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Article

The Premise of Interdisciplinarity and Its Actual Absence—A Bibliometric Analysis of Publications on Heavy Rainfall

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Abstract: Working together across disciplinary boundaries is considered to be the gold standard for conducting meaningful research tackling complex problems. As this is the nature of many issues concerning water, one would assume interdisciplinarity as being a widespread trait of water research. To review this assumption, we chose to conduct an analysis of research output considering issues of stormwater management and heavy precipitation, as reflected in the meta-information for more than 300,000 documents supplied by Elsevier's Scopus literature database. For this purpose, we applied a bibliometric measure based on Jaccard similarity determining the level of interdisciplinary cooperation between different fields of research on the topic above. Contrary to interdisciplinarity being depicted as highly desirable, it turns out to be a relatively marginal phenomenon, only growing slowly over the last 50 years.

Keywords: bibliometrics; interdisciplinarity; stormwater; flood; heavy rainfall; co-citation

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1. Introduction

Following the Fifth Intergovernmental Panel on Climate Change (IPCC) synthesis report, heavy precipitation events are expected to increase in many parts around the globe [1]. This is of particular concern in urban areas with many impervious surfaces resulting in large volumes of stormwater during precipitation events. Furthermore, ongoing soil compression and sealing enhances pluvial flood risk as infiltration capacity decreases while surface water runoff increases [2,3]. The potential damage, both economic and humanitarian, is enormous. Tragic evidence of this is provided by recent floods, e.g., in Western and Central Europe in 2021 and in Pakistan just this year [4,5]. Furthermore, due to economic reasons, the retention volume of sewer systems is restrained, which has consequences for the environment when the planned for rainfall intensity is exceeded [6]. In order to minimize flooding events, any volume that exceeds the designed limit is released into the environment, often into surface water bodies, consequently polluting aquatic ecosystems [7,8]. The spike in discharge not only causes problems in terms of water quality, but also the sudden increase in shear forces causes erosion, thus destroying aquatic habitats and promoting particle loads [8]. Policy objectives as laid out in the European Union's Water Framework Directive require consequences from heavy precipitation to be minimized [9]. Thus, nature-based solutions for stormwater management are going to be more important in addition to water retention measures in urban areas, such as multifunctional water plazas. This adaptation challenges the common practices of water management, and its implementation relies on its acceptance in politics and society [10]. Thus, the challenges of the water sector are diverse and complex. Environmental protection and maintaining or improving living conditions require an intensive interdisciplinary collaboration.

Nevertheless, contemporary research is institutionalized, mainly in a disciplinary manner [11]. Literature on interdisciplinary research acknowledges that disciplinary approaches are and will always be an important part of any problem-solving strategy [12]. However, to tackle environmental challenges, disciplinary approaches, knowledge and skills need to be integrated to address problems in their full complexity [12–14]. Experts from many disciplines must assist society in a collaborative way, developing solutions for pressing sustainability challenges [11,15]. Tackling complex and multifaceted problems is therefore one key argument for interdisciplinary research [16].

Whether and to what extent research is shifting away from its institutional disciplinary orientation are the subjects of this paper. Here, publications as the subject of scientific output will serve as a measure of interdisciplinary research. We apply a statistical similarity metric to evaluate whether research disciplines are approaching the increasing challenges of water management in an interdisciplinary manner. Using three different resolutions that delineate research fields with increasing levels of detail, we discuss the importance, challenge and opportunities of interdisciplinary research.

2. Understanding Interdisciplinary Research

Although the term interdisciplinarity is used ubiquitously, there is no universal definition [11,17,18]. According to Clark and Wallace, interdisciplinarity is one way to address knowledge specialization in order to solve complex problems [12]. While generally organized in disciplines, interdisciplinarity aims to integrate academic knowledge derived from usually distinct disciplines. Being therefore more demanding than the additive approach of multidisciplinarity, it is less sophisticated than transdisciplinarity. The latter focuses on transcending disciplines to a point where boundaries between them are blurred [12,19], which would achieve the highest degree of interdisciplinarity

Assessing interdisciplinarity faces the challenge of accounting for the degree to which the research output was conducted in an integrative manner [17]. Bibliometric approaches provide a diverse set of quantitative measures to describe research outputs in this regard and have been established as a reliable method (e.g., term counts, publication counts, citation analysis) [11,18,20–22]. The most common bibliometric approach is citation analysis [11,18]. It infers the relation between disciplines from the frequency of accompanying citations. It uses publications as the major research output, although other types of research outputs (e.g., publication counts or keyword counts) may be used [11,23,24].

A requirement for citation analysis is the subdivision of research into subject areas that correspond to disciplinary structures. Here, many bibliometric analyses inherit the categorization provided by scientific literature databases, e.g., Web of Science or Scopus [11,21,25–27]. While this is sufficient for investigating the distribution of subject areas, this does not account for any cooperation of researchers of different disciplinary fields. The subject areas of publications treating a certain issue could mirror the interest of a vast diversity of disciplines; however, all the underlying research may well be conducted in strict disciplines. Therefore, accounting for interdisciplinarity needs a more elaborate measurement indicating the cooperation between disciplines in publishing research outputs.

The core research objectives of this manuscript therefore are:

1. Introduce a measure of interdisciplinarity from citation analysis.
2. Generate a representation of interdisciplinary collaboration ("links") between individual research disciplines.
3. Gain insights into the interdisciplinary nature of research about heavy precipitation.
4. Account for the temporal development of interdisciplinary research on heavy precipitation.

3. Method

The extent of integration of knowledge from different research fields is an indicator for assessing interdisciplinarity, which is a real synthesis of approaches, whereas in multidisciplinarity, different units from different research fields conduct separate research on the same topic [11,23,24]. It can be measured by the differentiation of research fields of cited references. One approach is the integration score I (Equation (1). It implies that greater variety in cited research fields results in greater interdisciplinarity [28].

$$I = 1 - \sum \left(s_{ij} \cdot p_i \cdot p_j \right) \; 0 \leq I \leq 1 \tag{1}$$

s_{ij}: cosine similarity of research field ij
p_i: proportion of referenced research field i
p_j: proportion of referenced research field j

The integration score is based on the application of cosine similarity, expressed by the factor s_{ij}. It determines the similarity of two research fields based on the geometrically mappable distribution of referenced research fields [29]. The integration score is thus an expression of interdisciplinary research in one research field in relation to the entirety of all research fields.

