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The Landscapes of Sustainability in the Library and Information Science: Collaboration Insights

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Abstract: Despite the fact that the concept of sustainable development was born as early as the late 1980s, in the field of library and information science there has been a significant growth in interest only in recent years. This observation inspired the authors to explore this particular area with regards to productivity both in quantitative and qualitative terms. One of the important factors influencing scientific productivity is broadly understood research collaboration. Interestingly, in the scholarly literature dealing with the topics of scientific productivity, the researchers are most often representatives of the LIS field who study, also applying bibliometric methods, various scientific disciplines. However, so far there have been no studies on scientific collaboration concentrated around the discipline of sustainable library and information science (LIS) itself. Therefore, in this paper, the authors present the results of research into the phenomenon of co-authorship in this specific area. The results indicate not only the most important collaborating entities contributing to the research field and trends in research cooperation, but also verify certain general hypotheses put forward in the areas of the fundamental sustainable development of the discipline of sustainable LIS.

Keywords: sustainability; research collaboration; co-authorship; trend analysis; network analysis; library and information science

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1. Introduction

Nowadays, sustainability science has gained worldwide popularity and become even a sort of scientific ubiquity. Sustainability ideas, which are themselves of a multidisciplinary nature, have spread throughout virtually all scientific disciplines, countries and nations. This may be the reason why the research literature analyzing sustainability-related phenomena is equally vast and diversified. It can even be said that, at present, sustainability science is becoming a scientific field in and of itself [1].

However, in the sizeable subject literature it is also possible to find examples of analyses or considerations which are performed not only on general sustainable science literature, but which present a much narrower focus, i.e., precisely, a set of sustainable library and information science (LIS) publications. Sustainability ideas, and sustainable-development issues, have since also found their place in this particular field of study and infiltrated it, reaching the core of its research objectives, directions, and objects of interest. The range and shape of these processes were comprehensively summarized by the authors of the present article in their previous paper [2]. They indicated several main research topics which are commonly tackled by LIS specialists in their publications, and which are strictly connected to sustainability dilemmas. Almost all of them fit into the so-called "Green Library Movement" (see e.g., [3]), and are concentrated around possible methods of greening library buildings, and library practices, as well as making library collections sustainable in terms of their content, acquisition, and preservation techniques. Other frequently discussed themes encompass sustainable information science, with an emphasis placed on electronic-equipment exploitation, energy consumption and the carbon footprint of library services and devices. What is more, education towards sustainability, and information literacy aimed at raising public awareness of the issues in question, are also important research directions considered in the subject literature. Cultural aspects of sustainable development, since libraries are perceived as cultural institutions, constitute an additional part of the strain of research within the sustainable LIS domain, as well as a number of other sustainability-related matters. This last group is quite heterogeneous and can be roughly divided into categories such as: (i) the sustainable funding of library materials, (ii) library marketing and adopted business models and their sustainable dimensions, (iii) sustainable practices in libraries located in developing countries, (iv) assessment of libraries' future prospects on their way to sustainability, and (v) technological innovations, which can be beneficial from a sustainability point of view, etc.

The above-mentioned research outcomes are only a part of the latest sustainability movement and sustainable development-oriented research, which is currently fairly often conspicuous and conducted in LIS. It seems that all of the so-called sustainability pillars (which are sometimes also called the "triple bottom line"), i.e., the environmental, economic, social, and cultural, are constantly gaining popularity in this domain. The major research questions, and problems at the core of sustainability science, are commonly approached from both: a qualitative and quantitative manner. Their significance was recognized a long time ago (see e.g., [4]), and LIS is obviously no exception here. The main contributions that come from this specialty are undoubtedly in-line with environmental sciences, the economy and certain social-science views (see, also, the next section of the paper). However, according to some studies, the focus of sustainability research can be very different, depending on the country. Each particular country seems to have its own fields (or subfields) of interest regarding sustainability issues [5].

It may also be worth mentioning that the fourth pillar of sustainable development, i.e., culture, is a relatively new and not a fully explored area of research which appears to create many opportunities for subsequent studies. Nevertheless, it seems that in the library and information science field, there is still plenty of room for further research and analyses, which could be classified as belonging to one or more of the remaining pillars or may be carried out at the intersection of them.

Progress in these areas, as well as in the development of other fields of science and even the whole of civilization, is that the more entities interested in collaborating, the more efficient the progress is. This cooperation can be conducted as indirect when someone improves outcomes of the other one, or as direct when two or more individuals collaborate on a given subject matter. In the area of scientific research, this cooperation is manifested through writing processes—in the case of the first type by referring to other papers through citation apparatus, and in the second one through co-authorship of scientific articles.

In the systematic and quantitative studies of the state of the literature, including scientific literature, support can be found in the field of bibliometrics, which allows to objectively draw conclusions about the processes and phenomena occurring in the literature corpus of a particular area over time. Bibliometrics is a vast field, and many methods and tools have been developed as part of the research conducted within it [6,7].

In this paper, a bibliometric analysis of direct scientific collaboration (co-authorship) in the sustainable development of LIS is undertaken.

The following specific research questions are addressed:

- What are the most productive teams formed by researchers and institutions?
- Which types of institutions and which countries cooperate with each other the most?
- What are the trends in the relative numbers of joint articles and the types of joint articles (interindividual, international, interinstitutional, cross-sector) over the studied period?

Moving forward, this paper progresses in four steps. First, studies undertaken which form the background of in this paper will be highlighted along with the most important research results published by other authors so far. Second, the paper's methodology will be presented in more detail, especially as it concerns the data processing protocol and data analysis. Third, the results of the bibliometric analysis will be presented, including joined publication trends, shares of individual topical areas with respect to scientific collaboration and collaboration network analysis. Finally, these results will be brought together and critically discussed to suggest future directions for the research on sustainable development addressed within the LIS discipline.

2. Background

2.1. General Literature Reviews

As far as sustainable development challenges seen from the LIS point of view are concerned, the most recent review article, which focuses on such a perspective, was written by Khalid with Farid and Mahmood [8]. The authors gave a detailed review of literature indexed in LISA, LISTA, Scopus, Web of Science and Google Scholar databases spanning from 2000 to 2020. Their classification of main research themes was comprised of topics typical for the sustainable LIS discipline, i.e., (i) libraries' energy usage and carbon footprint, (ii) libraries' policy directed towards United Nations Sustainable Development Goals accomplishment, (iii) a transition from print to electronic resources in the frame of collection management, (iv) technological innovations applied in favor of environmental, social or economic sustainability, and (v) sustainable funding and sustainable issues' inclusion in the education sector and LIS courses' curricula [8]. Khalid et al. also indicated several obstacles which hinder the implementation of sustainability policy in library agencies and suggested that the reason for these may lie in clinging to old traditions and resistance to changes, which are required if a library is to take a step in the direction of sustainable development. Moreover, as can be seen, the categories that were distinguished by the authors are almost identical to the ones that were proposed by Kamińska et al. [2], which, in a sense, corroborates their adequacy to the sustainable LIS literature topical structure.

Among other more noticeable works that pertain to the same category, there is, e.g., Meschede and Henkel's [9] review article, whose aim was to analyze the content and methodological approaches that prevail among most of the research published within the sustainable LIS and to identify potential research gaps. The topics, which were identified by the authors, turned out to be similar, to some extent, to the main themes differentiated by Kamińska et al. [2]. They can be briefly characterized as follows: (i) greening library buildings, information dissemination and education; (ii) information and communication systems in developing countries, and monitoring of energy and water consumption; (iii) digital government and media pressure; (iv) sustainable development literature and eco-design; (v) gender equality, learning society, and ecovillages; (vi) geographical information systems and urban development; (vii) research institutes and universities; (viii) sustainable future and de-industrialization; and (ix) miscellaneous, e.g., food, waste disposal, or knowledge management [9].

In 2018, Meschede and Henkel published another article in which they made use of bibliometric methods. Meschede and Henkel's [10] work headed towards identifying possibilities for LIS to contribute to sustainability and sustainable development debate. The authors also detailed eight major topics that were most often addressed by LIS community members, and were once again very close to the ones that are listed above [10].

Next, Repanovici et al. [11] conducted a scientometric study of sustainable LIS literature in order to extract the most visible clusters of keywords, and thereafter to unveil the main research directions. In other words, the authors searched for a scientific frontier of the discipline, as well as the concepts, that are at present the dominant ones. In short, it can be stated that, once again, the topics extracted from the subject literature were in accordance with issues indicated previously by Meschede and Henkel [9,10], and the prime difference between them seems to lie in an emphasis placed on information literacy, information skills, library schools' curricula, and the competences of library personnel [11].

Beutelspacher and Meschede [12], in turn, examined the role of German public libraries in promoting environmental sustainability ideas and utilized a bibliometric method of algorithmic clustering to visualize a network of keywords which appeared in almost one thousand four hundred books, which were in libraries' possession at the time of their study. Thanks to the keyword-mapping technique, the authors were able to name the following thematic foci: (i) mobility and urban planning; (ii) consumer behavior and lifestyle; (iii) climate change; (iv) environmental management; (v) urban development and energy consumption; (vi) alternative economy models; (vii) construction and energy; and (viii) economic growth [12]. They used a VOSviewer tool, which is in essence a computer program for bibliometric mapping of some selected parameters or properties of literature corpora (see, e.g., [13]).

Whereas review articles are helpful mainly in terms of identifying the most crucial research problems, collaboration is the source of a method through which progress in the areas indicated by those reviews can be achieved. Scientific cooperation may be seen, in this context, as one of the major foundations of advancement of a research field. As such, it seems to deserve some attention within this section of a paper, especially in terms of its previous applications that demonstrated its scientific value. Furthermore, because collaboration in science is often analysed throughout its bibliometric dimension, the brief outline of prior studies of this nature will be also detailed below.

