

## Article

# Sustainability Research in the Wine Industry: A Bibliometric Approach

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**Abstract:** Currently, the wine industry has gained great relevance worldwide. At the same time, the sustainability of the business activity has positioned itself as one of the main challenges to be achieved in the coming years. Due to the great impact that agricultural processes can have on the environment, vine and wine production is particularly susceptible to the application of new technologies and processes that improve its sustainability in the medium and long term, while allowing the improvement of product quality. The main objective of this paper is to analyze the academic literature in the field of wine industry sustainability, to determine the main contributions carried out, as well as the most prominent authors, universities, and countries in this field of study. The methodology used is bibliometric analysis, specifically the Bibliometrix<sup>®</sup> R package, in its version 4.1.1. The results reveal that research in the field of sustainability in the wine industry has increased considerably in the last three years by several leading researchers, mainly from universities located in wine-producing regions. It is concluded that research shows a trend towards collaboration among stakeholders, especially in terms of innovation, which is postulated as the main tool to improve the sustainability of the sector in the coming years.

**Keywords:** sustainable agronomy; sustainable development; wine industry; *Vitis vinifera*; viticulture



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## 1. Introduction

In the past several decades, the worldwide wine industry has seen significant changes as a result of the global rise in the number of wine producers, the expansion of wine markets in the new world, and the alteration in wine consumer behavior on a global scale [1,2]. There are about 7.3 million hectares of vineyards worldwide [3]. The European Union is a prominent actor in this regard, with 3.2 million hectares, of which about 75 percent are located in Spain (>900,000), France (>790,000), and Italy (>688,000) [3,4]. Currently, viticulture is commercially valued for its contributions to wine production and the attractive landscapes it creates for tourism and hedonism [3]. However, like with other forms of intensive agriculture, the viticulture industry's extensive use of pesticides places it among those with the greatest environmental effect [5]. In the majority of the world's vineyards, conventional viticultural procedures entail the use of herbicides to soils and synthetic pesticides to plants to control diseases and insects [6].

Although society has become more organized against traditional viticulture techniques, the percentage of planted surfaces has not altered [7,8]. According to Gilinsky [9], by adopting a sustainable strategy in the wine business, future generations may reap the benefits of expansion, long-term profitability, and enduring success in the wine sector. In this regard, new technology and green management strategies may play a crucial role in facilitating the shift to more sustainable winegrowing and winemaking practices [10,11]. Moreover, in this business, sustainability may be a competitive component, a market-driving strategy, and an innovation process driver [12,13].

The worldwide wine trade is a difficult sector due to the fact that wine quality must adhere to specified criteria in order to be sold [14,15]. Although the winegrowers shared similar learning pathways, they often argued over the most successful viticultural methods and procedures. However, they are able to see the benefits of adopting sustainable habits and, in addition to economic incentives, have in-ternal motives to do so [16–18]. The wine business is dependent on operations governed by sustainability procedures [11,19]. For their part, wine product consumers have introduced the criterion for the acquisition of drinks produced from sustainable practices into their purchasing processes, with a tendency to conclude that sustainable practices improve wine quality, even if they do not have a clear understanding of what this means in practice [13,20–22]. Then, it seems that both consumers and producers are conscious of the need to balance expansion with the decrease of the negative effects it may have when pursued without planning and consideration for the environment, society, and economy [23,24].

Therefore, there are certain challenges to be faced in the coming years, as the lack of consensus on what constitutes sustainability in the wine industry, which might vary according on geographical area, wine kind, and participating individuals [25], the cost of implementing sustainable practices, which may require significant investment in new equipment, technology, or personnel [26], or the complexity of the supply chain, which involves multiple stages from grape production to wine distribution, making it challenging to track and manage sustainability practices throughout the entire process [27], among others.

The wine industry has a considerable impact on environmental degradation, waste production, and greenhouse gas emissions, whereby sustainable practices can help mitigate the environmental impact of wine production and contribute to improve the sustainability of the industry [28]. In this vein, research on sustainable practices can help wine producers, researchers, and politicians to identify the most effective and efficient practices for reducing the environmental impact of their activities, so that are both environmentally sound and economically feasible [26].

In addition, this may allow wine producers to navigate the complex regulatory environment surrounding sustainability in the wine industry and develop strategies in line with the existing regulatory frameworks in each region [29]. Furthermore, research can help the wine industry to meet increasing consumer demand for sustainably produced wine, as they are more conscious of the impact of their purchasing decisions on the environment and are looking for goods produced in a sustainable manner [27]. Thus, by implementing sustainable practices and communicating these practices to consumers, wine producers can differentiate their products in a crowded marketplace and appeal to environmentally conscious consumers.

However, few studies examine the implementation of sustainable practices in the wine industry, and how this can enhance the firms' competitiveness [30–32]. Therefore, it is necessary to do research on sustainable practices and social policies in the grape and wine business [33]. In addition, this industry may have a substantial influence on other complementary industries, promoting the economic growth of the areas where its producers are located [34,35].

The main aim of this work is to analyze the literature on sustainability in the field of vine and wine production, in order to try to reveal the main characteristics, such as the most important institutions, authors, and countries, using different indicators, as well as to try to unveil the main subfields developed by the researchers. This research presents a bibliometric analysis of sustainability in the field of viticulture and winemaking, taking into account all publications published until 31 of December of 2022, the day the data were collected. Using the R-based software Bibliometrix® in its version 4.1.1, this study is designed to penetrate beyond the intellectual structure to the conceptual and thematic underpinning framework, revealing subject classifications, research wedges, and future research prospects.

In this study, bibliometric analysis was chosen over traditional review methods because bibliometric techniques present some benefits for revealing unique but linked networks within a subject and for providing domain overviews, such as impartiality, clarity, objectivity, ruggedness, and usefulness [36]. Revisions conducted using bibliometric techniques have the potential to improve the field by allowing researchers to gain a thorough understanding, identify research holes, and conduct assessments of pertinent current scientific problems. The analysis is carried out over articles published until 31 December 2022, totaling 2096 publications by 7490 researchers from 91 countries. There are 143 single-authored documents written by 133 individuals, whereas the remaining 1953 papers have 4.77 authors on average. The articles analyzed have 96,233 references and garnered 35,674 citations. Regarding the structure of this research paper, in the following section, the employed methodology is described. The key results are then presented in the third part. Finally, conclusions, limitations, and future research directions are presented.

## 2. Materials and Methods

To gather academic papers, the Web of Science (WoS hereinafter) database (<https://www.webofscience.com> (accessed on 12 January 2023)) was selected, considered nowadays as one of the most prestigious, comprehensive, and reliable databases in the scientific community, which has a low duplicate document ratio and a high temporal search range [37,38]. The following sources were specifically selected: ESCI, SSCI, and SCIE (Emerging Sources Citation Index, Social Sciences Citation Index, and Science Citation Index Expanded, respectively). Afterwards, the following equation was introduced “TS = sustainab\*” AND [“grapevine” or “wine\*” or “viticult\*”] to collect all the papers published until 31 of December of 2022, obtaining a total of 2440 documents. Then, the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) was applied to filter these studies [39,40], as shown in Figure 1.

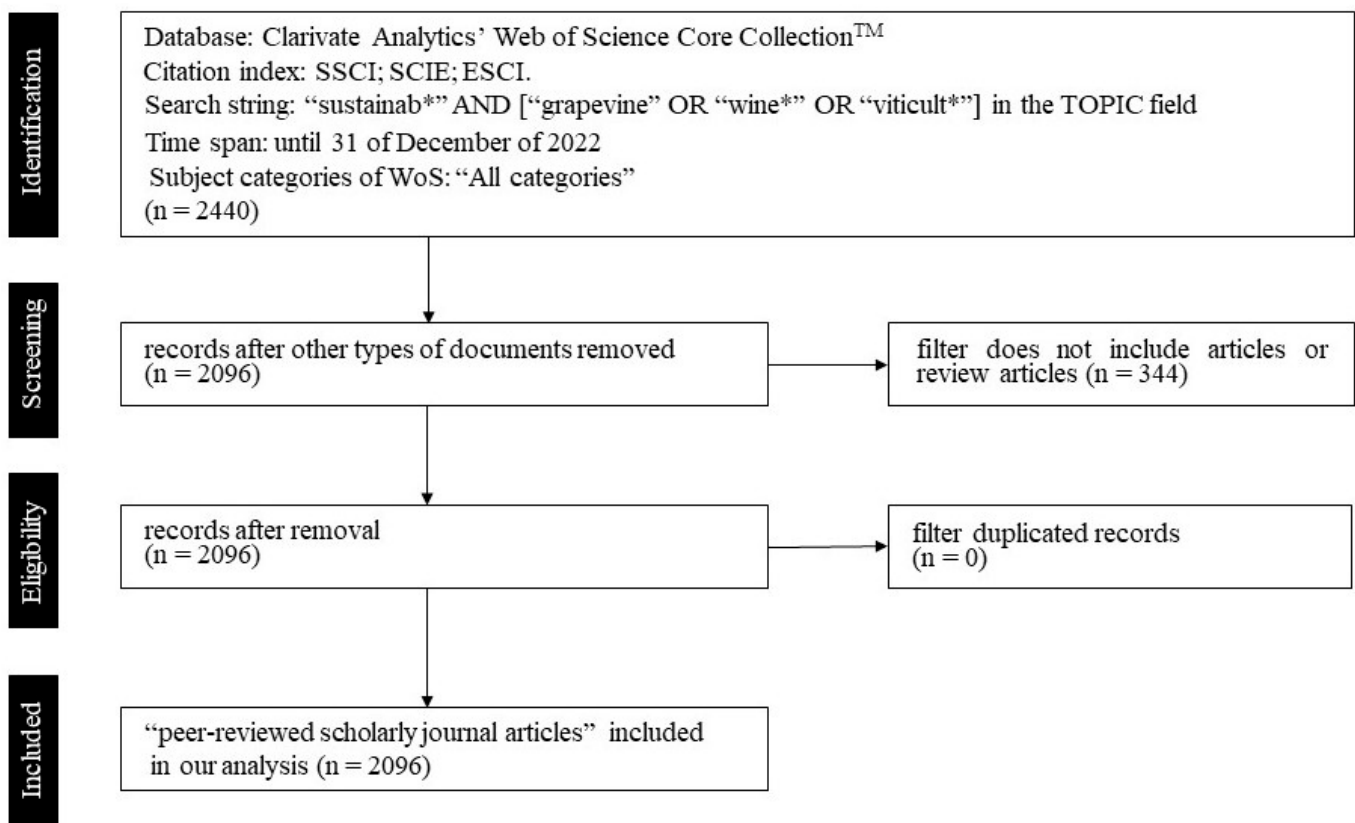


Figure 1. Screening by using PRISMA methodology.

