Review

Open Bioeconomy. A Review of the Literature

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Abstract: The purpose of this paper is to assess the degree of openness of scientific articles on bioeconomy. Based on a WoS corpus of 2,489 articles published between 2015 and 2019, we calculated bibliometric indicators, explored the openness of each paper and assessed the share of journals, countries and research areas of these articles. The results show a sharp increase and diversification of articles in the field of bioeconomy, with a beginning long tail distribution. 45.6% of the articles are freely available, and the share of OA papers is steadily increasing, from 31% in 2015 to 52% in 2019. Gold is the most important variant of OA. Open access is low in the applied research areas of chemical, agricultural and environmental engineering but higher in the domains of energy and fuels, forestry, and green and sustainable science and technology. The UK and the Netherlands have the highest rates of OA papers, followed by Spain and Germany. The funding rate of OA papers is higher than of non-OA papers. This is the first bibliometric study on open access to articles on bioeconomy. The results can be useful for the further development of OA editorial and funding criteria in the field of bioeconomy.

Keywords: bioeconomy; open science; open access

1. Introduction

The climatic context is forcing us to rethink our production and consumption methods to limit the damage to the environment. Not only the extensive use of non-renewable resources (with further depletion issues) but also irreversible impacts on life cycles are pointed out as the main causes [1]. The bioeconomy is part of this approach which aims to replace fossil resources - i.e. non-sustainable resources such as coal or oil - by "green" resources which are also called biomass, the process of which the rationalized processing would open more environmental-friendly perspectives to our Planet. Indeed, bioeconomy is more than a concept. It is a set of initiatives that reconciles both economic, environmental and social objectives [2]. Until recently, the concept of bioeconomy has been rapidly spreading in different spheres: institutional, scientific, and entrepreneurial. The concept of bioeconomy is used in scientific publications and mobilizes on the one hand, experimental sciences and agronomic and environmental techniques and, on the other hand, human and social sciences. Moreover, this concept has been the subject of strong public policy attention. The Organisation for Economic Co-operation and Development (OECD) is the first institution to underline the issues and the aims of bioeconomy through its pioneering work. According to [1], "the transition to bioeconomy gains significant footing towards the end of the 20th century and is now a strategic element on a transnational, national, and regional level" (p.67). Companies are applying new technologies to meet the demands of pollution abatement, innovation and profitability. In the field of research and development, there is an innovation model based on sharing and collaboration between stakeholders. This model, called "Open Innovation", suggests calling on stakeholders outside the company to

innovate [3]. In such an approach, a set of stakeholders can be profitably invested in the field of bioeconomy to achieve major advances both socioeconomic and environmental major advances.

Bioeconomy being a relatively recent and emergent field of research, a small but growing number of papers present results of bibliometric studies on this topic. A multilevel social network analysis has been applied by [1] to construct a holistic and visual definition of bioeconomy and to describe its evolution, based on scientific literature from the European Union, the United States, and China. Their data consists of 1,369 articles from 2008 to 2018, retrieved from the Web of Science (WoS) database; the study includes a content analysis of strategic policy documents. In 2016, a study showed how in terms of publications, the importance of biotechnology had grown in South Africa following the country's launch of its Biotechnology Strategy in 2001, with accompanying government financial support for R&D [4].

A large study on about 7,000 papers indexed in the Scopus database showed the decisive role of technology (industrial biotechnology, synthetic biology, metabolic engineering etc.) in the development of the bioeconomy and proposed a systemic model of 20 interacting factors influencing this development, such as research and innovation, energy consumption and policy [5]. Innovation is the main topic of a recent German study which aims to improve the measurement of innovation in bioeconomy, to discuss what kind of information may be needed to understand innovation patterns in bioeconomy and to assess the current data availability [6]. This study is particular insofar as it applies bibliometric methodology to patents, in order to highlight the innovation potential of bioeconomy and the public and private R&D funding activities and to contribute to the monitoring of the economic, social and ecologic developments of bioeconomy.

The relationship between bioeconomy and sustainability has been addressed by [7], providing evidence how visions about this relationship differ across scientific publications, ranging from positive to negative: the assumption that sustainability is an inherent characteristic of bioeconomy; the expectation of benefits under certain conditions; tentative criticism; and the expectation of a negative impact.

Another bibliometric study on 453 articles published between 2005 and 2014 analysed the meaning of the notion of bioeconomy by exploring the origins, uptake, and contents of the term "bioeconomy" in the academic literature [8]. Main results are an increasing visibility of bioeconomy research, mainly by researchers affiliated to a higher education institution, much less from the corporate sector; a rather fragmented research community, with a core of European and American regional clusters most active and networked in the field, and dispersed over many fields of science, yet dominated by natural and engineering sciences. They also identified three different visions of bioeconomy (i.e. bio-technology, bio-resource, bio-ecology) and described their implications in terms of overall aims and objectives, value creation, drivers and mediators of innovation, and spatial focus. [2] conducted a complementary bibliometric study on temporal and geographical distribution of publications, most popular publication platforms, salient keywords and emerging topics in order to compare circular economy, green economy and bioeconomy as global sustainability concepts.

[9] performed a bibliometric analysis on papers indexed by the Web of Science (WoS) for a number of South African authored publications and citations in bioeconomy, and compared them with Brazil, Russia, India and China (BRICS) and selected countries for the period 2008 to 2018. Based on a large and inclusive query, they retrieved 19,040 publications in bioeconomy disciplines with at least one South African author for the period 2008–2018; about 55% were written in collaboration with researchers from other countries, and the average percentage industry collaboration was at 1.3%. With a focus on biotechnology, [10] evaluated the research output of ten Indian universities between 1997 and 2006, identifying prolific authors, most relevant journals and different document types.

Other bibliometric papers deal with specific aspects of bioeconomy, like biomass, biorefineries and forest bioeconomy [11-13]. [14] performed a bibliometric analysis of a small corpus of 166 papers on bioeconomy retrieved through a systematic review of academic journals in social sciences. Their study confirms that most of the current analysis of the bioeconomy relates to genetics, chemistry, biotechnology, energy or biology issues and regrets that a proper interpretation of the significant implications of the bioeconomy from a social and economic perspective is still (too) scarce.

Most of these papers (9 out of 13) are based on WoS data; some are rather large and inclusive whereas others apply a more selective query approach. Half of them combine the bibliometric methodology with a conceptual analysis of the papers' content. However, so far none of the bibliometric papers investigated the accessibility of publications on bioeconomy on the Internet, to which degree the access to published research output is free, open and universal. Open access (OA) to academic papers and more generally, open science appears out of scope in this field of research.

Now, open science is one of the major challenges of the European research and innovation framework program (Horizon 2020, Horizon Europe[1]), along with bioeconomy. The objective is to accelerate the transition towards a sustainable European bioeconomy by reducing the gap between new technologies and their implementation. The position in favor of open science includes the obligation to ensure free access to publications resulting from funded projects. The European Commission defines open science as a way research is carried out, "disseminated, deployed and transformed by digital tools and networks. It relies on the combined effects of technological development and cultural change towards collaboration and openness in research" [2]. New technologies contribute to the improvement of scientific research and communication, and "by providing unlimited, barrier free, open access to research outputs, open science makes scientific processes more efficient, transparent and responsive to societal challenges" (ibid.).

The scientific and technical information brings together all the information produced by professionals in research, teaching, but also industry and economics. It covers all scientific and technical sectors and can be presented in several forms, such as articles, reviews, books, posters, technical documentation, patent notice, databases and gray literature [15]. The real challenge of research today is to democratize access to knowledge and to recognize that knowledge has a driving role for our society. The open access movement has focused on the communication and circulation of scientific publications while the open science movement values science and its evaluation by opening up research data and new measures to assess awareness, for example [16].

The aim of our paper is to assess the degree of openness of scientific articles on bioeconomy and related topics. Similar to [8], we calculated bibliometric indicators on the development, impact (citations), journals, authors, institutions, countries and research areas; we also investigated the internationality of the underlying research collaborations and the share and types of funding sources. Based on this dataset, we explored the openness of each paper, if it has been published in a gold or hybrid OA journal or if it is legally available on an institutional or a disciplinary repository or another, similar platform, and we assessed the share of journals, countries and research areas of open access (OA) articles on bioeconomy.

After a short description of the applied methodology (section 2), we present the results of the bibliometric analysis of scientific articles on bioeconomy published between 2015 and 2019, together with an assessment of their free and open availability on the Internet (section 3). The results are discussed in section 4, in particular regarding methodological limitations and downfalls, the differences with former studies and the impact of open science in this research field. We conclude our paper with some perspectives for further research.

The study has been carried out as part of a PhD thesis on the application of the principles of open science in the field of bioeconomy, especially on how open science can accelerate open innovation, how it can foster cooperation between stakeholders from different fields in the French region of *Hauts de France* as a case study, and how it can respond to the challenges of the bioeconomy. The research receives funding from the RECABIO project[3] which encourages collaboration between experimental sciences and the human and social sciences; also, our paper is a result of scientific cooperation between two very different research disciplines, i.e. chemistry and information and communication sciences.

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[1] EC Horizon Europe https://ec.europa.eu/info/horizon-europe_en

[2] EC Open Science https://ec.europa.eu/digital-single-market/en/open-science

[3] Cf. the presentation of the RECABIO project. http://www.isite-ulne.fr/index.php/fr/recabio/

2. Materials and Methods

2.1. Bibliometric analysis

We used the multidisciplinary bibliometric database Web of Science (WoS) Core Collection in order to retrieve relevant papers in the field of bioeconomy. The literature retrieval was limited to articles published in scientific journals between 2015 and 2019.

The following search terms and strings were used in the field TOPIC (article title, abstract, author keywords, WoS keywords): agro-based, agrobased, agro-sourced, agrosourced, naturality, bioeconomy, bio-economy, biobased economy, bio-based economy, biobased industry, bio-based industry, biobased society, bio-based society, biobased product*, bio-based product*, biobased knowledge economy, bio-based knowledge economy, circular economy AND biobased.