In order to map the collaboration between two individual research disciplines ("exclusively"), integration score and cosine similarity are not appropriate. By aggregating I as an association to all research disciplines s_{ij}, the information of functional composition is lost.

To avoid impairment of these relationships, they can instead be mapped using the Jaccard similarity matrix (Equation (2)).

$$\mathrm{J}(\mathrm{D_i}, \mathrm{D_j}) = \frac{|D_i \cap D_j|}{|D_i \cup D_j|} \tag{2}$$

It expresses the proportion of the intersection of two research fields $|D_i \cap D_j|$ to the entirety of their representations (union) $|D_i \cup D_j|$ in a data corpus. The multiplication of the Jaccard matrix J with the proportional parts p_i and p_j analogous to Equation (1) is omitted. The proportionality is already considered in the denominator (Equation (2)).

Both similarity metrics are based on frequency vectors or matrices that numerically capture the relationship between the research fields. Commonly, similarity metrics are calculated by strictly separating papers and references expressed by co-citation profiles [28,30]. A major drawback of this method is that integration is not properly mapped as the relation between research fields of papers and those of references is missing (Figure 1). Neither the interaction among the research fields of the paper (multidisciplinary), nor the interaction between the research fields of the different literature sources are taken into account (no integration, see Figure 2). Instead, a primary–secondary relationship between paper and the reference research field is induced. In the frequency matrix, only the relationship between paper and referenced research field is mapped as (unique) tuples. Each tuple ij leads to an increment in cells ij and ji of the frequency matrix (Figure 2).

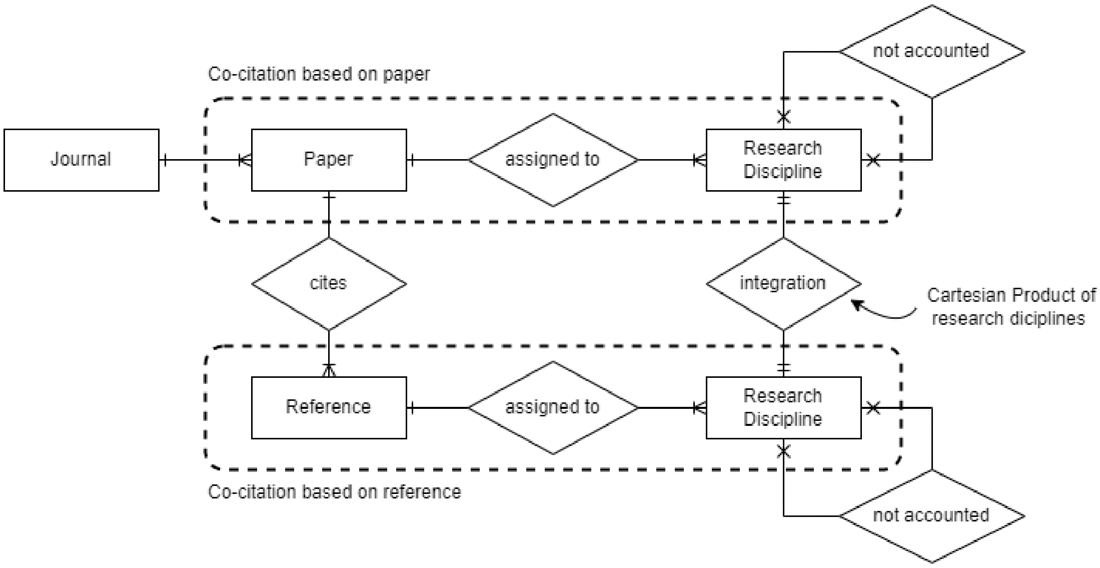

Figure 1. Primary–secondary relation between paper and its references. In conventional co-citation based on paper research disciplines the Cartesian relation between all research disciplines of a paper would be accounted for (upper dashed rectangle). Likewise, in conventional co-citation based on references the Cartesian relation between all referenced research disciplines would be considered (lower dashed rectangle). In this work, solely the Cartesian product between paper research disciplines and referenced research disciplines is considered.

Table 1. Corresponding frequency matrix for Figure 2.

	1 (Diamond)	2 (Circle)	3 (Star)	4 (Triangle)
1 (diamond)	2	1	1	1
2 (circle)	1	2	1	1
3 (star)	1	1	1	0
4 (triangle)	1	1	0	1

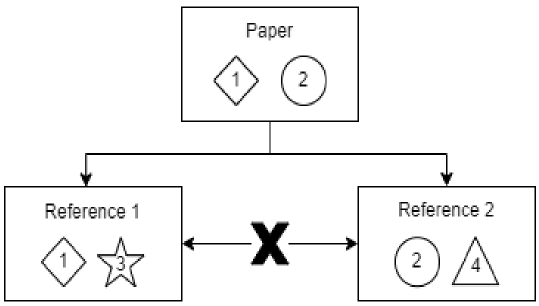

Figure 2. An arbitrary paper assigned to research disciplines 1 (Square) and 2 (Circle). It is assumed that integration of knowledge takes place between the research disciplines of the paper and those of the references, 1 (Square), 3 (Star) and 2 (Circle), 4 (Triangle), respectively. In common co-citation profiles the relation of references 1 (Square) and 2 (Circle) as common references of paper 1 are accounted for (line marked with X). However, there is no similarity between reference 1 (Square) and 2 (Circle), if it was not for the citing paper. Their relationship fails to satisfy the prerequisite of integration. Thus there is no increment for the relation of 3 (star) to 4 (triangle) in the corresponding frequency matrix (Table 1). On the main diagonal, the absolute occurrence of a research discipline is denoted.