This is an exhaustive methodology, which has acquired great popularity in recent years since, among other benefits, allowing to increase the reliability of the literature review processes [41–45]. After filtering by “articles” and “review articles”, since they are certified knowledge through the peer review processes [46], and checking the lack of overlapping between them, a total of 2096 articles were obtained.

The revision process may be seen as a control mechanism that validates the knowledge provided by peer-reviewed scientific journal publications [47,48].

A bibliometric approach was used to analyze the main academic contributions to wine industry sustainability research [49]. This technique is suitable to examine the status of an academic area using multiple factors, including highly influential and cited articles, journals, authors, institutions, and countries [50]. Additionally, it permits the examination of the network of cooperation among institutions, countries, and authors. Such a type of investigation facilitates the study of extensive published research at the macro and micro levels [51]. Therefore, bibliometric techniques can be used to conduct analyses concerning any topic in order to uncover unobservable and objective patterns [52–56].

The software Bibliometrix<sup>®</sup> was developed by Aria and Cuccurullo [57], both researchers and founders of K-Synth, a science-centric information and intelligence specialized firm located in Naples (Italy). Bibliometrix<sup>®</sup> is utilized to carry out the review and offers a comprehensive examination of scientific mapping through the tool “biblioshiny” [57]. In addition, researchers discovered that key scientific advances within a specific field were temporally interrelated, with newer findings often depending on earlier ones [58]. On the basis of the collected papers, besides analyzing the characteristics of research on sustainability of the wine industry, fundamental statistical characteristics are addressed. Several measures are utilized to evaluate the significance and utility of the publications [59], including the h-index, citations and the number of articles published. Furthermore, Bibliometrix<sup>®</sup> can be used to make a visual analysis of the results.

### 3. Results

The data set obtained from WoS and comprising papers on sustainability in the vine and wine industry is displayed in Table 1.

**Table 1.** Data set insights.

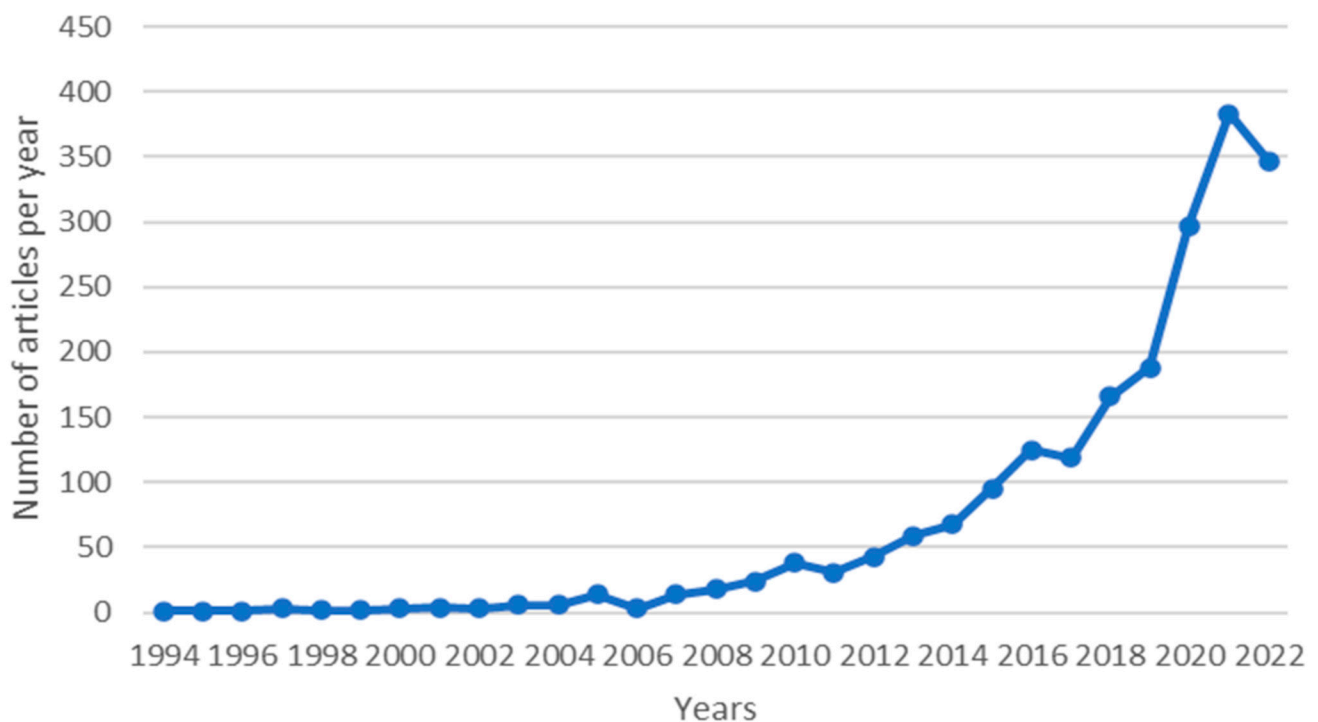
Main Information Data	
Sources	701
Documents	2096
Annual growth rate %	5.71%
Document average age	4.99
Average citations per doc	17.02
References	96,233
Document contents	
Keywords plus	5039
Author’s keywords	6382
Authorship	
Authors	7490
Authors of single-authored docs	133
Authors collaboration	
Single-authored docs	143
Co-authors per doc	4.77
International co-authorships %	27.19%

Source: Own elaboration.

It offers useful insights into the research analysis, as sources (journals), documents (articles), some features as annual growth rate of publications, average age and citations of the papers, and the total number of references used. In addition, it shows the number of different “keywords plus” and authors’ keywords, the amount of authors involved, and which of them have written solo articles. In this regard, there are 143 single-authored documents, which means that some of these authors have written more than one solo article. Furthermore, it is exposed the average number of co-authors per article, and the average percentage of international co-authorship.

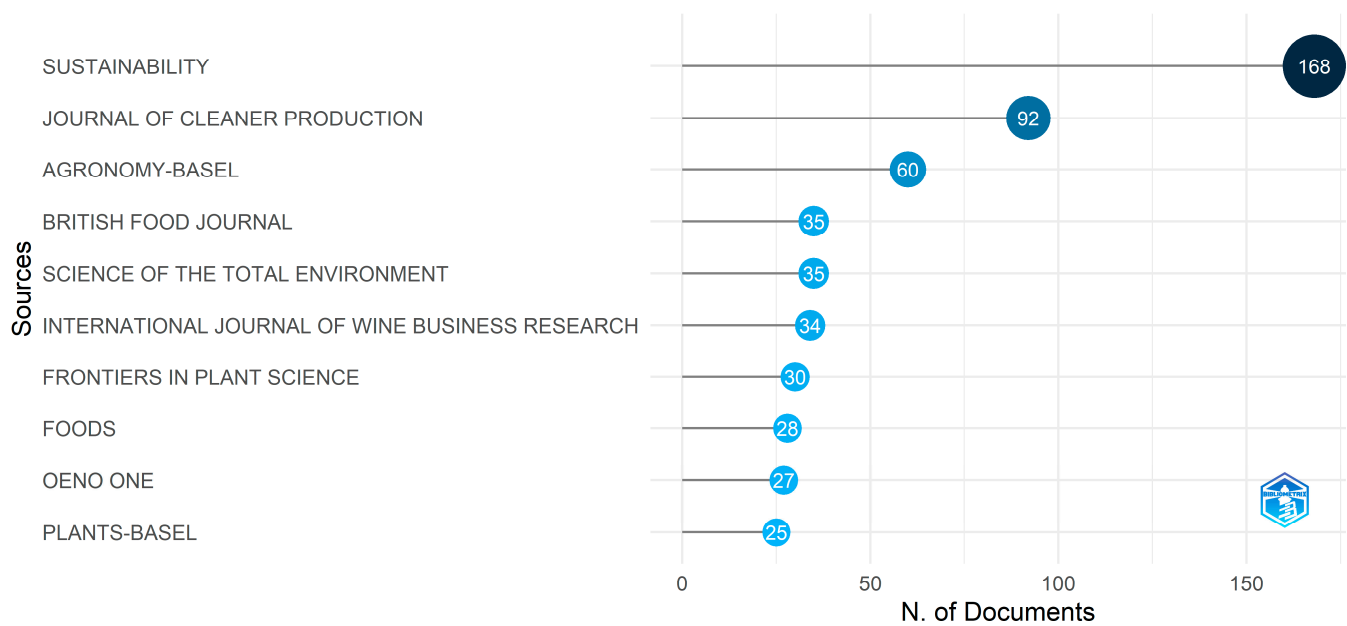
### 3.1. Leading Journals and Production in the Field of Sustainability in the Wine Industry

Although scientific research in the field of sustainability applied to the wine sector has gained importance in the last decade, existing research is insufficient, and greater efforts are required to try to establish a framework for action in this area [31,32]. While there is a general rise in interest in the topic; this increase is most pronounced from 2012 onwards. It is also observed that in 2019 the number of publications increases considerably with respect to previous years, as reflected in Figure 2.



**Figure 2.** Evolution of production over time.

Figure 3 displays the ten most important journals in terms of number of publications from the list of 701 journals in the domain of sustainability in the vine and wine industry. The leading journals on this list are *Sustainability*, *Journal of Cleaner Production*, and *Agronomy*.



**Figure 3.** Leading journals per number of publications in sustainability of the vine and wine industry.

These three journals published more than 15% of all the papers analyzed. Currently, these are some of the most influential journals focusing on sustainability in the vine and wine industry. As the most influential journals in these fields, their publishing rates over time have been studied and are shown in Table 2.

