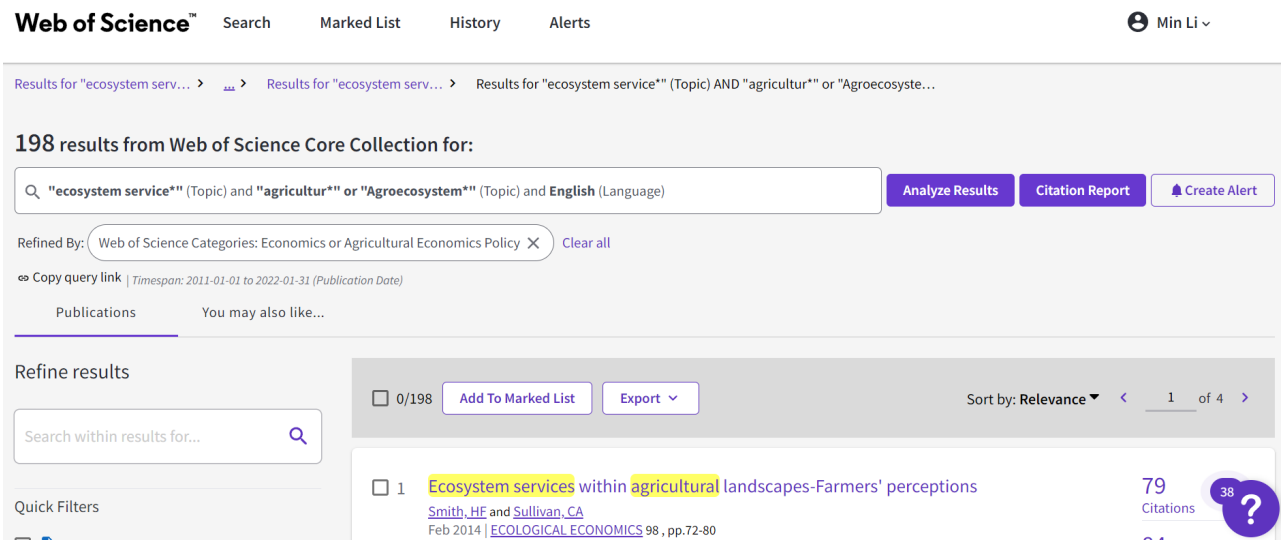

Figure 2. Screenshot of literature search results on Web of Science.

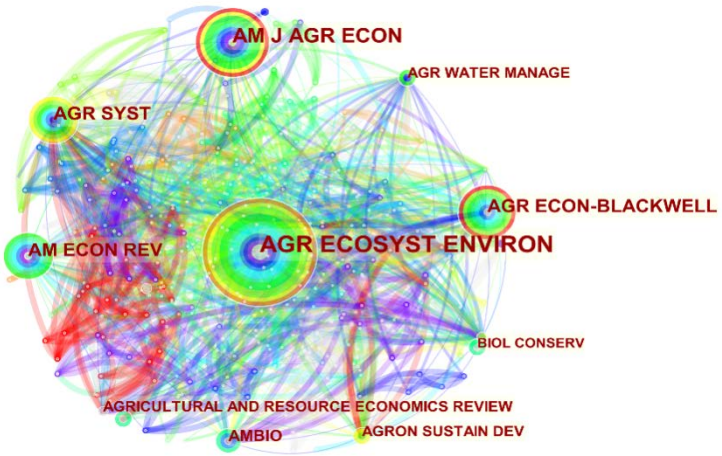

Figure 3. Visualization of the top 10 journals by citation and cluster frequency.

Table 1. Top 10 journals by citation frequency.

Frequency	Journal
155	ECOL ECON
104	SCIENCE
88	P NATL ACAD SCI USA
74	AGR ECOSYST ENVIRON
72	LAND USE POLICY
70	AM J AGR ECON
69	NATURE
67	ENVIRON RESOUR ECON
64	LAND ECON
61	BIOSCIENCE

3.2. Analysis of Countries and Institutions

Selecting node type of "country" with a threshold of 50, we retrieved the visualization map of countries, which is an important indicator of the most active research countries or regions. As is shown in Figure 4 the United States of America, Spain, Germany, Canada, Italy, and England are the most activated countries focusing on AES research. The USA is listed as the top 1 among all countries and regions, followed by Spain and Germany. Other countries and regions of great influence include Australia, France, Switzerland, Sweden, Canada, Italy, England, Scotland, and the Netherlands. It can be concluded that American and European scholars contribute the most in the domain of AES.