2.2. Scientific Collaboration Studies

Scientific collaboration and the phenomenon of co-authorship have been systematically studied at least since 1958, when Mapheus Smith [14] noticed an increase in the number of co-authored papers in psychology. The same inclination was also observed by de Solla Price [15], Clarke [16], Meadows and O'Connor [17], Beaver and Rosen [18], and many others (see, e.g., [19,20]). However, some authors, such as Derek de Solla Price, who reportedly used to say that science is "many-brained"; Henry Small; Eugene Garfield; and Belver Griffith are the real pioneers who gave birth to the regular research on this particular subject [21]. Derek de Solla Price [15] made a remark that many scientific phenomena, including co-authorship and the number of co-authored papers, exhibit an exponential rate of growth, and this prediction turned out to be, at least approximately, true, in the light of numerous later research endeavors (see, e.g., [22]).

According to Beaver and Rosen [23], the first collaborative paper in the history of science was written in 1665 by Robert Hooke; Henry Oldenburg, who is regarded as the founder of the Philosophical Transactions of the Royal Society of London journal; Giovanni Cassini; and Robert Boyle, and its subject was related to natural history and zoology [23]; see also: Andrade [24]; Luukkonen et al. [22]. Collaborative links which crossed national borders appeared for the first time, in turn, in the nineteenth century [22,23]. Cronin [25] gave a brief, synthetic yet comprehensive description of a holistic history of authorship, with its beginning dating back to Mesopotamian times, and summarized the further lineage and development of this phenomenon till contemporaneity.

The term "scientific collaboratory", at its roots, meant "a laboratory without walls", which stressed the presence of physical distance between collaborating scientists, who were provided with remote access to instrumentation [26]. Nowadays, research collaboration and its relation to co-authorship is one of the most willingly exploited and fertile areas of bibliometric and scientometric studies. One of the possible reasons behind this fact may be the wide diffusion of a "publish or perish" policy, which requires scholars to be productive, i.e., to publish a large number of (valuable) scientific papers. The issue in question has, likewise, the potential for promoting many different social, economic, or political agendas, such as sustainable development, democracy, and cultural integration. Worldwide collaboration among scientists was even called a "springboard for economic prosperity and sustainable development" by the U.S. Office of Science & Technology Policy [26]. It is presumably justified to say that scientific cooperation and joint publications are a characteristic of 20th- and 21st-century science, and sometimes are also considered to be a prerequisite for the contemporary manner of conducting any kind of meaningful scientific research [27]. They are also regarded as a pathway, which often leads to breakthrough innovations (see, e.g., [28]). These phenomena, i.e., collaboration and co-authorship, are, in reality, so omnipresent in today's world of science that some authors are using the term "hyperauthorship" to refer to papers that include truly massive numbers of authors. This kind of situation takes place, for example, in high energy physics, astronomy, the economy or biomedical and life sciences (see, e.g., [25,29]).

All of the above-mentioned factors may be seen as a possible explanation, or maybe a symptom of the fact that collaboration in science "pays off", i.e., it is perceived as advantageous with respect to cooperating scientists' renown, productivity, and their papers' citation counts. It is sometimes said that co-authorship elevates a paper's epistemic authority [19]; see, also: [26,29–31]. In other words, there is empirical evidence of the higher impact of multiauthored papers, and of the existence of a positive correlation between productivity and the intensity of collaboration between researchers, especially when it comes to international collaboration [19].

For example, the data gathered and analyzed by Glänzel [32] indicated that, on average, publications of an international provenance are cited more frequently and attract more attention than publications ensuing from purely domestic cooperation. Similarly, Glänzel and Schubert [20] found that collaboration influences citation behavior, and effectively promotes and supports scientific activity, productivity, and impact. In light of the fact that inter- and multinational research outcomes usually appear in high-impact journals, and that they are then able to reach a broad audience, it is reasonable to agree that the visibility and reception of such outcomes are expected to be far greater than the world's average [20].

Beaver [30] further developed the question about the epistemic authority of collaborative papers and presented qualitative and quantitative arguments to support this hypothesis. He argued that there is a common tendency to trust collective judgment more than an opinion expressed by a single person due to the fact that in the first case the research outcomes had to stand the test of many different subjectivities [30]. A team of researchers is, thus, in a privileged position, and the same fact holds in the case of the likelihood of recognizing some novel aspects of a study or identifying its potential drawbacks or faults. Beaver, additionally, illustrated his reasoning by an analogy to Tycho Brahe's endeavor to affix and state precisely positions of stars through adding consecutive distances between more and more known stars creating a net of them, instead of using only a pair or a trio [30]. Beaver's empirical results obtained on account of this context suggested that his main hypothesis is correct, i.e., that, in fact, multiauthored articles bear a greater epistemic value [30].

Exactly the same problem, i.e., the relationship between the quality of a paper and its collaborative structure, was further investigated i.a. by Franceschet and Costantini [33]. The authors evaluated epistemic quality through the mean of a paper's citedness, and judgments of peer reviewers, based on data drawn from a national research assessment exercise (RAE) of Italian universities. The principal finding, from the perspective of this section of the article, the authors reported, is the evidence that the more heterogeneous were the authors' affiliations, the more enhanced was the performance of joint publications in terms of their citation impact, and peer judgment as well [33].

Next, Larivière et al. [31] provided an exhaustive historical analysis of the relationship between the impact a paper exerts on the scientific community, and the extent of collaboration between its authors, on the basis of articles indexed in Science Citation Index (SCI), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI), published from 1900 to 2011. In general, the authors observed a steady trend towards the increase in cooperation from 1900 onward. During the course of the century, this tendency was constantly strengthening, and this so-called inflation of collaboration phenomenon, by and large, allows the achievemenet of high citation scores [31]. What is more, although self-citations certainly contributed to this effect, they, according to the authors, are not yet a sufficient explanation of the observed correlation. In this context, Larivière et al. pointed to a popular hypothesis: that the most significant research results or problems are nowadays so complex that only a team of experts is able to solve them in a satisfactory manner, which is why in scientific enterprises, usually, "[team] size matters" [31].

Cainelli et al. [34], in turn, examined the relationship between the intensity of co-authorship and productivity of collaborating academics in the field of (Italian) economics. Using the set of publications of the entire identified population of academic economists, the authors showed that this discipline follows the same general pattern which can be observed in the whole network of science. That is to say, Italian economists who are more productive are the ones who, at the same time, are more engaged in collaborative practices. What is more, international collaboration is considered to be the foremost factor responsible for enhancing the level of productivity, and quality of a particular research endeavor [34]. A non-negligible variable, which also had to be taken into consideration, and which positively affects productivity, is the stability of the cooperation, i.e., its ability to last for a relatively long period of time [34].

2.3. Bibliometric Approach in Scientific Collaboration Studies

Bibliometrics has constituted an integral part of the LIS discipline for over a century, whereas scientometrics and informetrics supplemented the set of techniques used by LIS specialists shortly afterwards (see e.g., [35,36]). The analyses of quantitative aspects of library activities, information retrieval, information user behavior and other closely LIS-related objects, their properties, or relationships between them, have many different forms and utilize a wide range of methods. Common problems undertaken within this particular orientation of LIS research comprise, i.a., the constant growth in information resources; obsolescence of library materials; "laws" of bibliometrics, e.g., Bradford's law of scattering; citation analysis and citation-based authors' scientific performance indicators, etc. Cooperation and collaboration are also discernible amongst them and are investigated from many different angles.

One of the most recognized and influential works on the subject in question, i.e., a bibliometric perspective in cooperation studies, is a paper authored by Katz and Martin [19], in which the authors proposed a tentative categorization of main research directions taken within this problem area. The categories can be summarized as follows: (i) ways and means of measuring collaboration; (ii) factors encouraging (or hindering) collaboration; (iii) sources of collaboration, e.g., communication channels, physical or social proximity; and (iv) effects that collaboration exerts on productivity and the quality of co-authored papers [19].

Another relatively early paper, which is worth mentioning, is one written by Melin and Persson [27]. The authors decided to exploit a bibliometric approach in their analysis of numerous aspects of the collaboration phenomenon, as well as potential problems that a researcher can encounter when choosing this form of study. Within the frame of this task, they stressed the need for careful gathering, validation and standardizing of empirical data, and selecting the appropriate level of their aggregation, and emphasized the significance of considering the strength of interactions between the academic and industrial sectors, which are seen as a symptom of the advancement of research and development (R&D) activities [27]. Moreover, the authors ascertained that different fields are characterized by different shares of collaborative papers published in cooperation with some particular countries [27]. The last-mentioned phenomenon was also discovered by Luukkonen et al. [22], who showed that various domains of science are characterized by various (international) collaboration habits, practices, or conventions [22].

A deep, multidimensional analysis of international cooperation was conducted by Glänzel [32], who tried to answer four research questions: (i) how strong is the influence of economic and political circumstances on the collaboration patterns, (ii) is national publication strategy shaped by international collaboration, (iii) how far does international cooperation determine publication channels chosen by scientists, and (iv) do internationally co-authored papers have greater citation rates than the papers that resulted from purely national collaboration [32]. Glänzel and Schubert [20] gave special focus to multinational collaborations in the context of globalization and the political changes that arose in Europe during the last two decades of the 20th century. The authors made use of bibliometric data that were available in SCI, and substantiated the assumption that international co-authorship linkages were subjected to dramatic structural alterations directed towards the growth of the share of inter- and multinationally co-authored publications. The factors which influence the mechanisms and intensity of international cooperation are, according to

Glänzel and Schubert, chiefly of geographical, economic, geopolitical, and demographical nature. Besides that, there are also factors connected to the history, culture, and language that prevail in a particular country [20].

The global network of cooperating scientists has also become a subject of interest for Wagner et al. [37], who took into consideration the network properties inferred by the means of social network analysis (SNA), as well as their implications for current national science policy. Typical SNA techniques and coefficients, such as the number of nodes (i.e., countries), links (i.e., citations), network density, and betweenness and clustering coefficients, etc., allowed the authors to identify the rudimentary features of a network as a whole. The general evolution of the shape and properties of the network is, according to the authors, a result of interactions taking place between smaller, nationally driven networks. The authors pointed especially to the geographically isolated networks of scientists, as well as to the underdeveloped ones, and the ones that maintain exceptionally strong national identity (e.g., Scandinavian countries). On the other hand, there is the global, all-encompassing structure of scientific links which arises as a result of interactions taking place at the lower level of aggregation [37]. Wagner et al. stressed that such networks operate powered by rules of reciprocity, trust, openness, and mutual exchange, and those are the skills, requirements, or directions that a reasonable (and sustainable) policy of science needs to be oriented around [37].