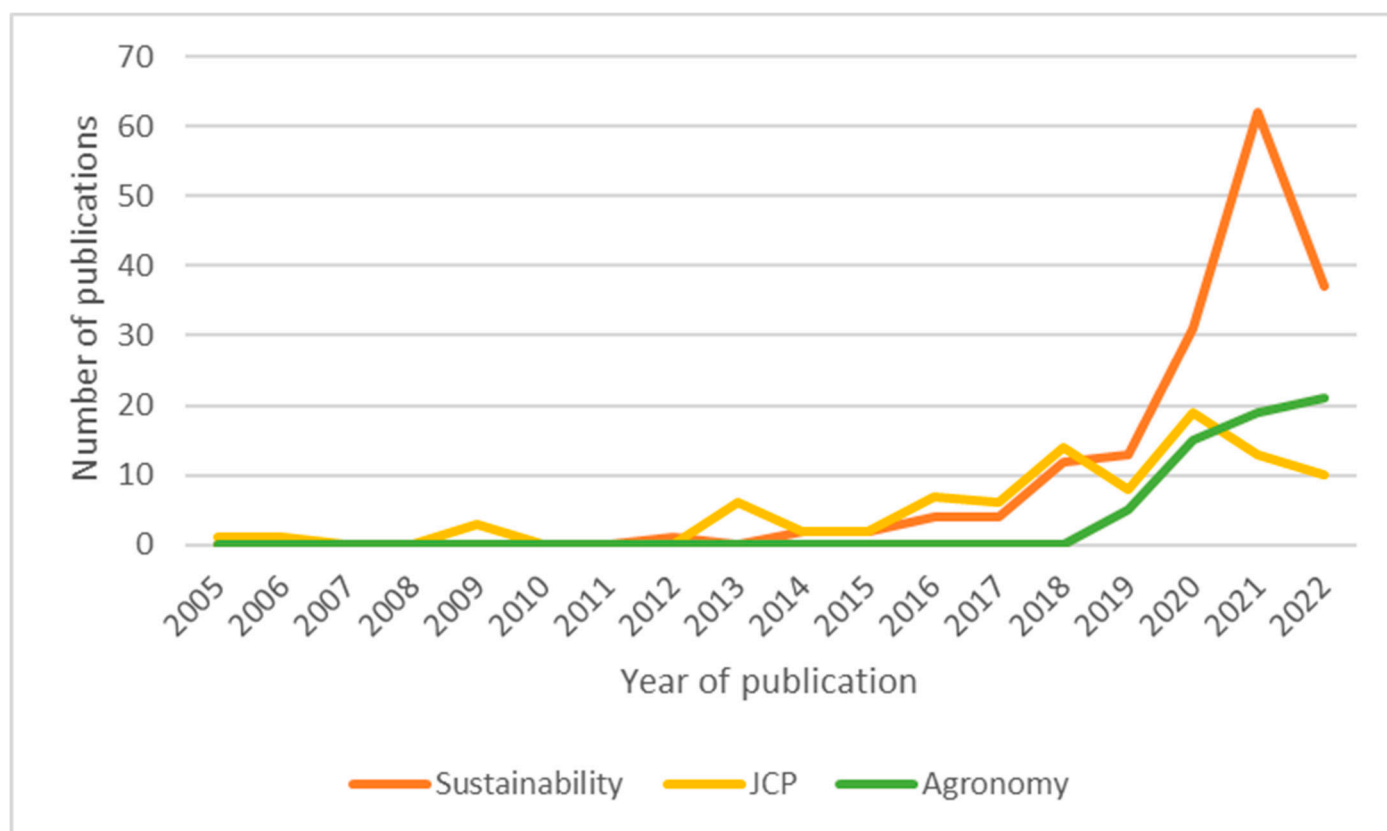
**Table 2.** List of articles published over time by the three leading journals identified.

Year	Sustainability	JCP	Agronomy	Total
2005	0	1	0	1
2006	0	1	0	1
2007	0	0	0	0
2008	0	0	0	0
2009	0	3	0	3
2010	0	0	0	0
2011	0	0	0	0
2012	1	0	0	1
2013	0	6	0	6
2014	2	2	0	4
2015	2	2	0	4
2016	4	7	0	11
2017	4	6	0	10
2018	12	14	0	26
2019	13	8	5	26
2020	31	19	15	65
2021	62	13	19	94
2022	37	10	21	68
Total	168	92	60	320
%	8.02%	4.39%	2.86%	15.27%

Source: Own elaboration. Note: JCP = *Journal of Cleaner Production*.

In order to ease presentation, these data are presented as a graph in Figure 4.





**Figure 4.** Evolution of the number of articles published by the three leading journals identified.

As can be seen, the first article of the database analyzed was published by one of these three leading journals in 2005, particularly by the *Journal of Cleaner Production*. Since 2019, the number of publications in these domains in the three top journals has increased considerably. *Sustainability* ranks first with 168 papers published in 2022, followed by the *Journal of Cleaner Production*, which remains second with 92 articles, and *Agronomy*, ranks third with a total of 60 articles. Therefore, these three journals gathered 15.27% of the total number of papers published in sustainability in the vine and wine industry by the 701 recognized journals.

### 3.2. Major Contributions to the Field of Sustainability in the Vine and Wine Industry

According to the classification of the top authors in terms of articles published, Table 3 displays the top ten list from the aforementioned database, taking into account the number of articles, citations, and h-index. Furthermore, shows the position of the authors with the highest number of local citations and h-index in the list.

For instance, Alonso A.D. is the most prolific author in the subject of analysis, both per articles published and per fractionalized articles published (that is, considering the number of co-authors), whereas Lamastra L. is second in terms of scientific output and first in regard with local citations. For its part, Medrano H. remains in the top three in all three classifications. In addition, a number of authors are included in many classifications, indicating the significance of their work in this area of research by various measures. Table 4 shows the publications of leading authors in terms of research output, although, in this case, it is measured taking into account the number of participants involved in the development of each paper.

The number of published articles fractioned is calculated according to the number of co-authors involved in the development of every paper. Thus, this reflects the “net” articles produced by the individual authors, considering the proportion of participation in the articles according to the number of co-authors.

**Table 3.** Classification of the leading authors in terms of number of publications, citations, and h-index.

Rank	Authors	A.P.	MLC Authors	Cites	Rank A.P.	Authors	h-Ind.	Rank A.P.
1	Alonso, A.D.	14	Lamastra, L.	162	2	Medrano, H.	10	3
2	Lamastra, L.	12	Medrano, H.	133	3	Cerda, A.	9	5
3	Medrano, H.	12	Schaufele, I.	126	199	Fraga, H.	9	8
4	Santos, J.A.	12	Hamm, U.	120	357	Santos, J.A.	9	4
5	Cerda, A.	11	Vazquez, R.I.	113	216	Alonso, A.D.	8	1
6	Fontaine, F.	11	Forbes, S.L.	109	325	Escalona, J.M.	8	12
7	Capri, E.	10	Pomarici, E.	109	100	Lamastra, L.	8	2
8	Fraga, H.	10	Vecchio, R.	106	58	Novara, A.	8	21
9	Li, H.	10	Wratten, S.D.	101	1449	Clement, C.	7	13
10	Pou, A.	10	Castka, P.	99	676	Galati, A.	7	18

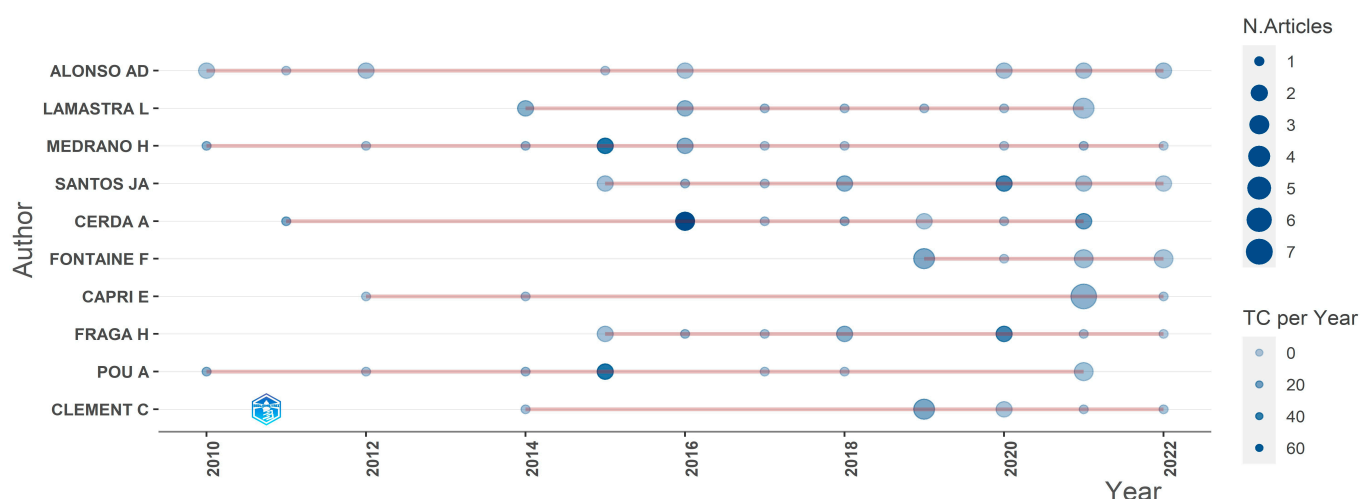
Source: Own elaboration. Note: MLC = Most local cited; A.P. = Articles published; h-Ind. = h-index.

**Table 4.** Classification of leading authors considering the number of published articles fractioned according to the number of authors.

Authors	Articles	A. F.	Authors	Articles	A. F.
Alonso, A.D.	14	7.33	Cerda, A.	11	2.77
Dressler, M.	7	5.00	Szolnoki, G.	5	2.70
Sabir, A.	8	4.42	Rodrigo, J.C.	9	2.48
Santos, J.A.	12	3.00	Fraga, H.	10	2.46
Herman, A.	3	3.00	Sgroi, F.	5	2.42

Source: Own elaboration. Note: A. F.: Articles fractionalized.

Furthermore, scientific output of the most prominent authors per published articles is showed in Figure 5. As we can see, all the production of these relevant researchers is clustered in the last twelve years.



**Figure 5.** Evolution of the leading authors' scientific production. Note: TC means Total citations.

Tables 5 and 6 include a full listing of the articles that have received the most citations both globally and locally, respectively. The total number of citations that a certain work has earned is referred to as its global citations, and it takes into account all the articles that have been published in any area and in any location. In turn, local citations make reference to the citations that every individual document got from the remaining papers that are a part of the collection that is being evaluated. Normalized total citations typically refer to the total number of citations that a research article or author has received, adjusted for the



number of years since publication and the average number of citations received by articles in the same field and time period, allowing to consider the differences in citation practices across fields and time periods, as well as the time-dependent nature of citation impact.