The statistics of institutions that are most influential in the AES field, as is declared in Table 2. Among the top 12 institutions, 11 out of 12 institutions are from the U.S. and European countries. To be more specific, almost half of them are American universities, with Michigan University being the first-ranked institution worldwide. Following that, Lund University from Sweden, the University of British Columbia of Canada, Iowa State University, and University of Delaware from the USA rank top in the list of the most influential institutions.

It can be concluded from above analysis that, researchers from developed countries are more interested in the theme. The reason why developing countries/regions and institutions from developing countries/regions are absent may lie in the difference of development stage. Developing countries are in a relatively lower level of development, and their priority is economic development, rather than realizing environmental or sustainable goals. While developed countries have already achieved economic success, their main concern is sustainable and green development that would minimize adverse effects imposed to the natural environment.

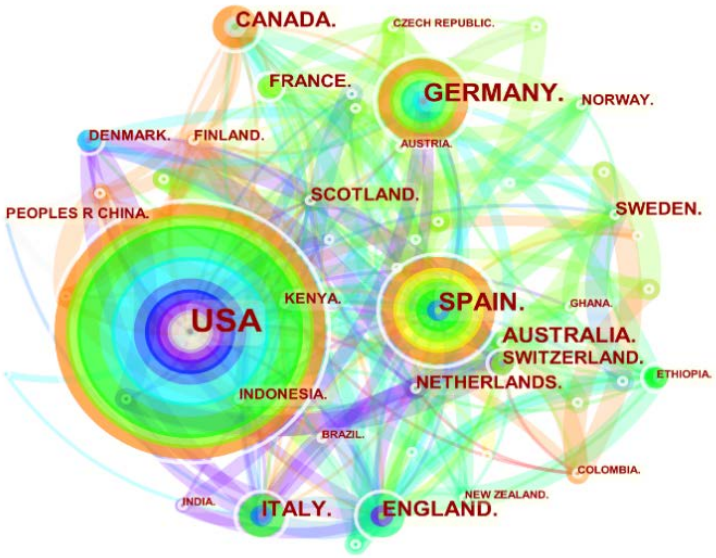

Figure 4. Visualization map of counties.

Table 2. Top 12 institutions focusing on AES by cluster frequency.

Frequency	Institution Name	Country location
8	Michigan State Univ	USA
6	Lund Univ	Sweden
4	Univ British Columbia	Canada
4	Iowa State Univ	USA
3	Univ Delaware	USA
3	INRA	France
3	Swiss Fed Inst Technol	Switzerland
3	Univ Calif Berkeley	USA
3	James Cook Univ	Australia
3	Univ Autonoma Barcelona	Spain
3	N Carolina State Univ	USA
3	Swedish Univ Agr Sci	Sweden

3.3. Analysis of Authors

The most influential researchers can be located through the frequent author co-citation network (shown in **Table 3**), which was achieved by setting node type = cited author. While the number of publications by one author suggests one's ability to produce knowledge, the citation counts reflect more accurately of their academic level and influence. For example, the most cited author in AES study is Wunder, who was quoted 32 times. At the same time, the centrality is 0.25, which far outpaces the others, indicating a broad citation relationship with other researchers. As a prestigious researcher focusing on ecosystem services, Wunder focuses on the payment of ecosystem services and their effectiveness in dealing with issues such as development and poverty. Costanza ranks second in individual influence with a citation count of 27 in the research field of AES. Costanza was one of the first to assess the value of ecosystem services, laying down a great foundation for subsequent studies.

3.4. Analysis of References

Analysis of references identifies the key authors and articles that contribute to the study of AES. The most cited papers are normally considered as milestones in the development of a research field (Chen et al., 2013). The top 10 cited papers in AES study were listed in **Table 4**. The article named Soil management in relation to sustainable agriculture and ecosystem services by Powlson DS et al. was the most cited paper, with a cited frequency of 256. This work explored factors affecting soil management practices that contribute to the sustainable development of agriculture, urged that systems such as payment for ecosystem service be found to encourage environmentally friendly practices (Powlson et al., 2011). The second-most-cited paper was published by Calvet-mir et al., who measured the impact of human consumption on ecosystem services, as well as

the loss of productivity of ecosystem services. They found out that land degradation caused significant adverse impacts on ecosystem services (Calvet-Mir et al., 2012). Sutton's research paper ranked third in the list, which identified and characterized the most important ecosystem services provided by home gardens, as well as conducted a valuation of the social significance of home garden ecosystem services (Sutton et al., 2016).

Table 3. Top 10 most cited authors based on citation counts.