One of the most intriguing and advanced propositions of the methodological application of mathematical methods to analyze scientific collaboration was recently presented by Zhang et al. [28]. The authors named three main forces, or mechanisms, which determine the process of the temporal evolution of the (social) scientific network of co-authorship. The first one, homophily, is a measure of the homogeneity of connected scholars. That is to say, this quotient informs us how members of a group express a tendency to make connections with those who are similar to them from some point of view. E.g., homogeneity can encourage scientists of a similar educational background to work together. The second force is transitivity, which imposes the emergence of connections between those nodes of a network which are already connected to some other joint node or nodes. It can be understood as a preference of scholars to find their own collaborators by looking at their co-authors' collaborators [28]. The last and key force that the authors refer to is the so-called preferential attachment, i.e., an inclination towadrs the linkage of a node with those nodes that already have many connections. This can be regarded as a process of the accumulation of connections and is directly related to Price's theory of cumulative advantage in science [28]; see also: [38]. These three mechanisms taken together are meant to grasp and apprehend a general type of authors' behavior, i.e., to predict what decisions, or motives, lie behind an author's choice of his or her collaborators.

2.4. Implications for the Present Study

What follows is the inference of the authors of the present article that, in contrast to other scientific disciplines, e.g., social sciences in general [39], economy [40], medicine [41], materials science [42], multidisciplinary sciences with a special consideration given to STM specialties [29,43,44], or even sustainability science itself (see e.g., [45–50]), up to now there has been no study which investigates collaboration forms and conventions precisely in the field of sustainable LIS.

In summary, it appears that, despite the fact that the practice of scientific collaboration has been thoroughly and fully investigated by the LIS-specialist community plenty of times, there is still a significant gap in the subject literature, which deserves attention. Thus far, there has been no study that would answer the questions posed by the authors, i.e., that would be fully dedicated to patterns of cooperation and co-authorship within the sustainable LIS domain. The authors of the present article intend to fill this research gap and present the results of their insights from quantitative and qualitative perspectives. In particular, the realization of this objective takes the form of investigating the research problems indicated above, reporting the relevant findings, interpreting the observed quantitative patterns in a qualitative manner, and relating the outcomes of the present study to some hypotheses and conjectures that have been presented in the subject literature before. Moreover, the theoretical and practical implications of the present research results have also been underlined.

3. Materials and Methods

3.1. Data Source and Search Query

The research input data were gathered from the Scopus bibliographic database during the systematic literature review [2] conducted as a first stage of the broader and holistic research being conducted by the authors, of which this paper is also a part. There, the main research directions (a.k.a., topical areas) of sustainable LIS were identified, also constituting the research context in this article. The search query, specified below, describing the scope/boundary of the studied field used for data retrieval was specified there as well, along with the justification of both its relevance and selection of the Scopus database as a data source of high integrity.

```
( TITLE-ABS-KEY ( sustainab* )
AND ( TITLE ( library  OR  librari*
OR  ‘‘information scienc*’’ ) )
)
AND  ( LIMIT-TO ( DOCTYPE , ‘‘ar’’ )
OR  LIMIT-TO ( DOCTYPE , ‘‘cp’’ )  OR  LIMIT-TO ( DOCTYPE , ‘‘ch’’ )
OR  LIMIT-TO ( DOCTYPE , ‘‘bk’’ )
)
```

Data was retrieved on the 4 July 2021. The Scopus database is also, of course, a source of data for bibliometric research, including topic modeling studies, for many other researchers, e.g., [51].

3.2. Data Acquisition, Cleaning and Preprocessing

To credibly investigate the subject matter of topics in this paper, additional research-data preparation was required. To properly research the phenomena of collaboration between individual institutions, the affiliation data had to be manually cleaned in a way to be able to identify them unambiguously at the highest level of the organizational unit (because the research on collaboration between individual universities or other entities, but not their departments, was the goal). The first review of data quality revealed that the process could not be effectively automated in any way, due to not only inconsistent names of departments, but also entire institutions. At this stage, each institution was also assigned to one of four categories to further investigate collaboration between the following sectors:

- *Science and research*;
- *Government*;
- *Private*;
- *Non-profit*.

The course of the above-described process and its results in numbers are shown in Figure 1. In the beginning, all the acquired records were validated in terms of their suitability to the subject matter, which resulted in the rejection of 82 scientific papers out of all 833. Then, all records were divided into those with one author and those with multiple authors. At this stage, it turned out that three records had no authorship information at all. Among the scientific papers with many authors, 11 records did not have information about affiliation, and the data in 15 records did not allow for an unambiguous assignment of the affiliating institution. Ultimately, the analyzed dataset contained 293 single-authored records and 429 multi-authored records.

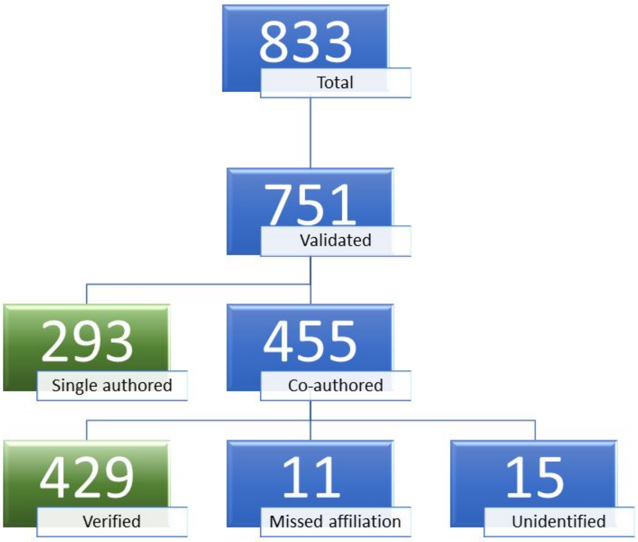

Figure 1. The protocol of data cleaning.

3.3. Trend, Relative Share and Network Analysis

In order to address the research questions formulated in the introduction, the descriptive statistical analysis along with network analysis were performed.

Filtering, sorting, and aggregation of data was performed using an SQL database using data manipulation language (DML) expressions which are part of the structured query language (SQL) specification. A visualization of the descriptive analysis results was made using the capabilities of rendering of charts (enabled by a spreadsheet application) presenting the cumulative share of collaboration (interindividual, international, interinstitutional and cross-sector) over time, broken down by topical areas discovered in the former research of the authors [2]. These are:

- *Information and ICT*;
- *Collections*;
- *Buildings*;
- *Education*;
- *Culture*;
- *Other*.

In each chart, a linear regression line was plotted with the equation describing it and the value of the R-squared coefficient. It should be emphasized, however, that this only served to make general observations, and one should not attach too much importance to the values of individual coefficients, as well as being cautious about predicting the future (extrapolation) on their basis, because linear regression works better to address interpolation issues.

The relational database management engine was also used to prepare input data describing network structures for the Gephi platform [52], which is a tool dedicated to the analysis of network/graph structures, especially in the field of social network analysis (SNA). Gephi is an environment quite often used in bibliometric research, and its support in the field of SNA offers additional interesting possibilities beyond traditional bibliometric analyses [53].

The scientific collaboration network is a network where nodes are authors and links are co-authors, as the latter is one of the most well-documented forms of scientific collaboration [20]. Scientific collaboration can also be studied at higher levels of aggregation—i.e., the authors' institutions with which they are affiliated or the countries from which they come. As collaboration networks are being described by weighted (the collaboration relationship between two given authors is stronger as they cooperate more frequently with each other) but not directed (the authorship is the symmetric relationship) networks, the appropriate SNA metrics to outline the collaboration phenomena should be used. The basic measure for studying collaboration networks in this paper was weighted degree. It can be formalized as:

$$s_i = C_D^w(i) = \sum_j^N w_{ij} \tag{1}$$

where i is the focal node, j represents all other nodes, N is the total number of nodes, and w is the weighted adjacency matrix, in which w_{ij} is greater than 0 if the node i is connected to node j, and the value represents the weight of the edge [54]. As a result, the value of this measure for entities (network nodes) having more collaborators and having collaborators of heavy collaboration.

Additionally, for more complex networks (e.g., authors' collaboration networks), the Leiden community detection algorithm [55] was applied to increase the visibility of the different groups of collaboration. To obtain clean layouts of the network structures, the algorithms based on the force atlas concept [56] and the Fruchterman and Reingold [57] methods were used, which allowed consideration of the weighted nature of collaboration networks.

The weights of edges for all collaboration networks presented in this paper were calculated using the fractional counting method (as opposed to the full counting method), as it is presently believed that the fractional counting method offers a more useful perspective than the full counting one [58].

4. Results

As noted in Section 2, scientific cooperation offers the opportunity to strengthen research activities in terms of quality or pace of development; therefore, research in this area allows for verification of the degree of the actual usage of the potential it brings. Research collaboration can be studied at different levels of aggregation, and this paper explores four levels:

- Interindividual;
- International;
- Interinstitutional;
- Cross-sector.

In the studied period, the average percentage of joint articles in the total number of articles accounted for 38.78%. The first articles from the researched dataset in sustainable LIS were published in 1994, while the first joint article was a year later. However, the regular publishing efforts in terms of joint works (meaning year by year, without any significant breaks) have been made since 2000, which is why the time span of 2000–2020 for the trend analysis was chosen. The smallest team size was obviously composed of two co-authors (the highest percentage was of two-authored works from the total number of joint works, namely, 43%), while the largest team consisted of 14 co-authors (only one paper). In the whole time period studied, the average team size was 2.34 co-authors.

The annual share of joint articles in the total number of articles shows an increasing trend which is presented in Figure 2. The same figure shows that the increasing trend can be observed especially from 2010. As data presented in that figure are broken down by topical areas, a minimal share of the cultural topics can be observed starting from 2011. From the very beginning of the studied time span, the area of *Information and ICT* is the greatest subject studied by joint working, and right behind it is the area of *Other* topics.

