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The formation of a field: sustainability science and its leading journals

Marco Schirone[1,2]

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Abstract
This study investigates the scholarly field of sustainability science between 2001 and 2021 from the perspective of 18 frequently cited journals. For this purpose, the article employs the concept of the "scientific field" developed by the sociologist Pierre Bourdieu and the associated methodology of Geometric Data Analysis (GDA). Thus, two GDA approaches, the Principal Component Analysis (PCA) and the Multiple Correspondence Analysis (MCA), as well as analyses of co-citation and co-authorship relations, were used to identify the positions of these journals in the field. One key finding is the historical shift from an earlier dominance of chemistry-related journals to publications more broadly concerned with sustainability research. The MCA analyses show that the selection of research topics is in line with a "weak" rather than "strong" interpretation of the concept "sustainability." Networks based on co-authorship relations reveal an overall increment in this type of collaboration, both at the level of organizations and countries. Since 2008, Chinese universities have notably increased their presence in the output of the journals examined in the study. Three strategies in shaping the field through its journals are discernable: publications strongly characterized by a systems theory perspective, notably *Sustainability Science*; generalist journals committed to sustainability research in a broader meaning; and publications that address sustainability issues mainly within a specific discipline.

Keywords Sustainability science · Sustainability · Bibliometrics · Scientometrics · Pierre Bourdieu · Geometric data analysis

Background and aim of the study

Bibliometrics has a long tradition of studying the historical developments of knowledge domains (Garfield, 2004). In particular, emerging fields have attracted the attention of researchers because of the challenge represented by their resistance to being filed under existing classifications (González-Alcaide et al., 2016; Muñoz-Écija et al., 2019).

Marco Schirone
marco.schirone@hb.se

1 Swedish School of Library and Information Science, University of Borås, S-501 90 Borås, Sweden

2 Department of Communication and Learning in Science, Chalmers University of Technology, Göteborg, Sweden

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Sustainability science is a burgeoning research field centered on the concept of sustainable development and related challenges (Kates, 2011). This field requires the synthesis of disparate theories and methods, along with the unification of complementary and conflicting knowledge perspectives (Jerneck & Olsson, 2020) and new "models of knowledge generation" (White, 2013, p. 186) and a "wide range of outlooks regarding what makes knowledge usable within both science and society" (Kates et al., 2001, p. 641). As already remarked by Leydesdorff (1997) long ago, research in this area is closely intertwined with policymaking. In this respect, Kajikawa (2022) has recently set the agenda for "transdisciplinary bibliometric research" and emphasized the need to integrate bibliometric analyses into evidence-based policymaking. This type of bibliometric research should address the diversity of policy contexts and the characteristics of policy-oriented transdisciplinary sciences, such as the interactions between scientists and other stakeholders. Notably, a recent case study on the validity of altmetric measures as proxies for societal impact investigates one research center with a sustainability science profile (Kassab et al., 2020).

Bibliometric studies of journals can be a valuable approach for gaining insights into the intellectual and social organization of scientific fields. (Åström, 2007; Leydesdorff, 2021). This approach has also been applied to the sustainability science field (Buter & Van Raan, 2013; Kajikawa et al., 2014). In particular, Bautista-Puig et al. (2021) have provided a valuable classification of the journals of this field based on citation data. The disciplinary status of the research in sustainability science has been described as multidisciplinary, cross-disciplinary, interdisciplinary, and transdisciplinary (Kajikawa, 2008). Among these four interpretations, the multidisciplinary one requires the least integration between the theories and methods offered by the individual sciences. The disciplinary status of a field as cross-disciplinary, interdisciplinary, and transdisciplinary implies an increasing level of synergy between the contributing sciences. The interactions between scholarly fields—their cross-, multi-, inter-, and transdisciplinarity—are recurring topics in the bibliometric literature (Hammarfelt, 2011; Hellsten & Leydesdorff, 2016; Larivière, 2012a). A seminal bibliometric study by Buter and Van Raan (2013, p. 266) found that the interdisciplinary approach to sustainability science was still being developed, and "a trend towards a state of transdisciplinary research" was yet to be seen. Their conclusion agreed with research in sustainability science from the same period (Lang et al., 2012).

Existing bibliometric research on sustainability science has primarily focused on the semantic aspects of organizing the field, examining clusters of research topics (Buter & Van Raan, 2013) or the taxonomy for the journals in the field (Bautista-Puig et al., 2021). While this research is insightful and valuable, the current article takes a different approach by using the sociologist Pierre Bourdieu's (2004) perspective on scientific fields as social fields. Moreover, this article follows the path of "transdisciplinary bibliometrics" recently proposed by Kajikawa (2022), which aims to apply bibliometric methods to transdisciplinary sciences, as well as the historical approach in bibliometrics (Pölönen & Hammarfelt, 2020). By doing so, this study contributes to the existing body of knowledge represented by earlier bibliometric investigations on sustainability research (Bautista-Puig et al., 2021; Buter & Van Raan, 2013; Kajikawa et al., 2014) and further develops the Bourdieu-inspired approach to the bibliometric study of scholarly fields (Schirone, 2023). More specifically, the overarching aim of the current study is thus to examine the emergence and development of sustainability science as a field, drawing upon Bourdieu's conceptual framework and the methods he developed.

Bourdieu (1975) has argued that the power struggles between scientists regarding prestige, academic advancements, and economic resources affect how a scientific field is structured intellectually and socially. Even if economic capital is an essential component of the science system, another intangible capital also plays a crucial role in shaping scholarly fields' social and intellectual organization. Contrarily to the economic capital, this other capital—the symbolic capital or "the mastery of symbolic resources based on knowledge and recognition" (Bourdieu, 2005, p. 195)—cannot easily be translated into countable units of value and thus measured. Yet, the structure of scientific fields is, for Bourdieu, shaped by a "symbolic" economy that values knowledge and peer recognition (Bourdieu, 2004). Essential to this economy is the symbolic capital, which is a second-order type of asset ultimately depending on two first-order, or "primary" in Bourdieu's (1986) terms, types of capital: the cultural capital, which represents the field's specific knowledge; and social capital, which pertains to the networks and personal connections within the field.

The value of the symbolic capital, although not readily translatable into monetary assets, can still be visible. For instance, scientific prizes and rank in citation indexes are "the most objectified of the indices of symbolic capital" (Bourdieu, 1988, p. 76). From this perspective, scientific journals can be seen as artifacts that represent—or, in Bourdieu's terminology, objectify—a specific volume of capital. The value of capital that journals incorporate can be monetary as, for instance, goods that generate revenues in the publishing market. At the same time, in the "market of symbolic goods" (Bourdieu, 1985), journals incorporate other capital not reducible to mere economic assets: knowledge or cultural capital, as well as the social capital represented by the collaboration between researchers, departments, universities, and countries. If seen as symbolic goods, journals incorporate not only cultural or social capital (Denord et al., 2011) but also symbolic capital. The value of symbolic goods rests, in fact, on the extent to which the agents of the field perceive them as valuable, that is, their symbolic capital. This type of capital, in turn, depends upon the specific historical shifts in the value attached to the cultural and social capital specific to the field. Field Bourdieu (1991b) states that understanding such value shifts requires examining its past. Notably, Gingras' (1991, 2008) works on the history of physics have developed this Bourdieusian historical perspective in bibliometrics, also through the study of journals (Khelfaoui & Gingras, 2020).

Against this background, the present study frames the leading journals of a field as artifacts where symbolic capital is incorporated as objectified capital. Being perceived as valuable objects by the agents of the field, such "symbolic goods" function as gatekeepers, endorsing legitimated knowledge, establishing research areas appropriate for the discipline, and bestowing recognition upon authors and their associated institutions (Bourdieu, 1985). Therefore, this study investigates the leading journals of the sustainability science field and their place in the intellectual and social organization of this field (Whitley, 2000). The research questions that guide the article are:

RQ1 Based on the symbolic capital that sustainability science's leading journals represent, which position in the field do these publications occupy? Which is the position of their publishers?

RQ2 Which position do the most productive research organizations and countries occupy in the field?

The following section gives a short introduction to the field of sustainability science, followed by a description of the data sources and methods used in the current study. Thereafter, its findings are presented according to the bibliometric methods used to analyze the symbolic capital that the leading journals incorporate. The article also presents an overarching discussion and a conclusion that suggests future research paths.

Sustainability science

The roots of sustainability science can be traced to the domain of policymaking when a set of international policy efforts addressed the challenge of global economic growth that managed not to be detrimental to the environment. Although the term "sustainable development" had circulated since the '70 s, the UN's report *Our Common Future* in 1987 represented a milestone for establishing sustainability policy (Brundtland Commission, 1987). The report famously defined the concept of "sustainable development" as development that meets the needs of future generations.

The concepts of "sustainability" and "sustainable development" and a scientific praxis that would address them have been conceived in several ways (Mino & Kudo, 2020). De Vries (2012) underlines that the initial criteria for conceptualizing a development that had to be sustainable were rooted in ecological thinking. However, from the '90 onwards, social scientists, and economists in particular, advanced the perspective of "welfare economics and societal cost–benefit analyses" (p. 4). Sustainable development is, in this sense, "a societal negotiation" in which the economic/social perspective is added to the environmental one (De Vries, 2012, p. 4). The commitment of academia towards addressing sustainable development issues was an outcome of the United Nations Conference on Environment and Development in 1992 (Mino & Kudo, 2020). This conference, also known as the Rio Summit, is another pillar, after the *Bundtland Report*, in the history of the scientific study of sustainability. To that point, key concepts in the policy narrative of sustainable development were the integration between the needs of environmental preservation and economic growth, societal participation, and information (Nolin, 2010). The *Agenda 21* signed at the Rio Summit played a crucial role in advancing the social dimension of sustainable development. It brought to the fore sustainability goals, such as fighting poverty and promoting social equality, which earlier held an ancillary position vis-à-vis the environmental and economic dimensions. Subsequent summits (the Millennium Summit 2000, the Johannesburg World Summit on Sustainable Development 2002, and the New York World Summit 2005) confirmed *Agenda 21* with minor revisions until another milestone was reached with the agreement in 2015 on the 17 Sustainable Development Goals (SDGs) of the *Agenda 2030 for Sustainable Development* approved by all UN Member States (Nolin, 2010). As the *Agenda 2030* emphasized "science, technology, and innovation" in achieving sustainability goals, the idea of a field dedicated to the study of sustainable development grew in parallel with this reinforced involvement of science in the domain of policy (Colglazier, 2015, p. 6252).