The data basis for the frequency matrices $|D_i \cap D_j|$ and $|D_i \cup D_j|$ according to Jaccard is an excerpt from the Scopus database. The excerpt is based on the search string (Figure 3). On the one hand, the search string must be specific enough to represent the key topics of the chain of effects of a heavy rain event up to the urban flash flood. On the other hand, it has been chosen to be abstract enough to include all disciplines and as many subdisciplines as possible. Therefore, commonly used terms were used as hints for the database query. The coverage of the disciplines in the search hits was checked manually. Random 5% of the search hits (881 of 17,622) were manually checked for false positives, and 1.25% (11) of the subset was flagged accordingly. Assuming equal distribution of false-positive hits, the proportion was found to be negligible.

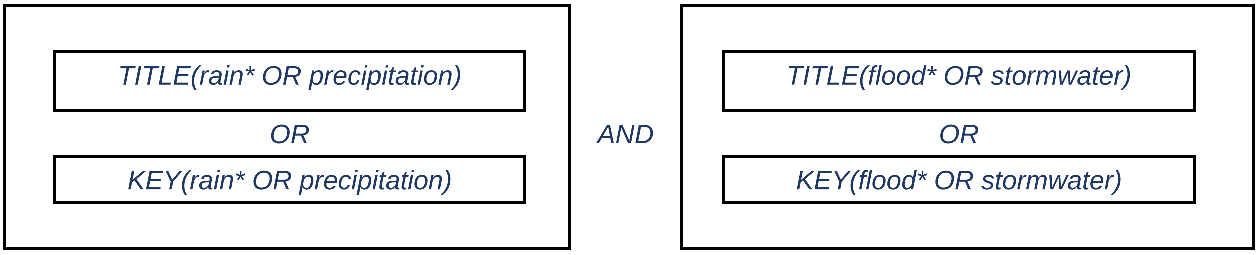

Figure 3. Search string to delimit the research field.

The disciplines are determined based on the Scopus categorization and are presented in three resolutions. Four clusters are divided into 27 areas and the latter are aggregated from 318 classifications (Table S1).

The bibliometric data were retrieved from Scopus via its API using Python 3.7 and the library pybliometrics [31]. Jaccard matrix was computed using Python. Statistical analyses were performed with R (v. 4.1.0). Non-metric multidimensional scaling (NMDS) was performed based on the Jaccard matrix with 1000 permutations using the R package Vegan [32]. The mean of the subject clusters was statistically compared using a pairwise Wilcox test [33,34]. Results were visualized with the R package ggplot2 [35] and CorelDraw21.

4. Results

A total of 17,622 articles from the period 1972 to 2020 with a total of 300,918 references were recorded using the search string. In total, 4,936,622 subject–area relationships were determined from the paper–reference ratios. The frequency distribution among the 27 subject areas can be seen in Table S2.

4.1. Resolution of Interdisciplinarity

The method results in a symmetric Jaccard matrix (Tables S3 and S4). Each cell of the matrix describes pairwise similarity between two disciplines. The hierarchical relationship between a paper and its references (Figure 1) induces integration; thus, each cell is a unitless measure of interdisciplinarity. The larger the entry, the higher the interdisciplinarity between these two subject areas. The column or row sum is an expression of the overall interdisciplinarity of a discipline. A completely transdisciplinary discipline would have the value 1 in each field, D_{ij} for $i \neq j$, in the column- or row-wise consideration of the Jaccard matrix (Equation (3)) as transdisciplinarity is defined as a fully integrative manner of knowledge without boundaries between individual research fields [11]. The maximum interdisciplinarity is then represented with $I = n - 1$ (with n = number of research fields).

$$\sum_{i=1,j=const.}^{i=n,j=const.} D_{ij} \text{ or } \sum_{i=const.,j=1}^{i=const.,j=n} D_{ij} \text{ for } \quad i \neq j \tag{3}$$

For the $n = 27$ subject areas of the studied dataset, I can be represented with values between 0 and 26. Here, no subject area pairing has a transdisciplinary relation since all $D_{ij} < 1$.

Expression I behaves linearly, and larger k-fold expressions signal k-fold interdisciplinarity. The actual summed interdisciplinarity of the subject areas ranged from $I_{min} = 1.121 \times 10^{-4}$ to $I_{max} = 6.839 \times 10^{-1}$ (Figure 4A). Thus, compared to the potential maximum value, the results are low. The mean value is $I_m = 2.030 \times 10^{-1}$. Based on the average aggregated interdisciplinarity of subject areas, a hierarchy can be derived for the disciplines. The frontrunner physical sciences is 3.724 times more interdisciplinary than health science, 2.492 times more than social sciences and humanities, and 1.625 times more than life sciences.