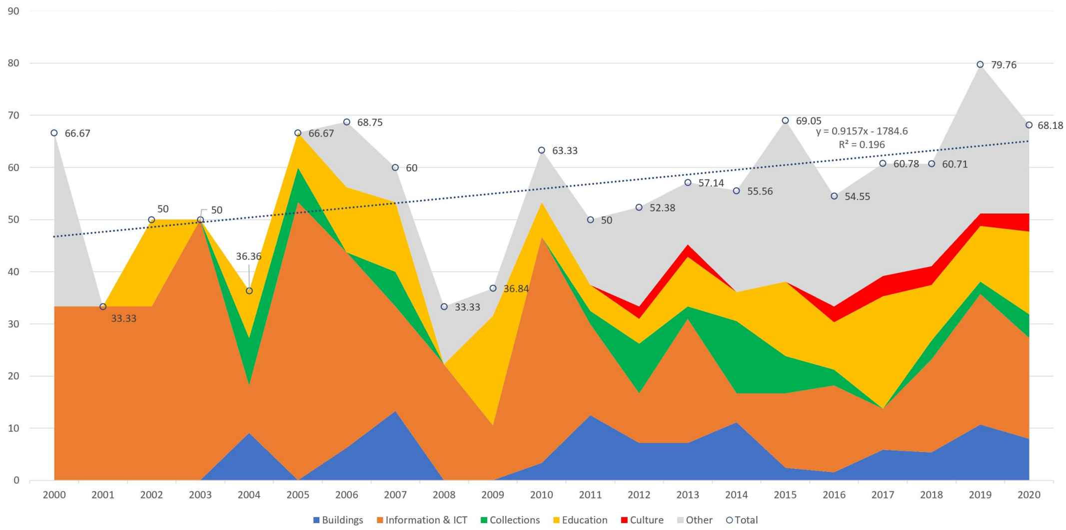

Figure 2. The cumulative share of the joint works in the total number of works in LIS.

Figure 3 presents the data describing international collaboration (defined as the articles co-written by authors affiliated with at least two different countries) in the form of the share of international works in the total number of joint works in LIS. The plotted trend line shows a downward natuer, but one should notice the high dispersion of the data and the resulting low value of the R-squared coefficient. The complete absence of topics related to *Culture* and the small presence of issues related to *Buildings* and *Collections* should be noted here. The percentage value of internationally co-authored scholarly works is 7.2%, which is the minimum value among all studied aggregation levels. The vast majority of international articles were written by authors affiliated with two different countries (76.92%). Fewer collaborative efforts were made between authors affiliated with three different countries (11.54%). Articles written by authors affiliated with four and more different countries also constituted 11.54% of the total number of international articles. The maximum size of co-authorship in terms of internationality was six different countries (two works). Across the studied period, the average team size in terms of internationality was 1.104 countries.

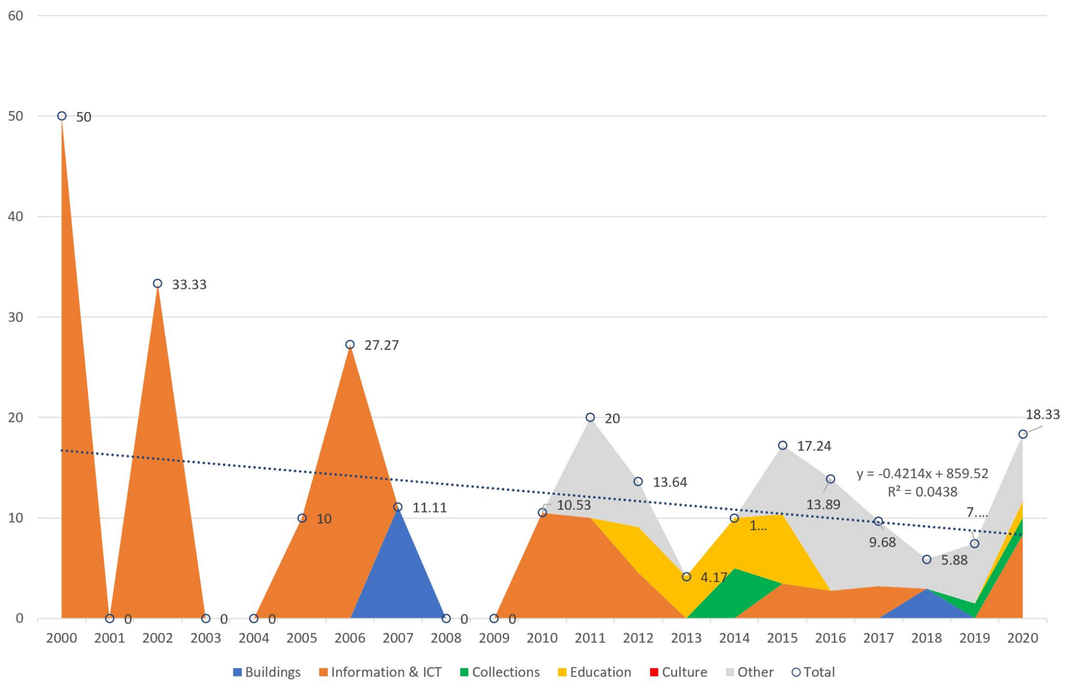

Figure 3. The cumulative share of international works in the total number of joint works in LIS.

The average team size increased to 1.46% when interinstitutional collaboration is the subject of analysis. In addition, in that case, the percentage value of interinstitutionally co-authored scholarly works quadrupled (28.95%) compared to those produced internationally. Unfortunately, the downward orientation of the trend line also became steeper. However, as in the previous case, the value of the R-squared coefficient ratio does not give significant credibility to this trend. Particularly noteworthy here is the presence of much more topical diversity as since 2012 the area of *Culture* appeared, and interest in areas of *Building*, *Education* and *Collections* significantly increased, which can be clearly seen in Figure 4. Remarkably, since 2018, in both cases (i.e., international and interinstitutional collaboration phenomena), only increases have been recorded.

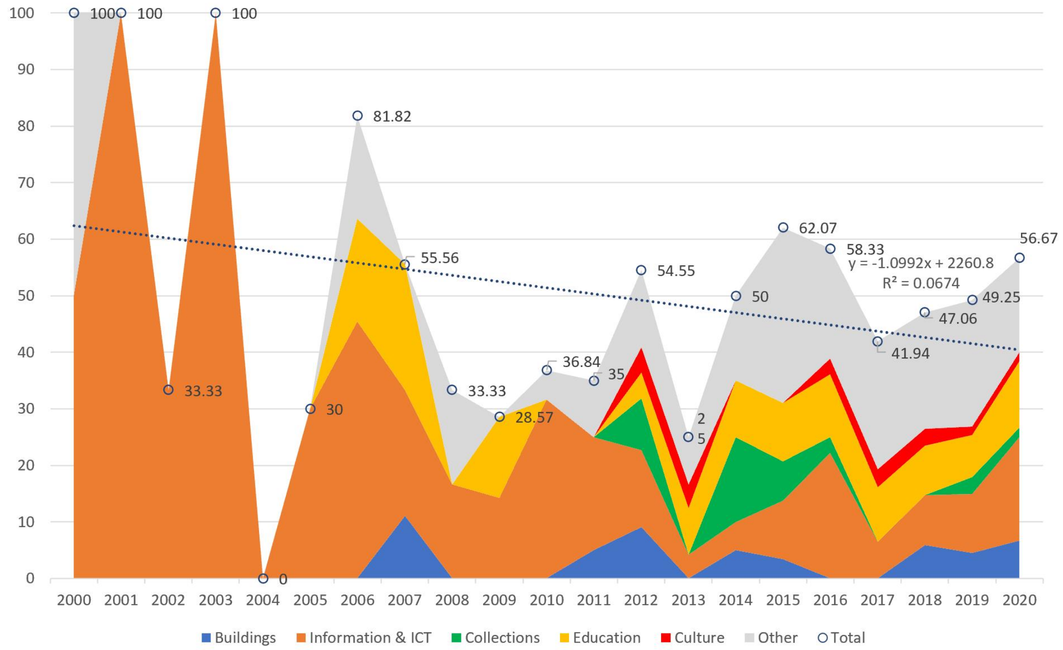

Figure 4. The cumulative share of the interinstitutional works in the total number of joint works in LIS.

When it comes to cross-sector cooperation presented in Figure 5, it appears to be the least optimistic point of the analysis carried out so far. As in the case of international cooperation, since 2008 it has remained below the 20% threshold, but in this case, it is difficult to say that the last three years showed a clear upward trend. An interesting observation is a fact that, in recent years, the *Information and ICT* area is the least represented here, while in every other case it was at the forefront. The percentage share of cross-sectoral scholarly works, however, is slightly higher than that of international ones and amounts to 9.28%. The average team size in terms of cross-sector co-authorship is the lowest (1.098), which means that, on average, all the authors of a given scholarly work were affiliated to institutions of one sector, and only occasionally did the team include authors affiliated with an institution of another sector.

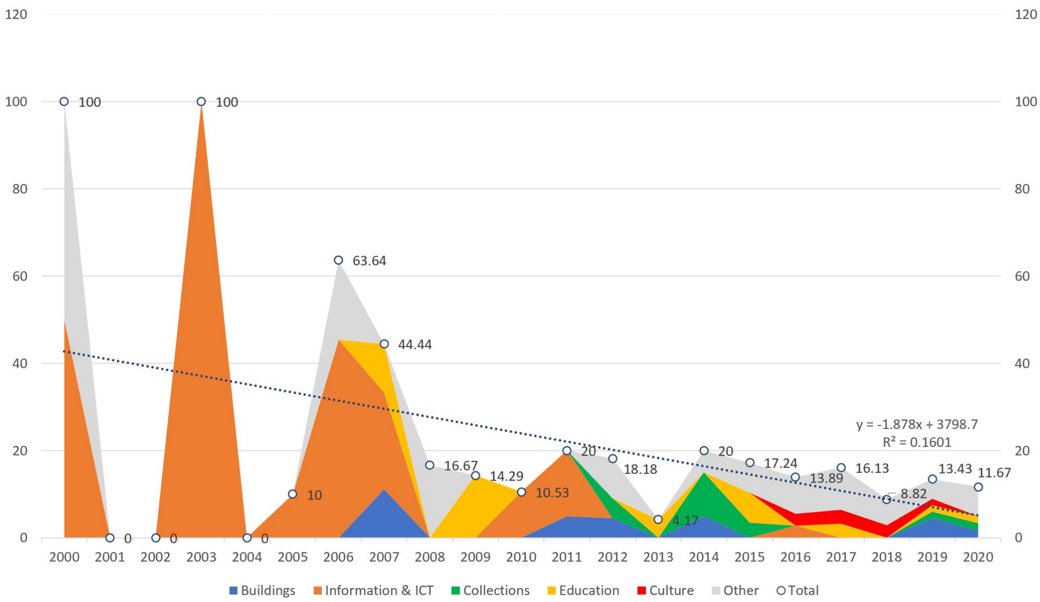

Figure 5. The cumulative share of cross-sector works in the total number of joint works in LIS.

