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To cite this version:

Flor Regus, Isabelle Laffont-Schwob, Rayhane Hamrouni, Nathalie Dupuy, Anne-Marie Farnet da Silva. Using bibliometrics to analyze the state of art of pesticide use in vineyard agrosystems: a review. Environmental Science and Pollution Research, 2022, 10.1007/s11356-022-23285-1 . hal-03817640

HAL Id: hal-03817640

https://hal.science/hal-03817640v1

Submitted on 17 Oct 2022

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Pré-print

Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-022-23285-1

REVIEW ARTICLE

Using bibliometrics to analyze the state of art of pesticide use in vineyard agrosystems: a review

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Received: 9 March 2022 / Accepted: 22 September 2022

Using bibliometrics to analyze the state of art of pesticide use in vineyard agrosystems: A review.

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ABSTRACT:

The production of wine dates to ancient civilization and has heavily influenced different landscapes around the globe. Nowadays, wine is still an important sector in terms of land use and income source in many countries, more specifically in the European Mediterranean region. However, to control pests and regulate wine growth, the extensive use of pesticides is common.

The effects and persistence of agrochemicals in the environment is well known and defined in scientific literature as well as the environmental and human health risks of these compounds. The purpose of this review was to do a state of art of worldwide production of academic literature using bibliometric principles and analysis to identify thematic areas of this type of agriculture, and its challenges in a changing world. For this review the focus is on current practices to see what may evolve for more sustainable viticulture. It was found that the three main producers of wine i.e. Spain, France and Italy are also three top producers of scientific literature on this topic. The use of bibliometric methodologies defined the main thematic areas on this subject as following: soil-plant transfer of agrochemicals, heavy metal accumulation in vineyard soils, management practices in viticulture, water pollution transport, effects of viticulture on the living part of soil, sustainable alternatives to pesticides. We found that Spain, France and Italy work the most on developing sustainable alternatives for agricultural practices, however sustainable alternatives and practices were also the least developed thematic in general.

Keywords: copper accumulation; soil pollution; sustainability; transfer of pollutants; viticulture.

DECLARATIONS

ETHICAL APPROVAL: Not applicable

CONSENT TO PARTICIPATE: All authors have freely agreed and consented to participate in the elaboration of this review.

CONSENT TO PUBLISH: All authors gave consent for the submission and publication of this manuscript.

AUTHORS CONTRIBUTIONS: All authors contributed to this review and agreed on its content. Idea for this review was presented by Nathalie Dupuy. Keywords were selected by Anne-Marie Farnet Da Silva, Isabelle Laffont-Schwob and Flor Regus. Literature search, analysis and draft elaboration were performed by Flor Regus. Critical reviews were performed by Anne-Marie Farnet Da Silva, Flor Regus, Isabelle Laffont-Schwob, Nathalie Dupuy and Rayhane Hamrouni.

FUNDING SOURCES: Funding for this manuscript was received by ITEM institute under the project ALCOVE (AMX-19-IET-012).

COMPETING INTEREST: Authors have non relevant financial or non-financial interest to disclose.

AVAILABILITY OF DATA AND MATERIALS: All the analyzed information for this publication is included in the manuscript. Additional information could be provided upon reasonable request to corresponding author.

INTRODUCTION

The incidence of extreme weather events such as of heat waves, intense rainfall and agricultural drought is likely to increase within the next decade (IPCC 2021). Climate change is troublesome for agriculture since it influences water stress, duration of growing season as well as the intensity and frequency of heat waves (Aryal et al. 2020). Along with the effects caused by climate change another issue in agriculture is the toll conventional agricultural practices have in the environment. In order to meet the demand of agricultural goods, agriculture leans on techniques such as tillage and the excessive use of agrochemicals to ensure supply in an overpopulated world (Wezel et al. 2014; Meena et al. 2020). This unsustainable use of agricultural land and resources creates an imbalance in the ecosystems in terms of nutrient cycling, soil and water quality (Garini et al. 2017).

A culture particularly fragile to the effects of climate change is viticulture. Wine quality strongly depends on climate and land (Fraga et al. 2012; Marín et al. 2021; Santos et al. 2020). Most of the world's wine grapes production, and wine production, is located in Mediterranean Europe between France, Spain and Italy (Jackson, 2016; OIV 2019). Viticulture is no strange to the issue of unsustainable practices, and Mediterranean viticulture is highly dependent on the use of agrochemicals (Prosdocimi et al. 2016). There are two factors that make viticulture in the Mediterranean region highly dependent in agrochemicals. Mediterranean soils are characterized by low organic matter and nutrient content and the *Vitis vinifera* plant is highly sensitive to phytopathogens (such as *Plasmopara viticola* or *Botrytis cinerea*) (Serpa et al. 2017). Amongst agrochemicals used in viticulture, pesticides against phytopathogens, are extensively used (Campbell et al. 2021). The use of pesticides has been extensively studied in the scientific field because of their potential toxicity (Schreck et al. 2008).One example of the risk for toxicity in humans is described in recent studies in developing countries showed that,

although this part of the world uses only 20 % of the world's agrochemicals, this region suffers 99 % of deaths induced by pesticide poisoning and victims are mostly farmers (Curl et al. 2020).

Many authors have identified the accumulation of pesticides in vineyard soils as a threat (Komárek et al. 2010; Sánchez-Martín et al. 2000; Semhi et al. 2018). The accumulation of pesticides also poses an environmental risk since there is a risk of diffusion of the parent chemical compounds and their by-products (Sonoda et al. 2019; Zambito Marsala et al. 2020). Copper-based compounds are amongst the most used pesticides to prevent fungal infections in vineyards (Fernández-Calviño et al. 2010). Because of its accumulation in soils, copper tends to reach toxic concentrations, affecting the living part of the soil (Campillo-Cora et al. 2019; Mackie et al. 2013; Rusjan et al. 2007). Due to accumulation of copper on the environment, in 2009, the European Union regulated the use of agrochemicals and decided to list copper as a candidate for substitution Regulation (EC) No.1107/2009. The decision to find a substitute for copper was again ratified in 2018 with Regulation (EU) 2018/1981.)