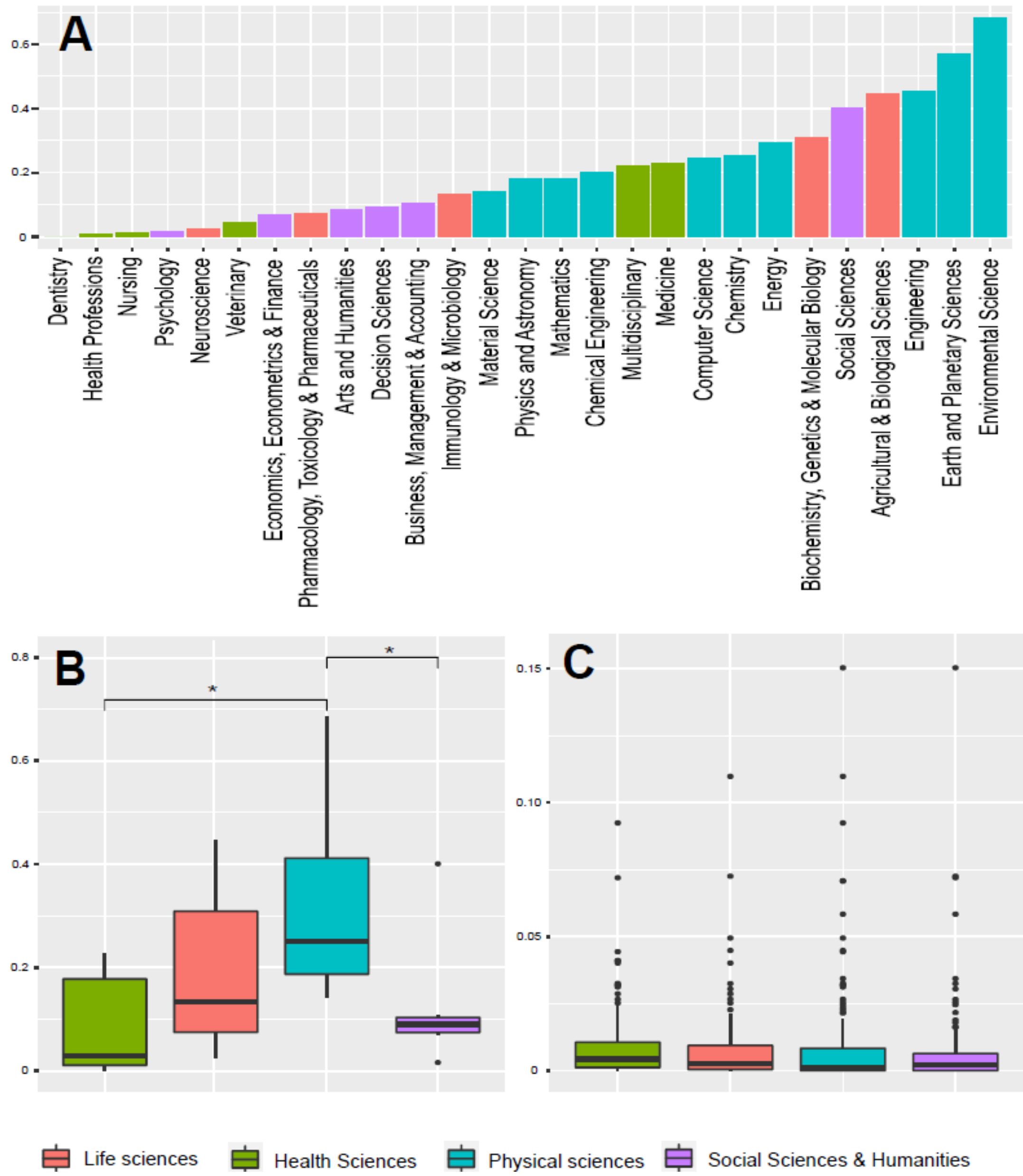

Figure 4. (**A**) Aggregated Jaccard similarities per "Subject Area" for the whole dataset ranging from 1972–2020. Showing the total interdisciplinarity per "Subject Area". Colors denote the affiliation to scientific disciplines. (**B**) Boxplots of the aggregated Jaccard similarity per discipline (Table S1) for the complete time span. (**C**) Boxplots of the Jaccard similarity per "Classifications" per discipline. Significant differences are marked with an asterisk and denote a p-value of less than 0.05.

Statistical relevance is tested by comparing the aggregated Jaccard values per subject area among the scientific disciplines (Figure 4B). Pairwise comparison of the subject area means shows that physical sciences are significantly more interdisciplinary than health sciences and social sciences and humanities ($p < 0.05$), while there is no significant difference between physical sciences and life sciences ($p = 0.093$).

However, the upper whiskers or upper outliers and their difference to the median indicate that this observation is based on pioneers of interdisciplinarity (Figure 4B) (e.g., the "Subject Area": "Social Sciences"). This observation is confirmed in the finest resolution ("Classifications") as shown by the median close to the lower quartiles (Figure 4C). Here, there are clear outliers upwards but not downwards, as the median and 75% of the values are close to zero. This gives evidence that despite all indications of interdisciplinarity, the default mode of research is disciplinary.

4.2. Temporal Development of Interdisciplinarity

Hierarchy and statistical relevance (Figure 4) of the clusters is constant over time with the data split into ten-year time intervals from 1983 on (Figure 5). This analysis indicates a trend to higher interdisciplinarity over time. A steep rise took place from 1983 to 1992, after which the development plateaued over the next three decades. The most recent decade has shown another growth in interdisciplinarity.