Author	Citation counts	Centrality
Wunder S	32	0.25
Costanza R	27	0.11
Tilman D	26	0.13
Zhang W	24	0.13
Millennium Ecosystem Assessment	21	0.14
Engel S	21	0.09
Power AG	20	0.16
Ferraro PJ	20	0.04
Daily GC	20	0.09
Bateman IJ	20	0.15

Table 4. Top 10 most cited papers based with co-citation frequency.

Frequency	Authors	Reference
256	Powlson DS (2011)	Soil management in relation to sustainable agriculture and ecosystem services
146	Calvet-mir L (2012)	Beyond food production: Ecosystem services provided by home gardens. A case study in VallFosca, Catalan Pyrenees, Northeastern Spain
119	Sutton P (2016)	The ecological economics of land degradation: Impacts on ecosystem service values
115	Reed et al. (2013)	Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options
113	Winfree et al. (2011)	Valuing pollination services to agriculture
108	Dominati et al. (2014)	A soil change-based methodology for the quantification and valuation of ecosystem services from agro-ecosystems: A case study of pastoral agriculture in New Zealand
86	Reed et al. (2017)	Trees for life: The ecosystem service contribution of trees to food production and livelihoods in the tropics
84	Johnson et al. (2012)	Uncertainty in ecosystem services valuation and implications for assessing land use tradeoffs: An agricultural case study in the Minnesota River Basin
80	Smith & Sullivan (2014)	Ecosystem services within agricultural landscapes-Farmers' perceptions
76	Ma et al. (2012)	Farmers' Willingness to Participate in Payment-for-Environmental-Services Programmes

3.5. Analysis of Research Emphasis

Research focus and its trend can be revealed by the analysis of keywords (Leung et al., 2017; Wang et al., 2020). By selecting the node type of keywords, a visualization network of word co-occurrence was obtained as shown in **Figure 5**. **Table 5** presents a list of the top 10 co-occurring keywords based on frequency. It can be recognized that the keywords with the most occurrences are ecosystem service, conservation, biodiversity, management, agriculture, and land use. Note that the keyword environmental service appeared as the seventh in the list, which is another expression for ecosystem service. Based on the frequency and centrality of the top occurring keywords, major research topics were categorized into the following three aspects: basic theory of agricultural ecosystem services, ecosystem services valuation, and payment for ecosystem services (PES).

Table 5. Top 20 keywords.

Frequency	Keywords	Centrality
111	ecosystem service	0.1
37	conservation	0.31
37	biodiversity	0.38
26	management	0.07
24	agriculture	0.27
19	land use	0.11
16	choice experiment	0.24
13	environmental service	0.04
12	carbon sequestration	0.14
12	impact	0.02
12	climate change	0.06
11	benefit	0.17
10	diversity	0.05
10	payment	0.03
10	valuation	0.05
10	policy	0.11
9	willingness to pay	0.03
8	biodiversity conservation	0.04
8	preference	0.05
7	design	0.1

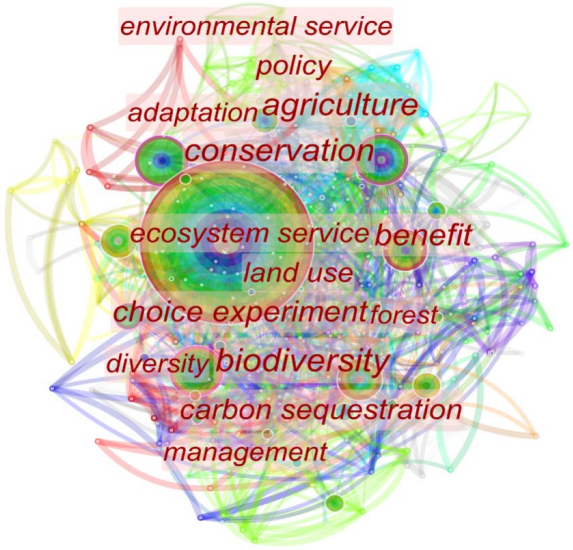

Figure 5. Visualization of keywords in publications focused on agricultural ecosystem services.