The WoS Core Collection set we used consists of the following content, with coverage time spans:

- Science Citation Index Expanded: 1991-present
- Social Sciences Citation Index: 1991-present
- Arts & Humanities Citation Index: 1991-present
- Emerging Sources Citation Index: 2015-present

The WoS queries were performed on June 24, 2020. The retrieved references have been downloaded as a CSV-file and processed as Excel spreadsheets. Some variables needed curation and cleansing, in particular the data on publishers and affiliated organisations. Network maps were created with VosViewer 1.6.15. In case of missing data, articles were excluded from the analysis. Appendix A provides a list of the calculated indicators.

2.2. Evaluation of openness

In a second step, we selected those articles with an DOI. For these articles, we performed a search in the open database Unpaywall in order to assess if the articles are freely available on the Internet (open access) or not, especially in gold or hybrid open access (OA) journals or in institutional or disciplinary repositories.

The queries via Unpaywall were performed on August 24, 2020. The retrieved references with all relevant information about open access have been downloaded as JSON and CSV files and the data were added to the WoS references. Appendix A provides a list of the calculated indicators.

3. Results

The search in the entire WoS Core Collection based on the selected keywords described above produced 6,728 references. From these references, 5,073 are identified as journal articles (75.4%). 2,489 articles have been published from 2015 to 2019. These articles are the sample for the following bibliometric analysis. From this sample, 2,329 articles have an DOI (93.6%) and serve as the subsample for the assessment of openness.

3.1. Articles and citations

Our search in the WoS Core Collection identified 2,489 articles for the period 2015-2019. The annual number of published papers doubled from 2015 to 2019, with an annual increase rate between 15% and 30% (Figure 1). The articles from 2019 include 28 papers published by the journal in an early access version.

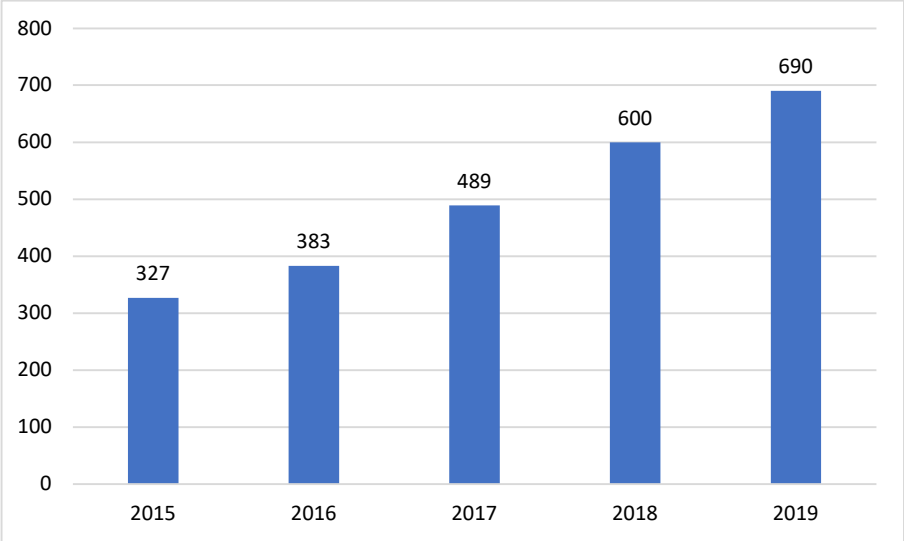

Figure 1. Number of articles per year (N=2,489)

The annual increase in bioeconomy is well above the average global growth of published papers worldwide which is, for the given period, between 5% and 10% (WoS Core Collection).

At the time of the WoS query, the articles of our sample have been cited 18,431 times. As in [8], the distribution of the citations is skewed but in a more long-tail way (Figure 2).

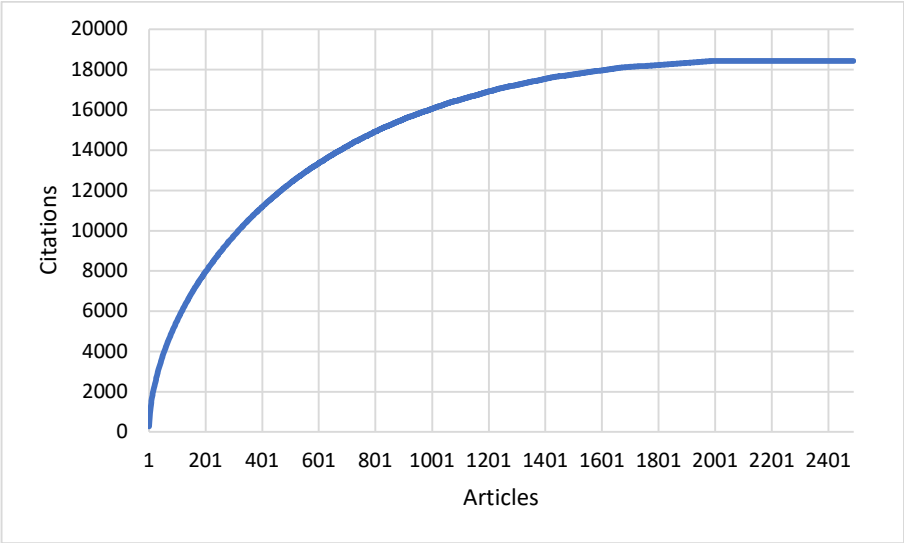

Figure 2. Distribution of the article citations (N=18,431)

The most cited paper published in the period 2015-2019 - Roger Sheldon's paper on "The E factor 25 years on: the rise of green chemistry and sustainability" published by the Royal Society of Chemistry journal *Green Chemistry* [17] - received so far 269 citations; the five most cited papers (the "top of the charts") are at the origin of 5.9% of all citations (Table 1). The 15 most cited articles received 10.7% of all citations.

Article #1	269 citations
Article #2	258 citations

Article #3	207 citations
Article #4	202 citations
Article #5	144 citations

Table 1. Number of citations received by the five most cited articles

20% of all articles received 66.9% of all citations while 80% of all citations are "produced" by 31% articles. This is not a classic 80/20 Pareto-like distribution but moves to the so-called "long-tail" distribution [18]. On the other extreme of the ranking, 332 articles (19.7%) received one citation only while 490 articles (13.3%) were not cited at all.

The median number of citations per article is low, with only 3 citations per article. For articles published in 2015, the median is 7 citations while for those published more recently in 2019, it is only 1 citation (Table 2).

Publication year	Median of citations
2015	7
2016	7
2017	5
2018	3
2019	1
All years	*3*

Table 2. Median number of citations per year, for all articles

3.2. Journals and research areas

The 2,489 articles of our sample have been published in 932 different journals. From these journals, 607 (65.1%) have published only one article on bioeconomy in the given period 2015-2019. Again, the distribution is skewed. The five journals with the highest number of articles on bioeconomy and related subjects, together represent 332 articles (13,3% of all articles). Their articles received 3,247 citations (17.6%). The journal which published the most articles in the field of bioeconomy in the given period 2015-2019, was the *Journal of Cleaner Production*, an international, transdisciplinary journal focusing on cleaner production, environmental, and sustainability research and practice[4], published by Elsevier, followed by the MDPI open access journal *Sustainability*, an international, cross-disciplinary, scholarly journal of environmental, cultural, economic, and social sustainability of human beings[5] (Table 3).

Journal	Nb art	% art	Nb cit	% cit
Journal of Cleaner Production	121	4.86%	1,529	8.3%

[4] *Journal of Cleaner Production* https://www.journals.elsevier.com/journal-of-cleaner-production

[5] *Sustainability* https://www.mdpi.com/journal/sustainability

Sustainability	76	3.05%	596	3.23%
Agricultural Systems	49	1.97%	340	1.84%
Industrial Crops and Products	47	1.89%	576	3.13%
Ecological Economics	39	1.57%	206	1.12%

Table 3. The journals with the highest number and share of papers and citations

The first twenty journals published together 703 articles on the topic (28.2%). These articles received 6,362 citations (34.5%) (Appendix B).

The journals of our sample are published by 360 different publishers but some of them belong to the same publishing house. The most important publishers, in terms of papers and citations, are Elsevier, Springer Nature, Wiley, MDPI and Taylor & Francis (Table 4); except for the new open access publisher MDPI from Switzerland, these publishers belong to "big five" academic publishers. Together, the five publishers represent 1,565 articles (62.9%) and 12,473 citations (67.7%), confirming in this particular, emerging field of research the global oligopoly of academic publishers [19].

Publisher	**Nb art**	**% art**	**Nb cit**	**% cit**
Elsevier	792	31.8%	7,773	42.2%
Springer Nature	273	11.0%	1,852	10.0%
Wiley Blackwell	244	9.8%	1,501	8.1%
MDPI	154	6.2%	1,007	5.5%
Taylor & Francis	102	4.1%	340	1.8%

Table 4. Most important publishers with number and share of papers and citations

Sage Publishing, the fifth of the "big five" academic publishers, produced only 27 articles over the given period, which received 274 citations. Clearly, Elsevier is in a significant, dominant position, as well in terms of production (papers) as in terms of impact (citations). The only surprise is the emergence of the newcomer MDPI, with a different publishing and business model based on 100% open access (see below).

Publications on bioeconomy are dispersed over many fields of science, yet dominated by natural and engineering science [8]. In our sample, we identified 161 WoS categories of research areas, most of them - the long tail - covered by few papers. Figure 3 shows the fifteen most important WoS research areas, representing the highest number of papers; one paper can be indexed in more than one research area.