**Table 5.** Leading articles per number of citations.

Document	TC	TC per Year	Normalized TC
Myles, S., 2011, P Natl Acad Sci USA [60]	460	35.38	10.89
Fleet, G.H., 2008, Fems Yeast Res [61]	347	21.69	5.87
Park, S.E., 2012, Global Environ Chang [62]	332	27.67	10.44
Prosdocimi, M., 2016, Sci Total Environ [63]	269	33.63	8.07
Fontana, A.R., 2013, J Agr Food Chem [64]	265	24.09	8.88
Medrano, H., 2015, Crop J [65]	259	28.78	8.94
Keller, M., 2010, Aust J Grape Wine R [66]	252	18	7.51
Tagliavini, M., 2001, Eur J Agron [67]	246	10.7	1.91
Prosdocimi, M., 2016, Catena [68]	236	29.5	7.08
Novara, A., 2011, Soil Till Res [69]	231	17.77	5.47

Source: Own elaboration. Note: TC = Total citations.

**Table 6.** Ranking of the most relevant articles by local and global citations.

Document	Year	LC	GC	LC/GC Ratio	NLC	NGC
Forbes, S.L., 2009, J Clean Prod [70]	2009	92	172	53.49	8.4	3.18
Christ, K.L., 2013, J Clean Prod [30]	2013	90	142	63.38	12.29	4.76
Schaufele, I., 2017, J Clean Prod [22]	2017	85	190	44.74	20.64	7.25
Gabzdylova, B., 2009, J Clean Prod [71]	2009	83	158	52.53	7.57	2.92
Pomarici, E., 2014, J Clean Prod [72]	2014	76	141	53.9	14.12	4.69
Szolnoki, G., 2013, J Clean Prod [16]	2013	66	90	73.33	9.01	3.02
Rugani, B., 2013, J clean prod [73]	2013	62	149	41.61	8.47	4.99
Flores, S.S., 2018, J Clean Prod [74]	2018	52	57	91.23	14.01	2.64
Villanueva-Rey, P., 2014, J Clean Prod [75]	2014	45	114	39.47	8.36	3.79
D'amico, M., 2016, J Clean Prod [76]	2016	43	106	40.57	9.72	3.18

Source: Own elaboration. Note: LC = Local citations; GC = Global citations; NLC = Normalized local citations; NGC = Normalized global citations.

Table 7 displays the leading affiliations in the field of sustainability of the vine and wine industry, as determined by the rating that was published in the WoS database.

**Table 7.** Ranking of the Top-10 most relevant affiliations.

Rank	Affiliations	Location (Country)	Articles
1	University of Milan	Italy	59
2	University of Padova	Italy	59
3	University of Lisbon	Portugal	54
4	Sacro Coure Catholic University	Italy	52
5	University of Trás-os-Montes e Alto Douro	Portugal	52
6	University of Palermo	Italy	47
7	University of California, Davis	U.S.A.	43
8	The University of Adelaide	Australia	38
9	University of Bologna	Italy	35
10	University of La Rioja	Spain	34

Source: Own elaboration.

The ranking was based on relevance to the field, measured through the number of publications. Italian universities of Milan, Padova, Sacro Coure Catholic, Palermo, and Bologna are in first, second, fourth, sixth, and ninth position, respectively, with a total of 59, 59, 52, 47, and 35 papers published, being the most prominent country in this ranking in terms of number of universities. Furthermore, Portuguese universities of Lisbon, and

Trás-os-Montes e Alto Douro are in third and fifth place, with 54 and 52 articles, respectively. Then, the universities of California (U.S.A.), Adelaide (Australia), and La Rioja (Spain), occupy the seventh, eighth, and tenth positions, with 43, 38, and 34 articles published. It is interesting that five out of ten affiliations on the list are situated in Italy, which is one of the leading nations in wine production since, together with France and Spain, it produced 47% of the world wine production in 2021. Thus, some Italian universities are devoting a significant amount of time and resources to the task of enhancing the long-term sustainability of the wine industry by investing in research in this area.

In connection with the previous table, Table 8 analyzes research in the field of wine industry sustainability at the country level, in an attempt to determine the research output of each nation, both in terms of publications and citations received. Again, Italy is ranked first but, this time, Spain and the U.S.A. are classed second and third, all three in both classifications. Furthermore, it is worth noting that in this case, by taking into account publications at the national level, some wine industry powers that did not appear in the previous list are ranked, such as France, Germany, South Africa, and Brazil. However, some major producing countries, such as Chile and Argentina, are missing from this list. This could be interpreted as an underinvestment by Latin American institutions in research on the sustainability of the wine industry.

**Table 8.** Top-10 countries by scientific production and by number of citations.

Rank	Country	A.P.	SCP	MCP	MCP Ratio	Country	Cites	A.A.C.	Rank by A.P.
1	Italy	505	381	124	24.60%	Italy	8671	17.17	1
2	Spain	265	218	47	17.70%	Spain	4311	16.27	2
3	U.S.A.	148	115	33	22.30%	U.S.A.	4084	27.59	3
4	Portugal	143	107	36	25.20%	Australia	3176	26.03	5
5	Australia	122	73	49	40.20%	France	2351	20.27	6
6	France	116	69	47	40.50%	Portugal	1977	13.83	4
7	Germany	80	53	27	33.80%	Germany	1525	19.06	7
8	China	64	47	17	26.60%	New Zealand	941	24.76	13
9	Brazil	56	44	12	21.40%	Brazil	780	13.93	9
10	South Africa	42	34	8	19.00%	Canada	722	17.61	11

Source: Own elaboration. Notes: A.P. = Articles published; SCP = Intra-country collaboration; MCP = Multi-country collaboration; A.A.C. = Average article citations.

Keywords reflect, in a summarized manner, the thematic scope of the research work. Therefore, by analyzing them, it is possible to determine the field of research to which the paper belongs, and to determine the most studied topics. In Table 9, the most frequent keywords used in the papers analyzed are displayed. The first keyword reflects the importance of management in the sustainability of the wine industry (169 occurrences), so that this seems to be a relevant topic in research on sustainability of vine and wine industry. There are also some words directly related to the production process, the outcomes of the business, environmental sustainability, and health care applications. In this regard, some keywords, such as sustainability, climate change, impact, or behavior, seem to be related to the preservation of the environment. In addition, other terms, such as management, performance, growth, consumption, yield, or industry, are connected to the topic of economics in a more direct manner. Furthermore, there are keywords that are more associated with the agricultural process for the production of grapes and the subsequent process of winemaking, such as wine, quality, *Vitis-vinifera*, food, life-cycle assessment, grapevine, or soil, in addition to others that may be more associated with health care, such as phenolic compounds or antioxidant activity.

**Table 9.** Keywords most frequently used by authors.

Rank	Words	Ocur.	Rank	Words	Ocur.
1	Management	169	11	Consumption	76
2	Wine	165	12	Yield	73
3	Quality	143	13	Phenolic Compounds	70
4	Sustainability	117	14	Industry	62
5	<i>Vitis-vinifera</i>	111	15	Behavior	59
6	Performance	101	16	Life-Cycle Assessment	58
7	Impact	100	17	Grapevine	57
8	Growth	98	18	Diversity	56
9	Climate-Change	84	19	Soil	55
10	Food	82	20	Antioxidant Activity	54

Source: Own elaboration. Note: Ocur.: Occurrences.

Although Table 9 allows us to reveal to a certain extent the main topics analyzed by the studies that make up the database analyzed, it is necessary to go deeper into their analysis in order to clarify their effective linkage. To try to reveal, as far as possible, the main topics analyzed by the most frequently used keywords, a co-occurrence analysis was carried out. The results are shown in Table 10.