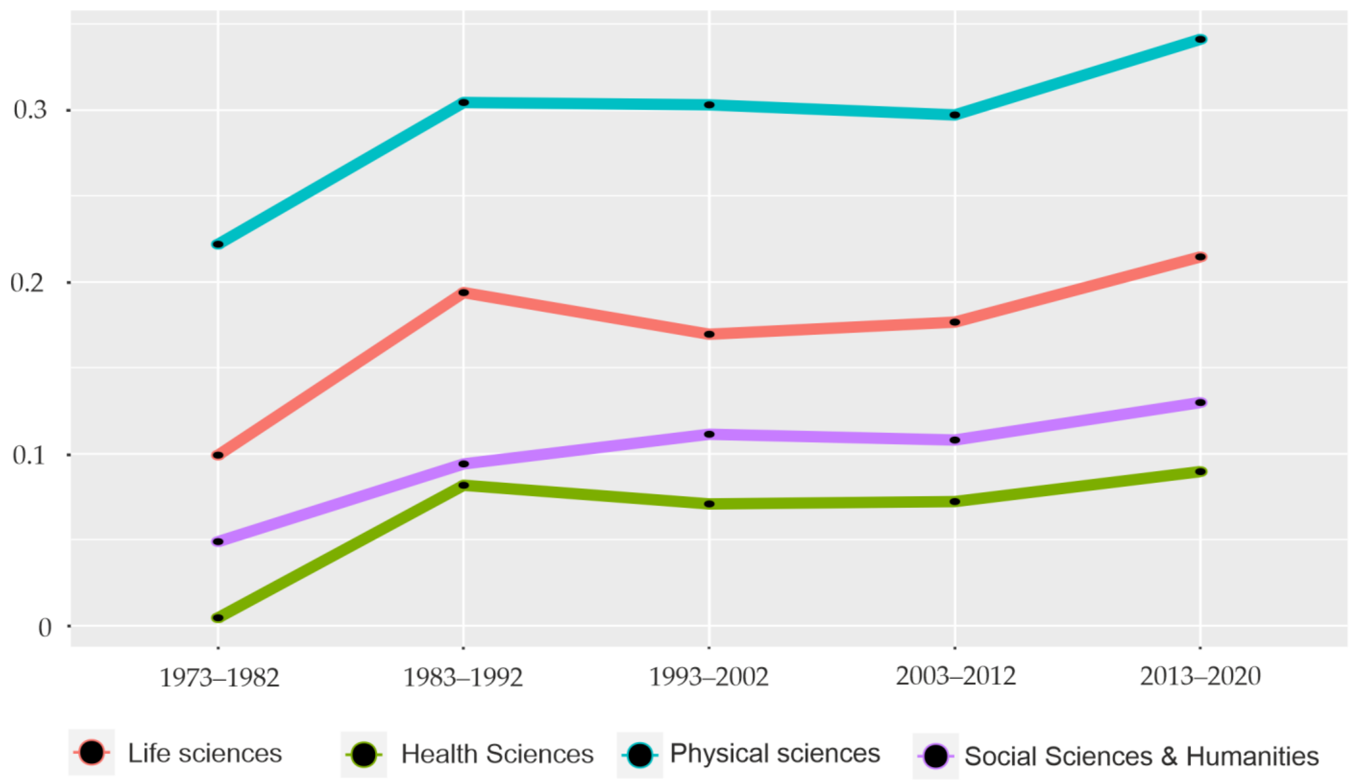

Figure 5. Aggregated Jaccard similarities per "Subject Area" over time. Dots denote the aggregated Jaccard similarity per time span and colors denote the affiliation to distinct "Clusters".

4.3. Interdisciplinary Placing

Figure 6 shows the interdisciplinarity of individual subjects and their affiliation to individual scientific disciplines. The stress value of 0.137 denotes a decent ordination. The ordination is determined by the number of edges and their rank-based strength. Nodes close to each other are more similar, thus more interdisciplinary. Generally, nodes in the center are more interdisciplinary as their ordination in the center is based on a relatively high similarity, thus interdisciplinarity, with all other nodes. A clear pattern is observable as distinct scientific disciplines form clusters. Namely, "Physical Sciences" are rather located in the middle and the other clusters are rather close to nodes from their own cluster. This ordination shows that subject areas are rather more collaborative within their cluster than with other clusters. Physical sciences form the center of the ordination, thus distinguishing it as the most interdisciplinary cluster. Taking the strength of edges into account points out that the strongest connections are between the physical sciences, social sciences and Humanities and life sciences, indicating that these disciplines exhibit a higher interdisciplinarity. The results stay relatively stable when using a higher resolution, namely, scientific classification instead of scientific areas (Figure S1).

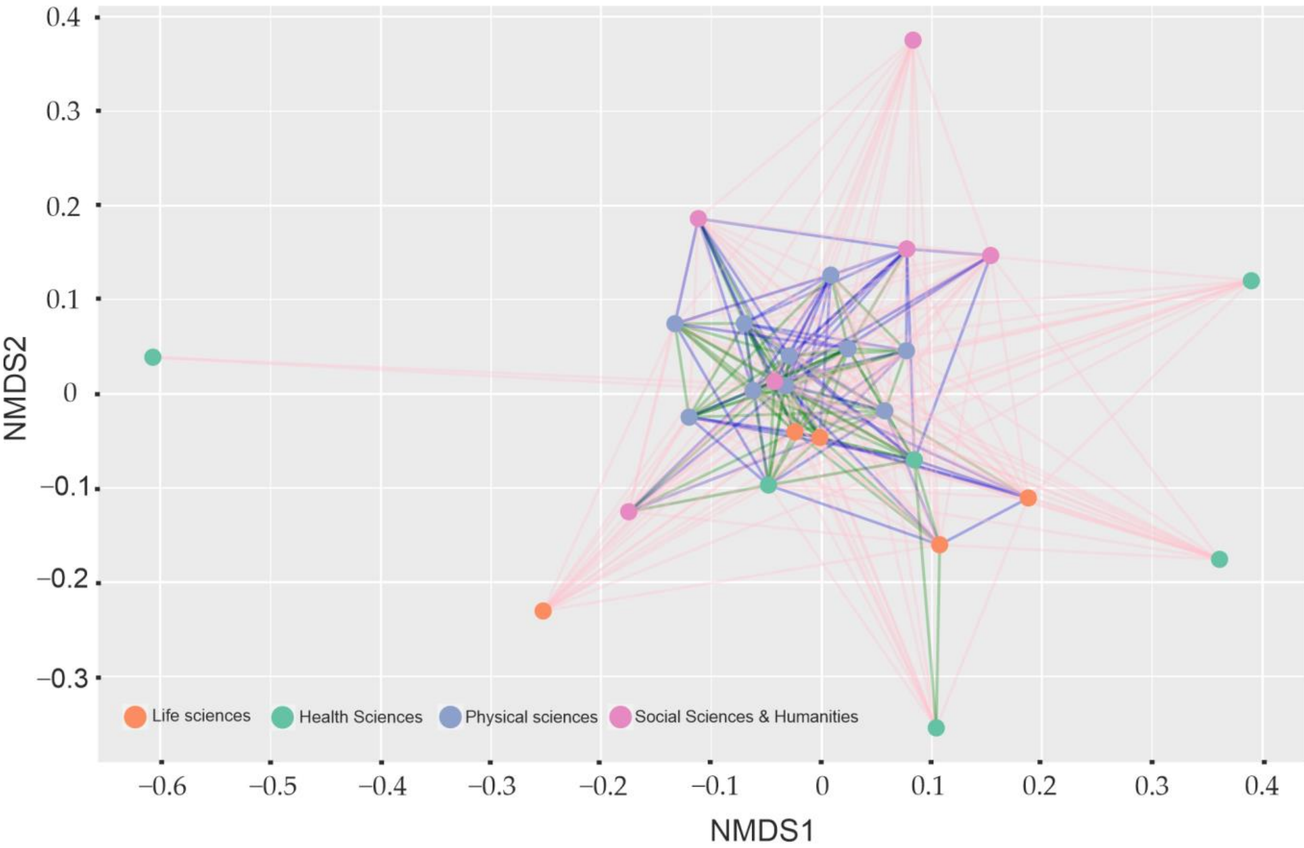

Figure 6. NMDS of the scientific disciplines based on Jaccard dissimilarities. Stress value: 0.137. Point colors denote the affiliation of individual "Subject Areas" to scientific disciplines. Orange: life sciences, pink: social sciences and humanities, blue: physical sciences, green: health sciences. Lines denote the pairwise Jaccard similarity between nodes. Red: below the median of the dataset (0.02967), blue: below the mean (0.06486), green: higher than the mean.