Sustainability science is concerned with the interactions between nature and society, and in particular, the interplay between global systems and local human and ecological environments (Kates et al., 2001). A review by Kajikawa (2008) identifies ten domains of sustainability-related research: economic development, climate, biodiversity, agriculture, fishery, forestry, energy and resources, health, lifestyle, and water. Notably, Spangenberg (2011) distinguishes between two approaches in sustainability research: a science *for* sustainability and a science *of* sustainability. The term "science for sustainability" applies to disciplinary fields that address sustainable development issues within their own knowledge domain. To be able to tackle sustainability issues, the disciplinary fields that make for this science *for* sustainability ought to be interdisciplinary, or at least "interdisciplinarity-ready" and open to a dialogue with other fields (Spangenberg, 2011, p. 276). The emerging scholarly field labeled "sustainability science" or "sustainability studies" (Lam et al., 2014) corresponds to Spangenberg's definition of the "science of sustainability" as a separate field with a specific research agenda that targets sustainable development as the predominant study object. Research of this type addresses the global perspective of a sustainable world and conceptualizes sustainability as "a condition, or the state of a system" (Lam et al., 2014, p. 161). The notion of sustainability stems from the need to integrate the many societal, economic, and environmental systems and, in particular, harmonize their sustainable development. The role of systems theory in the formation of this field has been underlined by De Vries (2012), who has also traced back to the research field known as Global Change Science or Earth System Analysis as the catalyzer for an array of new scientific fields such as atmospheric and ocean science, marine biology, human ecology, and ecological economics. The historical origins of sustainability science can be found in these new sciences and, more generally, in systems theory, besides the global policy initiatives for sustainable development mentioned above.

In addition to the heterogeneity of the sciences contributing to sustainability research, another source of variability in sustainability science derives from the different interpretations of sustainable development, most notably in the distinction between "weak" and "strong" sustainability. Söderbaum (2007, p. 613) has characterized the struggle between advocates of the different understandings of sustainable development as a "power game." Readings of the concept vary from the business-as-usual-interpretation, "in the sense of 'sustained economic growth' and 'sustained profits' in business," to the Ecological Modernization path to sustainability (p. 614). This latter standpoint promotes implementing environmental management systems and similar certification schemes, corporate social responsibility, and methods such as life cycle analysis and environmental impact assessment. More radical interpretations emphasize the social and environmental dimensions of sustainable development and the impact of processes that cannot be easily translated into monetary assets. Ruggerio (2021) distinguishes between "weak" sustainability research, exemplified by research on green economy and circular economy, and "strong" sustainability research. This latter conceptualizes the "environment and sees its components as being more than commodities and services traded in markets" (p. 8). Examples of strong sustainability research are the scientific output inspired by the idea of degrowth, which is based on the hypothesis "that it is possible to organize a transition and live well under a different political-economic system that has a radically smaller resource throughput" (Kallis et al., 2018, p. 292).

To sum up, sustainability science has a complex, although recent, history characterized by ties with the domain of global policy and different conceptualizations of sustainability. The history of the topics discussed in the journals reflects the knowledge and social connections, that is, cultural and social capital, which characterize the scientific field. As symbolic goods, highly cited journals incorporate the field's cultural and social capital in the form of symbolic capital. The following section describes the bibliometric methods used in this article to study sustainability science from the perspective of these symbolic goods and their place in the field.

Data sources and methods

Data selection

Although notoriously controversial (de Rijcke & Rushforth, 2015), the Journal Impact Factor (JIF) can be useful to detect the "status" of journals (Bollen et al., 2006) or, in Bourdieusian terminology, their "symbolic capital" (Khelfaoui & Gingras, 2020), in particular, frequently cited journals represent higher-than-average symbolic capital (Chipidza & Tripp, 2021). The present study uses the JIF as a proxy measure for the prestige of these "elite subsets" (Vinkler, 2019). The calculation of the JIF for 2020, the last completed year available at the time of the data collection, was obtained from the Clarivate Analytics database Journal Citation Reports (JCR).

Figure 1 illustrates the workflow. In Step 1 of the study, following the study by Bautista-Puig et al. (2021), the field of sustainability research was operationalized by using the category *Green & Sustainable Science & Technology* in the JCR classification (66 journals were associated with the category at the time of the data collection, March 2022). The Journal Citation Indicator (JCI) is a measure that normalizes the JIF according to the world average for the field. Thus, it was used to identify the elite sources whose citation score is higher than this average and listed in decreasing rank of JCI as follows: *Nature Sustainability*, *IEEE Transactions on Sustainable Energy*, *Green Chemistry*, *Journal of Cleaner Production*, *Journal of Sustainable Tourism*, *ACS Sustainable Chemistry & Engineering*, *Sustainable Development*, *ChemSusChem*, *Renewable Energy*, *Sustainable Cities and Society*, *Journal of Industrial Ecology*, *Sustainability Science*, *Sustainable Materials and Technologies*, *Agronomy for Sustainable Development*, *Renewable & Sustainable Energy Reviews*, *International Journal of Sustainability in Higher Education*, *International Journal of Precision Engineering and Manufacturing-Green Technology*, and *Sustainable Production and Consumption*. These 18 journals reported (as of March 31, 2022) a value of JCI higher than one—the value one is given to the world average for publications in a specific field based on the same document type and period.

In Step 2 of the workflow, the metadata information of documents published in the 18 journals was retrieved (on March 31, 2022) from the Clarivate Analytics database Web of Science Core Collection (WoSCC). The range considered for the selection was the period 2001–2021, and the documents included belonged to the type "article," whereas editorial materials and reviews were excluded. The need to create comparable subsets of documents motivated the choice of 2001 as the starting point for the dataset of documents to include for analysis. As shown in Table 2 in the Supplementary Material, most of the documents have been published in the last period, which strengthens the choice of excluding documents published before 2001. The last complete year at the time of data collection was 2021, thus chosen as the other end of the timeline. The final dataset comprised 71,871 documents, 1,819,331 references, and 122,760 author-assigned keywords. Metadata information on the documents was saved as an R data frame in the environment of R version 4.1.3 (R Core Team, 2023) and analyzed using the package for science mapping *bibliometrix* (Aria & Cuccurullo, 2017).

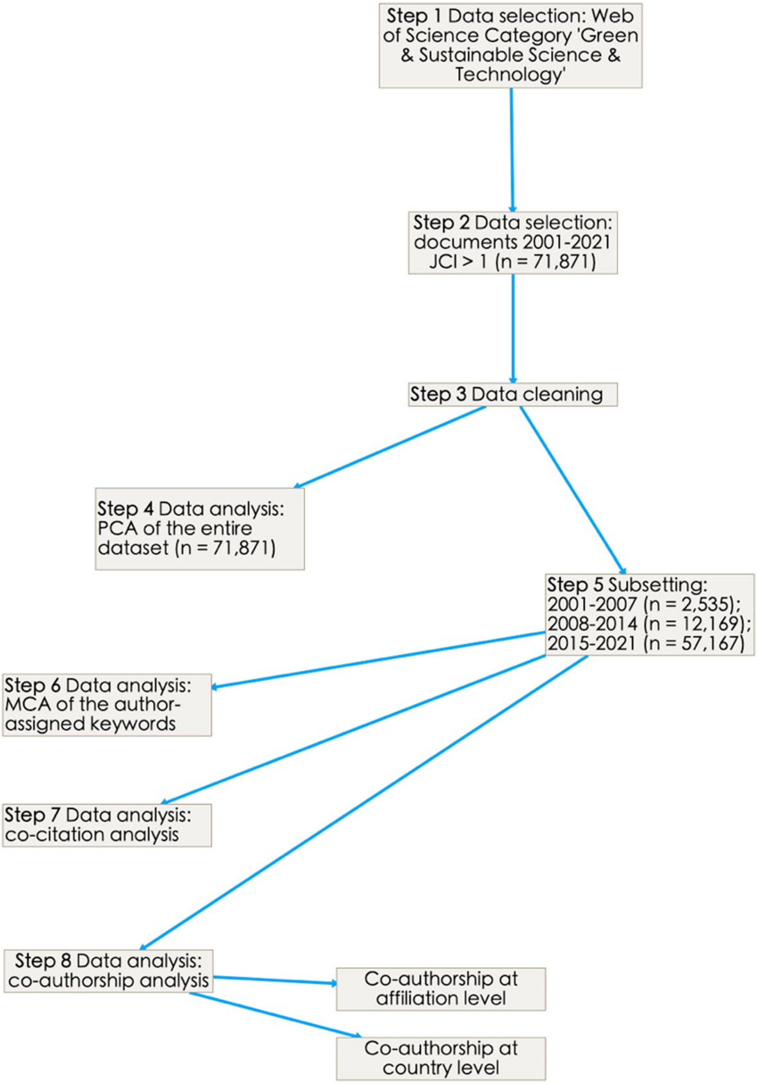


Fig. 1 The workflow of the study note. JCI means Journal Citation Indicator (Clarivate Analytics). PCA and MCA are the respective abbreviations for Principal Component Analysis and Multiple Correspondence Analysis

GDA approaches and network visualizations of the field

In Step 3, in addition to the default data cleaning routines implemented in bibliometrix, the R package tidyverse (Wickham et al., 2019) and the data wrangling tools OpenRefine (Ham, 2013) and Trifacta (https://www.trifacta.com) were used to obtain metadata information of a higher quality (see also Petrova-Antonova & Tancheva, 2020). As pursued by Bourdieu (1988, 2008) and others (Blasius et al., 2019; Ekelund, 2016), the present study employs GDA (Le Roux & Rouanet, 2004, 2010). This methodology, alternatively known as Principal Components Methods (Husson et al., 2011), was used to map the organization of sustainability science. Two GDA methods were used to gain an overview of the capital embedded in the 18 journals: the Principal Component Analysis (PCA) and Multiple Correspondence Analysis (MCA). Following the research by Ekelund (2016) on citation behavior, the present article combines GDA methods with the Bourdieusian perspective on the sociology of science.