**Table 10.** Co-occurrence network: betweenness centrality.

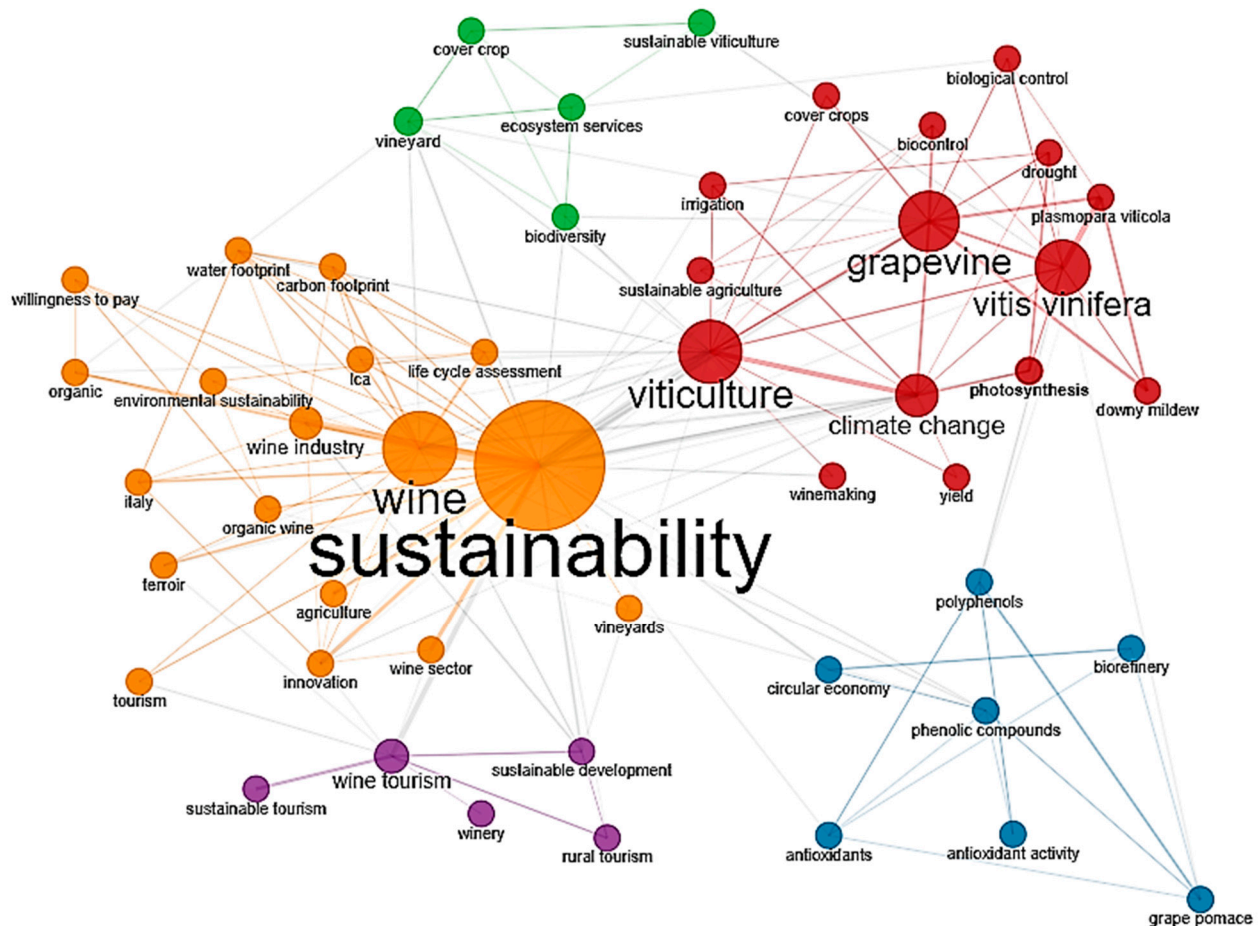
Node	Ct	Btw. Centr.	Node	Ct	Btw. Centr.
Grapevine	1	125.305843	Biodiversity	3	22.901330
<i>Vitis vinifera</i>	1	137.024610	Cover Crop	3	1.808153
Viticulture	1	141.168234	Wine Tourism	4	98.229400
Climate Change	1	43.058369	Sustainable Development	4	2.171703
Plasmopara Viticola	1	3.523096	Sustainable Tourism	4	0.000000
Sustainable Agriculture	1	0.266388	Winery	4	0.000000
Winemaking	1	0.000000	Rural Tourism	4	0.000000
Irrigation	1	0.703643	Sustainability	5	637.486707
Biocontrol	1	2.172058	Wine	5	92.651472
Biological Control	1	4.918098	Wine Industry	5	9.175069
Downy Mildew	1	0.000000	Life Cycle Assessment	5	4.181970
Drought	1	1.755485	Innovation	5	13.435261
Photosynthesis	1	0.938191	Vineyards	5	0.000000
Yield	1	0.000000	Wine Sector	5	0.000000
Cover Crops	1	0.000000	Agriculture	5	0.000000
Polyphenols	2	18.207417	Italy	5	0.222682
Grape Pomace	2	10.988662	Carbon Footprint	5	0.200362
Circular Economy	2	32.863631	Organic Wine	5	3.344754
Phenolic Compounds	2	51.549430	Water Footprint	5	1.443470
Antioxidant Activity	2	0.491278	Lca	5	0.095405
Antioxidants	2	18.635521	Terroir	5	0.293027
Biorefinery	2	1.206039	Willingness To Pay	5	1.532672
Vineyard	3	54.518675	Environmental Sustainability	5	0.752020
Sustainable Viticulture	3	7.732478	Organic	5	0.703370
Ecosystem Services	3	3.239581	Tourism	5	0.104445

Source: Own elaboration. Note: Ct: Cluster; Btw. centr.: Betweenness centrality.

This index was built considering the degree of betweenness centrality. In the context of co-occurrence analysis, keywords with high betweenness centrality are those that are central to the flow of information between other keywords in the network. These keywords may represent key concepts or topics that are relevant to multiple areas of research within

the network. Identifying keywords with high betweenness centrality can be useful in understanding the structure and organization of the research landscape within a particular field or discipline and can help to identify important areas of research that may require further investigation.

Co-occurrence analysis of keywords in bibliometric studies is a method used to identify patterns and relationships between the keywords used in a set of documents, such as scientific articles or academic papers. Then, keywords that frequently appear together in the same document are considered to be related to each other and are grouped together. This analysis is based on the assumption that the keywords used in a document reflect its content and provide insight into the topics that are being discussed. By analyzing the frequency of co-occurrence of keywords across multiple documents, common themes and topics that are relevant to the field under study can be identified. Co-occurrence analysis typically involves constructing a matrix of all possible pairs of keywords and calculating the frequency of co-occurrence for each pair. This matrix can then be visualized using techniques such as network analysis or clustering to identify patterns and relationships between the keywords. Figure 6 provides a representation of these links in order to make the information more easily comprehensible.

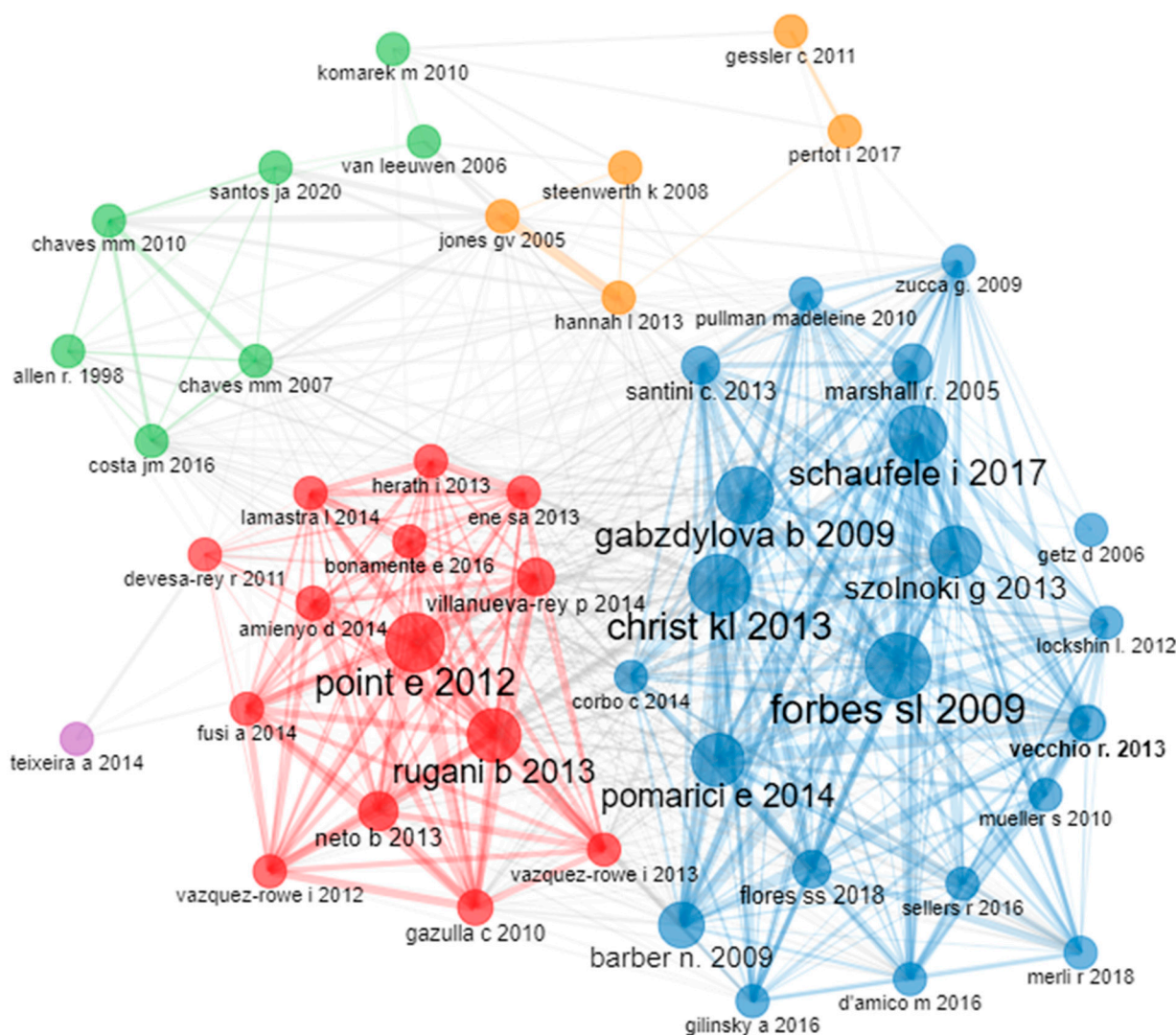


**Figure 6.** Co-occurrence network of keywords.

Betweenness centrality is a measure of the importance of a node (in this case, a keyword) in a network. In co-occurrence analysis, a network is constructed based on the co-occurrence of keywords across a set of documents, where each keyword is represented as a node in the network, and edges are drawn between nodes that co-occur in the same document. The betweenness centrality of a node is calculated by determining the number of shortest paths between pairs of nodes in the network that pass through that node. Nodes



with high betweenness centrality are considered to be important in maintaining the flow of information between other nodes in the network, as they act as key intermediaries. According to the above, keywords have been classed into five clusters. Those ones that are more closely associated with an agricultural approach have been placed in the first cluster (red). This cluster refers to a variety of difficulties that are connected to the cultivation and management of grapevines. The second category (blue) contains keywords associated with the medicinal benefits of grapes and wine, while the third group (green) consists of terms associated with environmentally responsible farming practices. Finally, wineries and wine tourism are the subjects of the keywords that make up cluster four (purple), while cluster five (orange) is concerned with the topics of sustainability, efficiency, and innovation in vineyard and wine company operations. Figure 7 shows the groups of papers resulting from the co-citation analysis.



**Figure 7.** Co-citation network.

Table 11 shows the results of the co-citation analysis. When two papers are both referenced in a third work, they are co-cited [57,77]. Co-citation provides a valuable metric for assessing intellectual production in a given field as well as for tracking the evolution of currents of thought [77]. The main collaborations established between research institutions at the international level are shown in Figure 8, which shows the importance of collaborations between Spain, France, and Italy, the three main viticultural powers in the European Union. There are also collaborations between other countries that are important

in this industry, such as Australia, the U.S.A., Chile, and Germany, among others. An analysis of Table 12 shows that Italy and Spain are two of the main driving forces in the establishment of international research collaborations, while the U.S.A., Australia, and France are other important countries in this field.