Environmental affairs are a transverse issue covering different areas such as ecology, human health and policy making. The transverse specificity of environmental issues is not new. For example, in 2004, concept "One Health" was developed. This concept looks at ecosystem's health, fauna, and human health at once (Destoumieux-Garzón et al. 2018). This new concept highlights the need to have a holistic approach based on interdisciplinarity embracing all the components of an ecosystem including living soil, plants, animals, and humans. Due to the transverse properties of environmental affairs, analysis of scientific literature can be a complex task, with bias linked to non-systematic requests on literature databases. The use of bibliometric methods can help overcome this complex task. Bibliometric methods have been established in the scientific field (specially applied sciences) to study different aspects of science (Ellegaard et al. 2015) in order to establish a state of art. Bibliometric methods are used to analyze scientific production, techniques and methodologies available by measuring and interpreting

105 the production metadata of scientific publications (Subramanyam 1983). For this review, a
106 bibliometric approach was used to create a state of art regarding the conventional practices in
107 viticulture that focuses on pesticides. The work consists of studying the evolution of annual
108 publications (between 1990-2020) and the different countries affiliated to each publication. This
109 later allowed the analysis of thematic areas by grouping keywords from the publications into
110 clusters. The creation of clusters later allowed us to see the geographical distribution of thematic
111 areas.
112

113 ## 1. MATERIALS AND METHODS

114 The scientific database Web of Science was used to obtain scientific publications that include
115 the studies of problematics in viticulture regarding the use of pesticides. On September 27,
116 2021, a search was done and the metadata were downloaded using the words ("viticulture" OR
117 "grape" OR "grapes" OR "wine" OR "wines" OR "vineyard" OR "vineyards") AND
118 ("pesticide" OR "pesticides" OR "copper*", "Cu") AND ("phytopathogen" OR
119 "phytopathogens" OR "soil" OR "soils" OR "plant health") were used as keywords. The star
120 symbol (*) was added to include the different forms of a word, for instance the word "copper*"
121 will also cover "copper based". Time frame was set to 1990-2020 to observe the evolution of
122 this topic over time. For this search all fields available were used. This was done to maximize
123 the collected data since the analysis accounts for article subject and geographical affiliation. No
124 additional sub-databases or collections were used. The analyze citation tools from web of
125 science was used to assess the evolution of keywords over time, geographical distribution of
126 publications and authorship as well as the distribution of publications throughout journals.
127 Finally, this search does not account for grey literature or another scientific database. The
128 metadata of this bibliographical search was analyzed using the software Matheo Analyzer,
129 France. Keywords of each publication were extracted and grouped in clusters to reveal thematic

areas. Keyword clusters were created using K-means methods following Malechaux et al. (2020). *K*-Means is an algorithm for data clustering. The keywords are grouped into *K* clusters (user-determined number) based on a specific distance measurement, so that the sum of distances between each keyword and its cluster centroid is minimized. The procedure consists of the following three steps:

(i) The algorithm is initiated by creating *K* different clusters. The samples, included in the analysis, are first randomly distributed between these *K* different clusters.

(ii) As a next step, the distance between each keyword and its respective cluster centroid is calculated.

(iii) keywords are then attributed to the nearest cluster (K_1 or K_2) based on the sample-cluster centroid distance.

The number of iterations is the number of times that the *K*-means algorithm is repeated to obtain an optimal clustering solution, each time starting with random initial clusters. Keywords occurring at least 15 times were used to build the clusters. The keywords used in the search (viticulture, grape, pesticides, copper etc.) were left out of the data clustering to avoid bias and high word co-occurrence on the analysis. These parameters were set to have quality clusters with strong links between the keywords in each cluster. The results for this bibliometric review are limited to Web of science since different citation collection methods from various databases would have led to a set of data that are not compatible with software Matheo Analyzer.

2. RESULTS AND DISCUSSION

The use of these parameters resulted in a database of 1317 publications. This includes 1205 scientific articles, 114 proceeding papers, 37 review articles, 12 book chapters. Focusing on a single scientific Database Web of Science provided a large range of results for this topic.

3.1 Evolution of publications through time

The development of new technologies allowing the rapid acquisition of data influences the increase in publications over time. Figure 1 shows the number of publications over time from 1990-2020. This figure also includes an exponential regression to reveal the inflection point. The first period covered by this search, between 1990-1994, only six papers were published. This number increased to 97 between 2000-2004, i.e. an increment of 16 times. Together with technological and scientific developments, different political events could explain this increase in publications. For example, in 2002, the European commission restricted the use of copper, Regulation (EU) 2018/1981. Then in 2003, an EU commission study showed that viticulture was the largest pesticide consumer per acre of all large-scale cultivated crops in the European Union (Moneyron et al., 2017). Years 2005-2009 saw a pivotal change in the number of publications. During this time (2005-2009), publication numbers had almost doubled compared to period 2000-2004. By 2009, the European Union listed copper as a compound that should be substituted in agriculture. After 2009, the number of publication of articles doubled every 4 years. This trend is likely to continue since there is more political pressure about this problematic. The decision to look for alternatives to copper in agriculture was again rectified in 2018 Regulation No. (EU) 2018/1981.

3.2 Evolution of keywords over time

The evolution of the selected keywords overtime was also analyzed. Figure 2 represents the number of times a specific keyword was used in an article in each time frame. The words copper, pesticide, and soil increased over time. Overall, this highlights how the focus on this problematic lies mostly on the effects of pesticides and copper-based pesticides in soil. A pivotal change after 2000-2004 can be observed. After 2004, soil indeed becomes the most used keyword followed by copper and then pesticides. The last period, between 2015-2020,

177 illustrates how the effect of copper-based pesticides can be considered as an issue for soil
178 properties and fertility and thus for the sustainable production of grapes and wine.