A summary of the data used in the above analyses (but without a breakdown into topical areas) is presented in Table 1.

Table 1. Team size in terms of co-authorships of published works.

Analyzed Works	Number of Works
Interindividual collaboration (collection of N = 442 works)	
Joint works:	442
2 authors	196
3–5 authors	207
6–10 authors	34
≥11 authors	5
Interinstitutional, international and cross-sector collaboration (collection of N = 722 works)	
Single-country works	670
International works:	52
2 countries	40
3 countries	6
4 countries	3
5 countries	1
6 countries	2
Single-institution works	513
Interinstitutional works:	209
2 institutions	141
3 institutions	43
4 institutions	11
5 institutions	5
≥6 institutions	9
One-sector works	655
Cross-sector works	67

Moving on to the analysis of research collaboration networks, the discussion begins with international collaboration visualized on a world map presented in Figure 6. The colors of the territories of individual countries are warmer the more that given country is active with regard to international cooperation. Countries that have not cooperated with other countries at all are gray areas. The phenomena of cooperation between countries are shown by means of green arcs connecting them, while the thicknesses of individual arcs show the weight of the edges of the cooperation network, i.e., the intensity of cooperation—the thicker the arcs connecting two countries, the stronger they cooperate with each other. Out of 78 countries dealing with the topics of sustainable LIS in the analyzed period, 50 countries did so in cooperation with other countries. Each of these 50 countries cooperated on average with a little fewer than four other countries (3.8 to be exact), but the distribution of individual values was far from being evenly distributed. The leading countries cooperating with the largest number of other countries include the USA (19), UK (12), Poland (9), Germany (9), Chile (8), Sweden (8), Denmark (7), Ukraine (6), Norway (6) and South Africa (6).

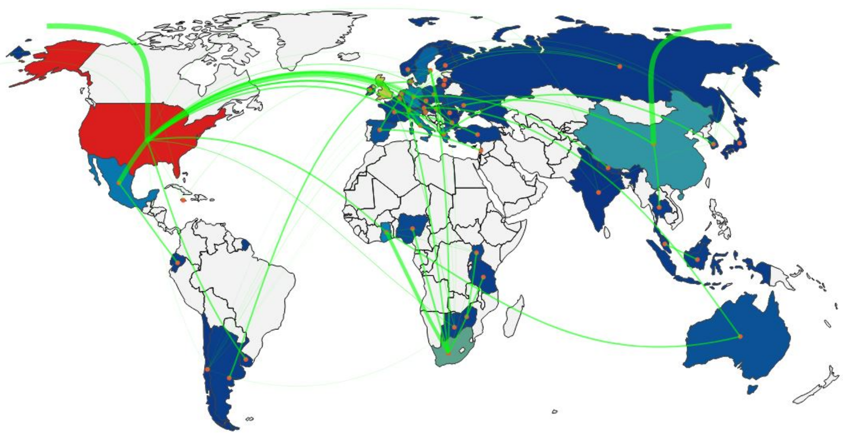

Figure 6. International collaboration in the field of sustainable LIS.

Another perspective is to analyze not the number of cooperating countries, but the amount of effort put into international cooperation calculated by the number (as explained in Section 3 it is calculated fractionally here) of research papers produced internationally. The undisputed leader of that ranking is the United States again, whose total intensity of cooperation is more than twice as high as that of the second most collaborative country—the United Kingdom. The following countries are ranked next: South Africa, China, Ghana, Germany, Greece, Mexico, Italy, and Sweden. The three most intensively cooperating pairs of countries include the USA, and they are: USA–UK, USA–China, and USA–Mexico. Next in the ranking are especially intensively cooperating pairs of countries worth noting: South Africa–Ghana, UK–Italy, South Africa–Nigeria, and Germany–Switzerland.

Although European countries are sparse in the above descriptions, it is worth noting that the collaboration strength of individual European countries in total is more than twice as high as the leader—the USA—and the third most internationally cooperating continent (after North America) is Africa, although it is largely local cooperation, i.e., between countries of this particular continent.

The vast majority of issues raised in the international arenas concerned the topics of *Information and ICT* and *Other*, while the subject of *Building* was the least discussed—this was the case only for two pairs: UK–Denmark and Spain–Lebanon.

In the next step, the phenomenon of interinstitutional collaboration was analyzed. The network of worldwide cooperation between the institutions is shown in Figure 7. In the given period, a total of 705 institutions participated in the preparation of all analyzed scientific works, of which 436 collaborated with another institution at least once. Each of these 436 institutions collaborated, on average, with 2.5 other (2.518 to be exact) institutional entities; however, almost half (202) cooperated with only one other partner. The institutions that collaborated with the greatest number of other entities were the University of California (12), the Information Society Development Foundation (10) and Washington University in St. Louis (10). At first glance, the graph reveals that it depicts a relatively sparse network.

The node-placement algorithm applied ensures that the most important (in the sense of the most intensively cooperating) institutions are placed in the center of the network, while the entities that are less interested in scientific collaboration are placed outside. However, some clusters of connected entities that, nevertheless, find themselves outside may attract attention as well. These are, however, the cases of groups of numerous institutions, but cooperating in the development of sparse scientific works. For example:

- Blue cluster (10 o'clock)—[59,60];
- Orange cluster (8 o'clock)—[61];
- Pink cluster (2 o'clock)—[62].

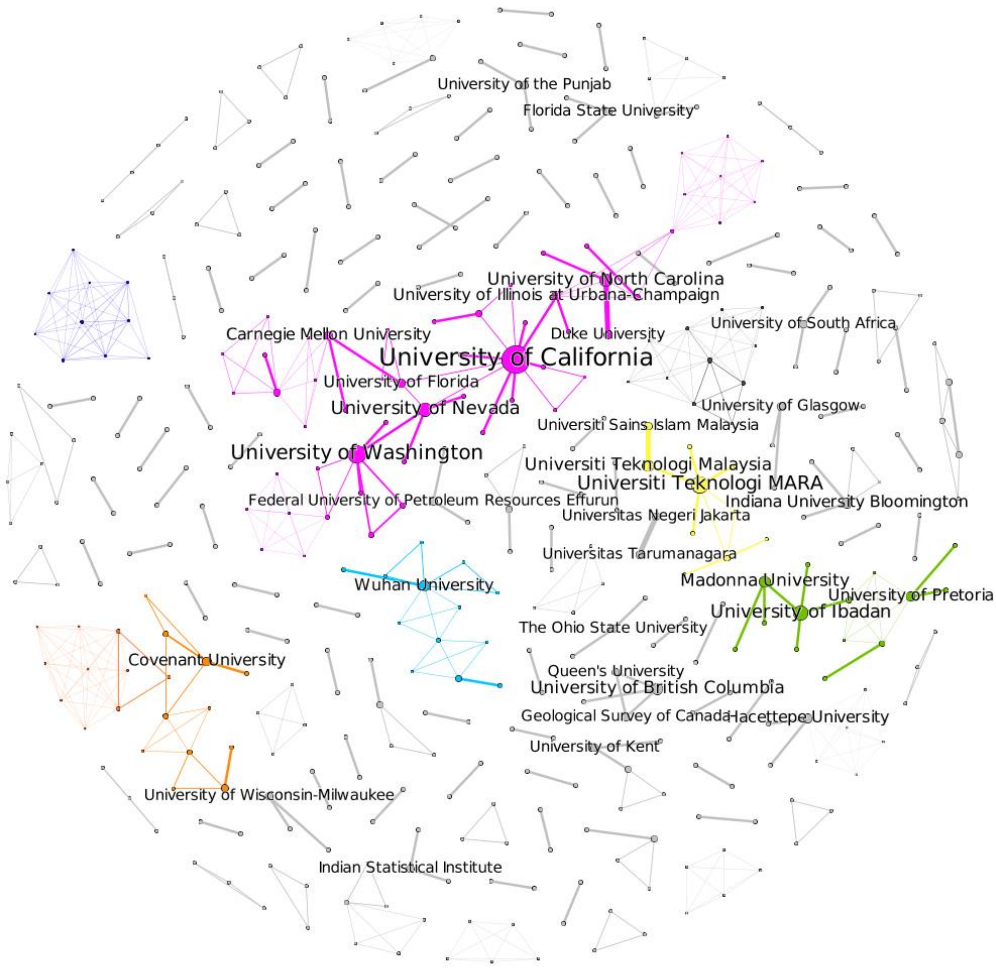

Figure 7. The network of interinstitutional collaboration in the field of sustainable LIS.

However, focusing on the leaders, it is worth noting that the size of the node shows the degree of cooperation between institutions, and the size of the node label is proportional to the size of the node. In order not to obscure the graph, it was decided to label only a few leading institutions of ranking. These are (in descending order):

- University of California (USA);
- University of Washington (USA);
- Universiti Teknologi MARA (Malaysia);
- University of Ibadan (Nigeria);
- University of Nevada (USA);
- University of North Carolina (USA).

On the other hand, the strictest cases of cooperation between two institutions are (in descending order):

- University of North Carolina (USA)–Duke University (USA);

- Universitas Negeri Jakarta (Indonesia)–Universitas Tarumanagara (Indonesia);
- Universiti Sains Islam (Malaysia)–Universiti Teknologi (Malaysia).