5. Discussion

A bibliometric method assessing interdisciplinarity based on papers and their cited references was introduced, based on Scopus entries between 1972 and 2020. Interdisciplinary collaboration was mapped by a co-citation matrix based on integration employing a bottom-up approach [9]. For the first time, a picture of interdisciplinary research in the field of heavy precipitation is drawn.

The literature agrees on interdisciplinarity as a highly desirable paradigm for multisectoral research. In recent years the demand and application of interdisciplinary collaboration has gained popularity [36–39]. However, the analysis presented here highlights this being only partly implemented in research on heavy precipitation (Figure 4A). Although interdisciplinarity has increased, its actual numerical increase is negligible (Figure 5). A small number of "Classifications" account for a large share of the research area's interdisciplinarity (Figure 4C), indicating that relatively few areas of research are characterized by interdisciplinary work. At the same time, this implies that the majority of research areas show a lack of interdisciplinarity. Since many universities, research institutes and funding bodies are still structured in a disciplinary manner, it is not surprising that the results reveal the described pattern [40,41]. Furthermore, it proves that even in the digital age with extensive information availability, disciplinary glasses are worn and interdisciplinarity is not the modus operandi (Figure 6).

As with other challenging research topics, the collaborative research output related to heavy precipitation events has experienced an increase over the last 50 years [42]. However, an appreciable temporal development of interdisciplinarity is not detectable (Figure 5). The level of interdisciplinarity has remained relatively constant over the last 40 years with an initial increase 50 years ago, while the number of publications has generally increased over time. Hence, based on these results, it is obvious that despite the simplicity in exchange and availability of information in the age of the Internet, complex issues in socio-economic contexts are often not addressed in an interdisciplinary manner.

This result becomes even more intriguing considering the ever-growing number of branches of research. With newly emerging research fields, an increase in interdisciplinarity is mandatory for the subject disciplines as any collaborative effort leads to more interdisciplinarity. Thus, measured by the initial and final values, which behave linearly, the actual increase over the last 40 years is trivial. Thus, the assumption of a growth in interdisciplinarity over time can be refuted. However, increased interdisciplinarity could still be particularly true for individual disciplines (Figure 4C).

The analysis detected some collaborations and placing between and within clusters. "Physical Sciences" were found to be the most interdisciplinary cluster (Figure 6 and Figure S1, but also see Figure 4A,B and Figure 5). Thus, it is pivotal for research on heavy rainfall. For a long time, the issue of heavy precipitation events have been an important topic in many subject areas in physical sciences, particularly in "Environmental Science", "Earth and Planetary Science" and "Engineering", for which environmental-related scenarios are at the core of their research. The hierarchy of the four subject areas with respect to heavy rainfall events is coherent, namely, in descending order: physical sciences, life sciences, social sciences and humanities and, finally, health sciences. Heavy rain events have the very first point of contact with physical sciences, as they deal with the immediate problem; be it solutions for the drainage of large water volumes or the interim storage of water. However, after the failure or the overuse of physical strategies, which can happen for various reasons (e.g., climate change, growing population), other areas are affected to a greater scale. Certainly, this is generalized, as for the physical solutions, but the encouragement of the other areas is needed.

Life sciences, second in the order, are affected after the management of heavy rainfall fails, even for short time events or even single events. Stormwater runoff is known for carrying particular loads and pollutants, thus having eventual toxic and anaerobic effects for aquatic organisms. The impairment of biological services and functions (e.g., ecosystem services, unusable recreational areas) call for the third subject area, social sciences and humanities, to come into play, which ensures that public understanding is sensitized and that the acceptance of making the scarce resource of money available is increased. Health sciences are last in line; however, that does not imply that it is of less importance. Heavy rainfall events cause threats to human life and not just by physical factors. Pathogens are known to be discharged into the environment due to sewage overflow, thus posing risk to human health. At this point one has to acknowledge that the used search string may be selective for individual scientific fields or even subject areas, which does not make the results less trustworthy, but makes them highly specific for the heavy rainfall events. Analyzing another dataset created with a different search string will certainly change the hierarchy of subject areas regarding their interdisciplinarity. However, it was not the objective of this study to make a general statement about interdisciplinarity or the interdisciplinarity of another challenging research field, but to investigate the interdisciplinarity regarding research affiliated with heavy rainfall events by using a new approach.

Certainly, bibliometric analyses are affected by limitations [43]. Drawing general conclusion of interdisciplinarity is not possible when applying pre-selective search strings. For doing that, one has to use either a neutral search string, which is barely possible due to the unique and biased language in different research fields, or one has to work with randomly chosen publications, which are large enough in number to be representative for the used database. Using the shown method here, with a representative and randomly chosen publication dataset, would be a promising approach to make a statement about the general interdisciplinarity. Bibliometric databases such as Scopus or Web of Science vary concerning their coverage of research areas and types of publications [23,26]. Authors from the "Social Sciences", "Humanities" and some applied fields often publish in books, reports, proceedings and journals, which are not recorded by bibliometric databases [11]. Furthermore, "Social Sciences" and "Humanities" results are often published in the language in which they were collected. Therefore, Scopus and Web of Science are unbalanced between countries and languages [26]. Furthermore, scientific databases such as Scopus, Web of Science or Google Scholar use different assignments of scientific fields. Therefore, interdisciplinarity varies based on the underlying codification [11]. In addition, this study is limited due to the defined search term. The pre-selection, performed by the use of search terms, enabled it to perform a bibliometric analysis on the research areas dealing with heavy rainfall events. However, at the same time a search term always either defines the topic too narrowly or is too general to precisely cover the desired research field.