179 *3.3 Geographical distribution of publications and authorship.*

180 From 1990 to 2020, there were 86 different countries working on this topic. When
181 observing the geographical distribution of scientific literature, it appears that research groups
182 are scattered around the globe. Some examples of this, are counties such as Australia (Ying et
183 al. 2000), Spain (Pose-Juan et al. 2015) and Slovenia (Al Nasir et al. 2001). For this section,
184 we will focus on the top10 publishing countries. These countries have contributed for more than
185 87% of total publications in this database. These countries were Spain (199), France (157), Italy
186 (183), China (138), USA (133), Brazil (101), Australia (88), India (50), Romania (47) and
187 Germany (44). First, it is not surprising that Spain, France, Italy appear within the top ten
188 countries publishing on that topic. Indeed, these countries are the main producers of wine
189 (millions of hectoliters) in the world according to the 2019 Statistical Report on World
190 Viticulture (OIV 2019).

191 Figure 3 shows two maps: map A shows the total number of articles published between
192 2014-2018 for the top-10-publishing countries and map B shows the total production of wine
193 (millions of hectoliters) according to the report by OIV (2019) for the same countries. All
194 countries in Figure 3, except for India, are considered major wine producers. Wine production
195 in India is low, though there is a large area in this country dedicated to the production of table
196 grapes.-In 2018, India had 151 thousand hectares of vineyards, accounting for 2% of vineyards
197 on the globe. Time frame for these maps is limited to 2014-2018 as these years are the only
198 ones reported to this date for wine production by the OIV.

199 Another descriptive parameter analyzed was the co-authors and their country of
200 affiliation. Authors with the highest number of publications on our search are presented in Table

1. Authors have a minimum of 18 articles (equivalent to approximately 1.4% of the total publications). There is a link between collaborating authors and geographical areas. For example, according to Table 1, Arias-Estévez (the author with the highest number of publications) and Fernández-Calviño are co-authors and their country of affiliation, according to the Web of Science, is Spain. This occurs again with authors such as Nicoloso and Tiecher two co-authors from Brazil. Research collaborations about viticulture between wine-producing countries are very limited. However, the country of affiliation of the authors does not provide an accurate vision of how publications are scattered globally. In Table 1, the same high publishing authors work together, limiting the number of countries of affiliation shown on the table. Thus, this leaves other high publishing countries such as France and Italy out of this Table because the same author does not publish as much on the same topic.

3.4 Publication's categories & publishing journals

There was a total of 55 categories identified on this database where the categories with the most articles were: Environmental Sciences/ Ecology with 529 articles, Agriculture-438~~,~~ ; Chemistry~~,~~ 250;~~,~~–Food Sciences Technology~~,~~ 196;~~,~~ Plant sciences~~,~~ 125. It is important to mention that one publication can belong to more than one category. The categories before mentioned represent the categories covered by most journals in this database, where a total of 461 publishing journals can be found. The journals with the highest number of publications are shown in Table 2. Along with journal's categories, the Journal Impact Factor (JIF) is also presented in Table 2. The JIF is an index based on the number of citations of publications during a specific time. The JIF was created in 1955 as a way to source journals (Garfield, 2006). A large range of JIF from 1.327 to 10.588 can be found in Table 2. This large range of JIF is not surprising since it changes depending on the field (Althouse et al., 2009). For example, for Environmental Sciences, JIF ranges from 0.323 to 38.532 according to the Web of Sciences'

Journal citation report (*Journal Citation Reports*, 2021). The total number of times an article was cited is presented in Table 3. Citations on this table varies from 241 to 435.

Table 3 gives an idea of the readers' interest within this topic. For example, the most cited article by Komárek et al. (2008) compiles studies regarding the contamination of vineyard soil with organic and inorganic fungicides. It is followed by Wezel et al. (2014) where agricultural practices are evaluated and compared. In this article, organic fertilization, biological pest control, crop selection, reduce tillage and drip irrigation showed a high potential for the future in agriculture. The third article by Štajnbaher et al. (2003) describes a methodology to analyze different pesticides. The fourth article produced by Brun et al. (2001) looks at the transfer of copper accumulation from soil to plants (specially the roots). Finally, the last article by Giusquiani et al. (1995) in this table looks at the effect of soil amendments on different parameters such as C, Cu and Pb. In this table, the main categories are Environmental Science, Agronomy and Plant Sciences to mention a few.

3.5 Keyword Clusters

A total of six clusters were created. The clusters are presented in Figure 4, showing the keywords associated to each cluster. To facilitate reading, only keywords that appear 16 times or more are presented in the Figure. Due to cluster building parameters, not all publications were included in these clusters. Each cluster is described below:

- Cluster 1(Soil-plant transfer of agrochemicals)

The main thematic present in this cluster is the effects of persistent compounds in a soil-plant system. This cluster indeed contains words such as residue, sorption, dissipation, and liquid chromatography.~~:~~ These are all terms used to describe the behavior and transport of persistent compounds from soil to plant as well as techniques like liquid chromatography used to quantify such compounds. For exemple, Matei et al. (2015), and Vázquez-Vázquez et al.

(2016) look at the presence of heavy metals in a soil-plant interactions and the transport of pollutants from soil to the plant. Another thematic of this cluster is the risk of exposure associated with the transfer of persistent agrochemicals to the final product (wine or table grapes). For instance, this topic regarding the risk of exposure is included in publications from Wightwick et al. (2013a) or Guang-Guo et al (2000). For this cluster, China is affiliated to 62 publications and Spain is affiliated to 56 publications. The publications in this cluster account for 20% of all the publications analyzed.

- Cluster 2 (Heavy metal accumulation in vineyard soils)

This cluster includes pollution and accumulation of heavy metals in soils, and ICP-MS (Inductively coupled plasma - mass spectroscopy) as a technique for their analysis. The main thematic here is soil inorganic pollution in vineyards due to heavy metals. This cluster focuses on the occurrence of heavy metals and their persistence due to low degradation rates in vineyard soils as described in Bălc et al. (2018). It also deals with the accumulation of copper in soil due to the use of pesticides as highlighted by authors such as Wightwick et al. (2008) and Komárek et al. (2008), and with the behavior of copper in soils (Blotevogel et al. 2018; Rusjan et al. 2007). Another theme discussed in this clusters is the bioavailability of heavy metals and more precisely how bioavailability influences the toxicity and risk due to heavy metals (Mirlean et al. 2007). The countries publishing the most articles here are Spain, Romania and France. Publications in this cluster account for 19.8% of all the publications.