GDA comprises approaches that involve quantitative and qualitative data, as in the case of the bibliometric data outputted by bibliometrix in the context of this article. The present study uses two of these approaches, (Robust) PCA and MCA, which are dimensionality reduction techniques used for different purposes. PCA typically reduces the complexity of datasets based on quantitative variables, while MCA applies to categorical variables. The present article utilizes both approaches because it analyzes quantitative variables (e.g., the number of citations received by a journal) and qualitative ones (i.e., the keywords associated with the articles published in the journals). However, neither the Robust PCA nor the MCA, based on the data used for this study, could render the extent of research collaboration in the field. Therefore, approaches to approaches to network analysis and visualization— the Leiden algorithm (Traag et al., 2019) and the Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991)—were also used to gauge this social component of the distribution of symbolic capital in the field (see Step 8 below).

The PCA approach, effectively applied in previous bibliometric research by Zopiatis et al. (2015), "simplifies the complexity in high-dimensional data while retaining trends and patterns" and targets quantitative variables (Lever et al., 2017, p. 641). In Step 4, which corresponds to RQ1, the PCA was performed with the software JPM version 17 (https://www.jmp.com) based on three quantitative variables: the number of articles published in the journal in 2001–2021, the number of years, that is, the years in which documents published in the journal were included in the data, and the number of citations received per year in the time frame of the study. Two supplementary qualitative variables were included in the PCA: the journals' titles and—following Bourdieu's (2008) study of the French publishing market—their publishers' names. The four quantitative were not normally distributed, according to the Shapiro–Wilk test. Therefore, this study chose the version of PCA developed by Candès et al. (2011) as Robust PCA, available in JMP 17, which addresses specifically skewed distributions, a known challenge for PCA.

In Step 5, the dataset was split into three time periods: 2001–2007 (2,535 documents, seven journals), 2008–2014 (12,169 documents, 15 journals), and 2015–2021 (57167 documents, 18 journals). Such a subsetting of the dataset provides an equal number of years across the three periods.

Step 6 aimed to investigate the symbolic capital incorporated in the journals, as required by RQ1. This stage of the data analysis corresponds to the MCA of the 50 most recurring author-assigned keywords for each period. The MCA method is comparable to PCA, although this latter requires quantitative variables rather than categorical ones (Le Roux & Rouanet, 2004, 2010). A list of words to exclude (the name of countries) and another one of synonyms and alternative terms (e.g., "life cycle assessment," "life-cycle assessment," and "LCA") complemented the default term-matching routines of the package bibliometrix. Step 7 also addresses RQ2 and, in accordance with Bourdieu's analyses in *Homo Academicus* and existing bibliometric research inspired by his work, treated the citation score as a proxy measure for the symbolic capital (Bourdieu, 1988; Cronin, 2005; Khelfaoui & Gingras, 2020). More specifically, the co-citation relations between articles (the relation between document A and document B whenever both are cited by a third document C) were used to analyze the distribution of symbolic capital embedded in the 18 journals (Gingras & Wallace, 2010). The co-citation networks computed in R were visualized on a sphere rather than a two-dimensional plane to gain more realistic images (Perry et al., 2020).

In Step 8, which answers RQ2, the co-authorship relations between documents were analyzed. Abbasi et al. (2014) have considered co-authorship relations as additional measures that operationalize the journal's symbolic capital. The resulting networks formed by these relations were analyzed at the level of the author's affiliations and countries, respectively. The Leiden algorithm for community detection was used to cluster the co-cited journals in Step 7 and the co-authorship relations in Step 8 (Traag et al., 2019). The Fruchterman-Reingold algorithm was used to visualize the co-authorship relations based on the authors' affiliations (Fruchterman & Reingold, 1991).

Further details on the methods used and additional analyses are available in this article's Supplementary Material.

Table 1 Analyzed journals (2001–2021) in decreasing rank of Journal Citation Indicator (JCI)

Journal	Year	Articles	Total citations	JCI
Nature Sustainability	2018	377	15,984	3.22
IEEE Transactions on Sustainable Energy	2010	1830	76,240	1.74
Green Chemistry	2001	7256	35,3585	1.66
Journal of Cleaner Production	2002	24,488	71,8400	1.51
Journal of Sustainable Tourism	2008	1032	38,468	1.51
ACS Sustainable Chemistry and Engineering	2013	10,094	260,153	1.50
Sustainable Development	2001	820	22,643	1.42
ChemSusChem	2008	4481	16,6581	1.40
Renewable Energy	2001	12,732	39,7844	1.32
Sustainable Cities and Society	2011	2952	60,515	1.32
Journal of Industrial Ecology	2005	1262	42,373	1.28
Sustainability Science	2006	752	18,393	1.06
Sustainable Materials and Technologies	2017	254	3619	1.06
Agronomy for Sustainable Development	2005	635	13,768	1.05
Renewable and Sustainable Energy Reviews	2013	1310	19,709	1.05
International Journal of Sustainability In Higher Education	2010	566	9370	1.04
International Journal of Precision Engineering and Manufacturing-Green Technology	2014	486	6508	1.02
Sustainable Production and Consumption	2017	544	7055	1.02

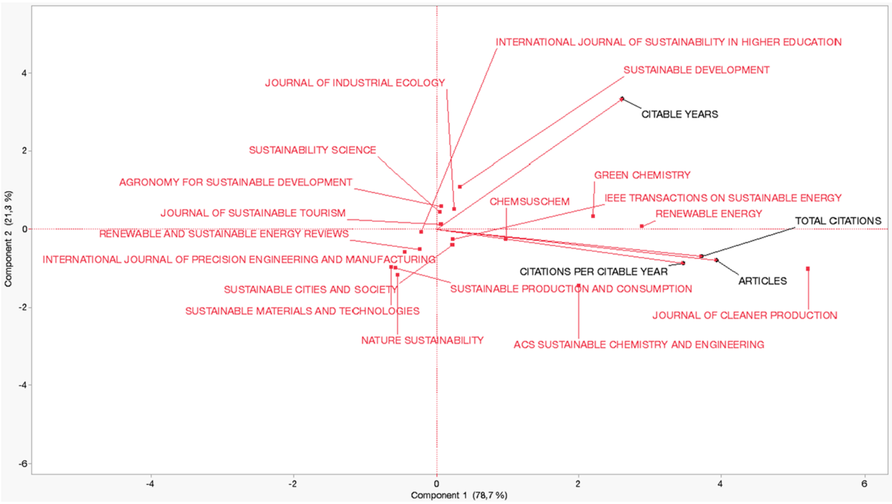
Note. The number reported in the column "Year" indicates the beginning of the timeline chosen as inclusion criteria (i.e., 2001) or, for more recent sources, the first year of publication. The column "Total Citations" specifies the number of citations received by the journal based on the index of the entire database. The metric Journal Citation Indicator (JCI) is based on the calculations for the year 2020 available from the Journal Citation Reports (Clarivate Analytics)

Results

From the Bourdeusian perspective discussed earlier, journals are artifacts in which capital of various types is incorporated (Bourdieu, 1985). Their emergence, disappearance, and historical development correspond to variations in the volume and type of capital of a field.

Table 1 below presents key characteristics of the journal (the year when they were first indexed in the database and the number of articles and citations in the period 2001–2021). Thereafter, the data analysis is presented according to the methods used to analyze the journals' symbolic capital and their respective position in the field, thus providing answers to RQ1. More specifically, the Robust PCA of publication and citation data provides answers to RQ1 on the position of journals and their publishers. The MCA of the keywords and the co-citation analyses complement the picture of the field obtained with the PCA by visualizing the symbolic capital incorporated in the journals and observable through the research

a *A PCA Biplot of the Field: 18 Leading Journals (2001-2021)*



b *A PCA Biplot of the Field: The Publishers (2001-2021)*

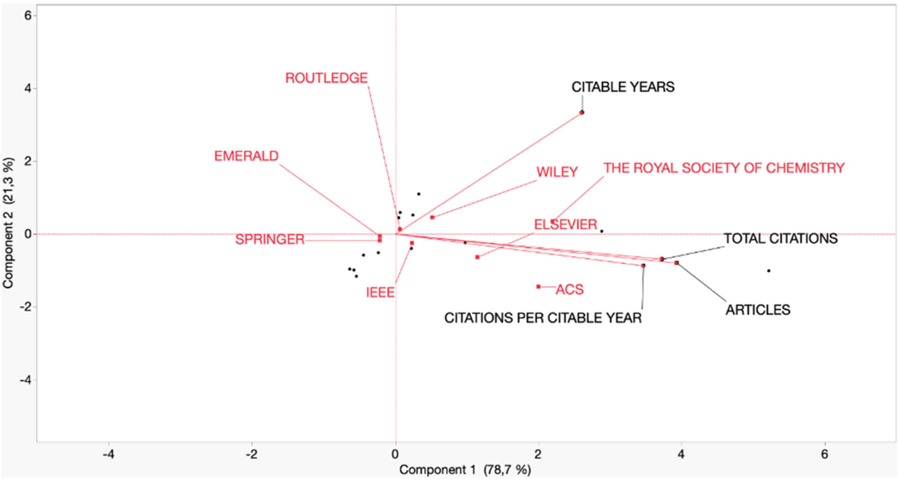


Fig. 2 **a** A PCA Biplot of the Field: 18 Leading Journals (2001–2021) **b** A PCA Biplot of the Field: The Publishers (2001–2021). In a and b, the label "Years" indicates the number of years (1–21) for which the dataset includes documents published in a journal between 2001 and 2021

topics chosen and the citation relations between publications. Finally, the study of the co-authorship at the level of analysis of research organizations and countries addresses RQ2.