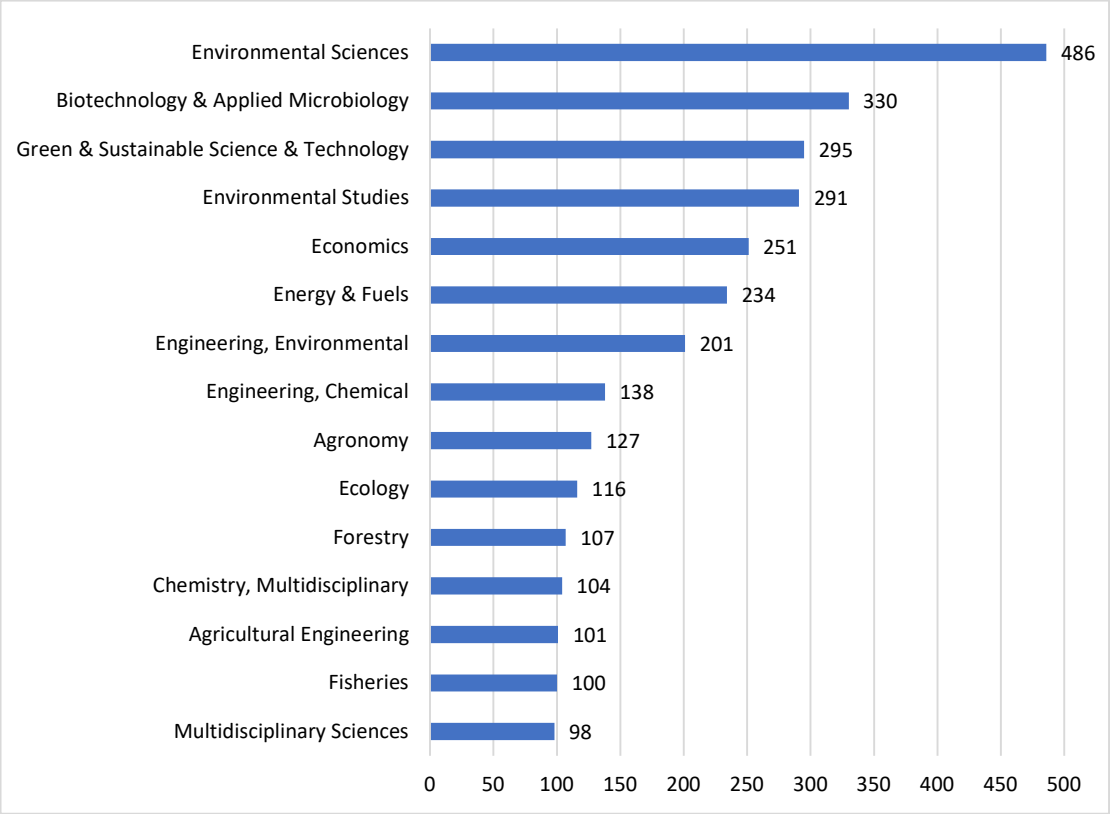

Figure 3. Number of articles per research area (n=2,489)

The most important research areas contributing to the growing corpus of journal articles on bioeconomy and related topics are, for the period 2015-2019, environmental sciences (19.5% of all papers), followed by biotechnology & applied microbiology (13.3%), green & sustainable science & technology (11.9%), environmental studies (11.7%) and economics (10.1%). A more detailed analysis of these figures provides complementary insight:

- Ranking: the comparison of the annual ranking of the different research areas reveals that while over the whole period environmental sciences remain the first research area in terms of papers, four areas are gaining importance (green & sustainable science & technology; environmental engineering; forestry; multidisciplinary chemistry); three other areas become relatively less important (ecology; fisheries; agricultural engineering).
- Journals: in some research areas, papers on bioeconomy are more dispersed than in others, i.e. are published in a relatively higher number of journals. More dispersion: multidisciplinary sciences; chemical engineering; multidisciplinary chemistry. Less dispersion: agricultural engineering; green & sustainable science & technology; environmental engineering.
- Citations: in some research areas, papers are averagely more cited than in others and thus have a higher potential impact. Higher citation average per paper: multidisciplinary chemistry; environmental engineering; green & sustainable science & technology; agricultural engineering. Lower citation average per paper: economics; forestry; fisheries.

3.3. Authors, organisations and funding

The articles of our sample were written by 8,566 authors. 8,447 (98,6%) authors contributed only to one paper on the topic of bioeconomy, which represents 2,090 articles of the corpus. The ten most prolific researchers authored between 9 and 17 articles, together 125 articles which received 1,153 citations, which is above the average number of citations per article (Table 5). The most prominent

author, S.Venkata Mohan, is working at the Council of Scientific and Industrial Research funded Indian Institute of Chemical Technology (CSIR-IICT), Hyderabad, India. The two following authors, Mario Pagliaro and Rosaria Cirminna, are both working at the Institute for the Study of Nanostructured Materials (ISMN) of the Italian National Research Council (CNR) at Palermo, Italy, while Qingling Zhang is working at the Northeastern University, Shenyang, China.

Author	Papers	Citations
Mohan, S.V.	17	149
Pagliaro, M.	16	212
Cirminna, R.	14	212
Zhang, Q.	13	146
Sanchirico, J.N.	13	72
Blumberga, D.	12	49
Thraen, D.	11	91
Monti, A.	10	117
Dragicevic, A.Z.	10	19
Zanetti, F.	9	86

Table 5. The ten most prominent authors with number papers and citations

The median number of authors per paper is 4; the maximum number is 89, for a paper on the emerging field of marine biotechnology in Brazil with 20 main authors and a network of 69 other researchers.

Among the references, the authors listed affiliations to 2,471 organisations. The most performant institution, in terms of published papers in the field of bioeconomy but also in terms of impact (citations), is the Dutch University of Wageningen, followed by the French public National Institute of Agricultural Research (INRA)[6], the US Department of Agriculture (USDA), the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Swedish University of Agricultural Sciences (Table 6). Except for USDA and CSIRO, all organisations are from the European Union member states.

Organisation	Nb art	%art	Nb cit	%cit
Wageningen University (NL)	80	3.2%	1,064	5.8%
National Institute of Agricultural Research (F)	54	2.2%	326	1.8%
US Department of Agriculture (USA)	40	1.6%	249	1.4%

[6] INRA merged in 2020 with IRSTEA, another French research organisation, to become the new National Research Institute for Agriculture, Food and Environment (INRAE).

Commonwealth Scientific and Industrial Research Organisation (AUS)	37	1.5%	198	1.1%
Swedish University of Agricultural Sciences (SE)	37	1.5%	201	1.1%
Technical University of Denmark (DK)	37	1.5%	417	2.3%
University of Hohenheim (D)	37	1.5%	260	1.4%
University of Helsinki (FI)	32	1.3%	464	2.5%
National Research Council (I)	31	1.2%	279	1.5%
Delft University of Technology (NL)	30	1.2%	740	4.0%

Table 6. The ten most important organisations, with articles and citations

These ten organisations together produced 415 papers (16.7%); their articles received 4,198 citations (22.8%). In terms of impact, the most important organisations are the Dutch universities of Wageningen and Delft, followed by the German Helmholtz-Centre for Environmental Research (which is ranked #11 and not part of table 6), the University of Helsinki and the Technical University of Denmark.

85% of these organisations could be clearly attributed to a specific type of academic or other structure. More than half of the organisations are Higher Education institutions (mainly universities), and they contributed to 86% of all articles (Table 7). They are followed by research institutes (like INRA, CNR or CSIRO) which represent 18.5% of all institutions but contributed to 32.4% papers. Corporate companies (5.2%) authored or co-authored 6.5% articles.

Type of organisation	Nb org	%org	Nb art	%art	Nb cit	%cit
Higher education institution	1,312	53.1%	2,151	86.4%	15,778	85.6%
Research institute	456	18.5%	806	32.4%	6,577	35.7%
Company	128	5.2%	163	6.5%	1,658	9.0%
Government organisation	95	3.8%	232	9.3%	1,695	9.2%
Public agency	92	3.7%	131	5.3%	1,043	5.7%
International organisation	17	0.7%	45	1.8%	627	3.4%

Table 7. Number and share of articles and citations per type of organisation (N=2,100)

1,677 papers (67.4%) acknowledge some kind of funding, from one (30.0%) or more funding bodies (37.4%). However, when this indicator - the funding rate - is broken up by the research areas, significant differences appear. Some research areas - especially (but not only) the most important in terms of published papers - show funding rates well above 70% or 75%, like green & sustainable science & technology, agricultural engineering but also marine & freshwater biology or fisheries, for instance (Figure 4). In other research areas, the funding rate is lower, i.e. the published results have less often received specific funding; this is the case for papers indexed in economics and management, similar to a long tail of papers covering less important or less central fields of bioeconomy.

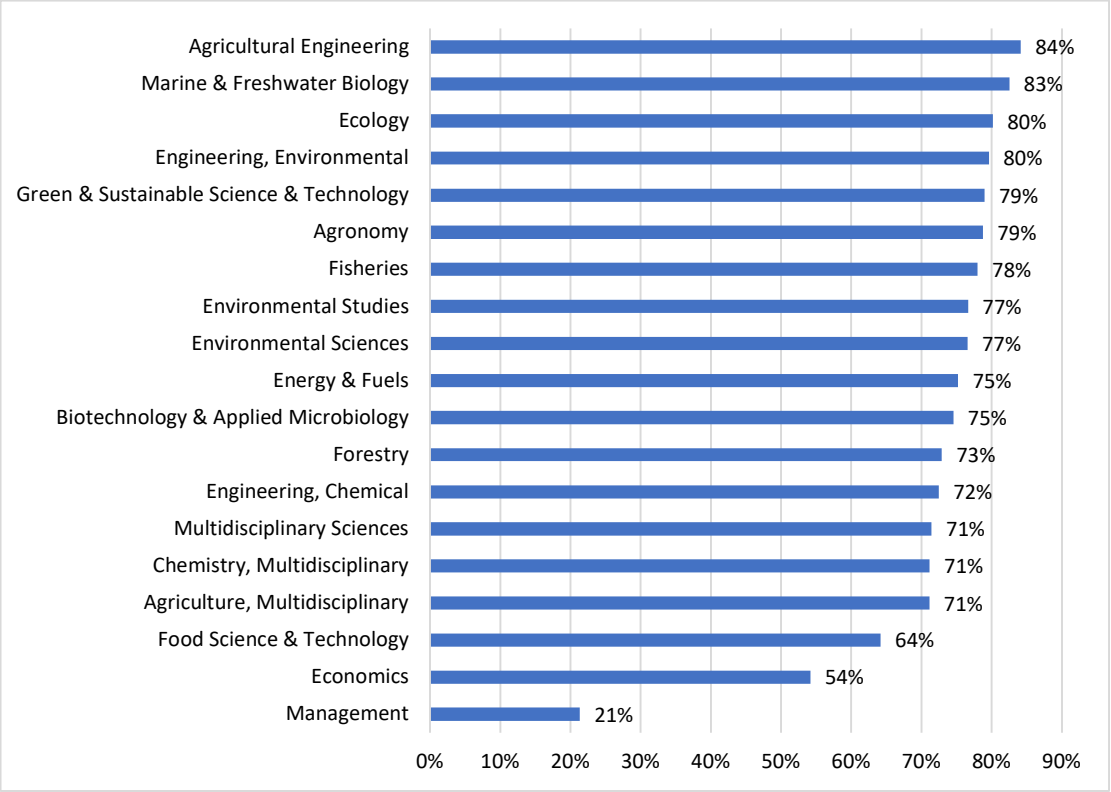

Figure 4. Funding rate per research area (N=1,677 papers)