When comparing the results of research on international cooperation and on interinstitutional cooperation, significant differences can be noticed. In the most common case, the nationality of the institution does not coincide with the most intensively cooperating countries. An attempt to explain this phenomenon has been made in the next chapter.

Regardless of the previously described ranking of the most intensively cooperating institutions and the cases of the most fruitful cooperation between pairs of entities, it is advisable to pay attention to the clusters of cooperating institutions represented by individual colors in Figure 7. Magenta, yellow, blue, orange, and green clusters are clearly visible here. The magenta-colored cluster comprises a total of 54 institutions, mainly from the USA, but also from Mexico and African countries. The yellow cluster is made up of 10 institutions, 8 of which are from Malaysia and 2 are from Indonesia. The green group consists of 14 institutions, 12 of which are from African countries, 1 from the USA and 1 from Sweden. The blue cluster includes 13 very diverse institutions (China, UK, USA, Italy, Slovenia), while the orange cluster includes 11 institutions of African countries exclusively.

When analyzing the cross-sector collaboration, it appeared that the sector of the greatest collaboration (46.23%) is *science and research* (i.e., universities, research institutes, academies of sciences), which is in-line with the expectations of the authors of the present article, as most of the LIS area is about science. It is surprising, however, that *government* units were the least involved (9.8%) in cross-sector cooperation. All relationships between the different types of institutions are shown in Figure 8. The larger the given node is and the warmer its color, the more it is involved in cross-sector cooperation. The edge thickness, on the other hand, shows the intensity of cooperation between the two given types of institutions. It is clearly visible that the sectors of *science and research* and *non-profit* cooperate most willingly, while the weakest cooperation is recorded between *private-other* sectors and between *government–non-profit* ones.

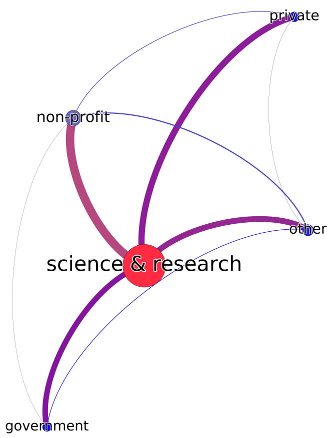

Figure 8. The graph of collaboration among institution types in the field of sustainable LIS.

5. Discussion and Conclusions

5.1. Limitations of the Study

Through the use of bibliometrics and social-network analysis, this paper has mapped out the trends in scholar collaboration as well as the collaboration networks structure within research related to the field of sustainable LIS. Certainly, research conducted within this paper is not without limitations. The use of only one database may have excluded some results. While the Scopus database, which was used for data retrieval in this study, is considered the most complete [63], there are also other good sources of bibliographic information, such as Web of Science and Google Scholar. Similarly, though the language of the publications was not an explicit exclusion criterion, the search terms were not translated into other languages. This means that the scholar contributions of non-English speaking countries have likely been minimized. One more possible limitation was also the form of the literature sources taken into consideration. To put it differently, due to the indexing policy adopted by Scopus, some materials other than journal articles, e.g., books, conference proceedings, legal acts, patents, doctoral theses, etc., could have been unintentionally excluded from the authors' perception.

It seems also worth mentioning that relying solely on written publications could be perhaps seen as a quite serious restriction when one considers the fact that sustainability issues are so strongly connected to the whole public sphere. That is to say, sustainability ideas spread not only through scientific papers but are present in today's society in the form of events, meetings, social-media initiatives, schools' curricula, exhibitions, and governmental programs, etc. Therefore, it is important to notice that the wide range of ways in which the sustainability movement is manifested is obviously too difficult to grasp in a single paper. That is why all of these phenomena were excluded from the analysis on the basis of the authors' initial research assumptions.

5.2. General Considerations

Nevertheless, in addition to the numerical results presented in the previous chapter, some conclusions and comments of a more general nature can also be drawn. First, what seems obvious, but should anyway be emphasized here, it should be remembered that the field of LIS, as such, is a highly interdisciplinary area that deals with issues that often fall into orthogonal categories of classifications of fields and disciplines of science (e.g., Civil and Environmental Engineering, Culture, IT).

Each of these core disciplines may have and do have different inclinations in terms of research collaboration, i.e., cultural issues tend to be more resistant to cross-national or cross-continental propagation, civil engineering may be more resistant to crossing the boundaries of climate zones, while information technologies are unlikely to encounter such barriers. This assumption seems to be not only consistent with the empirical results presented in Figure 3, where the almost complete absence of the *Cultural* and *Building* topical areas may be observed, but also with findings of other researchers of sustainable development fields, such as Yarime et al. [5].

Another interesting observation is that in the case of the studied field, the phenomenon of intensification of international cooperation is almost not connected with the intensification of inter-institutional cooperation. In other words (with the exception of the undisputed leader of both rankings—the USA), the countries with the most developed international cooperation did not have the most developed interinstitutional one. This, in turn, may mean that, for example, less developed countries are aware of the need to "import" foreign knowledge that they would not have a chance to obtain by limiting themselves to interinstitutional cooperation. In addition, vice versa—institutions in countries where domain science is well-developed more willingly cooperate with nearby institutions. However, it should be remembered that the relationship of co-authorship is not a directed relationship; therefore, it is impossible to clearly define the directions of the aforementioned "importing" of knowledge here.

5.3. Properties of Collaboration Networks

As already mentioned, the global networks of scientific collaboration in sustainable LIS research are relatively sparse, i.e., fragmented with a large number of isolated (independent) research endeavors, even when one takes into consideration the existence of a few more conspicuous research hubs (see: Figures 6 and 7). Essentially, a similar conclusion can be drawn on the basis of the data presented in Table 1, i.e., the numbers of collaborating institutions, countries, and sectors drop sharply when the number of parties involved rises. For example, the number of papers written by authors from more than two countries is five times smaller than the number of works resulting from cooperation between two countries. This may indicate that each country has its own specialization within the sustainable LIS domain, and it is presumably no easy task to find a potential research partner outside an author's environment, i.e., a co-author from abroad. Furthermore, this is precisely the same situation which was reported by Yarime et al. [5] , who stated that the focus of the research on general sustainability dilemmas, i.e., discounting the sustainable LIS specialty, is very different depending on the country. In the light of the authors' results, it could be hypothesized that the same holds true in case of sustainability LIS literature.

A markedly uneven network of interinstitutional and international cooperation could also be interpreted in the categories of the field's level of interdisciplinarity and consistency, which can, to a degree, determine the state, structure, and shape of the considered network. In other words, sustainable-oriented LIS discipline, at the very core of it, might be not consolidated enough to assure even possibilities for many diverse scholarly communities to exchange ideas, and mutually stimulate each other intellectually (see, e.g., [64]).

Previous studies by authors [2] showed an overall increase in research productivity over time, as measured by the number of published research papers. As shown in Figure 2, this growth is also accompanied by an increase in interindividual collaboration. Unfortunately, the same cannot be said unequivocally about international and interinstitutional cooperation. On the other hand, the trend lines are falling, but they are drawn starting from years when scientific works on LIS fields were not too numerous, and, therefore, they may be unrepresentative. Nonetheless, looking from the perspective of the last few years (more specifically, from 2018), it can be said that there is an upward trend after all. When it comes to trend analysis, it is also worth noticing that the perspective of cross-sector cooperation looks the worst, where, regardless of the adopted observation time range, it is difficult to recognize any upward trends.

The outcomes of the authors' research for the presented article confirm the commonly maintained assertion that, indeed, in terms of a number of co-authored works published in the period of study, there is a pronounced tendency towards greater engagement in collaborative enterprises by members of sustainable LIS specialists' worldwide community (see: Figure 2). Nevertheless, when one turns his or her perspective to the intensity of cooperation between different units, i.e., institutions or countries, the situation changes. Instead of dynamically evolving and advancing scientific relationships, additionally spurred by the more and more common cooperation activities, there is a sort of stagnancy with only slightly growing pervasiveness of collaboration, and co-authorship practice, as measured by parametric indicators applied by the authors. This aspect of the network visualized by the authors seems to be a characteristic mark of the discipline under study, i.e., the sustainable LIS domain, and this is in stark contrast with a great deal of other sustainability-related fields of science. Other social sciences and, admittedly to a lesser degree, humanities, have since been significantly affected by the "collaboration inflation" phenomenon, which was shown in the subject literature (see e.g., [29,39,65–68]). For instance, Wuchty et al. [29] reported a noticeable shift towards teamwork which took place in social sciences between 1955 and 2000. Whereas in 1955, the social-scientist community wrote 17.5% of the published papers in teams, in 2000 they wrote as much as 51.5% co-authored works, which, according to the authors, is an increase similar to the one which occurred in natural sciences and engineering. The authors also made a remark that the mean size of a team has, likewise, grown considerably each year [29]. After 2000 this trend continues, which was observed, i.a., by Henriksen [39]. The author stated, namely, that between 1980 and 2013 the majority of social research fields have shown a compelling rise in the share of co-authored and also internationally co-authored publications, as well as in numbers of authors per paper. However, there were large variations between particular disciplines in the scope of these increases [39]; see also: [69,70].

Disciplines other than social or humanistic ones, on the other hand, are an example of yet another state of affairs. Engineering, technology, natural and biomedical sciences are witnessing so powerful a rise in co-authorship that it is difficult even to compare it to the one that is taking place in soft sciences. It is sometimes said that, nowadays, we are facing "the demise of a lone star" in the scientific publication landscape [40]; see also: [71,72].