- Cluster 3 (Management practices in viticulture)

Cluster 3 includes keywords such as agrosciences. Contrary to the previous clusters, here, a more global view at the agrosystem scale is considered. This cluster is related to the practices and management within the field of viticulture for example weed control (Olmstead et al. 2012). More importantly, this cluster deals with the response of the agroecosystem to

273 certain practices such as the application of copper-based pesticides (Brunetto et al. 2016), and
274 the effect of tillage and fertilizers on soil. This cluster also provides information about
275 alternative management techniques such as the use of amendments (Dobrei et al. 2016), and
276 how the use of amendments interacts with agrochemicals present in soil (Pinna et al. 2008).
277 Additionally, this cluster also looks at how alternative management techniques affect land with
278 authors such as Likar et al. (2015) and how to reduce the use of pesticides in viticulture
279 (Diaconu et al. 2017). Countries that had the higher number of articles were France, Spain, and
280 Italy. Publications in this cluster account for 12.6% of all the publications.

281 - Cluster 4 (Water pollution transport)

282 Keywords in this cluster include water, heavy metal, and trace element. The transfer and
283 diffusion of pollution from viticulture via water is described in this cluster. Water is the main
284 mode of transport of dissolved pollutants from soil particles as described by Oliveira et al.
285 (2015). Themes such as leaching of pesticides and heavy metals caused by rain (Meite et al.
286 2018), and downstream export of pollutants, such as copper, due to rainfall and runoff from
287 headwater watershed (Imfeld et al. 2020) are covered in this cluster. This cluster also looks at
288 the occurrence of pesticides in groundwater bodies because of pesticide use in viticulture
289 (Zambito Marsala et al. 2020; Suciu et al. 2020) as well as estimating ecotoxicity of pesticides
290 in freshwater using models such as Pest LCI 2.0 (Renaud-Gentié et al. 2015). In this cluster,
291 copper is listed as having the greatest toxicity potential for freshwater ecosystems (Peña et al.
292 2018). Here, the main publishing countries are France, Spain, and Italy. Publications in this
293 cluster account for 10.5% of all the publications.

294 - Cluster 5 (Effects of viticulture on the living part of soil)

295 Some of the keywords included in this cluster are toxicity and enzymatic activity. This
296 cluster covers different themes regarding the living part of soils in vineyards. The negative

297 effects of pesticides in soil resulting from viticulture as land use are described. Firstly, the
298 toxicity of different pesticides in soil is discussed in different articles for example Komárek et
299 al. (2010); and more precisely how the accumulation of pesticides, such as copper-based
300 fungicides, has an effect of soil's enzymatic activities (Fernández-Calviño et al. 2010;
301 Wightwick et al. 2013b). This clusters also includes the degradation of pesticides by soil
302 microbes (Hugo et al. 2014; Tykva et. al 1999). Additionally, this cluster lightly covers
303 ecotoxicological soil studies considering different soil invertebrates such as *Enchytraeus*
304 *aldibus* (Ruyters et al. 2013) and *Typhlodromus pyri* (Gadino et al. 2011). Finally, the effects
305 of different practices used in viticulture on soil microbes (Okur et al. 2009; Probst et al. 2008)
306 are also covered. Countries that published the most in this cluster are Brazil, France, and Spain.
307 Publications in this cluster account for 9.7% of all the publications.

308 - Cluster 6 (Sustainable alternatives to pesticides)

309 Keywords in this cluster include biological control and farming practices. Unlike cluster
310 3, this cluster describes alternatives that intend to make viticulture more sustainable, rather than
311 describing the management of vineyards, while focusing on alternatives to reduce pesticide use.
312 For example, it includes the use of i) more resistant vine varieties in order to manage fungal
313 infections (Pedneault et al. 2016), ii) cover crops to select beneficial arthropods while
314 decreasing antagonistic arthropods (Vogelweith et al. 2017), and lastly iii) amendment to
315 mitigate bioavailability of heavy metals (Cutillas-Barreiro et al. 2017). Moreover, the term
316 biocontrol is persistent within this cluster. Here, examples of biological control are either
317 considered in the form of microorganism such as *Bacillus ginsengihumi* (Calvo-Garrido et al.
318 2019), or of metabolites produced by microorganism (Billet et al. 2019; Zhihui et al. 2008).
319 This cluster has the least number of articles (it accounts for 7.6% of all the publications) and
320 France and Italy share the largest quantity of articles followed by Spain.

321 *Cluster distribution throughout Journals*

Currently, the published research on the topic of vineyards is evolving from techniques and tools specific to agriculture to other objectives coming from different scientific domains of environmental sciences. This can be appreciated by looking at the names of the journals that publish articles within these clusters as presented in Figure 5. This Figure shows the top publishing journals for each cluster. These journals also happened to be within the group of journals that publish the most data on the selected topic (see Table 2). In here the journals with the highest number of papers are those that published under the category of Environmental Science, Agronomy, Biological Sciences to mention a few categories. These journals focus on interdisciplinary sciences, such as Environmental Sciences, meaning they all publish in interdisciplinary categories. For example, the Journal of Agricultural and Food chemistry published within categories such as Agriculture, Applied Science and Food Science and Technology.

Geographical distribution of clusters

The number of publications linked to a particular cluster is heterogenous. Publications in clusters 1, 2 and 3 account for approximately 54% of all publications of this database. Geographical distribution varies amongst clusters There is a large involvement of France, Spain, and Italy in each cluster.

In cluster 1, France, Spain and Italy have participated in 46 % of the publications e.g. a publication by Andrades et al. (2001), regarding the importance of soil properties in fungicide mobility in vineyard soil, where Spain is the country of affiliation. For cluster 2, France, Spain and Italy participated in 42% of the publications regarding the accumulation of pollutants in soil e.g. Blotevogel et al. (2018) describing the fate of copper in vineyard soils. In this article France is a contributing country. For cluster 3, Spain, France and Italy participated in 42% of the publications. For example, the article from an Italian team, Pinna et al. (2008), described the effect of practices in vineyards such as the use of amendments in an article.