3.4. Affiliation countries and international collaboration

Based on the affiliations, the following table shows the cumulative number of articles and citations for the most "productive" countries in the field of bioeconomy research (Table 8).

Country	Nb art	Nb cit
USA	436	3,496
Germany	299	2,872
Italy	200	2,002
France	172	1,151
UK	166	1,728
Netherlands	161	2,036
Spain	145	1,000
India	142	864
People's Republic of China	122	1,239
Australia	115	655

Table 8. The ten countries with the highest number of articles

These ten leading research countries in the field of bioeconomy represent 1,958 articles (78.7%) and 17,043 citations (92.5%). The researchers from US organisations, the best ranked country, have authored or co-authored 17.5% of all papers and received 19.0% of all citations. Papers from France, Spain, India and Australia are in average less well cited than from the other countries.

Two-third of the articles are domestic, i.e. written by authors working in the same country (1,685 articles, 67.7%). Most of the international articles have been published by authors from two or three countries (705 articles, 28.3%); yet, one paper, a comparative property rights analysis on Europe's private forests, has authors from 29 different countries.

The topological map (Figure 5) represents the affiliate network according to the share of international articles by country.

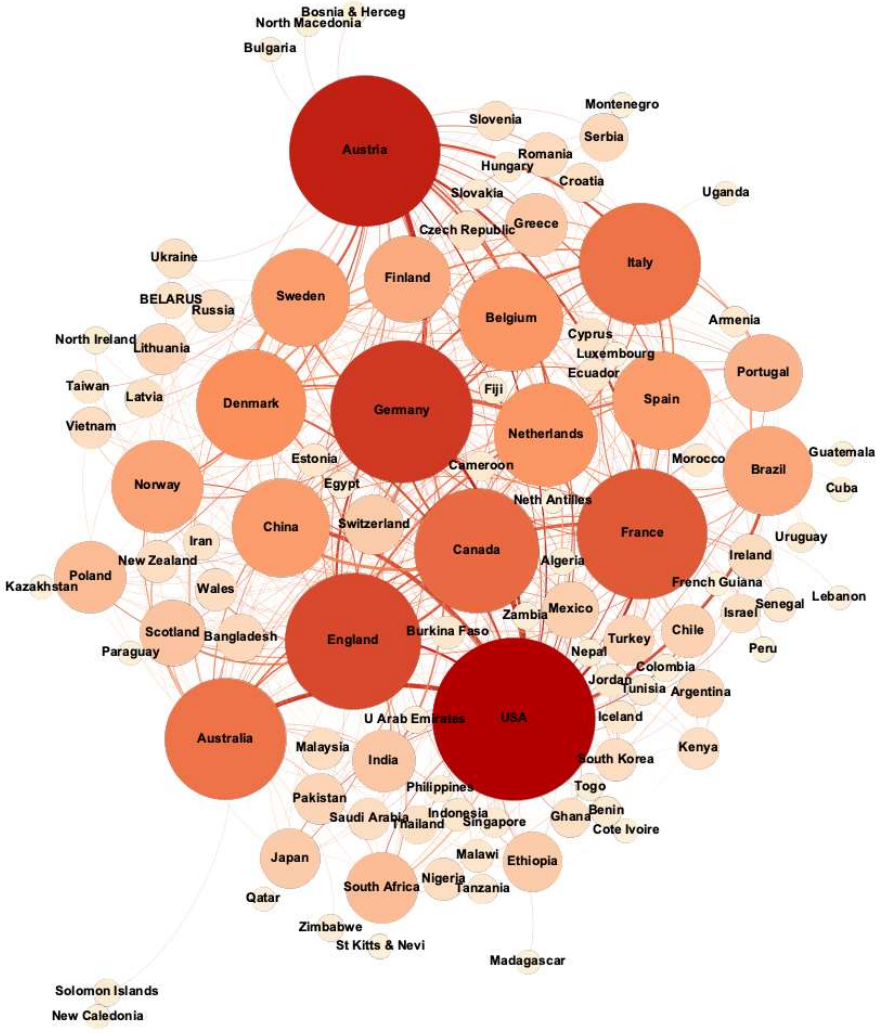

Figure 5. Representation of international articles per country (N=790 articles, Gephi software)

Figure 5 highlights the international collaboration between different countries. The majority of countries that maintain international collaboration are developed countries: USA, Austria, Germany, England, France, Italy, Nordic countries, and other countries from Europe. Interesting: the central role of Austrian research for partnerships with countries from Central and East Europe. Interesting,

too, the strong partnerships of the US with the Commonwealth countries England, Canada and Australia, but also with China and Brazil and, less, with Germany and France.

Figure 6. Representation of domestic articles per country (N=790 articles, Voyant Tools software)

The word cloud represents the share of domestic articles per country, i.e. highlights countries that have produced articles without international collaboration. Germany, the US and Italy are countries with a high amount of domestic research; yet, all of them are also strongly invested in international collaborations (see Figure 5 above). More interesting is the case of India, with an important number of domestic research but less international partnerships.

3.5. Openness

1,135 articles from the sample have been identified as freely available in open access (45.6%), nearly as much (1,194 articles) are not open access but behind a paywall (48%); for the other 160 articles, because of lacking DOIs, Unpaywall could not identify the status (Figure 7).

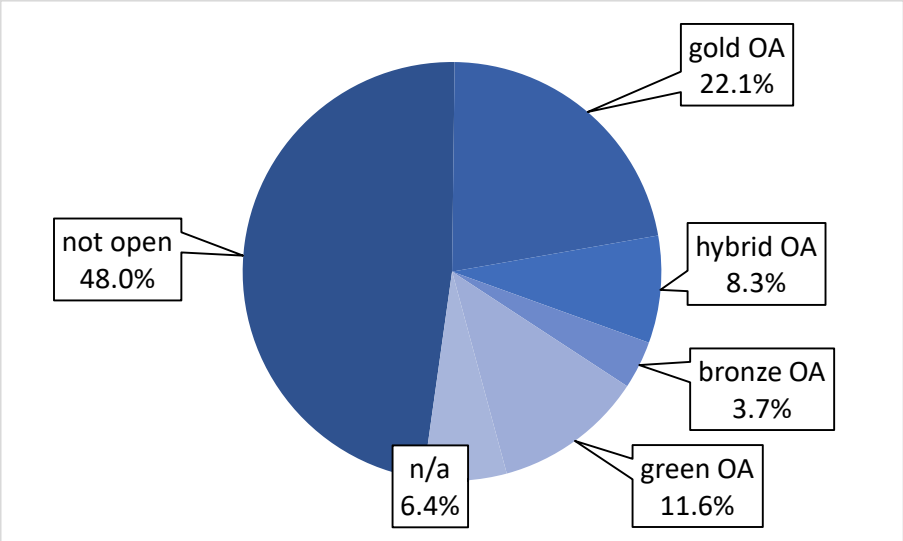

Figure 7. The part of open access (N=2,489 articles)

Figure 7 shows also the distribution of different variants of open access:

- Green open access (papers that are also available in an institutional or other open access repository): 11.6%. This percentage doesn't include preprints or other unpublished papers.
- Gold open access (papers published in an open access journal): with 22.1% of all papers, the 549 gold OA articles represent 48.4% of all OA articles and is clearly the most important variant of OA.
- Hybrid open access (papers in a subscription journal that are open access with a clear license): 8.3% articles are freely accessible in subscription journals.
- Bronze open access (papers published in a subscription journal that are open access without a license): 3.7% articles have been made freely accessible by the publishers.

To summarize, in the field of bioeconomy, open repositories provide 25.4% of the open access to published articles, while the journals cover the other 74.6%.

The share of OA papers is steadily increasing, from 31% in 2015 to 52% in 2019 (Figure 8).