The first category is the basic theory of ecosystem services, including the concept, function, and classification of ecosystem services. Many studies have touched on the topic of various benefits humans gain from the nature dating back to the mid-1960s (King, 1966; Helliwell, 1969; Odum & Odum, 1972), but no unified terms were adopted to describe these benefits or services until later. The term ecosystem service was first proposed by Daily in 1997 (Daily, 1997), referring to services or benefits provided by the ecosystem that benefit human beings both directly and indirectly, the benefits can be monetary or socio-cultural (Chan et al., 2012). Building on Daily's work, many scholars performed researches that define the concept, functions, and provision of ecosystem services (Costanza et al., 1997; Limburg & Folke, 1999; Daily et al., 2000). Its popularity skyrocketed during and after the Millennium Ecosystem Assessment (Ma et al., 2012). Researchers generally divide the functions of ecosystem services into four categories: provisioning services, regulating services, supporting services, and cultural services (Ma et al., 2012; Kumar, 2011). Among them, provisioning services refer to material or energy outputs of goods including food, water, fuel, fiber, and so on; regulating services are biophysical processes providing benefits such as climate regulation, flood prevention, waste treatment, and water purification; cultural services encompasses recreational, aesthetic, and spiritual benefits; and supporting services represent various processes that are necessary for the production of all the other ES, such as soil formation, photosynthesis, and nutrient cycling (Ma et al., 2012; Kumar, 2011). Some scholars applied this way of classification to specific agricultural ecosystems. For example, Martin-Collado et al. (2019) analyzed the services and disservices of agroecosystems, especially those of livestock farming system; Jónsson and Davíðsdóttir (2016) addressed in detail the services provided by the soil ecosystem; Yang et al.

(2021), specified the services provided by grassland. Apart from the classification and specification of agroecosystem services, many researchers have focused on the tradeoffs and synergies of agricultural production and various ecosystem services (Accatino et al., 2019; Jia et al., 2014; Li et al., 2020).

The second hot topic is the valuation of agricultural ecosystem services. As argued by numerous scholars, agroecosystems provide us with many benefits that have not been accounted in the assessment of our economic system, which result in the neglecting of environmental effect in our daily production behavior. Therefore, it is necessary to perform economic valuations of the ecosystem services, so as to achieve sustainable development both economically and environmentally in the long haul. In terms of assessing the economic value of AES, the services provided by the agroecosystem must be identified, classified, and then valued economically (Kumar, 2011; MEA, 2005). The importance (or "value") of ecosystems is roughly divided into three types: ecological, socio-cultural, and economic value. The papers by Farber et al. (2002), Limburg et al. (2002), Wilson and Howarth (2002), Costanza et al. (1997) were the first to perform the valuation of global ecosystem services. Costanza et al. (1997) divided global ecosystem services into 17 functional types and calculated the average annual economic value of ecosystem services, which amounted to 3300 billion dollars. Their ground-breaking work is a milestone in the valuation of ecosystem services. Following their research, researchers conducted ecosystem service valuations on national or provincial/county levels (Frelichova et al., 2014; Han & Dong, 2017). Many other scholars have find interest in services provided by various agroecosystems such as forest, watershed, grassland, arable land, and farmland (Li et al., 2007; Fleischer & Tsur, 2000; Logsdon & Chaubey, 2013; Vallet et al., 2016; Du et al., 2018; Wilson & Carpenter, 1999).

The third focus of research is the widely advocated mechanism of payment for ecosystem services. As research on ecosystem services became more extensive, some began to pay attention to the management of ecosystem services, especially how to incentivize people to adopt environmentally friendly production behavior. Voluntary transactions between providers and users of ecosystem services could not reflect the "fair" value provided by ecosystems (Wunder, 2015), Payment for ecosystem services was advocated widely as a potential solution to pollution problems faced in agricultural production. Research on payment for ecosystem services originated from payment programs for rainforests in Central and South America, and gradually expanded into other fields, including agricultural land conservation programs, organic farming payments, and so on (Jaeck & Lifran, 2014; Accatino et al., 2019; Borghesi et al., 2022). In addition, implementation issues were explored in-depth, such as shareholder or farmer's willingness to accept payments, consumer's willingness to pay for organic or green products, the appropriate level of compensation, and factors affecting participants' behaviors (Atinkut et al., 2020; Choruma & Odume, 2019; Huang et al., 2018; Jaeck & Lifran, 2014; Li et al., 2020; Pouta et al., 2021).

3.6. Research Trends

Based on the visualization of keywords, bursts of the results can be analyzed. Bursts represent terms that occur multiple times or is used actively in a relatively short period of time (Zhu et al., 2021). The trends in a given domain of study can be judged from the change in bursts. It can indicate specifically what is the theme or topic in trend, as well as infer potential research topic for the near future. Figure 6 demonstrates the trend in AES research. It can be concluded that scholars' interest in a specific topic usually lasts for around 3 years. During the time period of 2011-2013, there was no obvious hot topic, possibly because this domain has just begun to attract scholars' attention and publications were sparse.