The two PCA planes in Fig. 2a and b outline the sustainability science field from the perspective of leading journals and their publishers, the two supplementary qualitative variables designated by red labels. Black color denotes the four quantitative variables. The label “Citations per citable year” in Fig. 2a and b refers to the number of citations received by a journal divided by the number of citable years, i.e., the years in which the dataset includes articles published in the journal. The number of documents included in the dataset is the variable labeled in the biplots “Articles.”

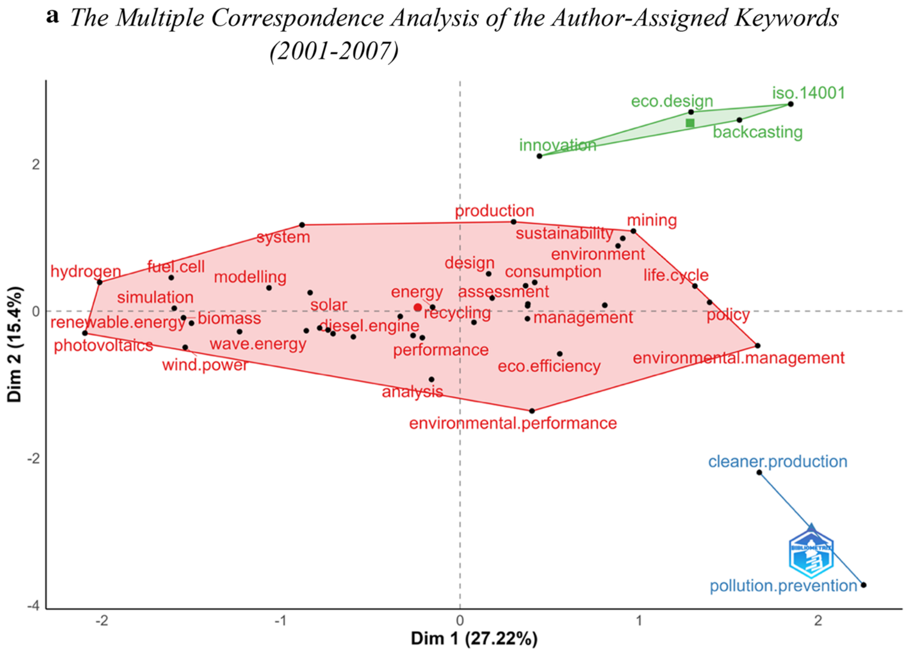
The plane structured by the Robust PCA is characterized by two principal components or dimensions, which account for most of the variability in the data: the first principal component—corresponding to the x-axis—accounts for 78.7% of the variance, whereas 21.3% is the percentage explained by the second dimension represented by the y-axis. The two first dimensions suffice for a satisfactory description of the data as they together explain 100% of the variance of the axes, (based on the eigenvalues associated with the axes). In the plane, the position of the 18 journals, i.e., the individuals in the calculation of the PCA, is interpretable according to the following two criteria: (1) “an individual is on the side of the variables for which it takes high values” (Husson et al., 2011, p. 27); and (2) “differences between individuals can be explained by the variables, and relationships between variables can be illustrated by individuals” (Husson et al., 2011, pp. 39–40).

The variables Year correspond in the Euclidean space of the PCA to the temporal dimension, or the field’s history, in Bourdeusian terminology (Bourdieu, 1991b). In Fig. 2a, for instance, the journal *Nature Sustainability* is represented in the dataset from 2018. Given the period 2001–2021 as inclusion criterium for this study, the journal is thus represented in the dataset for four years. *Nature Sustainability* is found in the bottom-left section of the plane in Fig. 2a, corresponding to the more recently published journals. That same section also includes periodicals that have received more citations according to the following calculation: the number of citations received by a journal between 2001 and 2021 divided by the years of the journal’s inclusion in the dataset. More cited journals incorporate more symbolic capital and, in the case of *Nature Sustainability*, the symbolic capital of this publication can be interpreted in light of the recent research by Khelfaoui and Gingras (2020) on *Nature*’s “spin-off journals.” The brand value of this prestigious publication of the publisher Springer Nature could be deemed a contributing factor in the citation impact of this spin-off *Nature Sustainability*.

More generally, with regard to the publishers, the PCA approach allows calculating the position of the journal’s publishers in the Euclidean space in Fig. 2b (Blasius et al., 2019). The PCA biplot shows Wiley as being the publisher which has invested in journals of the field earlier than any other. The label corresponding to this publisher is found in the top-right section of the plane, corresponding to more years of inclusion in the dataset compared with the rest of the plane. The American Chemical Society (ACS) and Elsevier are found in the bottom-right section of the plane, occupied by individuals with a higher-than-average number of citations for articles published between 2001 and 2021.

The MCA of the author-assigned keywords

The study utilizes the author-assigned keywords as proxies for the scientific topics discussed in the journals and, ultimately, the symbolic capital embedded in these publications. The topics investigated in the sustainability research published in these journals provide



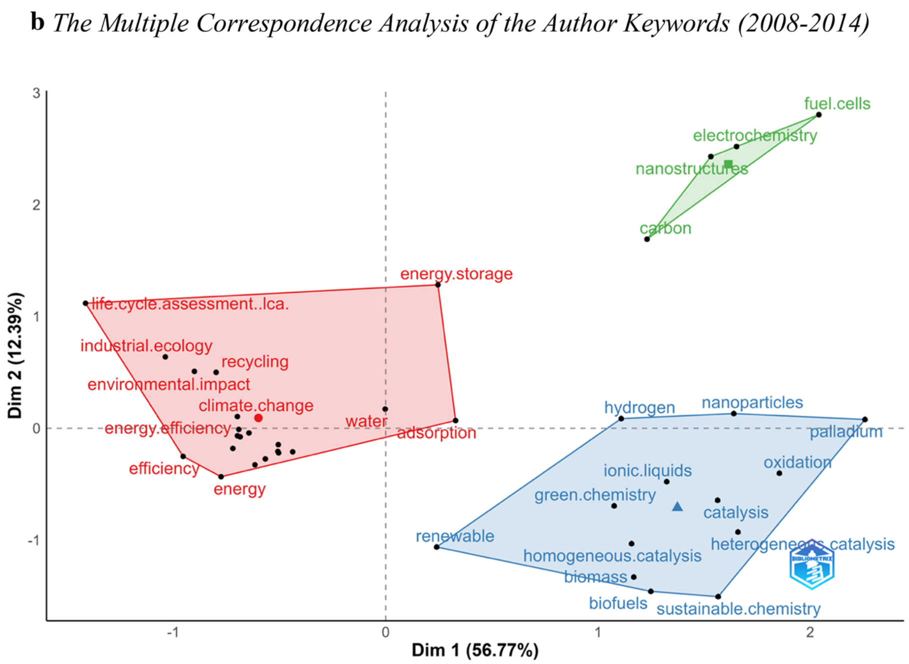


Fig. 3 **a** The multiple correspondence analysis of the author-assigned keywords (2001–2007). **b** The multiple correspondence analysis of the author keywords (2008–2014). **c** The multiple correspondence analysis of the author-assigned keywords (2015–2021)

c *The Multiple Correspondence Analysis of the Author-Assigned Keywords (2015-2021)*

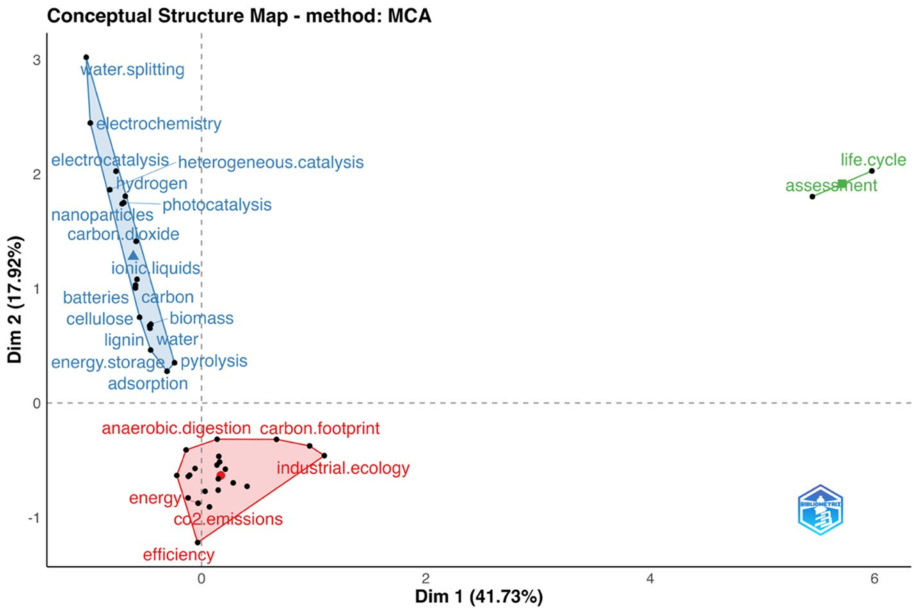


Fig. 3 (continued)

information on the terminology used, which is informed by the primary forms of capital, the cultural and social capital, and at a second-order level, also of the symbolic capital—being recognized as a legitimate agent of the scientific field.