When it comes to the other three clusters 4, 5 and 6, explaining the effects of viticulture, these three countries have an even larger representation compared to other countries. These three clusters account for a total of 27% of all the literature. In cluster 4, regarding the transfer of pollution to water resources, these countries have contributed to approximately 42% of the publications (for instance Italy with publications such as Suciu et al. 2020). In cluster 5 regarding the effects of these practices in soil microorganisms, these countries have contributed to approximately 44% of the publications, e.g. Spain with the publication from Fernández-Calviño et al. (2010) where the co-authors look at soil enzymatic activities to assess the damages linked to the use of copper based fungicides. It is important to note that, particularly for this cluster regarding ecotoxicity, most of the studies dealt with the effects of pollutants at a molecular level (for example enzymatic activities) or using ecotoxicological models, while studies assessing toxic effects on soil invertebrates are few. Finally in cluster 6, regarding sustainable alternatives to pesticides, these countries (Spain, France, and Italy) participated in at least 46% of the publications e.g. a publication from Calvo-Garrido et al. (2019), discussing biocontrol against phytopathogens based on microbial antagonisms. Geographical heterogeneity of the clusters indicates there is a consensus on the fact that there are high pollutant concentrations in soil-plant systems as a product of conventional practices in viticulture. The three main producers of wine, France, Spain and Italy are extensively present in the thematics from clusters 4, 5 and 6while other countries, such as China and Romania, focus more on the present state of pollution, themes cover in clusters 1-3.

Cluster evolution over time

Figure 6 shows the evolution of clusters over time from 1990-2020. Increase in publications for each cluster seems to double every four years. Cluster 1 and Cluster 2 had the greater increase between years 2005-2009, suggesting that researchers focused on the interactions between soil and plant since these clusters focus on the fate of pollutants in soil and

final products (i.e. wine and grapes). It was around this time that legislation started to regulate agricultural practices that have a negative effect on soil. Clusters 3 and 4 have had an increase since the period 2000-2004. This concerns management of viticulture as well as transfer of pollution. During this time (2000-2004), the increase in cluster 5 was stronger. However, in the time frame between 2015-2020, there was a drastic increment in articles for cluster 3 (Figure 6) and it is during this time period (2018), that the use of copper was restricted to 28kg/ha of copper in a time frame of 7 years by the European Commission Regulation (EU) 2018/1981. The decision making for this legislation could have been based on themes included in clusters 1, 2 and 4 since most legislation regarding environmental issues is based on scientific facts (Liu et al. 2008). For cluster 6, the number of articles was not high until 2009, when European legislation started to watch the concentrations of some pesticides. As seen in Figure 6, topics regarding ecotoxicity and sustainability (clusters 4, 5, 6) have been on the rise. One example of this change in trend is showed in the article by Droz et al. (2021), looking at the transport of copper in soil as well as modeling of copper concentrations in soil.

3. CONCLUSION

In the last couple of years, publications regarding the effects of viticulture on the environment have been on the rise, proving there is an increasing interest about the relationship between the use of pesticides and soil health. The present bibliometric investigation from 1990 to 2020 on the conventional practices in viticulture that focuses on pesticides shows an increase in publications overtime since 1990.

France, Spain and Italy were responsible for15% of the total wine production globally and of the production of 37% of all publication during period 2014-2018. This bibliometric analysis puts the European Union as one of the leaders of research on this topic. The strong European presence throughout this topic indicated the important economic, social, and political influences besides the scientific and agricultural perspective. Since many European countries have an ancient wine culture, viticulture has a vital socio-economical role in these countries. However, co-authors' country of affiliation is not a proper indicator of geographical distribution of literature since authors tend to collaborate more with peers within the same geographical location.

The creation of keywords clusters allowed the observation of main research themes and there is heterogeneous geographical distribution of a publication's country of affiliation in each cluster. The two major themes were the presence of pesticides in a soil-plant systems and the accumulation of pesticides in vineyard soils. The adverse effects of current agricultural practices in viticulture have been extensively studied. However, there is a lack of ecotoxicological studies targeting the effects of pesticides in macro or mesofauna communities of the soil. Themes regarding ecotoxicity and sustainable alternative to pesticides are the least developed.

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Table 1. Top 10 publishing authors, from 1990-2020, including the number of total publications on the topic, geographical affiliation of the authors, authors' total number of citations (without self-citations) and most cited articles. Total number of citations represents the total number of citations for the author. It is important to note that authors might not be the first author of the paper.

Name	**Number of publications**	**Country of affiliation**	**Total citations**	**Most cited article**
Arias-Estevez	49	Spain	696	(Fernández-Calviño et al. 2010)
Brunetto	44	Brazil	370	(Brunetto et al. 2016)
Fernández-Calviño	38	Spain	543	(Fernández-Calviño et al. 2010)
Novoa-Muñoz	28	Spain	370	(Fernández-Calviño et al. 2009)
Sanchez-Martin	26	Spain	378	(Herrero-Hernández et al. 2011)
Ceretta	25	Brazil	228	(Miotto et al. 2014)

Rodriguez-Cruz	23	Spain	319	(Herrero-Hernández et al. 2011)
Nicoloso	20	Brazil	178	(Miotto et al. 2014)
Tiecher	20	Brazil	219	(Miotto et al. 2014)
Dong	18	China	277	(Dong et al. 2012)
Zheng	18	China	275	(Dong et al. 2012)

Table 2. Top 15 publishing journals within this search including the total number of publications on the topic in the Web of Science database (1990-2020), journal's Impact factor (JIF_{2020}) and Categories include their ranking for category. The most cited article on each journal of this search is listed as "the most cited article within search."