The first trending topic is cost, many researchers focused on the cost of human behavior on agricultural ecosystem services. Based on the burst and keyword frequency, it can be inferred that from 2014 to 2016, research on the cost and valuation of ecosystem services were in trend. But it can be inferred that the more popular expression for ecosystem service was environmental service back then. It should be noted that research on watershed ecosystem service was one of the fields that took on an early start. Then, starting from 2016, studies on ecosystem services of forests began to gain popularity, which has lasted for a long time and shows no sign of stopping. As for the most current trend, payment for agricultural ecosystem services is a definite hot topic. Among the earliest research on payment for ecosystem services, most focused on forest conservation programs in Central and South America (Alix-Garcia et al., 2012; García, 2011). Scholars then gradually expanded the scope of research to exploring PES of watersheds, arable lands, rangeland, as well as environmentally friendly practices of

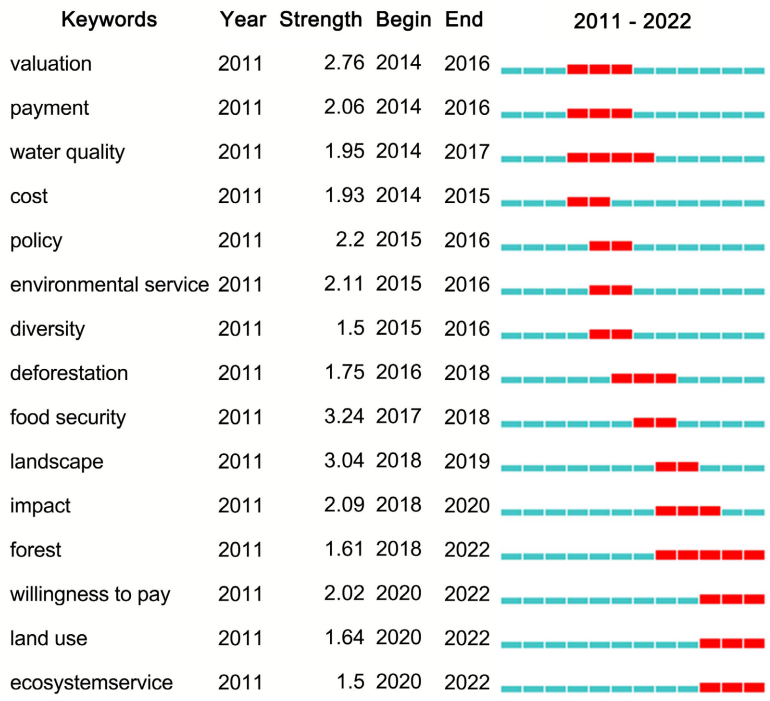

Figure 6. Top 15 keywords with the strongest citation bursts.

farmers and agricultural businesses (Jaeck & Lifran, 2014; Accatino et al., 2019; Borghesi et al., 2022).

Judging from the most recent keyword bursts of "forest", "willingness to pay", "land use", and "ecosystem service" are the most recent trends. Therefore, it can be concluded that in the foreseeable future, PES will continue to be one of the most relevant focal points for most researchers, especially PES for land and forest, as well as beneficiaries' willingness to pay for compensation programs.

4. Conclusion

This study employed bibliometric and visualization methods to review literature in the field of agricultural ecosystem services. As the results show, the top 3 academic journals with the most citation concerning AES are Ecological Economics, Science, Proceedings of the National Academy of Sciences of the United States of America. In terms of publications' countries/regions and institutions, it is clear that publications from developed countries have the most citation frequency. Through comparing aggregate citation counts and references, it was concluded that the three most influential authors in AES are Wunder S, Costanza R, Tilman D. Further, analysis on references was conducted, the most highly cited papers were located, that is *soil management in relation to sustainable agriculture and ecosystem services* by Powlson DS et al. (2011) with a citation count of 256. Most importantly, an in-depth analysis of research emphasis in the field of AES was conducted based on the frequency and centrality of the top occurring keywords. According to the results, we categorized major topics into three aspects: basic theory of agricultural ecosystem services, ecosystem services valuation, and payment for ecosystem services (PES). We then performed mini-reviews surrounding each aspect. Lastly, judging from keyword bursts, we identified trends in main research focuses over the past two decades, and pointed out that future trend lies in payment for agricultural ecosystem service, especially in relation to land and forest conservation.

This paper is limited on the extensity of literature in that we only performed literature review on publications from Web of Science Core Collection. In future work, we plan to broaden the scope of search by adding other well-recognized databases such as Scopus when performing literature search, so that we can obtain a more comprehensive understanding of the field. Other than that, more detailed work can be done on specific topics within the field of AES, such as land ecosystem services, water ecosystem services, ranch ecosystem services, and so on.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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