In the specific case of Fig. 3a, the multiple correspondence analysis of the dataset (with the author-assigned keywords as qualitative variables) identifies three clusters. The large red cluster comprises most of the terms: it stretches from the center of the Euclidean space (with terms such as "sustainable development," "life cycle assessment," "analysis," "system," and "recycling") to the right section that includes the terms "hydrogen," "photovoltaics," "biomass," and "wind power." In the top-left corner, the blue cluster includes the terms "sustainability," "backcasting," "policy," and the term "ISO 14001," which corresponds to the standard for environmental management systems (International Organization for Standardization, 2015) and, more broadly, to the Ecologic Modernization Path, that is, the approach to sustainability which emphasizes the use of environmental certifications and regulations for private companies (Cohen, 2006). The terms "pollution prevention" and "cleaner production" are found in the smallest cluster at the bottom-left of the plane.

Figure 3b shows the MCA analysis of the author-assigned keywords of the second period. The green cluster at the upper-right section of the plane is chemistry-related, as shown by the terms "electrochemistry," "carbon," and "nanostructure." The cluster in blue on the left-bottom hand of the plane is also chemistry-related (as implied by the terms "green chemistry," "sustainable chemistry," and "catalysis"). On the left of the Euclidean space, the red cluster comprises the terms which contribute to the second dimension (e.g., "life-cycle assessment," "industrial ecology," "climate change," and "environmental impact"). The terms "sustainability" and "sustainable development" are also found in this cluster. If a line is drawn between the origin and the dots corresponding on the plane to the variables "sustainable development" and "sustainability," the angle formed by the two lines and having a vertex in the origin would be smaller than the angle formed in the same way on the MCA plane of 2001–2007. Thus, “sustainable development” and “sustainability” are more closely associated with each other in articles published in 2008–2014 than in the previous period.

Figure 3c reports three clusters generated from MCA analysis of author-assigned keywords. One difference compared with the preceding period is the more significant presence of terms from the field of systems modeling, e.g., “analysis,” “performance,” “optimization,” “simulation,” and “uncertainty.” This finding agrees with the earlier assessment of the field based on citation networks by Kajikawa et al. (2017), according to which “environmental and social systems” and “economy and business systems” were the largest topic clusters found in the mapping of the sustainability research of this period. Moreover, the term “uncertainty” was the most used author-assigned keyword during 2015–2019 in Chinese research in environmental flow science, a field related to sustainability research (Hao et al., 2021). The blue cluster in the bottom section of the plane includes chemistry terms such as “biomass,” “biogas,” and “cellulose.” The keyword “water splitting” is found at the top-left corner of the plane, far from any other terms and, at the same time, positively contributing to both dimensions of the plane, which grants the topic particular relevance in the research context depicted by the MCA plane. According to the seminal review of the field by Kajikawa (2008), water-oriented research was the least studied subfield in sustainability science.

The review by Ruggerio (2021) has discussed the distinction between research focused on (a) “sustainable development” or “weak sustainability,” with an emphasis on the green and circular economy, and (b) “sustainability” as “strong sustainability.” This latter conceptualization is typical of more radical proposals, as with degrowth-oriented schools of thinking for which “the notion of sustainable development is not a premise for degrowth” (Ruggerio, 2021, p. 786). Even if the weak and strong conceptualizations of sustainability can be, or should be, differentiated, the hypothesis of two separate research paths—for weak sustainability and strong sustainability, respectively—in 2001–2021 is not corroborated by this study’s findings. Regarding the examples of weak sustainability research given by Ruggerio (2021), the only one found is “circular economy” (see Tables 17 and 22 in the Supplementary Material of this article). Neither the weak-sustainability term “green economy” nor the strong-sustainability term “degrowth” are found in any of the MCA plots.

Journal co-citation relations

The function for extracting metadata information with bibliometrix *metaTagExtraction* was used to identify the journal’s name of each document included in three datasets of the 18 periodicals divided according to time periods (Aria & Cuccurullo, 2017). Thus, based on the name of the journals associated with each document, the relations of co-citation between the 18 periodicals were further computed with bibliometrix and visualized in Fig. 4a–c; more details on the journal co-citation analysis are available from Tables 13, 18, and 23 in the Supplementary Material.

The co-citation map in Fig. 4a shows two clusters. Journals with a chemistry disciplinary profile constitute a larger one (in blue). *Green Chemistry* and the *Journal of the American Chemical Society* are the most prominent ones based on the size of their nodes on the map (i.e., the links of co-citations). The other cluster in red color includes energy research journals, e.g., *Solar Energy* and *Renewable Energy*. Noteworthy in the co-citation

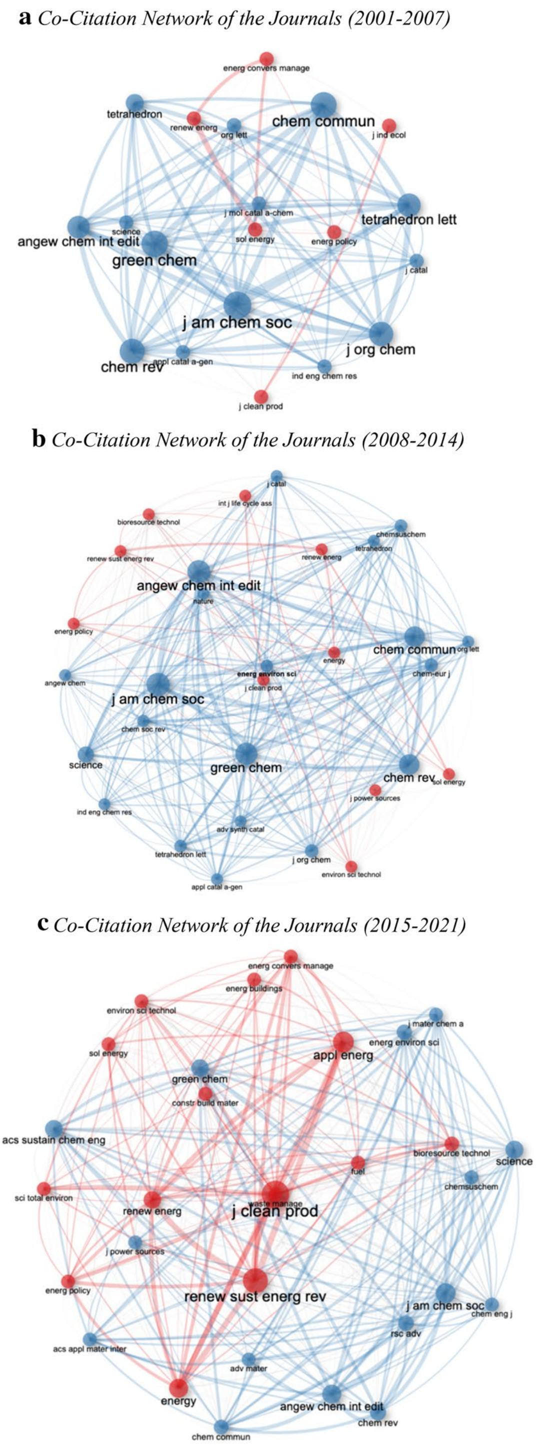


Fig. 4 **a** Co-citation network of the journals (2001–2007). **b** Co-citation network of the journals (2008–2014). **c** Co-citation network of the journals (2015–2021)

network is the multidisciplinary journal *Science*, a highly cited multidisciplinary journal whose coverage of chemistry and engineering has been found by Milojević (2020) to be higher than the other prestigious general science journals *Nature* and *PNAS*.

In the period 2008–2014, the journals publishing the most articles are *Renewable Energy* ($n = 2959$), the *Journal of Cleaner Production* ($n = 2523$), *Green Chemistry* ($n = 2465$), and *ChemSusChem* ($n = 1438$), and *ACS Sustainable Chemistry and Engineering* (n = 552). The sources with the most citations in the Web of Science Core Collection are *Green Chemistry*, with 168,973 citations; the *Journal of Cleaner Production*, with 153,859 citations; and *Renewable Energy,* with 150,062 citations. Some journals published their earliest issue in this period and, thus, had less time for accruing citations and the corresponding symbolic capital in the field. An example of these periodicals is *Sustainable Cities and Society*, which started in 2011 and received 169 citations in this period. In terms of symbolic capital, represented through co-citation links in Fig. 4b, the cluster of chemistry journals in blue is still the one that is composed of the most nodes and the nodes with the most co-citation links and, therefore, of a larger diameter on the map.

The co-citation map in Fig. 4c shows the broadening of the cluster (in red) that includes the *Journal of Cleaner Production*. This latter's position in the network, and that of energy fields publications such as *Energy* and *Applied Energy*, are more predominant in this third period than in the previous two. The blue cluster, formed by journals with a chemistry profile and by the multidisciplinary *Science*, shrinks in 2015–2021 compared with the previous two periods.

The co-authorship relations (Affiliations)

Co-authorship is just one type of scientific collaboration and, consequently, of the symbolic capital involved in knowledge production. Nevertheless, co-authorship relations between affiliations and, on a larger scale, between countries show capital incorporated into a set of publications. The collaboration between research organizations, as measured by co-authorship relations, is illustrated in Fig. 5a–c. Although the level of cooperation may seem sparse from these network visualizations, it is important to note that a threshold was applied to improve the readability of the graphs. In all three figures, the maximum number of nodes that could be shown in the visualization was limited to 50, based on the algorithms used to construct the graph (Fruchterman & Reingold, 1991; Traag et al., 2019) from co-authorship data. Biblioshiny, the web application of bibliometrix, was used to export network structure in a Pajek file (Batagelj & Cerinšek, 2013), which was subsequently visualized using VOSviewer (van Eck & Waltman, 2010), as it is also found in recent scientometric studies (Chaudhari & Pawar, 2021; Guleria & Kaur, 2021). The clustering in VOSviewer was based on a threshold of a minimum of 10 items per cluster.