6. Conclusions

The method introduced here makes interdisciplinarity more tangible and measurable. Furthermore, this approach is replicable and based on already accessible data structures. It shows how the current state of research is still struggling to accomplish multisectoral outcomes. While interdisciplinarity is required and encouraged, we show here that the actual interdisciplinarity of research fields dealing with heavy rainfall events is mostly considered to be low. This implies that the vast majority of research fields are not satisfactorily interdisciplinary and that despite the recent popularity of interdisciplinarity, it is a rather rare phenomenon. In addition, we show that when different research fields collaborate, most of them work under a common overarching research cluster (e.g., life sciences and health sciences).

However, crossing disciplinary boundaries in a more ambitious way is feasible. This is proven by a few fields of research excelling over others in terms of their interdisciplinary collaboration.

If interdisciplinarity is the gold standard for complex challenges such as research regarding heavy rainfall events, one would have expected a more dynamic growth. Over the last five decades, interdisciplinarity has increased, but, especially under the premise of extensive information availability, this development can be neglected. Accordingly, the underlying potential to address a wide variety of issues (e.g., heavy rainfall events) is enormous, creating tremendous opportunities as soon as a truly interdisciplinary approach is employed. Starting from the results of this analysis, obstacles must be identified and ways of overcoming them have to be sketched out.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w14193001/s1. Table S1: Dictionary of the existing Scopus hierarchy of individual subject areas, associated classification abbreviation and codes, Table S2: Frequency distribution of the 27 subject areas within the data corpus, Table S3: Symmetric Jaccard similarity matrix of the 27 subject areas, Table S4: Symmetric Jaccard dissimilarity matrix of the 318 Classifications, Figure S1: NMDS of the "Classifications" based on their affiliation to their superordinate "Subject Areas" and their Jaccard dissimilarities, after removing outliers to enhance the resolution, as individual single "Classifications" had a dissimilarity of 1 to every other "Classification". Stressvalue: 0.0586. Point color denote the affiliation of individual "Classifications" to "Clusters". Orange: life sciences, pink: social sciences & humanities, blue: physical sciences, green: health sciences.

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References

1. Allen, S.K.; Barros, V.; Burton, I.; Campbell-Lendrum, D.; Cardona, O.-D.; Cutter, S.L.; Dube, O.P.; Ebi, K.L.; Field, C.B.; Handmer, J.W.; et al. Summary for Policymakers. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*; Cambridge England Press: Cambridge, UK, 2012; pp. 3–22. [CrossRef]
2. Alaoui, A.; Rogger, M.; Peth, S.; Blöschl, G. Does soil compaction increase floods? A review. *J. Hydrol.* **2018**, *557*, 631–642. [CrossRef]
3. Jacobson, C.R. Identification and quantification of the hydrological impacts of imperviousness in urban catchments: A review. *J. Environ. Manag.* **2011**, *92*, 1438–1448. [CrossRef] [PubMed]
4. Bundesministerium der Inneren und für Heimat; Bundesministerium der Finanzen. *Bericht Zur Hochwasserkatastrophe 2021: Katastrophenhilfe, Wiederaufbau und Evaluierungsprozesse*; BMI: Berlin, Germany, 2021.
5. Shahzad, A. Pakistan Floods Cost at Least $10 Billion, Planning Minister Says. Available online: https://www.reuters.com/world/asia-pacific/initial-economic-losses-pakistan-floods-least-10-bln-planning-minister-2022-08-29/ (accessed on 19 September 2022).
6. Sales-Ortells, H.; Medema, G. Microbial health risks associated with exposure to stormwater in a water plaza. *Water Res.* **2015**, *74*, 34–46. [CrossRef] [PubMed]
7. Schertzinger, G.; Itzel, F.; Kerstein, J.; Tuerk, J.; Schmidt, T.C.; Sures, B. Accumulation pattern and possible adverse effects of organic pollutants in sediments downstream of combined sewer overflows. *Sci. Total Environ.* **2019**, *675*, 295–304. [CrossRef] [PubMed]
8. Gabe, J.; Trowsdale, S.; Mistry, D. Mandatory urban rainwater harvesting: Learning from experience. *Water Sci. Technol.* **2012**, *65*, 1200–1207. [CrossRef] [PubMed]
9. European Commission, Directorate-General for Environment. *The EU Water Framework Directive*; Publications Office of the European Union: Luxembourg, 2014; Available online: https://data.europa.eu/doi/10.2779/75229 (accessed on 19 September 2022).
10. Netzel, L.; Drewing, E.; Netzel, L.; Denecke, M. Understanding Public Acceptance of a Multifunctional Water Plaza: A Case Study. *Water* **2021**, *13*, 576. [CrossRef]
11. Wagner, C.S.; Roessner, J.D.; Bobb, K.; Klein, J.T.; Boyack, K.W.; Keyton, J.; Rafols, I.; Börner, K. Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature. *J. Inf.* **2011**, *5*, 14–26. [CrossRef]
12. Clark, S.G.; Wallace, R.L. Integration and interdisciplinarity: Concepts, frameworks, and education. *Policy Sci.* **2015**, *48*, 233–255. [CrossRef]
13. Röhlig, A. *Interdisziplinäre Zusammenarbeit im Verbundprojekt: Herausforderungen und kritische Faktoren einer erfolgreichen Forschungskooperation, HWWI Research Paper, No. 181*; Hamburgisches Welt Wirtschafts Institut (HWWI): Hamburg, Germany, 2018.
14. Annan-Diab, F.; Molinari, C. Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *Int. J. Manag. Educ.* **2017**, *15*, 73–83. [CrossRef]
15. DeFries, R.S.; Ellis, E.C.; Chapin, F.S.; Matson, P.A.; Turner, B.L.; Agrawal, A.; Crutzen, P.J.; Field, C.; Gleick, P.; Kareiva, P.M.; et al. Planetary Opportunities: A Social Contract for Global Change Science to Contribute to a Sustainable Future. *BioScience* **2012**, *62*, 603–606. [CrossRef]
16. Valcke, P.; Graef, I.; Clifford, D. iFairness—Constructing fairness in IT (and other areas of) law through intra- and interdisciplinarity. *Comput. Law Secur. Rev.* **2018**, *34*, 707–714. [CrossRef]
17. Pellegrino, M.; Musy, M. Seven questions around interdisciplinarity in energy research. *Energy Res. Soc. Sci.* **2017**, *32*, 1–12. [CrossRef]
18. Abramo, G.; D'Angelo, C.A.; Zhang, L. A comparison of two approaches for measuring interdisciplinary research output: The disciplinary diversity of authors vs the disciplinary diversity of the reference list. *J. Inf.* **2018**, *12*, 1182–1193. [CrossRef]