Journal name	**Total of articles within search**	**JIF_{2020}**	**Journal categories**	**Most cited article within this search**
Science of the Total Environment	55	7.963	Environmental Sciences Q1	(Ballabio et al. 2018)
Environmental Sciences and Pollution Research	41	4.223	Environmental Sciences Q2	(Liu et al. 2016)
Journal of Agricultural and Food Chemistry	39	5.279	Agriculture, multidisciplinary Q1 Applied Chemistry Q1 Food science and Technology Q1	(Almeida and Vasconcelos 2003)
Chemosphere	29	7.086	Environmental Sciences Q1	(Brunetto et al. 2016)

Food Chemistry	26	7.514	Applied Chemistry Q1 Food Science & Technology Q1 Nutrition and Dietetics Q1	(Sun et al. 2018)
Journal of Environmental Science and Health part B Pesticides Food Contaminants and Agricultural Waste	26	1.99	Environmental Sciences Q4 Public, Environmental & Occupational Health Q3	(Monaci et al. 2011)
Ecotoxicology and Environmental Safety	25	6.291	Environmental Sciences Q1 Toxicology Q1	(Tiecher et al. 2016)
Environmental Monitoring and Assessment	25	2.153	Environmental Sciences Q3	(Al Nasir et al. 2001)
Environmental Pollution	25	8.071	Environmental Sciences Q1	(Jacobson et al. 2005)
Communication in Soil Sciences and Plant Analysis	21	1.327	Agronomy Q3 Analytical Chemistry Q4	(Deluisa et al. 1996)

			Plant Sciences Q3 Soil SciencesQ4	
Water Air and Soil Pollution	21	2.52	Environmental Sciences Q3 Meteorology Atmospheric Sciences Q3 Water Resources Q3	(Hindersmann et al. 2014)
Geoderma	20	6.114	Soil Sciences Q1	(Pietrzak and McPhail 2004)
Journal of Hazardous Material	19	10.588	Environmental Engineering Q1 Environmental Sciences Q1	(Nogueirol et al. 2010)
Journal of Soil and Sediment	18	3.308	Environnemental Sciences Q2 Soil Sciences Q2	(Fan et al. 2011)

Table 3. Most cited articles followed by the total number of citations, journal of publication of the article, journal impact factor (IF_{2020}) and research categories of the journal.

Title	Number of citations	Journal of publication	JIF_{2020}	Journal's category	Reference
Contamination of vineyard soils with fungicides: A review of environmental and toxicological aspects.	423	Environment international	9.621	Environmental Science	(Komárek et al. 2010)
Agroecological practices for sustainable agriculture. A review	356	Agronomy for Sustainable Development	5.932	Agronomy Green sustainable Science & Technology	(Wezel et al. 2014)
Multiresidue method for determination of 90	249	Journal of Chromatography A	4.759	Biochemical Research Methods	(Štajnbaher and Zupančič-Kralj 2003)

pesticides in fresh fruits and vegetables using solid-phase extraction and gas chromatography-mass spectrometry.				Analytical Chemistry	
Evaluation of copper availability to plants in coper-contaminated vineyards soils	242	Environmental Pollution	8.071	Environmental Sciences	(Brun et al. 2001)
Urban waste compost effects on physical; chemical, and biochemical soil properties	241	Journal of Environmental Quality	2.751	Environmental Sciences	(Giusquiani et al. 1995)

Fig 1: Number of publications in the search over time (1990-2020), including an exponential regression line

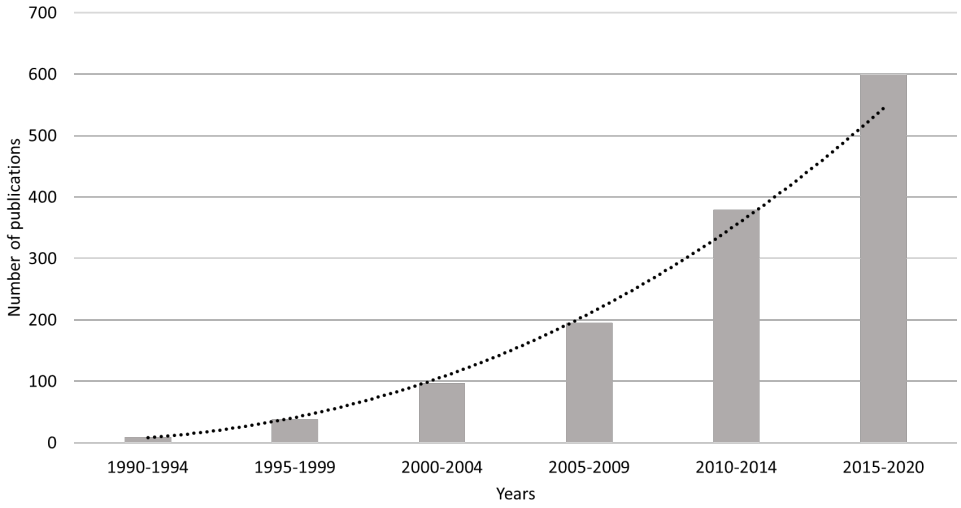

Fig 2: Publications keywords in the search over time. Each bar represents the number of times a keyword was used between 1990-2020