The co-authorship map in Fig. 5a on the links between the field's academic organizations shows the Delft University of Technology and The Queen's University of Belfast as significant collaboration hubs based on the number of co-authorship links.

In the network shown in Fig. 5b, organizations that could be found in 5a are still represented (such as the Delft University of Technology, Lund University, The Queen's University of Belfast, the University of Nottingham, and Monash University). However, several universities are found at the later stage of the history of the field represented in 5b, for instance, The University of Tennessee, Zhejiang University, and the University of Tokyo. Particularly close connections in the map are found between an organization in the

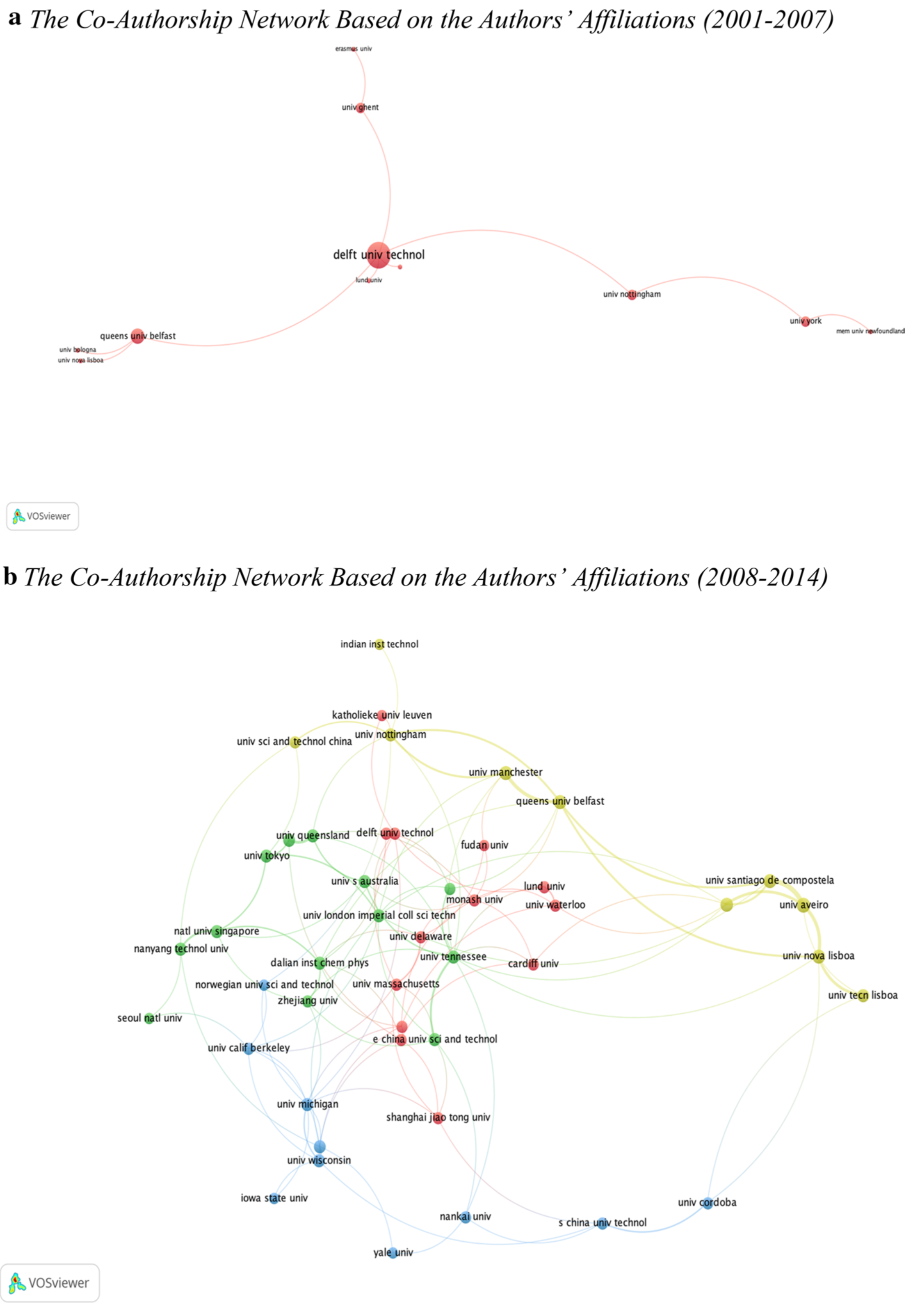


Fig. 5 **a** The co-authorship network based on the authors' affiliations (2001–2007). **b** The co-authorship network based on the authors' affiliations (2008–2014). **c** The co-authorship network based on the authors' affiliations (2015–2021)

c *The Co-Authorship Network Based on the Authors' Affiliations (2015-2021)*

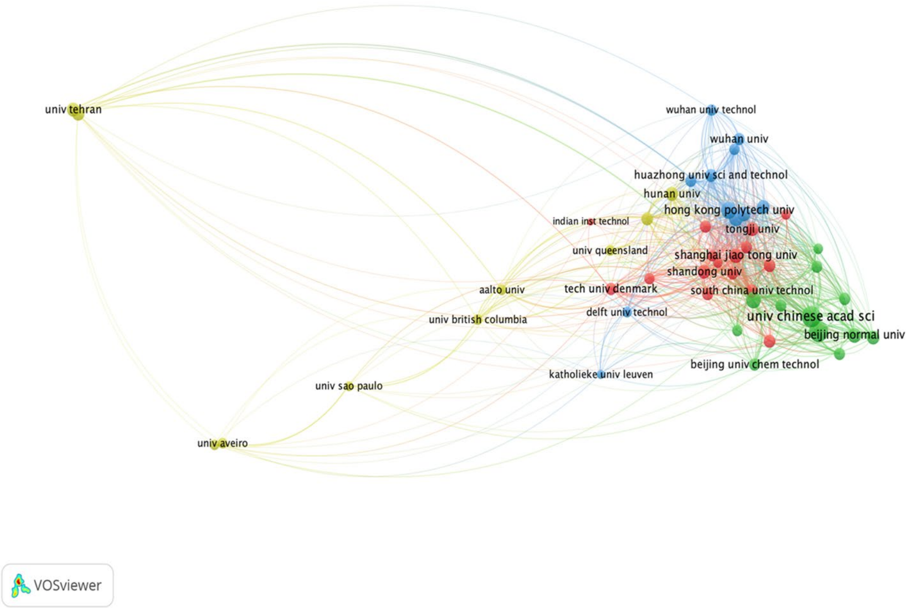


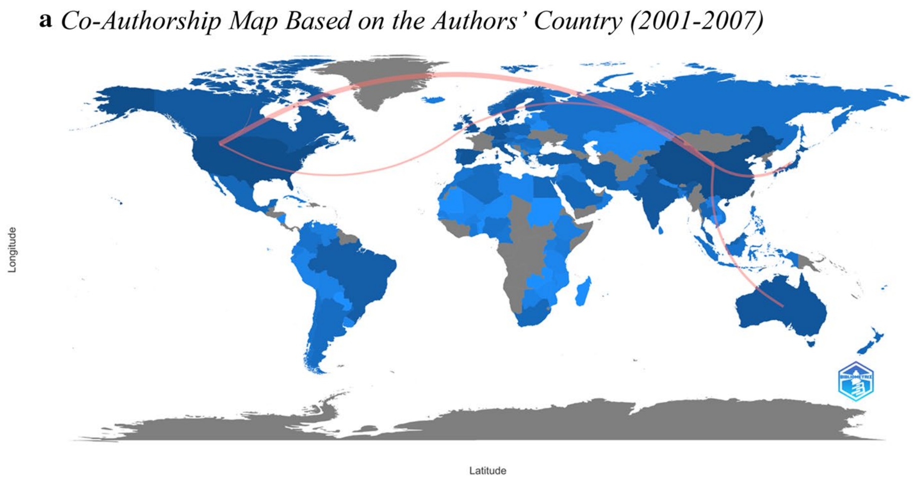
Fig. 5 (continued)

same country, e.g., The National University of Singapore and the (Singaporean) Nanyang Technological, between The Autonomous University of Barcelona and The University of Aveiro, and between The University of Manchester and The Queen's University of Belfast.

In the last period, 2015–2021, The University of the Chinese Academy of Sciences has the most links in this period, found in a portion of the graph which shows a high degree of collaboration between Chinese research organizations. Although scientific and policy discussions on sustainability in China predate this period (Liu, 2010), Liu et al. (2021) have more recently underlined the dominance of China in the sustainability research field in the period 2013–2019, with a particular focus on five areas: sustainable urbanization, carbon emissions, sustainable land use, sustainability calculation, and decisions for sustainability.