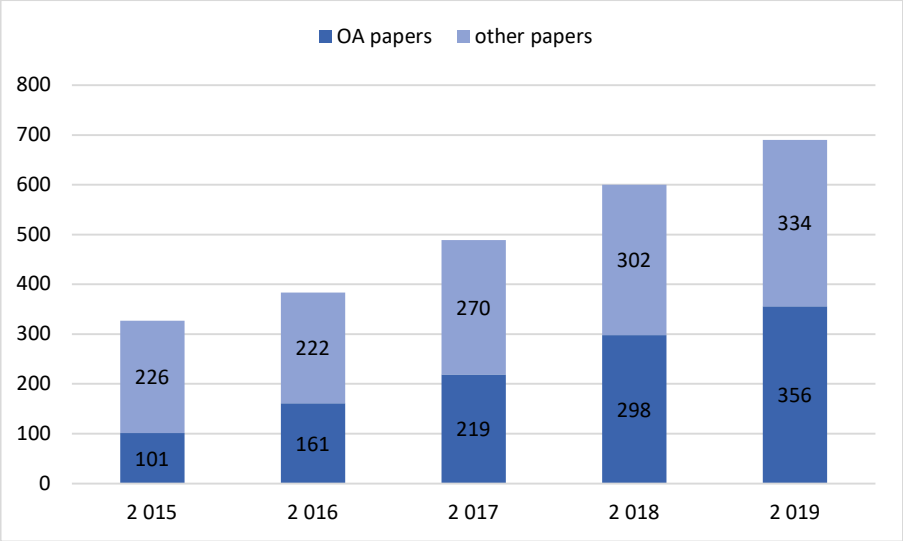

Figure 8. OA and other papers 2015-2019 (N=2,489)

The 1,135 open access articles come from 505 journals (54.2% of all journals), but only 83 journals (8.9%) have 3 or more articles in open access, either on their own platform, or on a green repository. Table 9 shows the five journals that published the highest number of open access articles.

Journal	Nb art OA	% art OA
Sustainability	76	6,70%
Journal of Cleaner Production	33	2,91%
Amfiteatru Economic	32	2,82%
Biotechnology for Biofuels	29	2,56%
Global Change Biology Bioenergy	23	2,03%

Table 9. The journals with the highest number and share of OA papers

The first twenty journals cumulate 326 OA articles on the topic, which represent 46.4% of all OA articles but only 13.1% of all papers (Appendix B). Elsevier published the most articles in bioeconomy (791), and Elsevier is also the publisher with the highest number of OA articles (216, equal 19% of all OA articles). But as table 10 shows, this represents only 27.3% of all papers published by Elsevier on bioeconomy, a share which is lower than the other "big five" publishers Springer Nature (37.7%), Taylor & Francis (39.2%) and Wiley Blackwell (44.2%).

Publisher	Nb art	% art	Nb art OA	% art OA
Elsevier	791	31.8%	216	27.3%
Springer Nature	273	11.0%	103	37.7%
Wiley Blackwell	242	9.7%	107	44.2%
MDPI	154	6.2%	154	100.0%
Taylor & Francis	102	4.1%	40	39.2%

Table 10. Most important publishers with number and share of papers and OA papers

The real difference, however, is with the MDPI publisher of open access journals: all MDPI articles are published in gold open access. With regards to open access, MDPI is already the second important publishers of papers on bioeconomy; with regards to open access compliant with the Plan S requirements[7] and the preference of funding bodies for gold OA, they are the most important OA publishing house. MDPI is not the only OA publisher in this field; however, the other gold OA publishers, like BioMed Central, Frontiers Media, Public Library of Science and Sciendo, are less important, at least for the moment, with an overall share of less than 10% of all articles.

The part of OA articles in the fifteen most important research areas (cf. figure 3) range from 16.7% (Engineering, Chemical) to 78.6% (Multidisciplinary Studies) (Figure 9). Especially the applied domains of agricultural, chemical and environmental engineering have low rates of OA publishing while, except for the relatively small number of multidisciplinary studies, all other important

[7] Plan S https://www.coalition-s.org/

research areas have average rates of OA publishing, between 40% and 50%. The full table with all WoS research areas in our sample is in Appendix C.

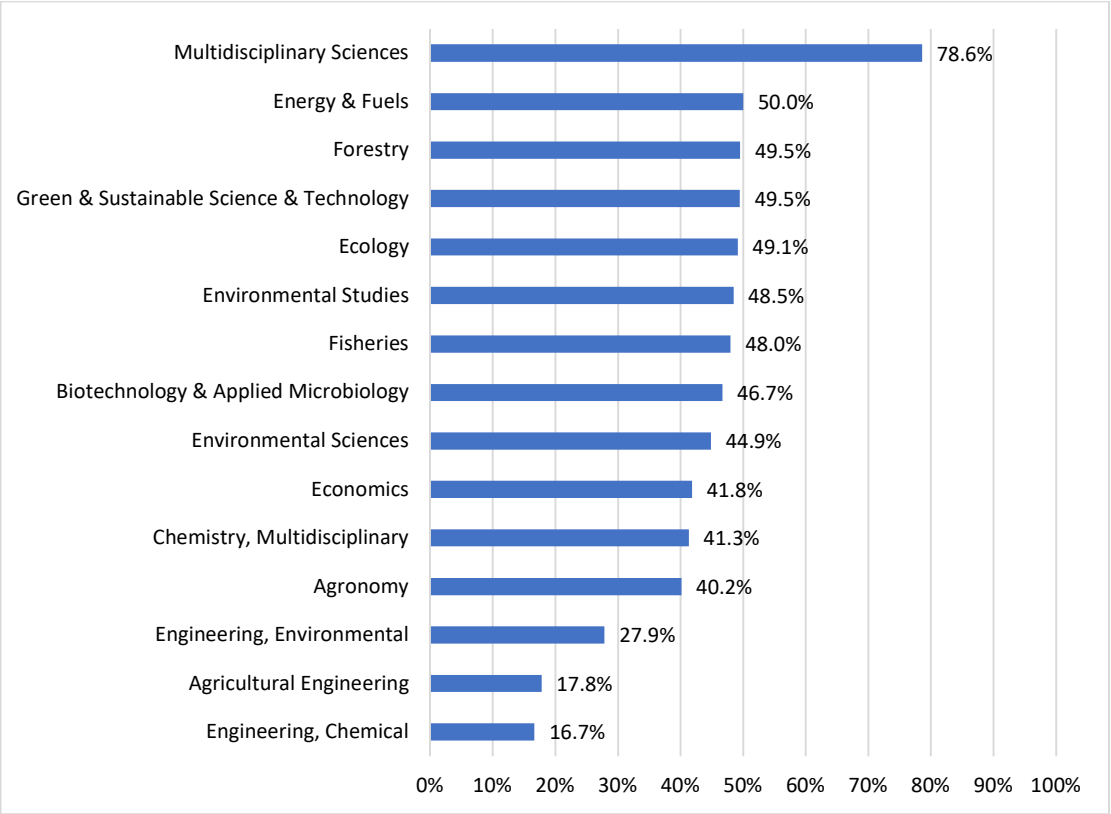

Figure 9. Share of OA papers in the 15 most important research areas

Some of the less important research areas show relatively high rates of OA articles, with more than 60% articles in OA journals or repositories. Some examples: marine and freshwater biology; business; management; microbiology; mathematics; plant sciences; biodiversity conservation. But because of the relatively small number of published papers, there may be a bias and this should not be over-interpreted.

Some research areas are more "OA gold", obviously preferring open access via journals (Biotechnology & Applied Microbiology; Green & Sustainable Science & Technology; Energy & Fuels; Agronomics) while others are more "OA green" with a preference for repositories as a vector of open access (Economics; Ecology; Fisheries).

Table 8 (see above) ranks the ten most important countries, according to the total number of articles published in the field of bioeconomy. Table 11 shows the same countries, this time with the number and percentage of OA articles.

Country	Nb art	Nb art OA	% art OA
USA	436	203	46.6%
Germany	299	170	56.9%
Italy	200	90	45.0%
France	172	92	53.5%

UK	166	115	69.3%
Netherlands	161	102	63.4%
Spain	145	86	59.3%
India	142	32	22.5%
People's Republic of China	122	43	35.2%
Australia	115	44	46.6%

Table 11. Ten countries with articles and OA articles

The leading countries regarding the part of open access are the UK, the Netherlands, Spain, Germany and France; while Germany and the Netherlands appear preferring the gold variant of OA, the UK has a preference for OA hybrid and gold journals, and France clearly prefers green.

Regarding the different types of organisations, the essential contribution to OA articles on bioeconomy comes from the universities which (co)authored 87.6% of all OA papers. However, the share of OA does not vary significantly between universities, research institutes, government organisations, companies etc.

A last result: 73.5% of the OA articles (834) present results from research that got funding from one or more funding bodies, a percentage which is slightly higher than the funding rate of the non-OA papers (66.2%).

4. Discussion

4.1. Methodological limitations

The WoS Core Collection is a representative but not exhaustive database. In order to obtain a more complete picture, we could have included other databases, especially Scopus from Elsevier, or used discovery tools like the BASE or Dimensions. We could also have considered other document types than journal articles, like books and book chapters, communications, dissertations, reports, preprints and other categories of grey literature. We made some comparative test queries in the field of bioeconomy; probably, Scopus would have produced 5-10% more articles while Dimension and BASE would have shown 50-80% more articles and two to three times more references, when other document types like reports, theses, preprints, books and book chapters, conference contributions etc. were included. Clearly, this means that (much) more publications and other academic papers are available on bioeconomy and related topics than in our sample. For our study, however, we preferred consistency, representativity and reliability to exhaustivity. Journal articles are (still) the most relevant type of scientific information, especially in the fields of science and technology, and they are the most important part of the Crossref DOI database, representing 72.9% of all content items[8], and of the Unpaywall search engine required for the OA assessment.

Another limitation is the preponderance of English papers in the WoS. Yet, searching through databases, catalogs and on the Internet reveals that at least for the moment, only few scientific articles have been published in French.

Our analysis of open access excluded all piracy platforms (e.g. Sci-Hub) and all academic social networks from the retrieval of OA papers, which probably contributes to an underestimation of the real open accessibility of bioeconomy papers.

4.2. Delineation, growth and diversification of the field of bioeconomy

[8] Figures from October 2019, cf. Crossref 2019 Annual Report https://doi.org/10.13003/y8ygwm5

The statistical delineation of bioeconomy remains a critical issue [6]. Setting boundaries, attributing some sectors to bioeconomy while excluding others depends on political and economic strategies and on academic definitions of what is or should be bioeconomy. However, so far there is no generally accepted and consensual definition, just more or less large and inclusive approaches.

Our empirical approach is based on the work of [8] and replicates their search strategy, with an opening towards agriculture: the search terms we've added are "agrobased", "agro-based", "agrosourced", "agro-sourced" and "naturality". These keywords enabled us to include research in the field of agriculture and the natural environment. This means that our corpus of published articles is potentially larger and covers more domains than that from the 2016 study.