**Table 11.** Co-citation analysis of articles.

Node	Ct	Btw Centr.
Point, E., 2012 [78]	1	140.787204
Rugani, B., 2013 [73]	1	83.582617
Ene, S.A., 2013 [79]	1	42.257337
Villanueva, P., 2014 [75]	1	38.186319
Neto, B., 2013 [80]	1	29.131225
Lamastra, L., 2014 [81]	1	17.928992
Herath, I., 2013 [82]	1	15.886463
Vazquez-R, I., 2013 [83]	1	12.764911
Gazulla, C., 2010 [84]	1	12.666454
Devesa-R, R., 2011 [85]	1	11.593714
Amienyo, D., 2014 [86]	1	10.340231
Bonamente, E., 2016 [87]	1	9.330247
Fusi, A., 2014 [88]	1	7.150223
Vazquez-R, I., 2012 [89]	1	3.475337
Christ, K.L., 2013 [30]	2	100.498067
Schaufele, I., 2017 [22]	2	83.205170
Forbes, S.L., 2009 [70]	2	45.670066
Gabzdylowa, B., 2009 [71]	2	35.977720
Zucca, G., 2009 [90]	2	24.608208
Barber, N., 2009 [91]	2	21.071125
Szolnoki, G., 2013 [16]	2	16.495530
Marshall, R., 2005 [92]	2	12.987370
Merli, R., 2018 [93]	2	10.804963
Flores, S.S., 2018 [74]	2	10.535808
Corbo, C., 2014 [94]	2	5.857861
Pomarici, E., 2014 [72]	2	5.562451
Santini, C., 2013 [95]	2	4.971298
Pullman, M., 2010 [96]	2	3.22788
D'amico, M., 2016 [76]	2	1.663052
Lockshin, L., 2012 [97]	2	1.468909
Gilinsky, A., 2016 [9]	2	1.325005
Vecchio, R., 2013 [98]	2	0.708654
Sellers, R., 2016 [99]	2	0.128536
Mueller, S., 2010 [100]	2	0.036869
Getz, D., 2006 [101]	2	0.000000
Komarek, M., 2010 [102]	3	14.10786
Chaves, M., 2007 [103]	3	12.24884
Costa, J.M. 2016 [104]	3	6.037696
Van Leeuwen, 2006 [105]	3	3.427013
Allen, R., 1998 [106]	3	0.605798
Chaves, M., 2010 [107]	3	0.250005
Santos, J.A., 2020 [108]	3	0.197947
Teixeira, A., 2014 [109]	4	0.061233
Hannah, L., 2013 [110]	5	86.072201
Jones, G.V., 2005 [111]	5	51.114464
Steenwerth, K., 2008 [112]	5	14.584636
Pertot, I., 2017 [113]	5	0.433756
Gessler, C., 2011 [114]	5	0.000000

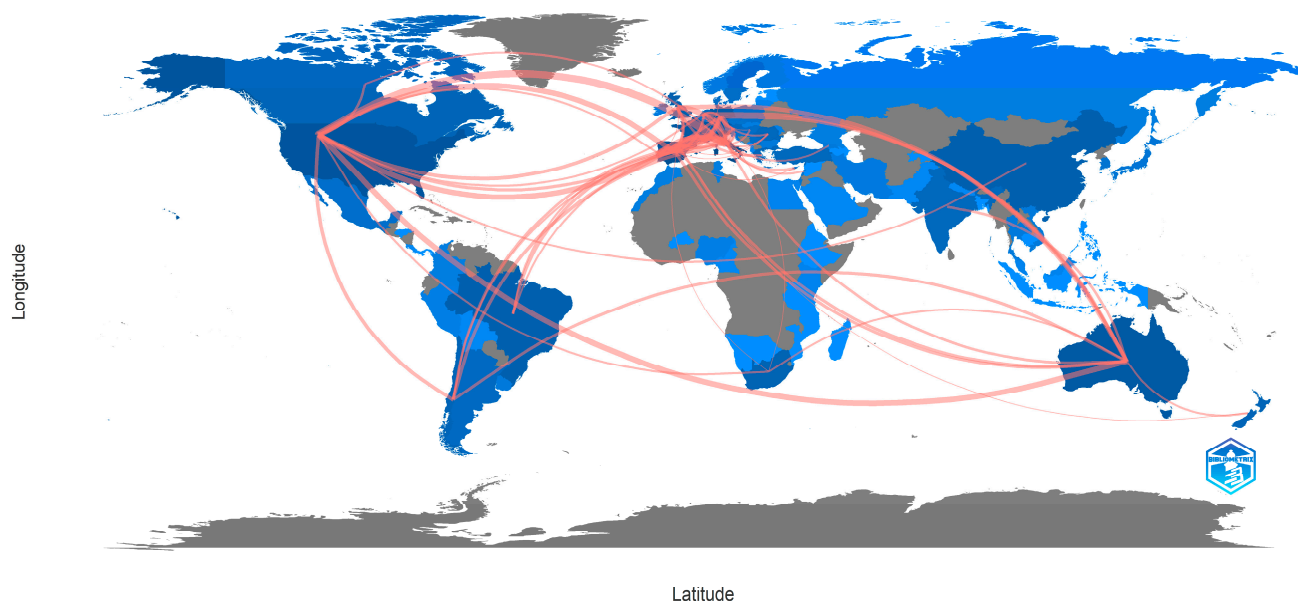
Source: Own elaboration. Note: Ct: Cluster; Btw. centr.: Betweenness centrality.



**Table 12.** International collaboration in research articles.

From	To	Frequency	From	To	Frequency
Italy	Spain	38	Italy	Chile	9
Italy	France	31	Italy	Netherlands	9
Italy	USA	31	Portugal	France	9
Spain	Portugal	29	Spain	U.K.	9
Spain	France	19	Australia	Chile	8
Italy	U.K.	18	France	Australia	8
USA	Australia	18	France	Switzerland	8
Italy	Germany	17	Italy	Cyprus	8
Spain	USA	17	Spain	Australia	8
USA	France	17	Spain	Brazil	8
Italy	Portugal	15	Spain	Netherlands	8
Spain	Germany	15	USA	Germany	8
Australia	U.K.	13	Australia	India	7
Italy	Austria	10	France	Chile	7
USA	Chile	10	Italy	Australia	7
USA	U.K.	10	U.K.	Greece	7
Australia	Germany	9	USA	Canada	7
Australia	Netherlands	9	Australia	New Zealand	6
France	Austria	9	Australia	South Africa	6
France	Germany	9	France	U.K.	6

Source: Own elaboration.

**Figure 8.** Collaboration world map.

#### 4. Discussion

Sustainability is a challenge that all nations must address to try to reduce the environmental impact of their productive activities and the population's lifestyle. In this regard, the grape and wine industries have grown considerably in importance in recent years, economically, socially, and culturally. For this reason, this paper attempts to establish, through the use of bibliometric techniques, which are the main authors, universities and countries, among other features, that contribute to the sustainability of this development. Then, in the following paragraphs, the content of the information displayed in the form of tables and figures is discussed.

Table 1 shows the main aggregate characteristics of the literature analyzed in this paper. In this regard, this paper analyses 2096 papers from 701 sources. As can be observed,

this relevant topic has gained popularity over the years, which is reflected in an average growth rate of 5.71%. This comprehensive topic can be analyzed from different perspectives (economic, agricultural, food, chemical, health, etc.), which is captured in the 6382 keywords used by authors. Furthermore, it is observed that the vast majority of the articles are co-authored, with an average number of authors exceeding 4 per paper, and a low percentage of sole authorship, around 6.8% of the total. It is worth noting that the number of authors (7490) is not equal to the total number of authors involved in the papers, since an author may have participated in more than one paper.

Sustainability and the wine industry are global phenomena, which have considerably increased their presence and influence at all levels of society in recent years. In this regard, this fact is reflected in the percentage of international cooperation, which is also substantial, surpassing the figure of 27%. Sustainable development has been established as a key goal to be achieved in the coming years in both developed and developing countries. In the field of grape and wine production, the development and implementation of measures aimed at increasing sustainability can favor the efficiency and growth of the sector, especially through better use of resources, increased quality of production, and improved business reputation with customers, both current and potential.

Figure 2 illustrates the considerable growth of the topic analyzed in the last five years and, especially, since the year 2019. This reflects the increasing importance of sustainability issues in the global wine industry and highlights the need for continued research and innovation in this area. By better understanding the current state of research in this field, researchers can identify areas where further research is needed, and help to support the continued growth and sustainability of the wine industry. Although the average rate of growth in the number of publications is 5.71% from 1994 (the year of the first publication) to 2022, it was not until 2012 that a considerable increase in the number of publications was observed which, until that time, remained below 50 publications per year. Therefore, as of the year 2020, the barrier of 300 publications per year was surpassed.

The top ten journals per number of publications in the field of study are displayed in Figure 3, in which it can be observed that the top three stand out from the rest, with a much higher number of publications. This information of the evolution of papers published yearly by these top three journals is presented in Figure 4. In this vein, the number of papers published by *Sustainability*, *Journal of Cleaner Production*, and *Agronomy*, the leading journals, is five, three, and two times higher than the amount published by the fourth leading journal, as shown in Table 2. However, it is worth mentioning that the difference between the rest of the journals ranked in this top ten is minimal (from 35 to 25 articles published by the fourth and tenth leading journals, respectively). When analyzing in detail the number of publications over time of the top three journals, can be seen that the first article in this field of study was published in 2005, 2012, and 2019 by *Journal of Cleaner Production*, *Sustainability*, and *Agronomy*, respectively. Then, the last one (*Agronomy*) draws attention, since in only three years it has managed to position itself as a top-three ranked journal in this field of study by number of publications.

Furthermore, this ranking is comprised by journals focused on different approaches of the fields analyzed, as sustainability (*Sustainability*, *Journal of Cleaner Production*, *Science of The Total Environment*), agriculture and botany (*Agronomy*, *Frontiers in Plant Science*, *Plants*), and food research (*British Food Journal*, *Foods*, *International Journal of Wine Business Research*, *Oeno One*). Therefore, the multidisciplinary scope of the topics analyzed is reflected in the top ten most prolific journals.