The co-authorship relations (Countries)

The map in Fig. 6a is based on the co-authorship relations between countries during the period 2001–2007. The visualization has a threshold of at least ten co-authorship links between countries. The shade of blue correlates with the number of papers associated with affiliations in that country. Although the contributors to the total publication output worldwide are several, the degree of collaboration is extremely limited. To improve the readability of the maps in Fig. 6a–c and avoid excessively numerous co-authorship links affecting the quality of the visualizations, a threshold of at least 50 co-authorship connections between countries was chosen. Therefore, in the time frame of the first period, even the most frequent connections between countries—the one between the US and the UK (15



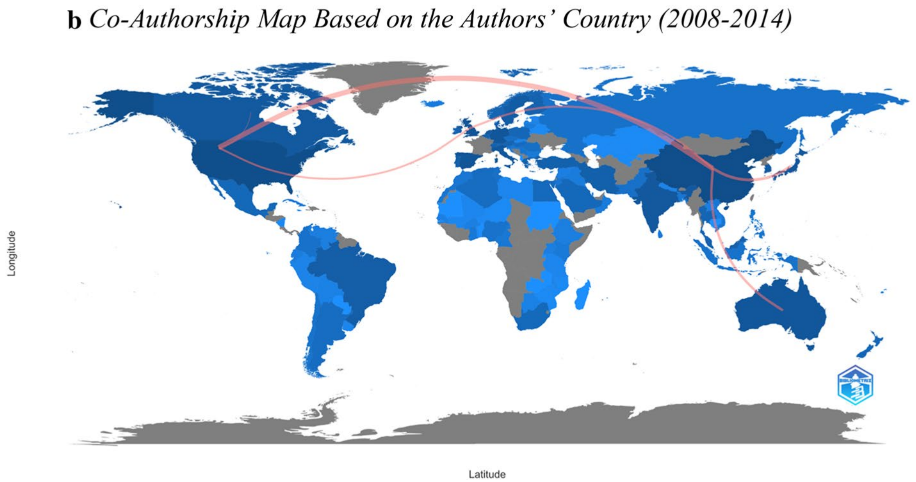


Fig. 6 **a** Co-authorship map based on the authors' country (2001–2007). The map is based on a threshold of at least 50 co-authorship links between countries. The shade of blue in which a country is represented is correlated with the number of papers associated with an author's affiliation in that country. **b** Co-authorship map based on the authors' country (2008–2014). The map is based on a threshold of at least 50 co-authorship links between countries. The shade of blue corresponds to the number of papers associated with an author's affiliation in that country. **c** Co-authorship map based on the authors' country (2015–2021). The map is based on a threshold of at least 50 co-authorship links between countries. The shade of blue in which a country is represented is correlated with the number of papers associated with an author's affiliation in that country

links) and the US and China (ten links)—are not visible on the map (see Table 15 in the Supplementary Material for further details).

Particularly collaborative countries between 2015 and 2021 are the US, China, the UK, Australia, and Japan. The foundation of the journal *Sustainability Science*, earlier in 2006, by the University of Tokyo contributed to explaining Japan's higher productivity and collaboration in this period (Kajikawa et al., 2017). The highest number of links is reached by the collaboration between the US and China (176 links), followed in decreasing order

c *Co-Authorship Map Based on the Authors' Country (2015-2021)*

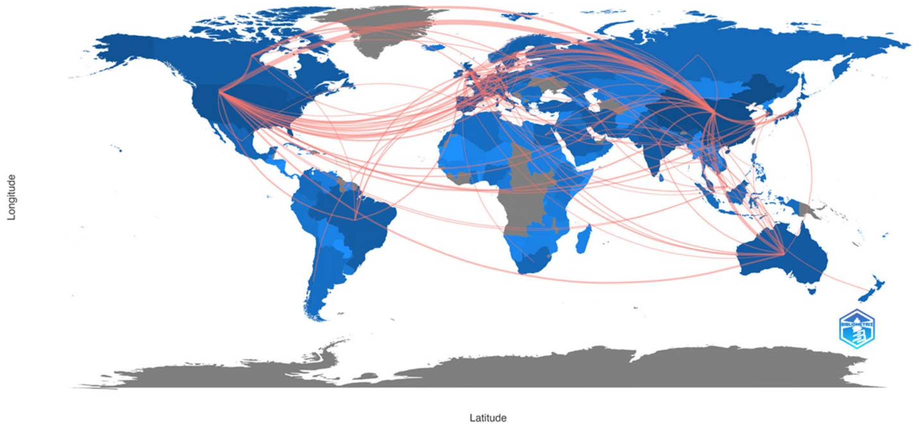


Fig. 6 (continued)

by the one between China and Japan (83 links), China and Australia (74 links), China and the UK (66 links), and the US and the UK (63 links). The 2013 initiative of The Ministry of Science and Technology (MOST) of China—the Citation Impact Upgrading Plan (CIUP)—should also be mentioned (Zhou & Leydesdorff, 2016). This policy initiative encouraged researchers, through financial support, to publish in journals with high impact measured according to bibliometric data from the Clarivate Analytics database Science Citation Index—Expanded (SCIE) and MedLine, or the Journal Impact Factor of the journals in which Chinese researchers publish their findings (Teixeira da Silva, 2017). These policies can be read through the lens of Bourdieu's (2005) sociology as interactions between the political and the scientific field with the mediation of the economic one. However, other financial incentives to publish in top-tier publication channels were in place in China before the CIUP initiative, as shown by the paper by Shao and Shen (2012), who criticized similar governmental strategies because of adverse effects such as several cases of research misconduct.

Taking a global perspective, it can be observed that from 2015 to 2021 there has been an overall increase in the degree of co-authorship. Besides China, the US, Canada, the UK, Spain, Germany and the Netherlands, Australia, and Japan are still highly collaborative countries. More countries from the Global South are represented on the map, with co-authorship links connecting former colonies with their former colonizing states, notably in the case of Brazil and Portugal (125 links) and India and the UK (120 links).

In this study, two series of co-authorship maps answered RQ2 on the position of research organizations and their countries in the field, respectively. The networks pictured in these maps show that most of the publications are associated with a Chinese or American affiliation. However, the period 2015–2021 is also characterized by the entry into the field of several more Global South countries. The dominance of Chinese universities in the second and, even more so, in the third period is a significant finding that cannot be explained merely by the increment of the Chinese publication output in general, and in particular, the one represented in the Web of Science's citation index. In fact, this article compares the three periods, always using leading journals as units of analysis. Thus, the study reveals Chinese universities' success not merely as newcomers entering the field.

They have secured a position in the symbolic economy of the field where the most prestige can be found. The last two periods see the increasing role of another Asian context, Japan. In particular, the publication success of this other country involves the foundation of the journal *Sustainability Science* and the investment in the field by the University of Tokyo (Kajikawa et al., 2014).

Discussion

This study identifies the leading journals' topical profiles, co-citation relations, and co-authorship networks, which in turn define, more broadly, their position in the field. In the remainder of the article, answers to the research questions RQ1-2 are paired with the fundamental question: "What kind of science is sustainability science?" (Kates, 2011). In all three periods, the survey of 18 leading journals conducted so far has shown particular prominence in the field of already established research fields, notwithstanding the generalized call for a transdisciplinary science *of* sustainability beyond the interdisciplinary and disciplinary science *for* sustainability (Spangenberg, 2011). These scientific fields can be identified as belonging to research areas of chemistry, renewable energy, and a more general topic area engaged with the topic of sustainability and sustainable development as well as life cycle management, recycling, and the entities which De Vries (2012) calls "socio-ecological systems" (SES). The historical contribution of these different research areas is visible through the MCA of the author-assigned keywords, where the "hard sciences" (Becher & Trowler, 2001), notably chemistry and energy research, have a leading position in the field. However, social science research on SES has been the most successful "soft science"-challenger of the "hard sciences."

The introduction of this article mentioned the seminal bibliometric study of sustainability science by Buter and Van Raan (2013), where the authors concluded through a fine-grained semantic analysis of research topics that the field had yet to become fully transdisciplinary. The research design of Buter's and Van Raan's (2013) article differs from the journal-oriented analysis of the field proposed in this study. However, the latter is partially relatable to the former. In fact, the findings presented so far have shown an increase in the transdisciplinarity of sustainability science if the field is seen from the perspective of the sustainability-specific journals in which scholars communicate their research. These new publication venues correspond to one criterium set for transdisciplinary sustainability science by Lang et al., (2012, p. 34, italics in the original text): "targeted 'products' for both parties." The term "products" does not mean only scientific articles, although it still comprises them. Thus, as shown in the present study, the *Journal of Cleaner Production*, explicitly defined as "transdisciplinary" in its aims, has progressively gained more symbolic capital (Elsevier, 2022, para. 1).

These findings can be read through the lens of a perspective that could be called the "Gingras-Bourdieu hypothesis." According to the historical analysis of the field of physics by Gingras (1991), which Bourdieu (2004) further discussed in one of his lectures at The Collège de France, a scientific field acquires prestige the more it becomes a social field of scientists and the less a field of practitioners. Specific, formalized, and esoteric knowledge discourages newcomers from entering the field, leading to a higher status for the agents already admitted to the field. This hypothesis corresponds to Bourdieu's conceptualization of the relative autonomy of scientific fields (Albert & Kleinman, 2011). The "mathematization" of physics following the discoveries of Newton created an intellectual threshold to access the field that left out those that could not master it, as with engineers and other practitioners of the field. The intellectual organization of a field, including its concepts and theories, has a profound impact on the social structure of the field, influencing who is granted access and participation within it. Publishing in journals is not the only way to enter a scientific field as a legitime member of its community (being part of learned societies is, for instance, another). However, authoring papers in the known journals of a field still constitutes a salient characteristic of those who are recognized as a legitime agent of a scientific field, as discussed by Small (2004) in broader terms, and by Larivière (2012b) in relation to the publication output of doctoral students. As Anzola (2019) underlines, although specialized languages are for Bourdieu (1991a, p. 137) compromises between expression and "censorship," i.e., between what an author wishes to express and what the scientific community allows, Bourdieu's understanding of what turns a field into a discipline hinges more on establishing the means to judge the researcher's contributions to the field than the birth of the language of the "academic tribe" (Becher & Trowler, 2001). Journals are those arenas where, through peer review, the contributions of the authors are scrutinized by other agents in the disciplinary field.