On the other hand, we could have gone farther and include more keywords, as for example "bio-sourced", "biosourced", "sustainability" or "biomass"; but we didn't because we preferred a reliable corpus of references to a larger sample. We are aware that this choice may reduce the visibility of certain topics, in particular the technical dimension of bioeconomy.

Compared with other studies, our more inclusive approach probably explains one part of the increase of publications, authors, institutions and domains. Our assessment produced 2,489 papers published between 2015 and 2019; for the period 2005-2014, [8] identified only 453 articles, while [2] found 646 articles on bioeconomy for the period 1990-2017 and [1] 1,369 papers published between 2008 and 2018. Beside more or less inclusive views and queries, different data sources are another probable explanation, Scopus for instance having a broader coverage than the WoS. However, all these results, like figures from other recent papers [11-12], may also reveal a real and significant increase of publications in this field, from 2014 and 2015 on, which is well above the global increase of academic articles.

This growth of the number of articles is accompanied by an increasing number of authors, affiliated organisations and journals. For instance, [8] counted 1,487 authors; our corpus contains more than 8,000 authors. They identified 459 organisations, in our study there were 2,471 organisations. The articles of their corpus were published in 222 journals, while this number in our study is 932. Obviously, this is more than a numerical increase. Compared to former and other studies, our results reveal an increasing diversification and inter- or pluridisplinarity. Research on bioeconomy is conducted in an increasing number of scientific domains, and the results are published in more and more journals covering a larger range of topics than before.

While the number of journals quadrupled, the number of articles per journal remained more or less stable, increasing slightly from 2 to 2.7. The analysis of citations shows the development of a long tail in the field of bioeconomy, with a less-skewed distribution of impact. In our study, 20% articles received 66.9% citations, and 80% citations were "produced" by 31.1% articles. Compared to [8], the most cited articles, i.e. the "top of the charts" [18], become less important. In their sample, the three most cited articles received 18% citations, in our study the percentage is only 4%. Table 12 gives more evidence on this evolution.

Most cited articles	Citations 2005-2014	Citations 2015-2019
0.7%	18%	11.4%
1.8%	30.9%	19.3%
3.3%	41%	27%

Table 12. Most cited articles and their part of citations (sources: [8]; own data)

On the other hand, the "far end" of the long tail becomes longer, with a higher percentage of articles that received only one or no citation at all - in our sample, this percentage is 32.8% while in the corpus of [8] it is only 21.2%. In summary, the figures indicate the development of a larger, more

diversified and less structured field of research, with less leading or "reference" papers and more and more studies with less or no impact.

4.3. Clusters of bioeconomy

It was not the purpose of our research to provide a conceptual analysis of the field of bioeconomy, similar for instance to [1, 8, 12]. Nevertheless, we conducted a co-occurrence analysis of the articles' keywords, for two reasons: we wanted to get a (visual) idea of the scope and the diversity of the research field, as a complement to the bibliometric assessment but also in order to control and adjust if necessary the underlying search strategy (WoS query); and we wanted to prepare a more detailed and differentiated evaluation of the development of open science in bioeconomy, based on the clustering of research papers, as a complement to the WoS indexing of research areas. Figure 10 presents the first results of this approach, a co-occurrence map based on 12,859 keywords.

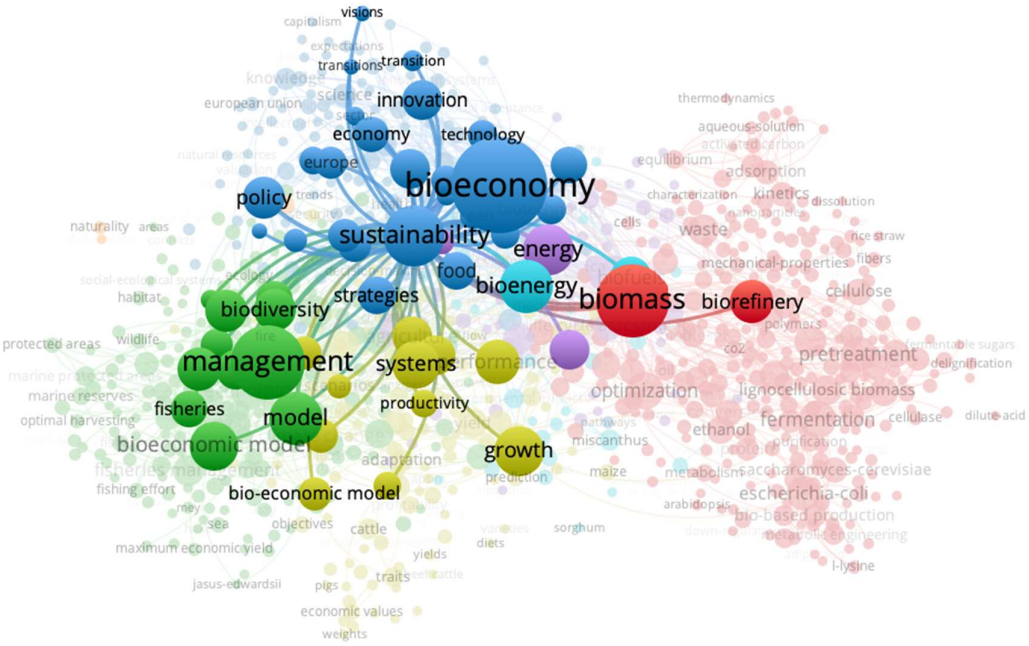

Figure 10. Key-word co-occurrence map (VOSviewer software)

For each paper, all keyword occurrences have been counted. Yet, in order to keep the map intelligible, the visualisation threshold was limited to those 861 keywords with at least five occurrences. The resulting map reveals three main clusters, among other, smaller clusters:

- General principles and challenges of bioeconomy (blue): bioeconomy, economy, policy, industry, sustainability, innovation. This cluster appears similar to [1] cluster 1 on bioeconomy, biopolitics, political economy etc., except for the biodiversity which is missing in our blue cluster. The cluster seems to express at least partly the "bio-technology vision" described by [8, 12], with a focus on economic growth, innovation, and investment.
- Natural resource management (green): management, bioeconomic model, biodiversity. This cluster shifts the focus on management and modelling, especially in the field of fisheries and marine protected areas. It seems quite similar to a "bio-ecology vision" [8] which is held by France for instance, following [1].
- Transformation of bioresources (red): biomass, biofuels, biorefinery, transformation, extraction, fermentation, bio-based production/products. The cluster is similar to [1] cluster 2 on biomass, biorefining and bioproducts and seems to express the "bio-resource vision"

described by [8] as focused on the processing and conversion of bio-resources into new products.

Other clusters are centered on bioenergy or on productivity, growth and a systemic approach while "naturality" appears (so far) out of scope and not related to bioeconomy; the analysis is still in progress. But for the purpose of this paper, two aspects are important: the similarities with other, recent studies on bioeconomy, which confirms the pertinence of our search strategy; and the reality of three large clusters of research that are interconnected, of course, but can be clearly distinguished and described, which makes them interesting and relevant for further assessment of open science, beyond disciplinary boundaries.

4.4. Openness

The overall part of papers on bioeconomy that are freely accessible in open access is 45.6%. Compared to the metrics of the European Commission's Open Science Monitor[9], this OA rate is above the average percentage of open access publications from 2015 to 2017 (Figure 8, in blue the EC Monitor's indicator, in green our own sample).

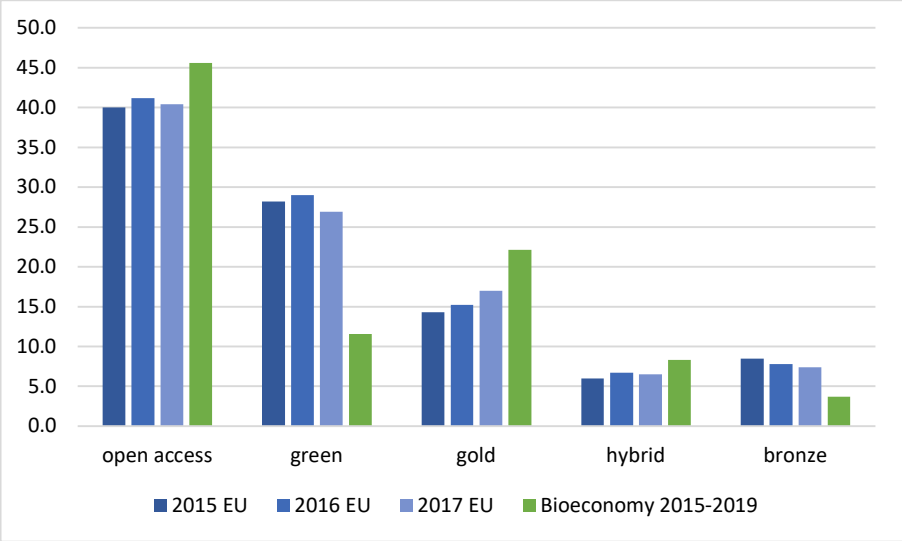

Figure 11. Percentage of open access papers (explication in the text)

Figure 11 shows that the open accessibility of our bioeconomy sample is well above the EC metrics based on a corpus of 1.7m to 1.8m references from the Scopus database, with slightly more than 40% open access. The figure shows, too, that the share between the different variants of open access is particular in the field of bioeconomy, compared to the large EC sample which covers all research areas:

- Green open access: much less bioeconomy papers (11.6%) are available in repositories than in the global EC sample (25-30%);
- Gold open access: the percentage of gold bioeconomy papers (22.1%) is well above the EC gold share (around 15%, increasing);
- Hybrid open access: similar to gold OA. There are more bioeconomy OA papers in hybrid journals (8.3%) than in the EC sample (6-7%);
- Bronze open access: fewer bronze papers in bioeconomy (3.7%) than in the EC sample (7-9%).