19. NAS Committee on Key Challenge Areas for Convergence and Health; Board on Life Sciences; Division on Earth and Life Studies; National Research Counci. *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond*; National Academies Press: Washington, DC, USA, 2014.
20. Baas, J.; Schotten, M.; Plume, A.; Côté, G.; Karimi, R. Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quant. Sci. Stud.* **2020**, *1*, 377–386. [CrossRef]
21. Khiste, G.P.; Paithankar, R.R. Analysis of Bibliometric Term in Scopus. *Int. J. Libr. Inf. Sci.* **2017**, *3*, 81–88.
22. Fiala, D.; Tutoky, G. Computer Science Papers in Web of Science: A Bibliometric Analysis. *Publications* **2017**, *5*, 23. [CrossRef]
23. Porter, A.L.; Cohen, A.S.; Roessner, J.D.; Perreault, M. Measuring researcher interdisciplinarity. *Scientometrics* **2007**, *72*, 117–147. [CrossRef]
24. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]
25. Durán-Sánchez, A.; Álvarez-García, J.; De la Cruz Del Río-Rama, M. Sustainable Water Resources Management: A Bibliometric Overview. *Water* **2018**, *10*, 1191. [CrossRef]
26. Mongeon, P.; Paul-Hus, A. The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics* **2016**, *106*, 213–228. [CrossRef]
27. Zhu, J.; Liu, W. A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics* **2020**, *123*, 321–335. [CrossRef]
28. Todeschini, R.; Baccini, A. *Handbook of Bibliometric Indicators Quantitative Tools for Studying and Evaluating Research*; WILEY-VCH, Verlag GmbH & Co. KGaA: Weinheim, Germany, 2016.
29. Leydesdorff, L. On the normalization and visualization of author co-citation data: Salton's Cosineversus the Jaccard index. *J. Am. Soc. Inf. Sci. Technol.* **2008**, *59*, 77–85. [CrossRef]
30. van Eck, N.J.; Waltman, L. Appropriate similarity measures for author co-citation analysis. *J. Am. Soc. Inf. Sci. Technol.* **2008**, *59*, 1653–1661. [CrossRef]
31. Rose, M.E.; Kitchin, J. pybliometrics: Scriptable bibliometrics using a Python interface to Scopus. *SoftwareX* **2019**, *10*, 100263. [CrossRef]
32. Oksanen, A.J.; Blanchet, F.G.; Friendly, M.; Kindt, R.; Legendre, P.; Mcglinn, D.; Minchin, P.R.; Hara, R.B.O.; Simpson, G.L.; Solymos, P.; et al. Vegan: Community Ecology Package_. R Package Version 2.5-7. 2020, No. November. Available online: https://CRAN.R-project.org/package=vegan (accessed on 19 September 2022).
33. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2021; Available online: https://www.r-project.org/ (accessed on 10 August 2021).
34. Bauer, D.F. Constructing Confidence Sets Using Rank Statistics. *J. Am. Stat. Assoc.* **1972**, *67*, 687–690. [CrossRef]
35. Wickham, H. *Ggplot2: Elegant Graphics for Data Analysis*; Springer: New York, NY, USA, 2016.
36. Dalrymple, J.; Miller, W. Interdisciplinarity: A key for real-world learning. *Planet* **2006**, *17*, 29–31. [CrossRef]
37. Parker, J. Competencies for interdisciplinarity in higher education. *Int. J. Sustain. High. Educ.* **2010**, *11*, 325–338. [CrossRef]
38. Tarrant, S.P.; Thiele, L.P. Enhancing and promoting interdisciplinarity in higher education. *J. Environ. Stud. Sci.* **2017**, *7*, 355–360. [CrossRef]
39. Das, K.; Paital, B. Future call for policy making to speed up interdisciplinarity between natural and social sciences and humanities in countries such as India. *Heliyon* **2021**, *7*, e06484. [CrossRef]
40. Yang, L.Y.; Yue, T.; Ding, J.L.; Han, T. A comparison of disciplinary structure in science between the G7 and the BRIC countries by bibliometric methods. *Scientometrics* **2012**, *93*, 497–516. [CrossRef]
41. Freiband, A.; Dickin, K.L.; Glass, M.; Gore, M.A.; Hinestroza, J.; Nelson, R.; Platt, V.; Rooks, N.; Sachs, A.; Stern, N.; et al. Undisciplining the university through shared purpose, practice, and place. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 172. [CrossRef]
42. Stricker, M.; Schmid, C.; Nicolai, B. Starkregenereignisse in Der Wissenschaftlichen Forschung. In *gwf-Wasser | Abwasser*; Vulkan-Verlag GmbH: Essen, Germany, 2021; pp. 1–12.
43. Robinson-Garcia, N.; Jiménez-Contreras, E. Analyzing the Disciplinary Focus of Universities: Can rankings be a one-size-fits-all? In *World University Rankings and the Future of Higher Education*; IGI Global: Hershey, PA, USA, 2016; pp. 161–185. [CrossRef]

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