From the standpoint of the Gingras-Bourdieu hypothesis and of Bourdieu's theory of scientific fields as relatively autonomous social fields within society, the foundation of the journal *Sustainability Science* by researchers from the University of Tokyo is a paradigmatic case (Kajikawa, 2008). In the market of the symbolic goods of the field, the creation of this specialized journal represents the explicit pursuit of disciplinary autonomy for this new scientific field (Kajikawa et al., 2017).

Three strategies for facing sustainability issues and three types of sustainability science journals discussed below correspond to decreasing levels of disciplinary autonomy. The journals of the field reflect the debate on the disciplinary status and defining features of sustainability science. A typology (a)–(c) of journals can be constructed based on the findings of this study and their relation to the debate on the disciplinary status of sustainability science:

(a) *Sustainability Science* exemplifies the type of publication that promotes the diversification of sustainability science from other existing sciences. The strategy here is to promote through a journal the establishment of a transdisciplinary albeit relatively autonomous field, with the potential of becoming an established discipline in Bourdieu's meaning of an academic community of agents that share common interests (intellectual and economic ones) as well as rules for regulating the entry and scrutiny of newcomers (e.g., acceptance to publish in the field's journals and speak at its conferences). To this strategy belongs also those perspectives that are open to sustainability as a "room of its own" beyond the difference between basic and applied science, e.g., as use-inspired "basic research" (Clark, 2007, p. 1737) or even as a field that seeks to utilize unprecedented types of knowledge (White, 2013), e.g., indigenous knowledge, which challenges the legitimized boundaries of "scientific authority" (Bourdieu, 1991b, p. 7).

(b) The second type of journal corresponds to the strategy of creating publication venues less concerned with the foundation of a new scientific field compared with journals of type (a) but equally oriented towards the topic of sustainability in a broad meaning, that is, without situating the journal in a disciplinary, thematic area (such as chemistry, agronomy, economics). *Nature Sustainability*, a newcomer in the field that appeared in 2018, could be ascribed to this second profile together with older publications such as the *Journal of Cleaner Production* and *Sustainable Development*.

(c) Specialized journals form the third group. The strategy is to treat "sustainability issues" within distinctive established disciplines (White, 2013). However, not all sciences appear to share this group, although sustainability issues should be relevant for all sciences (Nolin, 2021). This type includes *ACS Sustainable Chemistry* and *Engineering, Agronomy for Sustainable Development*, and the more recent *IEEE Transactions on Sustainable Energy*. As shown in the PCA biplot in Fig. 2a, discussed earlier in the paper, most of the leading journals belong to this third profile.

As a scientific field, sustainability science is conceived as more autonomous when being treated as a "room of its own" (Clark, 2007, p. 1737) in the (a) type of the (a)–(c) typology than in the other two cases. However, in contrast to the evolution of the field of physics with its disconnect from engineering professions, as extensively discussed by Gingras (1991), sustainability science—even according to strategy (a)—can never sever its connection with the field of sustainability practices and policies. It is not desirable that it would do so either. This emerging field is, in fact, a problem-driven science that hinges on focused on a normative concept: societies should strive to achieve sustainable goals or solutions to sustainability issues (Kates, 2011; White, 2013). These goals and solutions require the involvement of agents from other fields, e.g., the field of sustainability policy. The need for a new epistemology of "sustainability knowledge," as emphasized by White (2013) calls for new viewpoints on knowledge and science highly desirable. Transdisciplinary research strategies corresponding to the shift from Mode 1- to Mode 2-type of knowledge production (Gibbons et al., 1994) have been deemed by Lang et al. (2012) as the most adapted to tackle sustainability issues. This article is also the most cited document in the dataset during the subperiod 2008–2014 and the second most cited paper in the whole period 2001–2021 (see Tables 17 and 5 in the Supplementary Material). It should be noted that Lang et al. (2012) raise an important point on the disciplinarity of sustainability research: even if "transdisciplinary research is, in many cases, a promising choice," at the same time, "this does not undermine the relevance of disciplinary or interdisciplinary approaches" (p. 40).

Furthermore, several co-authorship patterns found in the present studies could be read as instances of "neo-colonial academia" (Yalkin & Özbilgin, 2022) and confirming the "post-colonial collaboration," for instance, between Brazil and its former colonizing country, Portugal. These findings confirm earlier studies that have found that the sharing of the same language favor collaboration between former colonies and colonizers (Boshoff, 2009). In any case, a more accentuated diversity in terms of countries of publication, including the Global South, found by the present study and also by earlier large-scale analyses (Confraria et al., 2017) can be expected to advance novel non-Western perspectives on sustainability and conceptualizations of "sustainable knowledge." An example could be the "strong sustainability" concept of *buen vivir*, which "originated in South American native cultures (in particular in Andean cultures) and substantially opposes the proposals of development and sustainable development, discussing the essence of Western culture […] that contrasts the anthropocentric conception with a perspective based on respect for Mother Earth and all living beings" (Ruggerio, 2021, p. 786). It is not excluded that the apport of the Global South to the publication output of the field will not only introduce to the field different perspectives, and, in particular, "strong sustainability" ones, but also the contribution of "softer sciences" from which some of these perspectives have originated, e.g., the field of environmental philosophy in the case of the deep ecology movement (Naess, 1973).

The discussion of the results so far has hinged on the historical formation of sustainability science, and it has provided a descriptive narrative of how the field has been shaped based on the leading journals. However, both Bourdieusian sociology of science (Bourdieu, 2004) and the research agenda of transdisciplinary scientometric research (Kajikawa, 2022) encourage seeking beyond the descriptive level of analysis a more normative approach. Although the question of what type of science sustainability science ought to be goes beyond the scope of this article, the findings allow for normative considerations.

As a normative concept, sustainable development establishes the ground for the emergence of specific norms, e.g., scientific and legal ones. From a Bourdieusian perspective, sustainability science can be seen as the scientific and self-reflexive study of sustainability-oriented norms and the processes that promote or obstacles them—within and beyond scientific fields. Sustainability is a research field close to the field of policy and the power structures of society. The idea of integrating the framing of sustainability issues into potentially all existing scientific discourses across the soft-hard science spectrum would superficially appear to imply that the maturity of the field would coincide with its disappearance. If sustainability thinking is found everywhere in the literature of all sciences, who would then need a science called sustainability science? However, this would be equal to saying that integrating social aspects in other sciences ought to exhaust the role of sociology as a field of research. Sociology is considerably more than that (Bourdieu & Wacquant, 1992). In this sense, much of Bourdieu's discussions regarding the connection between sociology and power structures and the need for reflexive sociology also apply to sustainability science (Bourdieu & Wacquant, 1992). In sustainability science, Jerneck & Olsson (2020) have emphasized the reflexive nature of the field. The concept of framing "examines the process to determine what is worthwhile to sustain in line with the direction of sustainable development" (Kudo & Mino, 2020 p. 9). Framing can be applied to sustainability issues (Mino & Kudo, 2020), to the notion of evidence in policy-making (Kajikawa, 2022), and also to the type of scientific discourse that is being created around sustainability, e.g., through scientometrics studies. When considering sustainability science from the meta-perspective of the scientific discourse on science, framing sustainability issues becomes self-reflexivity. In this regard, the perspective of symbolic capital helps gauge competition between agents and institutions and "power struggles" (Bourdieu et al., 2019, p. 165), e.g., not all universities can be the leading ones in a field. However, symbolic capital is a resource that can also be transferred and shared, which is the ground for alliances between sciences and between science and other societal actors—or synergies, to use the terminology of Leydesdorff (2021). Journals of the type (c) discussed above represent a synergy between some established disciplines, such as agronomy, and the newer field of sustainability research. Ultimately, for the sake of the self-reflexivity of sustainability science, research on sustainability journals is no less necessary than their creation.

Conclusion

Taken together, this study's findings have shown that Bourdieu's field theory and the correlated methodology of GDA can serve the purpose of "transdisciplinary bibliometric research," to use the term recently proposed by Kajikawa (2022). As emphasized by Bourdieu (2008) and, more recently, by other scholars of various social science fields

(Blasius et al., 2019; Ekelund, 2016; Lebaron, 2018; Lu et al., 2021), PCA, MCA and other GDA approaches have the strength of providing a picture of social fields based on the volume and type of capital. The present article has focused on symbolic capital and built on earlier bibliometric research inspired by Bourdieu's sociology of science (Schirone, 2023). The publication and citation data were processed with the R package *bibliometrix*, which already includes one GDA method, the MCA, as one of its features (Aria & Cuccurullo, 2017). An overview of the field and the position of journals and their publishers were obtained with another GDA approach, the PCA. As is often the case with bibliometric data, the study's data were skewed. Therefore, a variant of PCA, the Robust PCA, was preferred to the canonic version of PCA. Future research could apply and adapt this approach to the bibliometric and scientometric analysis of other research fields.

However, this study has limitations that need to be acknowledged: using one bibliometric database, Web of Science, and operationalizing the concept of "leading journal" with a value of Journal Citation Indicator that is higher than the world average. Therefore, the study could be replicated using other journal rankings. Another limitation of this study is the choice to include only research articles, which left the editorial material out of the study's dataset. Future research could clarify the editors' role in shaping the field.

To conclude, this study has revealed the picture of a scientific field organized around three main strategies to conceive sustainability science research (each strategy paired with a corresponding type of journal): sustainability science as a field of its own and, in particular, as the science of sustainable socio-ecological systems; this field as concerned with the subject of sustainability more broadly conceived; and as a specialty within other fields, that is, as the study of sustainability issues and their potential solutions from the perspective of green chemistry, renewable energy, and other sciences with their already established disciplinary status. The field's history also indicates a process of expansion to which more and more newcomers, in terms of journals, universities, and countries, are contributing.

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