To determine the most important authors in these fields, besides analyzing the number of published papers, the number of citations obtained by each of them were considered, taking into account the 2096 papers analyzed, as well as their h-index, which is displayed in Table 3. Then, it is worth highlighting the contribution of some authors, such as Medrano H., Lamastra L., and Santos J.A., which are ranked as top ten in the three classifications, while others, such as Alonso A.D., Cerda A., and Fraga H., are ranked in two of them. As shown in Table 4, some of these authors are also ranked in the top ten when analyzing the

number of articles fractionalized, such as Alonso A.D., Santos J.A., Cerda A., and Fraga H. In this vein, we can establish that these authors are some of the most important researchers in the fields analyzed.

Regarding the production over time of the top ten authors in terms of published papers, Figure 5 displays all their scientific production is clustered from 2010 to 2022 and, especially, from 2016 onwards. One of the main reasons of this is the growing awareness of the impact of climate change on agriculture and the need to develop sustainable practices that can mitigate these effects. As the wine industry is particularly vulnerable to the impacts of climate change, research on sustainability has become increasingly important [115]. Furthermore, another reason may be the growing consumer demand for sustainable products, as consumers are becoming more environmentally conscious and are increasingly seeking out sustainably produced products [116]. In this vein, there is a growing recognition among wine producers that sustainability is not only important for environmental reasons but also for economic reasons, as they can help to reduce costs and increase efficiency, which can ultimately improve the profitability of wine production [117]. Moreover, the increase in research on sustainability in the wine industry can also be attributed to the growing availability of funding for sustainable agriculture research, as governments, private organizations, and academic institutions are increasingly investing in research on sustainable agriculture, which includes research on sustainable wine production practices [118]. This information is in agreement with that shown in the second figure of this paper.

In Table 5, the top ten papers in terms of citations received are ranked. Furthermore, in Table 6 are exposed the ten documents with the higher number of cites considering local citations, also showing their degree of global citations. The last reflect a more cross-cutting approach, while local citations refer to highly specific research in a particular area of investigation, and therefore receive citations from specialized literature to a greater extent.

Regarding the most important affiliations, Table 7 presents the ranking of the most prolific affiliations. It is worth noting the outstanding presence of Italian universities in this classification, with five positions, including first (University of Milan) and second (University of Padova). In addition, there are Portuguese universities, in third (University of Lisbon) and fifth place (University of Trás-os-Montes e Alto Douro). Finally, we find the University of California (U.S.A.), The University of Adelaide (Australia) and the University of La Rioja, in seventh, eighth, and tenth position. All of them are located in countries with a large grape and wine production. In this line, and in connection to the most important countries in the fields of study analyzed, Table 8 displays the top ten countries.

The top three countries both in terms of papers published and citations received, are Italy, Spain, and U.S.A., in the same order, which makes sense, since Italy and Spain are the first and second largest wine producing countries in the world in terms of volume, and the third and first important countries in terms of vineyard extension, respectively, while U.S.A. is another important actor in this regard [3,4,29,117,118]. There are also other major players in grape and wine production, such as Australia, Portugal, France, Germany, China, New Zealand, Brazil, South Africa, and Canada. Furthermore, France and Australia are the countries with a higher ratio of multi-country collaboration, while South Africa and Spain have a lower amount in this respect. In terms of average number of citations per article, the top three countries are U.S.A., Australia, and New Zealand. Thus, although New Zealand is not in the top ten in terms of total number of citations, it does manage to enter the top ten ranking when analyzing the average number of citations per article. Although New Zealand is not at the top of the rankings of the largest wine producers, wine extension, or wine consumption, is an important player in research on sustainability of the wine industry due to its commitment to environmental stewardship and sustainability practices in winemaking, having implemented several sustainable initiatives in their vineyards, such as minimizing the use of pesticides, reducing water consumption, and adopting renewable energy sources, which lead to an increase in the number of organic and biodynamic vineyards in the country [119]. In this vein, New Zealand has established the Sustainable Winegrowing New Zealand program, which promotes sustainability practices in the wine

industry and provides a certification system for wineries that meet specific environmental standards. Thus, these countries are, for one reason or another, major players in the wine industry at the global level, each with their own unique wine regions and grape varieties that contribute to the diversity and richness of the global wine industry, and are investing in research to try to improve the sustainability and efficiency of their productive exploitations.

In Table 9, the keywords that are more commonly used by authors are analyzed. With respect to the fields analyzed, we can observe some keywords related with the care of the environment, as sustainability, climate change, impact, or behavior. The wine industry is a significant contributor to global greenhouse gas emissions, being responsible for approximately 0.1% of global greenhouse gas emissions [120]. Research on sustainable practices in winemaking can help to reduce emissions, which may allow to mitigate climate change, and is necessary to maintain the long-term viability of the industry [121]. Furthermore, other keywords are more closely linked to the economic area, as management, performance, growth, consumption, yield, or industry. In this respect, research has shown that implementing sustainable practices can not only reduce negative environmental impacts but can also improve the quality of the wine produced and increase profitability for producers [122]. Finally, besides finding keywords more related to the agricultural process for the production of grapes and the subsequent winemaking process, such as wine, quality, *Vitis-vinifera* L., food, life-cycle assessment, grapevine, or soil, we found two keywords that may be more associated with health care, such as phenolic compounds or antioxidant activity. This is understandable, considering that there are several studies that relate moderate wine consumption with health benefits, as a reduced risk of cardiovascular disease, stroke, type 2 diabetes, and certain types of cancer [123,124], as well as better cognitive function, a lower risk of dementia, and improved mental health [125].

Table 10 shows the classification of keywords in five groups, depending on their level or co-occurrence. Those keywords more related with the agricultural approach are classed in the first cluster, referring to different issues related to the process and control of grapevine. The wine industry relies heavily on the cultivation of high-quality grapes to produce premium wines. This requires careful attention to soil quality, climate conditions, pest and disease control, and vineyard management practices, e.g., different grape varieties have specific soil requirements, which must be met in order to produce optimal results [126], the temperature, rainfall, and sunlight levels in a particular region can significantly impact grape development and quality [127], grapevines are susceptible to a range of pests and diseases, including phylloxera, powdery mildew, and black rot [128], and factors such as pruning, trellising, and canopy management can impact the yield, quality, and flavor of grapes [129].

The second group is comprised of keywords related to the properties of grapes and wine for health care. In addition to its pleasant taste and social appeal, wine has been found to have a number of health benefits when consumed in moderation. Some of the key properties of wine that contribute to its potential health benefits include its antioxidant content, polyphenols, and resveratrol. In this regard, wine is a rich source of antioxidants, particularly flavonoids and phenolic acids, which have been shown to have anti-inflammatory, anti-cancer, and cardiovascular protective effects [130]. Polyphenols improve endothelial function, reduce oxidative stress, and lower blood pressure, all of which contribute to a reduced risk of cardiovascular disease [131]. Resveratrol has been found to have a range of health benefits, including anti-inflammatory, anti-cancer, and neuroprotective effects, as well as positive effects on glucose metabolism and insulin sensitivity, which may help to reduce the risk of type 2 diabetes [132].

The third one of those connected to sustainable agronomy. In recent years, there has been a growing recognition that sustainable agronomy practices can help to reduce the environmental footprint of the wine industry while also improving the quality of the wine produced, which involves organic farming practices, precision agriculture techniques, and biodynamic farming, among others. Organic farming refers to the use of natural fertilizers and pest management techniques, as well as the avoidance of synthetic chemicals, and

can help to improve soil health, reduce erosion, and enhance biodiversity, all of which contribute to more sustainable vineyard management [133]. Precision agriculture involves the use of technology, such as sensors and mapping tools, to optimize irrigation and fertilizer use, as well as to identify areas of the vineyard that may require additional attention, being useful to reduce water and fertilizer use, while also improving the quality of the grapes produced [134]. Regarding biodynamic farming, this is a holistic approach to vineyard management, which takes into account the interconnectedness of the soil, plants, and surrounding ecosystem, and may allow the enhancement of soil health, promote biodiversity, and reduce the use of synthetic chemicals, all of which contribute to a more sustainable vineyard management approach [135].

Cluster four is composed of keywords related to wineries and wine tourism. Wine tourism has been found to have a range of benefits for the wine industry, including increased sales and brand recognition, improved relationships with consumers, and the ability to diversify revenue streams. Wine tourism can lead to increased sales of wine, both at the winery and in retail outlets, as wine tourists are often more likely to purchase wine directly from the winery after having a positive experience, as well as being more likely to seek out the wine in retail outlets after their visit [136]. In this vein, they usually are more engaged with the wine they consume and are interested in learning about the production process, which is an opportunity for wineries to educate consumers about their wines, as well as to build brand loyalty and establish a sense of community [137]. In addition to these benefits, wine tourism can also provide wineries with an opportunity to diversify their revenue streams, as may provide wineries with additional revenue streams, such as through the sale of food or merchandise, or through the provision of accommodation or event spaces [138].

The last one, cluster five, is connected to sustainability, efficiency, and innovation in vineyard and wine businesses. Adopting sustainable practices, improving efficiency, and innovating new technologies and methods for producing wine can have significant benefits for the industry, including reducing costs, improving quality, and enhancing brand reputation. Sustainable practices can help to reduce the environmental impact of vineyard and wine businesses, while also enhancing economic and social sustainability, e.g., sustainable practices such as reducing water and chemical use, using renewable energy, and promoting biodiversity can help to reduce costs, improve soil health, and support local communities [139]. Furthermore, improving efficiency can help to reduce costs, increase productivity, and improve the overall competitiveness of businesses, e.g., the use of precision agriculture techniques, which involves the use of technology to optimize irrigation and fertilizer use, as well as to identify areas of the vineyard that require additional attention, can help to reduce waste, improve grape quality, and reduce the environmental impact of vineyard management [140]. In connection with this, innovation may drive growth and competitiveness in the wine industry, while also addressing key challenges such as climate change and changing consumer preferences, e.g., innovation in winemaking techniques, such as the use of alternative oak products, can help to improve the quality and consistency of wine, while also reducing costs and environmental impact [141]. These connections are displayed in Figure 6 to facilitate the visualization of the information.

Table 11 shows the intellectual structure of the fields under study. Co-citation analysis reveal the most influential authors and studies based on their co-citation patterns, allowing the identification of clusters of related studies and areas where there is a high level of co-citation activity, as well as emerging trends and areas of research, and also the identification of gaps in the literature that need to be addressed [142]. Through revealing hidden connections between authors, ideas, and concepts, this information identifies the most important and influential studies in a field, identifies emerging areas of research and trends, and map the intellectual structure of a field. This analysis provides a solid basis for future research to further study the relationships identified, allowing scholars to further deepen the knowledge base that supports all the investigations carried out in the established areas. Figure 7 displays this information in a visual form, which may facilitate its reading and understanding.