Taken together, the open access to articles in the field of bioeconomy is obviously more gold (including hybrid) than green. One reason may be that this is a young and emergent research area in

[9] EC Open Science Monitor https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy/open-science/open-science-monitor_en

need of quick communication and impact; perhaps bioeconomy is just some years ahead of the other research areas, regarding the preference of gold OA (journals) to green OA (repositories). Another reason may be the high degree of funding in this new field covering probably OA publishing costs (article processing charges). An indicator may be the higher rate of funding in OA articles, compared to non-OA articles.

A recent study from Finland reports market shares of open access in eighteen Scopus-indexed disciplines ranging from 27% (agriculture) to 7% (business); it also provides percentages of OA articles that are published in gold OA journals, by discipline [20]. Figure 11 compares the overall OA share of our bioeconomy sample (45.6%, green) with the OA metrics of five disciplines from the Finish study (gold) and of five similar disciplines from the EC Open Science Monitor (blue).

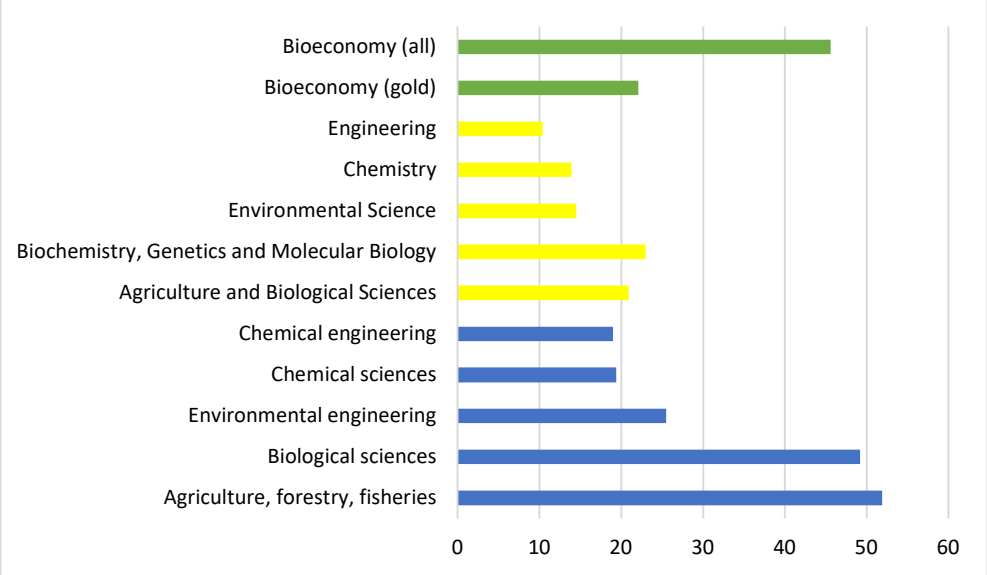

Figure 12. Percentage of OA papers (explication in text)

The OA rate of the bioeconomy papers is similar to the OA rates in biological sciences and agriculture, forestry and fisheries in the EC Open Science Monitor; it is two times higher than in chemical engineering, chemical sciences and environmental engineering (blue).

When compared to the Finish study, which considers only gold OA articles, it is obvious that the bioeconomy gold OA rate is slightly higher than in engineering, chemistry and environmental science but quite similar to biochemistry, genetics and molecular biology and above all to agriculture and biological sciences. These similarities confirm the disciplinary dominance of agriculture, biology and, to a lesser degree, of environmental studies and engineering in the new research area of bioeconomy. Economics (not in figure 9), on the other hand, has a much lower OA rate in the EC Monitor and the Finish study than our own sample and appears rather marginal, compared to the other disciplines.

5. Conclusions

Our paper presents the results of a first comprehensive, scientometric study on the development of open science in the research area of bioeconomy, based on a corpus of 2,489 articles from the WoS, published between 2015 and 2019. Among the main findings are the following:

- 45.6% of the articles are freely available in open access; the share of OA papers is steadily increasing, from 31% in 2015 to 52% in 2019.
- Gold open access represents 48.4% of all OA articles on bioeconomy and is the most important variant of OA, before green and hybrid.

- Elsevier published the highest number of OA articles, but MDPI is the first gold OA publisher in the field of bioeconomy.
- Open access is low in the applied research areas of chemical, agricultural and environmental engineering but higher in the domains of energy and fuels, forestry, and green and sustainable science and technology.
- The UK and the Netherlands have the highest rates of OA papers, followed by Spain and Germany, while the lowest rates can be observed in India and China.
- The funding rate of OA papers is higher than of non-OA papers.
- The global OA share of papers on bioeconomy is above the average OA rate in the European Union, and it is similar to the research areas of biological sciences, agriculture, forestry and fisheries.

Also, based on the study of keywords, other terms could and should be included in order to cope with the development of the research in the field of bioeconomy. Further, including the "bio-sourced" and "biosourced" keywords in the corpus would give a larger number of publications more centered on "technical" aspects of bioconomy with technologies of transformation of bioresources to platform molecules, semi-finished and finished goods.

The co-occurrence analysis of the articles' keywords is a first step to further research in this field, insofar it lays the foundations for a differential assessment of open access development in specific research fields, beyond the disciplinary boundaries. Other perspectives for further insight into open science in the field of bioeconomy:

- How does funding impact the OA publishing?
- In particular, does public funding increase the share of OA in general and gold and green OA in particular?
- Which is the part of OA in other research publications and documents, like conference papers and posters, dissertations, reports and working papers? Which importance have preprints in this research area?
- What can be said about research data in the field of bioeconomy?

A follow-up study in one or two years should provide additional evidence on the development of open science in this new research area. Also, we intend to "zoom" on the particular situation in France and to compare the French development of open science with other countries and regions.

Author Contributions: Marianne Duquenne: Data curation, Conceptualization, Writing - original draft, review & editing. **Hélène Prost:** Data curation, Writing - review & editing. **Joachim Schöpfel:** Data curation, Writing - original draft, review & editing, Funding acquisition, Project administration, Supervision. **Franck Dumeignil:** Writing - review & editing, Supervision.

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

Appendix A

The data were obtained in June and August 2020. The following indicators have been calculated:
WoS queries (June 2020):

- Number of articles per year
- Total number of citations
- Citations per article
- Average number of citations of each article per year
- Number of articles per journal
- Citations of articles per journal
- Number of articles per author

- Affiliation of authors (articles per country and per organisation)
- Number of articles per type of organisation
- Number of articles per research area (scientific field)
- Share of domestic and international articles per country and research area
- Distribution of funding sources

Unpaywall queries (August 2020):

- Number of articles in open access
- Share of articles in open access per journal, country and research area

Appendix B

Alphabetic list of the twenty journals with the highest number and share of articles, with number and share of citations, and number and share of open access articles.

Journal	Nb art	% art	Nb cit	% cit	Nb OA	% OA
ACS Sustainable Chemistry & Engineering	30	1,21	415	2,25	6	20
Agricultural Systems	49	1,97	340	1,84	14	28.6
Amfiteatru Economic	32	1,29	52	0,28	32	100
Biofuels, Bioproducts & Biorefining-biofpr	37	1,49	325	1,76	18	48.6
Biomass & Bioenergy	18	0,72	169	0,92	4	22.2
Bioresource Technology	33	1,33	402	2,18	8	24.2
Biotechnology for Biofuels	29	1,17	549	2,98	29	100
Ecological Economics	39	1,57	206	1,12	12	30.8
Environmental & Resource Economics	27	1,08	89	0,48	7	25.9
Fisheries Research	21	0,84	147	0,8	5	23.8
Forest Policy and Economics	21	0,84	250	1,36	5	23.8
Forests	16	0,64	43	0,23	16	100
Global Change Biology Bioenergy	24	0,96	129	0,7	23	95.8
ICES Journal of Marine Science	23	0,92	148	0,8	17	73.9
Industrial Crops and Products	47	1,89	576	3,13	5	10.6
Journal of Cleaner Production	121	4,86	1,529	8,3	33	27.3
Marine Policy	23	0,92	103	0,56	8	34.8
Natural Resource Modeling	20	0,8	31	0,17	8	40
New Biotechnology	17	0,68	263	1,43	0	0
Sustainability	76	3,05	596	3,23	76	100

Appendix C

List of Web of Science categories, sorted by numbers of articles and share of articles.

- % art: share of all 2,489 articles
- % OA: share of all 1,332 OA articles

- % OA art: percentage of OA articles for each research area

WoS research area	Nb art	% art	Nb OA art	% OA	% OA art
Environmental Sciences	486	19,5%	218	19,2%	44,9%
Biotechnology & Applied Microbiology	330	13,3%	154	13,6%	46,7%
Green & Sustainable Science & Technology	295	11,9%	146	12,9%	49,5%
Environmental Studies	291	11,7%	141	12,4%	48,5%
Economics	251	10,1%	105	9,3%	41,8%
Energy & Fuels	234	9,4%	117	10,3%	50,0%
Engineering, Environmental	201	8,1%	56	4,9%	27,9%
Engineering, Chemical	138	5,5%	23	2,0%	16,7%
Agronomy	127	5,1%	51	4,5%	40,2%
Ecology	116	4,7%	57	5,0%	49,1%
Forestry	107	4,3%	53	4,7%	49,5%
Chemistry, Multidisciplinary	104	4,2%	43	3,8%	41,3%
Agricultural Engineering	101	4,1%	18	1,6%	17,8%
Fisheries	100	4,0%	48	4,2%	48,0%
Multidisciplinary Sciences	98	3,9%	77	6,8%	78,6%
Agriculture, Multidisciplinary	97	3,9%	39	3,4%	40,2%
Food Science & Technology	81	3,3%	33	2,9%	40,7%
Marine & Freshwater Biology	80	3,2%	54	4,8%	67,5%
Management	61	2,5%	40	3,5%	65,6%
Agricultural Economics & Policy	57	2,3%	15	1,3%	26,3%
Business	56	2,2%	42	3,7%	75,0%
Agriculture, Dairy & Animal Science	51	2,0%	30	2,6%	58,8%
Oceanography	46	1,8%	24	2,1%	52,2%