The uncovered not-very-high involvement in scientific collaboration within the sustainable LIS could, then, be quite a unique attribute which should be further investigated, corroborated and explained qualitatively. At present, it could be only tentatively assumed that the lower level of cooperation observed in the authors' study might be ascribed to factors similar to those that were referred to above. Apart from that, it is also possible that there are other than purely scientific incentives, hard to detect social and conceptual dimensions of co-authorship, and that the number of co-authored works is rather a reflection of scientists' individual behavior; motivations; decisions; practices; or informal, local rules that prevail in a given institution, than a sign of intellectual contributions to strictly scientific cooperation (see e.g., [73–75]). Such problems are considered to cause a bias in quantitative studies and distort the picture of results obtained within their frame. Besides the already mentioned forces, Sonnewald [26] also named political ones, socioeconomic and socio-technical ones, legal ones, or administrative ones. The list of these comprises, thus, among others, available communication technologies, mutual learning skills, ways of disseminating research results, accessibility of resources, social networks, and other hard-to-detect personal factors [26]. All of these components are dynamic and intertwined with each other; their specificity is formal or informal; and the informal ones, e.g., traditions and norms, are sometimes said to be a truly powerful driving force in every scientific endeavor. In summary, all create an environment in which the real-life research process has to be realized. However, a more detailed examination of the role and scale of the impact of such non-scientific components of the research collaboration process requires other techniques of analysis, i.a., a survey, an interrogation, case studies etc., and such insights are outside the objective and scope of the present article.

The claim of Khalid et al. [8], that sustainable LIS is a fairly newly emerging research field , and bearing in mind the fact (or maybe a well-empirically grounded assumption), that such fields are in a phase of constant development, rapid expansion, differentiation, and slowly upcoming gradual unification of their key concepts, seem to be also in accordance with the aforementioned line of reasoning.

5.4. Concluding Remarks

The apparent contradiction between coauthorship patterns prevailing in the sustainable LIS domain and patterns dominant not only in the hard, but also in the soft sciences seems to deserve subsequent substantiation and explanation. This deviation is also one of the issues which has significant potential for further research directions. To put it another way, sustainable LIS, despite its high level of interdisciplinarity and strong ties with many different social and even technical disciplines, with respect to the identified properties, resembles the humanities more than any other group of sciences. It is a somewhat unexpected behavior, and, therefore, it gives the impression that this aspect of the authors' study is suitable for further exploration. In order to obtain a yet more complete landscape of the field of sustainable LIS, in addition to research on explicit collaboration (co-authorship) implemented in this study, it is also recommended to analyze implicit cooperation (i.e., citation phenomenon), and the scientific productivity within the individual, previously extracted by the authors, topical areas. These will, likewise, be the directions of the authors' future research. It is the authors' assumption that this kind of analysis should allow for the verification of a hypothesis concerning the possible acceleration of a field's pace of development being a result of the "collaboration inflation" phenomenon. Such verification could be performed, e.g., through the means of comparing indicators of collaboration intensity to the relative age of references cited in a discipline in a given time period. The second hypothesis, which could be substantiated or undermined on the grounds of sustainable LIS domain as a part of the authors' future work, is the one that deals with supporting and strengthening the process of technological innovation creation. In other words, if the boost in cooperation between groups of scientists indeed matters in this respect, this effect should be somehow visible in terms of their publication output. One way of measuring this influence might be to use patent data as a quantifiable coefficient of the hypothesized effectiveness of joint collaboration.

The theoretical and practical value of the present study can be summarized as follows. First of all, research on scientific cooperation contributes to a better understanding of modern scientific communication practices, which partly determine the quality and quantity of works published in a discipline. Secondly, bibliometric exploration of a chosen field of science can be beneficial for authors who develop and cooperate within this field. Through the bibliometric mapping of its thematic structure, the authors become aware of the level of advancement of its different subfields, and are then able to identify potential research gaps. Thirdly, detailed recognition of the most important and most recent research directions can assist librarians in expanding and updating information-retrieval languages. It appears that this aspect constitutes the possibility of improving the level of satisfaction of the actual library users. The last thing which comes up as advantageous is the authors' hope that their work will further arouse an interest in sustainability ideas among the other members of the scientific community, especially among librarians, which may result in new sustainable library concepts, activities, initiatives, and publications.

Generally speaking, the research results demonstrated in the present study can also be of practical value to scientific policymakers, for example, when they struggle to understand how to effectively bond together the various "niche strengths" in a given country and improve conditions, which usually relies on the establishment of interinstitutional, international, or cross-sector cooperation. Such conditions consist of factors such as, e.g., proper funding allocation; tenures received; serving scientific apprenticeships' establishing formal and informal professional relationships, e.g., "invisible colleges"; and deciding which conferences to attend, etc. The pragmatic potential of the results obtained by the authors seems to be also visible in one more sector. Namely, the surprisingly low share of governmental, private, and non-profit organizations in publishing efforts should certainly be highlighted. This is a clear symptom of a need to elaborate on a way of encouraging such units to engage in sustainability debates more deeply.

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References

1. Kajikawa, Y.; Ohno, J.; Takeda, Y.; Matsushima, K.; Komiyama, H. Creating an academic landscape of sustainability science: An analysis of the citation network. *Sustain. Sci.* **2007**, *2*, 221–231. [CrossRef]
2. Kamińska, A.M.; Opaliński, L.; Wyciślik, L. The Landscapes of Sustainability in the Library and Information Science: Systematic Literature Review. *Sustainability* **2022**, *14*, 441. [CrossRef]
3. Antonelli, M. The Green library movement: An overview of green library literature and actions from 1979 to the future of green libraries. *Electron. Green J.* **2008**, *27*, 1–11. [CrossRef]
4. Spink, A. Information and a sustainable future. *Libri* **1995**, *45*, 203–208. [CrossRef]
5. Yarime, M.; Takeda, Y.; Kajikawa, Y. Towards institutional analysis of sustainability science: A quantitative examination of the patterns of research collaboration. *Sustain. Sci.* **2010**, *5*, 115–125. [CrossRef]
6. Aria, M.; Cuccurullo, C. bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Inf.* **2017**, *11*, 959–975. [CrossRef]
7. Ozyurt, O.; Ayaz, A. Twenty-five years of education and information technologies: Insights from a topic modeling based bibliometric analysis. *Educ. Inf. Technol.* **2022**, *27*, 11025–11054. [CrossRef]
8. Khalid, A.; Farid, G.; Mahmood, K. Sustainable development challenges in libraries: A systematic literature review (2000–2020). *J. Acad. Librariansh.* **2021**, *47*, 102347. [CrossRef]

9. Meschede, C.; Henkel, M. Library and information science and sustainable development: A structured literature review. *J. Doc.* **2019**, *75*, 1356–1369. [CrossRef]
10. Meschede, C.; Henkel, M. Information science research and sustainable development. *Proc. Assoc. Inf. Sci. Technol.* **2018**, *55*, 871–872. [CrossRef]
11. Repanovici, A.; Rotaru, C.S.; Murzea, C. Development of sustainable thinking by information literacy. *Sustainability* **2021**, *13*, 1287. [CrossRef]
12. Beutelspacher, L.; Meschede, C. Libraries as promoters of environmental sustainability: Collections, tools and events. *Int. Fed. Libr. Assoc. Institutions J.* **2020**, *46*, 347–358. [CrossRef]
13. Van Eck, N.J.; Waltman, L. VOSviewer Manual. 2020. Available online: www.vosviewer.com/documentation/Manual_VOSviewer_1.6.15.pdf (accessed on 29 January 2022).
14. Smith, M. The trend toward multiple authorship in psychology. *Am. Psychol.* **1958**, *13*, 596–599. [CrossRef]
15. de Solla Price, D.J. *Little Science, Big Science*; Columbia University Press: New York, NY, USA, 1963. [CrossRef]
16. Clarke, B.L. Multiple authorship trends in scientific papers. *Science* **1964**, *143*, 822–824. [CrossRef]
17. Meadows, A.J.; O'Connor, J.G. Bibliographic statistics as a guide to growth points in science. *Sci. Stud.* **1971**, *1*, 95–99. [CrossRef]
18. de Beaver, D.; Rosen, R. Studies in scientific collaboration: Part II—Scientific co-authorship, research productivity and visibility in the French scientific elite, 1799–1830. *Scientometrics* **1979**, *1*, 133–149. [CrossRef]
19. Katz, J.S.; Martin, B.R. What is research collaboration? *Res. Policy* **1997**, *26*, 1–18. [CrossRef]
20. Glänzel, W.; Schubert, A. Analysing Scientific Networks through Co-Authorship. In *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems*; Moed, H.F., Glänzel, W., Schmoch, U., Eds.; Springer: Dordrecht, The Netherlands, 2004; pp. 257–276. [CrossRef]
21. Beaver, D. Reflections on scientific collaboration (and its study): Past, present, and future. *Scientometrics* **2001**, *52*, 365–377. [CrossRef]
22. Luukkonen, T.; Persson, O.; Sivertsen, G. Understanding patterns of international scientific collaboration. *Sci. Technol. Hum. Values* **1992**, *17*, 101–126. [CrossRef]
23. Beaver, D.; Rosen, R. Studies in scientific collaboration: Part I—The professional origins of scientific co-authorship. *Scientometrics* **1978**, *1*, 65–84. [CrossRef]
24. Andrade, E.N.D.C. The birth and early days of the Philosophical Transactions. *Notes Rec. R. Soc. Lond.* **1965**, *20*, 9–27.
25. Cronin, B. Hyperauthorship: A postmodern perversion or evidence of a structural shift in scholarly communication practices? *J. Am. Soc. Inf. Sci. Technol.* **2001**, *52*, 556–571. [CrossRef]
26. Sonnenwald, D.H. Scientific collaboration. *Annu. Rev. Inf. Sci. Technol.* **2007**, *41*, 643–681. [CrossRef]
27. Melin, G.; Persson, O. Studying research collaboration using co-authorships. *Scientometrics* **1996**, *36*, 363–377. [CrossRef]
28. Zhang, C.; Bu, Y.; Ding, Y.; Xu, J. Understanding scientific collaboration: Homophily, transitivity, and preferential attachment. *J. Assoc. Inf. Sci. Technol.* **2018**, *69*, 72–86. [CrossRef]
29. Wuchty, S.; Jones, B.F.; Uzzi, B. The increasing dominance of teams in production of knowledge. *Science* **2007**, *316*, 1036–1039. [CrossRef]
30. Beaver, D.d. Collaborative research have greater epistemic authority? *Scientometrics* **2004**, *60*, 399–408. [CrossRef]
31. Larivière, V.; Gingras, Y.; Sugimoto, C.R.; Tsou, A. Team size matters: Collaboration and scientific impact since 1900. *J. Assoc. Inf. Sci. Technol.* **2015**, *66*, 1323–1332. [CrossRef]
32. Glänzel, W. National characteristics in international scientific co-authorship relations. *Scientometrics* **2001**, *51*, 69–115. [CrossRef]
33. Franceschet, M.; Costantini, A. The effect of scholar collaboration on impact and quality of academic papers. *J. Inf.* **2010**, *4*, 540–553. [CrossRef]
34. Cainelli, G.; Maggioni, M.A.; Uberti, T.E.; de Felice, A. The strength of strong ties: How co-authorship affect productivity of academic economists? *Scientometrics* **2015**, *102*, 673–699. [CrossRef]
35. Hertzel, D. Bibliometrics, History of the Development of Ideas in. In *Encyclopedia of Library and Information Science*; Kent, A., Lancour, H., Nasri, W., Eds.; Marcel Dekker, Inc.: New York, NY, USA, 1987; pp. 144–219.
36. Hood, W.W.; Wilson, C.S. The literature of bibliometrics, scientometrics, and informetrics. *Scientometrics* **2001**, *52*, 291–314. [CrossRef]
37. Wagner, C.S.; Park, H.W.; Leydesdorff, L. The continuing growth of global cooperation networks in research: A conundrum for national governments. *PLoS ONE* **2015**, *10*, e0131816. [CrossRef]
38. de Solla Price, D.J. A general theory of bibliometric and other cumulative advantage processes. *J. Am. Soc. Inf. Sci.* **1976**, *27*, 292–306. [CrossRef]
39. Henriksen, D. The rise in co-authorship in the social sciences (1980–2013). *Scientometrics* **2016**, *107*, 455–474. [CrossRef]
40. Kuld, L.; O'Hagan, J. Rise of multi-authored papers in economics: Demise of the 'lone star' and why? *Scientometrics* **2018**, *114*, 1207–1225. [CrossRef]
41. Lundberg, J.; Tomson, G.; Lundkvist, I.; Skär, J.; Brommels, M. Collaboration uncovered: Exploring the adequacy of measuring university-industry collaboration through co-authorship and funding. *Scientometrics* **2006**, *69*, 575–589. [CrossRef]
42. Li, Y.; Li, H.; Liu, N.; Liu, X. Important institutions of interinstitutional scientific collaboration networks in materials science. *Scientometrics* **2018**, *117*, 85–103. [CrossRef]
43. Chiware, E.R.T.; Becker, D.A. Research trends and collaborations by applied science researchers in South African universities of technology: 2007–2017. *J. Acad. Librariansh.* **2022**, *44*, 468–476. [CrossRef]