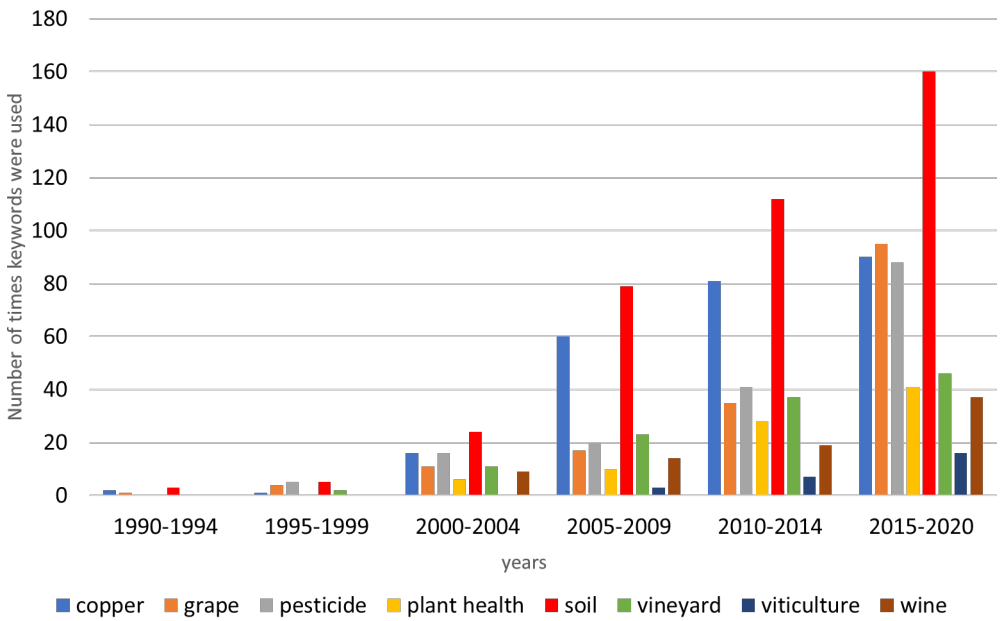

Fig 3: Map A: "Total number of publications for the 10 countries that published articles between (2014-2018) according to "Web of Science" (2021)." Map B: "Total millions of hectoliters of wine produced between (2014-2018) by the same countries (OIV 2019)."

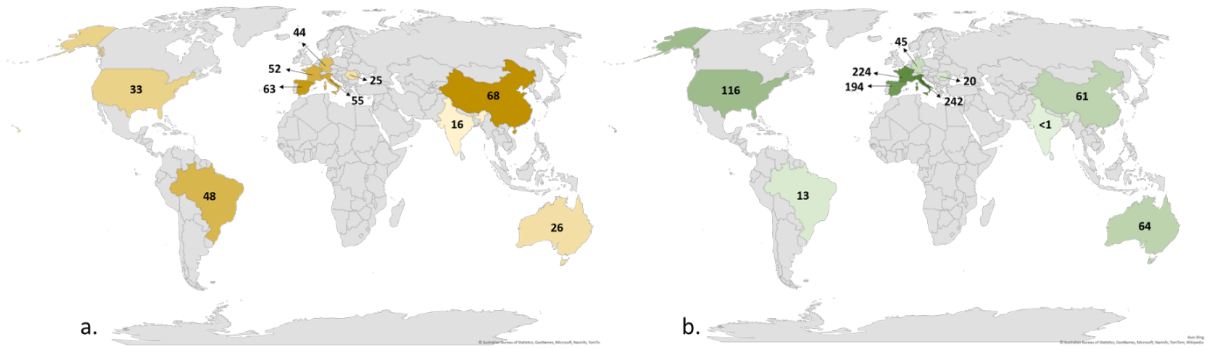

Fig 4: Graphical representation of keyword clusters. The number of articles is represented in the top right corner of every bubble containing the cluster number. The number of times a keyword appears in an article is represented by the number on the top right corner of each keyword. The grey line represents the link between a cluster and a keyword, the number in the middle of the grey line represents the amount a times a keyword appears in a cluster."

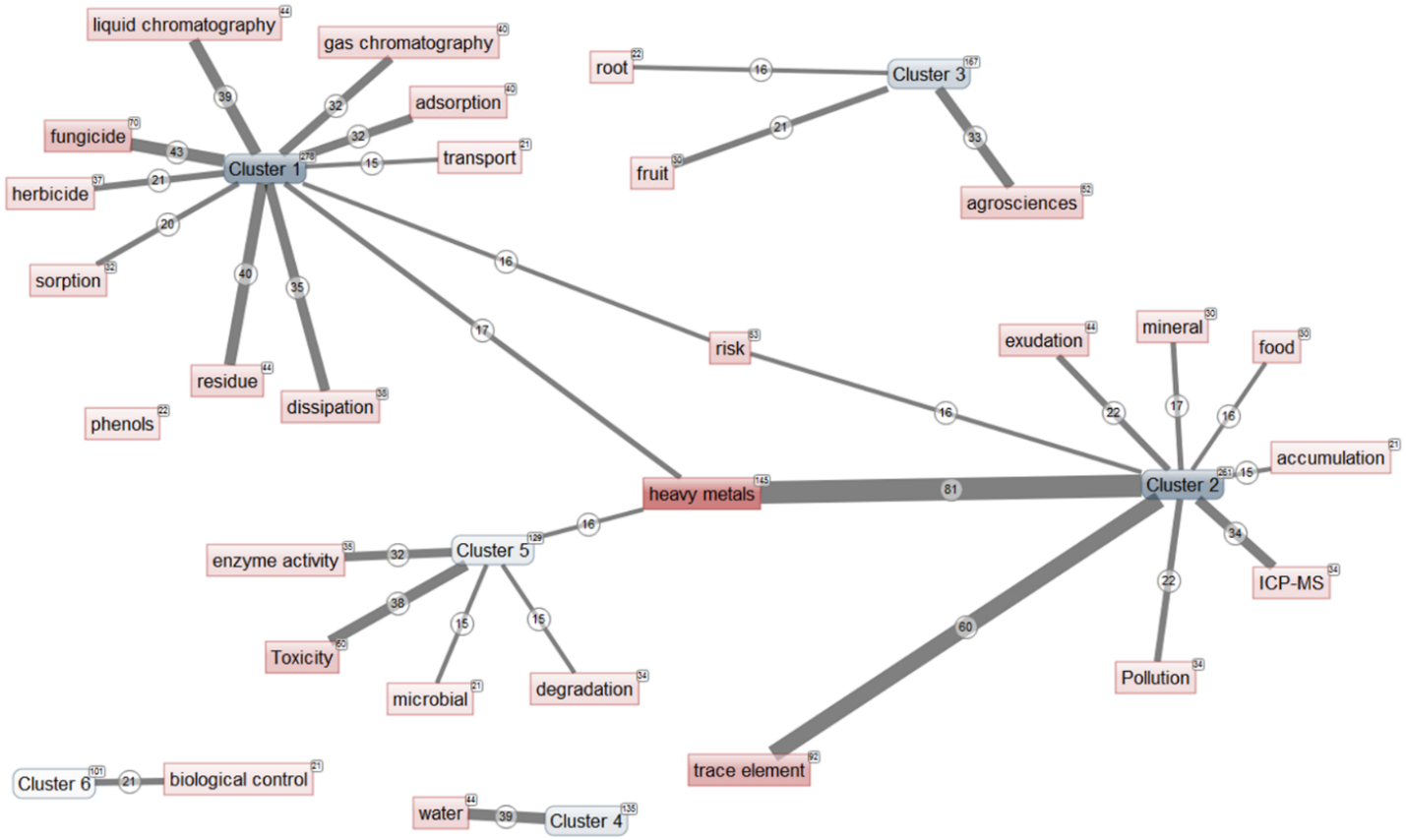

Fig 5: Distribution of clusters by journal in the search (1990-2020)