Finally, Table 12 presents the number of international research cooperation agreements carried out by the main countries in the fields under study in this paper, the role of Italy and Spain being highlighted as drivers of international collaboration in research articles. In this regard, international collaboration may improve our capacity to address global challenges facing the wine industry, such as climate change and disease outbreaks, leading to the exchange of knowledge about different winemaking practices and grape varieties, as well as providing opportunities for researchers to learn about different cultures and ways of thinking, among other important issues [143,144]. This may occur through the development of new networks and partnerships which can be used to promote the adoption of new technologies and practices, increase the impact of research on the wine industry, and promote sustainable and efficient wine production practices [145]. Furthermore, it can drive the development of shared databases and research protocols, allowing researchers to more easily access and analyze data from around the world, accelerating the progress in understanding grapevine genetics and developing new disease-resistant varieties [146].

In connection with the results, Spain and Italy are two of the world's most important wine-producing countries, with a long history of wine production and a wealth of knowledge and expertise in the field. These countries have a long tradition of sustainable wine production, with many producers using organic and biodynamic farming practices [147]. They are important contributors to international research on grapevine genetics and disease resistance, as have developed extensive grapevine collections and databases, which are used to support international research efforts, e.g., the Spanish Grapevine Germplasm Bank and the Italian Vitis International Variety Catalogue provide valuable resources for grapevine researchers around the world, enabling the identification of new disease-resistant varieties and the study of grapevine genetics [146]. In addition, Spain and Italy are well known for their high-quality wines and have developed a wealth of expertise in sensory analysis and wine evaluation [148]. This expertise has been increasingly being shared through international collaborations, which are helping to develop new methods for wine analysis and quality control [147,148]. Finally, they are two of the world's most popular wine tourism destinations, attracting millions of visitors each year, which drives the promotion of wine tourism as an important economic driver for the wine industry, and to develop new approaches to wine tourism marketing and management, allowing them to develop extensive expertise in wine tourism marketing and management, which is increasingly being shared through international collaborations [149]. As in the previous cases, Figure 8 was generated to facilitate the visualization and interpretation of these data.

On the basis of the data analyzed, the importance given to sustainability research on viticulture and wine production is evidenced by some of the main producing countries, mainly in North America and Europe, in addition to Australia, New Zealand and South Africa. In this regard, it is noteworthy that South American winegrowing and winemaking powers, such as Argentina, Chile, Peru, or Bolivia, are absent from the lists of the main countries in terms of scientific research in the fields under study. It is worth mentioning that this fact is not necessarily related to a lower productivity of researchers, but may be due to the existence of a smaller number of researchers, either in general terms or dedicated to this area of study. Moreover, Chile appears as one of the recipient countries of cooperation agreements initiated by the U.S.A., Australia, and France.

## 5. Conclusions

Although important changes have been undergone in recent decades, from an environmental standpoint, there is still a lack of influence from the wine industry on sustainability policies, which often results in inflexible and economically unsustainable laws, regulations and economic rules. In addition, they are often composed of several small and medium-sized businesses operating in very varied environmental and social situations. Therefore, winegrowers are locked into customary techniques by a complicated set of limitations, and the prevalent misconception that the issue can be rectified by "letting nature take its course" exacerbates the problem. In recent years, the devastation caused by climate change has



compelled governments and academics alike to reevaluate their strategies for reaching more sustainable practices. In the context of agriculture and other food-producing businesses, the devastation caused by environmental degradation has led to a rise in participation in collaborative research [150,151].

Concerning the theoretical ramifications, it is necessary to reassess the role of academic research in the creation of methods capable of facing the present problems for the sustainability of vineyards and the wine industry in a complicated global setting. The wine industry faces significant environmental and social challenges that require sustainable solutions [152]. In this regard, a transdisciplinary strategy including not only agronomic and biological disciplines, but also human and social sciences would be required. Then, it is vital to promote the creation of medium- and long-term plans, as well as the interaction between various academic fields, the players of the grape and wine sector, and public and commercial organizations, as well as the societal understanding of the significance of sustainability [153]. Wine production is a complex system that involves multiple stakeholders, including producers, suppliers, distributors, and consumers. Then, sustainable solutions require a holistic understanding of the wine industry and its interconnections with the environment, society, and the economy [154]. Regarding the above, open innovation processes with sustainable goals might assist in concentrating these players, resources, and talents to raise the possibility of achieving sustainable development goals in these areas. In this way, research is essential for acquiring the required knowledge foundation. In addition to the conventional belief that innovation is a result of the one-way transmission of research discoveries to practice, innovation also occurs on the ground when several stakeholders convene to debate practical challenges and to create solutions. This encompasses business, governmental, and private institutions, and societal actors.

According to the managerial implications, it is crucial for the wine industry's future growth to handle the problem of environmental and social sustainability while retaining economic viability. Achieving this objective involves, on the one hand, assistance for the application of sustainable practices by producers, and, on the other, increased consumer knowledge and marketing tactics that encourage customers to purchase sustainable wines. In order to increase the prevalence of sustainable practices among winemakers, it is essential to close the considerable information gaps regarding the perceived environmental advantages, economic benefits, and costs. Thus, enhanced research effort concentrating on the costs and advantages of various winegrowing approaches and implementation help might facilitate their spread. Additionally, a greater use of community-based and participatory initiatives would be ideal, in which producers collaborate as an industry group or via multi-stakeholder partnerships to promote practices that impart substantial environmental, social, and economic advantages to the larger community. In this regard, wine producers must communicate their sustainability practices and achievements to consumers, investors, and other stakeholders, as well as use third-party certifications and labels to build trust and enhance their reputation [155,156].

In addition, a greater understanding of the environmental advantages of sustainable practices and a greater perception of consumer efficacy should increase consumer engagement and attitude toward sustainable wine. In this regard, research on the effect of environmental practices on human health might encourage customers to purchase sustainable wine, while marketing efforts may otherwise simply appeal to the altruistic principles of environmentally conscious consumers. Major efforts must be made to improve communication with customers, since the proliferation of competing sustainable labels and claims causes consumer confusion and distrust. Additionally, it is crucial to have standard criteria for assessing environmental and social performance, which may be utilized to provide customers with accurate and trustworthy information. A tight partnership with the university may be advantageous for the wine business, since research findings may aid producers in adopting sustainable methods and give solutions to certain management concerns. The social responsibility of research may influence sustainability by distributing

findings that encourage economic actors to adopt a sustainable behavior and raise industry and consumer knowledge of sustainability.

The adoption of sustainability methods in the wine business must satisfy some fundamental requirements that are directly tied to the economic success of the firm, as well as the protection of biodiversity and social inclusion. A framework of sustainable practices may assist in highlighting and systematizing present practices or an endeavor to enhance wine management and foster innovative processes in wine areas. Sustainable practices in viticulture and winemaking can reduce production costs, improve product quality, and enhance brand reputation [157]. In addition, this may serve as a means of positioning the wine region among markets and consumers. In this way, the most recent publications from the International Organization of Vine and Wine and the advancement in sustainability evaluation tend to direct frameworks toward more effective propositions for enhancing wine sustainability, in order to strategically address operational issues. Wine producers must consider the entire value chain of their products, from grape production to packaging and distribution, when developing sustainable practices, to allow the identification of opportunities for cost savings and brand differentiation [158].

Furthermore, by investing in academic research, leading countries, such as Italy, Spain, or France, can stay ahead of their competition and maintain their position as top wine producers, through the implementation of new technologies, fermentation techniques, and grape varieties that can enhance the flavor, aroma, and texture of wines, as well as expanding their markets by developing new wine products that cater to changing consumer tastes and preferences, such as low-alcohol wines or canned wine [159,160]. As this industry requires a significant amount of natural resources, research may help leading countries to develop sustainable practices that reduce the environmental impact of its activities, as well as to maintain the health of the soil, reduce chemical inputs, and promote biodiversity in vineyards [161]. In this regard, grapevines are susceptible to a variety of diseases, including fungal infections, bacterial infections, and insect infestations, which can reduce crop yields and quality. Academic research may drive the identification and development of new disease control methods, such as the use of natural predators and biopesticides, that can reduce the use of harmful chemicals and improve crop yields [146].

Since the initial release of the database in 1994, this is a relatively new subject of research in contrast to others. Nonetheless, the number of papers in this area of research has increased dramatically since then, from one paper in 1994 to 347 articles published in 2022 and, particularly, since 2012. This is an astounding increase, indicating that researchers are paying more attention. This may be a result of rising concern among all social, political, and economic actors about the sustainability of the vine and wine industry.

Managers should interpret the sustainability challenge as an opportunity rather than a threat for business competitiveness and profitability. Companies can develop differentiation strategies that allow them to increase their revenue volume by building a quality image based, to a large extent, on a solid environmental reputation. In this sense, academic research seems to have taken a clear direction towards sustainability as a means to increase the competitiveness of the sector in the medium and long term. To the extent that society is increasingly aware of the importance of reducing the environmental impact of business activity, this factor is established as a key element in future purchasing decisions, which could affect the competitiveness of companies and the socioeconomic development of wine-producing territories. In this sense, collaboration between different entities and stakeholders, especially universities, can be fundamental for the development of innovations that increase the sustainability of the wine industry. Then, by collecting additional data from other relevant sources, the scope of this research could be expanded in the future.

While bibliometric analysis provides valuable insights into research performance, it also has certain limitations that should be considered. The number of citations a paper receives can be affected by factors such as the visibility of the topic or the journal's, author's, or institutions' reputation [162,163]. This means that a paper with low quality or impact could receive more citations than a high-quality paper in a less visible field or journal.

Furthermore, due to the fact that we used specific keywords to search for publications in sustainability of the wine industry, and the use of a single database (WoS), although a substantial part of the major papers in this area were considered in the review, it was not possible to include all of them.

Future research might employ, besides bibliometric methods, alternative methodologies, such as social network and factor analysis, to disclose ongoing tendencies in research by examining the latest publications and taking into account other pertinent databases. In addition, it would be interesting to carry out an in-depth analysis of the work identified through co-citation analysis, in order to reveal the possible lines that are currently being developed and that will shape future research trends.

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