44. Wagner, C.S.; Whetsell, T.A.; Leydesdorff, L. Growth of international collaboration in science: Revisiting six specialties. *Scientometrics* **2017**, *110*, 1633–1652. [CrossRef]
45. Bettencourt, L.M.A.; Kaur, J. Evolution and structure of sustainability science. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 19540–19545. [CrossRef] [PubMed]
46. Buter, R.K.; Van Raan, A.F.J. Identification and analysis of the highly cited knowledge base of sustainability science. *Sustain. Sci.* **2013**, *8*, 253–367. [CrossRef]
47. Hassan, S.U.; Haddawy, P.; Zhu, J. A bibliometric study of the world's research activity in sustainable development and its sub-areas using scientific literature. *Scientometrics* **2014**, *99*, 549–579. [CrossRef]
48. Quental, N.; Lourenço, J. References, authors, journals and scientific disciplines underlying the sustainable development literature: A citation analysis. *Scientometrics* **2012**, *90*, 361–381. [CrossRef]
49. Wichaisri, S.; Sopadang, A. Trends and future directions in sustainable development. *Sustain. Dev.* **2018**, *26*, 1–17. [CrossRef]
50. Zhu, J.; Hua, W. Visualizing the knowledge domain of sustainable development research between 1987 and 2015: A bibliometric analysis. *Scientometrics* **2017**, *110*, 893–914. [CrossRef]
51. Ozyurt, O.; Ozyurt, H. A large-scale study based on topic modeling to determine the research interests and trends on computational thinking. In *Education and Information Technologies*; Springer: Berlin/Heidelberg, Germany, 2022. [CrossRef]
52. Bastian, M.; Heymann, S.; Jacomy, M. Gephi: An Open Source Software for Exploring and Manipulating Networks. In Proceedings of the Third International AAAI Conference on Weblogs and Social Media, San Jose, CA, USA, 17–20 May 2009; Volume 3, pp. 361–362.
53. Kamińska, A.M. The application of methods of social network analysis in bibliometrics and webometrics. Measures and tools. *Nowa Biblioteka. Usługi Technol. Inf. I Media* **2018**, *2*, 29–46.
54. Opsahl, T.; Agneessens, F.; Skvoretz, J. Node centrality in weighted networks: Generalizing degree and shortest paths. *Soc. Netw.* **2010**, *32*, 245–251. [CrossRef]
55. Traag, V.A.; Waltman, L.; van Eck, N.J. From Louvain to Leiden: Guaranteeing well-connected communities. *Sci. Rep.* **2019**, *9*, 5233. [CrossRef]
56. Jacomy, M.; Venturini, T.; Heymann, S.; Bastian, M. ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PLoS ONE* **2014**, *9*, e98679. [CrossRef]
57. Fruchterman, T.M.J.; Reingold, E.M. Graph drawing by force-directed placement. *Softw. Pract. Exp.* **1991**, *21*, 1129–1164. [CrossRef]
58. Perianes-Rodriguez, A.; Waltman, L.; van Eck, N.J. Constructing bibliometric networks: A comparison between full and fractional counting. *J. Inf.* **2016**, *10*, 1178–1195. [CrossRef]
59. Audunson, R.; Aabø, S.; Blomgren, R.; Evjen, S.; Jochumsen, H.; Larsen, H.; Hvenegaard Rasmussen, C.; Vårheim, A.; Johnston, J.; Koizumi, M. Public libraries as an infrastructure for a sustainable public sphere: A comprehensive review of research. *J. Doc.* **2019**, *75*, 773–790. [CrossRef]
60. Audunson, R.; Aabø, S.; Blomgren, R.; Hobohm, H.C.; Jochumsen, H.; Khosrowjerdi, M.; Mumenthaler, R.; Schuldt, K.; Rasmussen, C.H.; Rydbeck, K.; et al. Public libraries as public sphere institutions: A comparative study of perceptions of the public library's role in six European countries. *J. Doc.* **2019**, *75*, 1396–1415. [CrossRef]
61. Rapkin, B.D.; Weiss, E.; Lounsbury, D.; Michel, T.; Gordon, A.; Erb-Downward, J.; Sabino-Laughlin, E.; Carpenter, A.; Schwartz, C.E.; Bulone, L.; et al. Reducing Disparities in Cancer Screening and Prevention through Community-Based Participatory Research Partnerships with Local Libraries: A Comprehensive Dynamic Trial. *Am. J. Community Psychol.* **2017**, *60*, 145–159. [CrossRef]
62. Engeszer, R.J.; Olmstadt, W.; Daley, J.; Norfolk, M.; Krekeler, K.; Rogers, M.; Colditz, G.; Anwuri, V.V.; Morris, S.; Voorhees, M.; et al. Evolution of an academic-public library partnership. *J. Med. Libr. Assoc.* **2016**, *104*, 62–66. [CrossRef]
63. Pranckutė, R. Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World. *Publications* **2021**, *9*, 12. [CrossRef]
64. Schoolman, E.; Guest, J.; Bush, K.; Bell, A. How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. *Sustain. Sci.* **2012**, *7*, 67–80. [CrossRef]
65. Hunter, L.; Leahey, E. Collaborative Research in Sociology: Trends and Contributing Factors. *Am. Sociol.* **2008**, *39*, 290–306. [CrossRef]
66. Ossenblok, T.L.; Verleysen, F.T.; Engels, T.C. Patterns of co-authorship in journal articles in the Social Sciences and Humanities (2000–2010). In *Proceedings of the 17th International Conference on Science and Technology Indicators (STI)*; Archambault, É., Gingras, Y., Larivière, V., Eds.; Observatoire des Sciences et des Technologies: Montreal, QC, Canada, 2012; pp. 640–650.
67. Tang, M.; Liao, H.; Wan, Z.; Herrera-Viedma, E.; Rosen, M.A. Ten years of Sustainability (2009 to 2018): A bibliometric overview. *Sustainability* **2018**, *10*, 1655. [CrossRef]
68. Uzun, A. Assessing internationality of scholarly journals through foreign authorship patterns: The case of major journals in information science, and scientometrics. *Scientometrics* **2004**, *61*, 457–465. [CrossRef]
69. Henriksen, D. What factors are associated with increasing co-authorship in the social sciences? A case study of Danish Economics and Political Science. *Scientometrics* **2018**, *114*, 1395–1421. [CrossRef]
70. Haddow, G.; Xia, J.; Willson, M. Collaboration in the humanities, arts and social sciences in Australia. *Aust. Univ. Rev.* **2017**, *59*, 24–36. [CrossRef]

71. Kwiek, M. What large-scale publication and citation data tell us about international research collaboration in Europe: Changing national patterns in global contexts. *Stud. High. Educ.* **2021**, *46*, 2629–2649. [CrossRef]
72. Wu, L.; Wang, D.; Evans, J.A. Large teams develop and small teams disrupt science and technology. *Nature* **2019**, *566*, 378–382. [CrossRef]
73. Laudel, G. Collaboration, creativity and rewards: Why and how scientists collaborate. *Int. J. Technol. Manag.* **2001**, *22*, 762–781. [CrossRef]
74. Laudel, G. What do we measure by co-authorships? *Res. Eval.* **2002**, *11*, 3–15. [CrossRef]
75. Ponomariov, B.; Boardman, C. What is co-authorship? *Scientometrics* **2016**, *109*, 1939–1963. [CrossRef]