Biochemistry & Molecular Biology	43	1,7%	20	1,8%	46,5%
Mathematics, Interdisciplinary Applications	38	1,5%	14	1,2%	36,8%
Chemistry, Applied	38	1,5%	7	0,6%	18,4%
Microbiology	37	1,5%	27	2,4%	73,0%
Chemistry, Physical	36	1,4%	11	1,0%	30,6%
Biochemical Research Methods	36	1,4%	10	0,9%	27,8%
Mathematics	32	1,3%	22	1,9%	68,8%
Materials Science, Multidisciplinary	31	1,2%	11	1,0%	35,5%
Materials Science, Paper & Wood	31	1,2%	8	0,7%	25,8%
Water Resources	30	1,2%	4	0,4%	13,3%
Plant Sciences	27	1,1%	19	1,7%	70,4%
International Relations	27	1,1%	10	0,9%	37,0%
Mathematical & Computational Biology	25	1,0%	9	0,8%	36,0%
Biodiversity Conservation	23	0,9%	16	1,4%	69,6%
History & Philosophy Of Science	23	0,9%	13	1,1%	56,5%
Veterinary Sciences	23	0,9%	11	1,0%	47,8%
Polymer Science	23	0,9%	10	0,9%	43,5%
Biology	23	0,9%	6	0,5%	26,1%
Social Issues	20	0,8%	14	1,2%	70,0%
Social Sciences, Biomedical	20	0,8%	11	1,0%	55,0%
Engineering, Multidisciplinary	20	0,8%	8	0,7%	40,0%
Geography	20	0,8%	8	0,7%	40,0%
Mathematics, Applied	19	0,8%	8	0,7%	42,1%
Genetics & Heredity	18	0,7%	15	1,3%	83,3%
Mechanics	15	0,6%	3	0,3%	20,0%
Philosophy	14	0,6%	8	0,7%	57,1%

Social Sciences, Interdisciplinary	14	0,6%	6	0,5%	42,9%
Geosciences, Multidisciplinary	13	0,5%	7	0,6%	53,8%
Regional & Urban Planning	13	0,5%	4	0,4%	30,8%
Meteorology & Atmospheric Sciences	12	0,5%	10	0,9%	83,3%
Sociology	12	0,5%	6	0,5%	50,0%
Computer Science, Interdisciplinary Applications	12	0,5%	5	0,4%	41,7%
Engineering, Civil	11	0,4%	5	0,4%	45,5%
Thermodynamics	11	0,4%	4	0,4%	36,4%
Engineering, Mechanical	11	0,4%	2	0,2%	18,2%
Ethics	10	0,4%	6	0,5%	60,0%
Entomology	10	0,4%	2	0,2%	20,0%
Nutrition & Dietetics	9	0,4%	3	0,3%	33,3%
Chemistry, Analytical	8	0,3%	5	0,4%	62,5%
Public, Environmental & Occupational Health	8	0,3%	5	0,4%	62,5%
Soil Science	8	0,3%	4	0,4%	50,0%
Physics, Multidisciplinary	8	0,3%	2	0,2%	25,0%
Anthropology	7	0,3%	5	0,4%	71,4%
Cultural Studies	7	0,3%	3	0,3%	42,9%
Automation & Control Systems	7	0,3%	2	0,2%	28,6%
Development Studies	7	0,3%	2	0,2%	28,6%
Operations Research & Management Science	7	0,3%	1	0,1%	14,3%
Communication	6	0,2%	2	0,2%	33,3%
Materials Science, Textiles	6	0,2%	2	0,2%	33,3%
Construction & Building Technology	6	0,2%	1	0,1%	16,7%
Electrochemistry	6	0,2%	1	0,1%	16,7%
Chemistry, Medicinal	5	0,2%	4	0,4%	80,0%

Geography, Physical	5	0,2%	4	0,4%	80,0%
Computer Science, Theory & Methods	5	0,2%	3	0,3%	60,0%
Engineering, Electrical & Electronic	5	0,2%	3	0,3%	60,0%
Instruments & Instrumentation	5	0,2%	3	0,3%	60,0%
Logic	5	0,2%	3	0,3%	60,0%
Nanoscience & Nanotechnology	5	0,2%	3	0,3%	60,0%
Remote Sensing	5	0,2%	3	0,3%	60,0%
Education & Educational Research	5	0,2%	2	0,2%	40,0%
Political Science	5	0,2%	2	0,2%	40,0%
Statistics & Probability	5	0,2%	2	0,2%	40,0%
Horticulture	5	0,2%	1	0,1%	20,0%
Law	5	0,2%	1	0,1%	20,0%
Mycology	4	0,2%	3	0,3%	75,0%
Humanities, Multidisciplinary	4	0,2%	2	0,2%	50,0%
Limnology	4	0,2%	2	0,2%	50,0%
Chemistry, Organic	4	0,2%	0	0,0%	0,0%
Education, Scientific Disciplines	4	0,2%	0	0,0%	0,0%
Computer Science, Information Systems	3	0,1%	3	0,3%	100,0%
Tropical Medicine	3	0,1%	3	0,3%	100,0%
Area Studies	3	0,1%	2	0,2%	66,7%
Physics, Applied	3	0,1%	2	0,2%	66,7%
Public Administration	3	0,1%	2	0,2%	66,7%
Engineering, Biomedical	3	0,1%	1	0,1%	33,3%
Engineering, Industrial	3	0,1%	1	0,1%	33,3%
Materials Science, Coatings & Films	3	0,1%	1	0,1%	33,3%
Materials Science, Composites	3	0,1%	1	0,1%	33,3%

Computer Science, Artificial Intelligence	3	0,1%	0	0,0%	0,0%
Engineering, Geological	3	0,1%	0	0,0%	0,0%
Language & Linguistics	3	0,1%	0	0,0%	0,0%
Literature	3	0,1%	0	0,0%	0,0%
Nuclear Science & Technology	3	0,1%	0	0,0%	0,0%
Astronomy & Astrophysics	2	0,1%	2	0,2%	100,0%
Business, Finance	2	0,1%	2	0,2%	100,0%
Evolutionary Biology	2	0,1%	2	0,2%	100,0%
Industrial Relations & Labor	2	0,1%	2	0,2%	100,0%
Integrative & Complementary Medicine	2	0,1%	2	0,2%	100,0%
Medicine, General & Internal	2	0,1%	2	0,2%	100,0%
Parasitology	2	0,1%	2	0,2%	100,0%
Pharmacology & Pharmacy	2	0,1%	2	0,2%	100,0%
Quantum Science & Technology	2	0,1%	2	0,2%	100,0%
Computer Science, Software Engineering	2	0,1%	1	0,1%	50,0%
Engineering, Petroleum	2	0,1%	1	0,1%	50,0%
History	2	0,1%	1	0,1%	50,0%
Mining & Mineral Processing	2	0,1%	1	0,1%	50,0%
Zoology	2	0,1%	1	0,1%	50,0%
Engineering, Manufacturing	2	0,1%	0	0,0%	0,0%
Linguistics	2	0,1%	0	0,0%	0,0%
Materials Science, Characterization & Testing	2	0,1%	0	0,0%	0,0%
Physics, Mathematical	2	0,1%	0	0,0%	0,0%
Social Work	2	0,1%	0	0,0%	0,0%
Toxicology	2	0,1%	0	0,0%	0,0%
Transportation	2	0,1%	0	0,0%	0,0%

Architecture	1	0,0%	1	0,1%	100,0%
Art	1	0,0%	1	0,1%	100,0%
Cell & Tissue Engineering	1	0,0%	1	0,1%	100,0%
Cell Biology	1	0,0%	1	0,1%	100,0%
History Of Social Sciences	1	0,0%	1	0,1%	100,0%
Immunology	1	0,0%	1	0,1%	100,0%
Infectious Diseases	1	0,0%	1	0,1%	100,0%
Information Science & Library Science	1	0,0%	1	0,1%	100,0%
Medicine, Research & Experimental	1	0,0%	1	0,1%	100,0%
Neurosciences	1	0,0%	1	0,1%	100,0%
Nursing	1	0,0%	1	0,1%	100,0%
Physics, Particles & Fields	1	0,0%	1	0,1%	100,0%
Radiology, Nuclear Medicine & Medical Imaging	1	0,0%	1	0,1%	100,0%
Asian Studies	1	0,0%	0	0,0%	0,0%
Behavioral Sciences	1	0,0%	0	0,0%	0,0%
Computer Science, Cybernetics	1	0,0%	0	0,0%	0,0%
Dentistry, Oral Surgery & Medicine	1	0,0%	0	0,0%	0,0%
Family Studies	1	0,0%	0	0,0%	0,0%
Health Care Sciences & Services	1	0,0%	0	0,0%	0,0%
Health Policy & Services	1	0,0%	0	0,0%	0,0%
Materials Science, Biomaterials	1	0,0%	0	0,0%	0,0%
Medical Ethics	1	0,0%	0	0,0%	0,0%
Medieval & Renaissance Studies	1	0,0%	0	0,0%	0,0%
Mineralogy	1	0,0%	0	0,0%	0,0%
Obstetrics & Gynecology	1	0,0%	0	0,0%	0,0%
Physics, Atomic, Molecular & Chemical	1	0,0%	0	0,0%	0,0%

Physics, Nuclear	1	0,0%	0	0,0%	0,0%
Psychology, Biological	1	0,0%	0	0,0%	0,0%
Psychology, Multidisciplinary	1	0,0%	0	0,0%	0,0%
Reproductive Biology	1	0,0%	0	0,0%	0,0%
Spectroscopy	1	0,0%	0	0,0%	0,0%
Transportation Science & Technology	1	0,0%	0	0,0%	0,0%
Urban Studies	1	0,0%	0	0,0%	0,0%
Women's Studies	1	0,0%	0	0,0%	0,0%

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