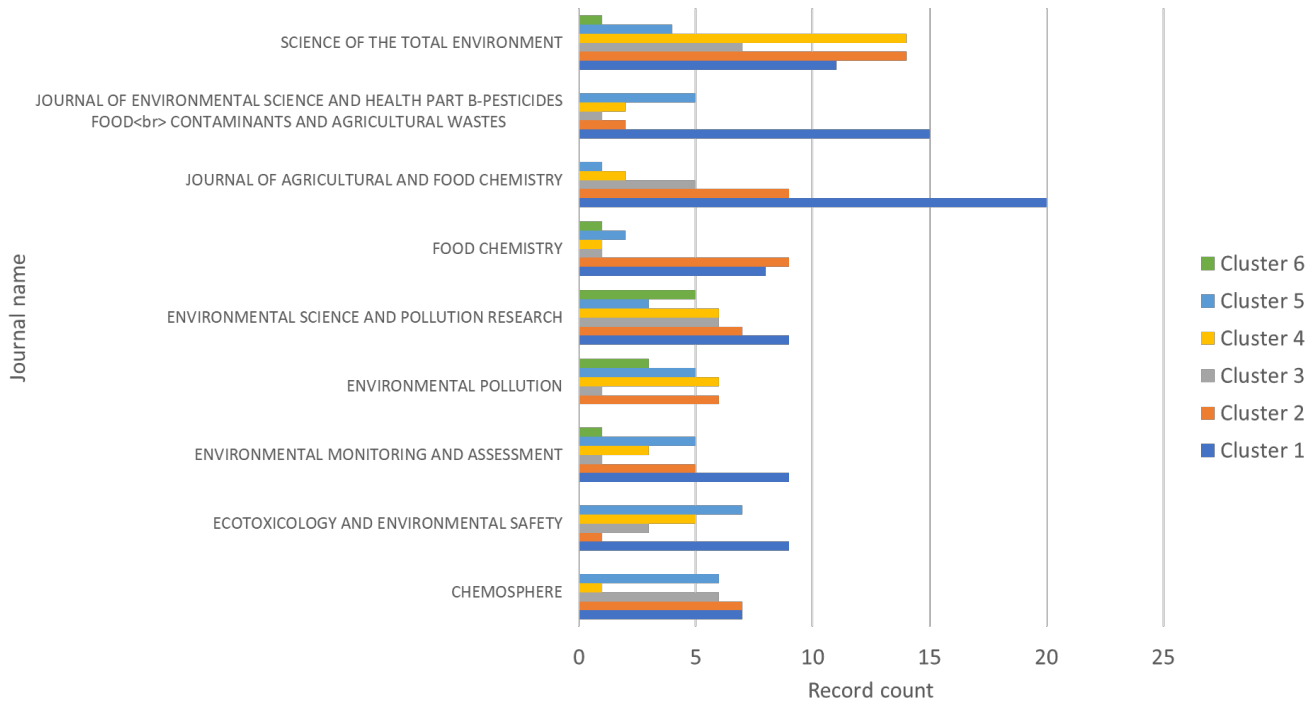
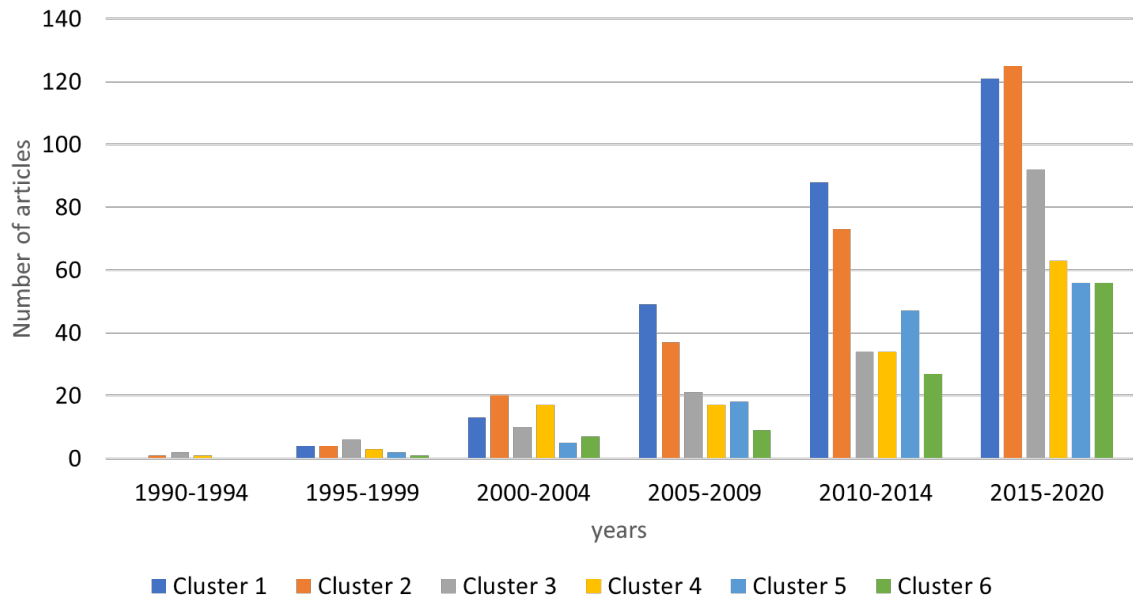
Fig 6: Evolution of clusters in the search over time. Each bar represents the number of articles in a cluster from 1990-2020