

Research contributions to Sustainable Development Goals: A comparison using the main bibliometric suites

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Abstract

The United Nations Sustainable Development Goals (SDGs) set an ambitious plan for society to create a world in which nobody is excluded. United Nations addressed all its country members to work on the achievement of the 17 goals that encompass 169 targets. The present bibliometric analysis summarises the research published globally on these universal goals. This analysis includes data from Web of Science, Scopus, and Dimensions. This is the first macro-level bibliometric assessment of InCites, SciVal and Dimensions Analytics between 2011-2020. SciVal captures the highest number of publications related to the SDGs, with Dimensions and InCites following behind. The publication results from SciVal and InCites have a very strong relation (0.93), allowing for the conclusion that both might be comparable. The two databases are well-accepted for being the most comprehensive citation databases with similar publication coverage. An exploratory factor analysis (EFA) and principal component analysis (PCA) were used to analyse the indicators related to the SDGs publications. This research suggests that statistical procedures can help us simplify complex and large numbers of indicators and reveal connections to Sustainable Development Goals.

Introduction

In 2015 the United Nations Sustainable Development Goals (SDGs) proposed the global community to construct a world with no exclusion. This plan is a universal international mandate that requires collective action to promote unity, prosperity, health, and well-being for all by 2030. The 17 Sustainable Development Goals (SDGs) and their 169 specific targets were constructed to take over the former 8 Millennium Development Goals (MDGs) that concluded in 2015. The move from 8 MDGs to 17 SDGs showed a change from a vertical to a horizontal strategy in handling international challenges (Stafford-Smith et al. 2017; Sweileh, 2020).

The yearly UN SDGs report is an important assessment of the world's implementation activities. It highlights areas where progress has been made and identifies the need for further steps to be taken. Achieving these goals requires the unwavering efforts of academics around the world. Universities' researchers and academic staff play a critical role in advancing the SDGs. According to Neary & Osborne (2018) and Purcell, Henriksen & Spengler (2019), researchers can provide authentic solutions and innovations to address the array of national and international issues that are blocking the path to the 2030 agenda. To reinforce the partnership with all stakeholders and accelerate progress towards the SDGs, it is essential that local and international governments accept the recommendations of research and academic staff and put them into a realisable agenda.

Bibliometric mappings are an approach for identifying patterns in a field of knowledge that is hard to detect through conventional research review practices and some hidden key elements in a particular theme (Cobo et al. 2011; Hallinger and Chatpinyakoo 2019; Prieto-Jiménez et al. 2021) We can find bibliometric studies examining the contributions to Sustainable Development Goals in the scientific literature. Yamaguchi (2023) undertook a bibliometric analysis of scientific publications that focused on “sustainable development goals” by using “sustainable development goals” as a keyword to locate the publications. Numerous

bibliometric studies have been performed in the area of SDGs research, yet most of them are restricted to specific disciplines, for example, SDG and the business sector (Pizzi et al. 2020), education (Prieto-Jiménez et al. 2021), poverty (Yu and Huang 2021), and there are only a limited number of bibliometric studies that cover the general aspects and development of SDGs. In any case, it is worth highlighting some interesting bibliometric studies of SDG trends, such as the work of Díaz-López et al. (2021), Meschede (2020), Yeh et al. (2022), and Sianes et al. (2022).

In recent years, it has become much easier to analyse and track scientific and technological advancements thanks to the increased digitisation of research papers and the proliferation of databases like Web of Science, Scopus, and Dimensions. This has allowed researchers and analysts to gain a deeper understanding of the trends and progress within specific fields (Hajikhani and Suominen, 2022). Academic institutions have turned to commercial firms like Elsevier, Clarivate, and Digital Science to measure their contributions to the Sustainable Development Goals. These firms have produced mappings to document publications related to these goals easily. In the method section of these mappings, the process is explained. This involves selecting and assigning keywords that characterise the SDGs. The search strings can be improved by utilising machine learning techniques and the input of specialists in the SDGs field.

Elsevier search strings on SDGs have become prevalent as they are incorporated into THE university impact rankings, offering universities the ability to analyse themselves and identify those which are making the most contributions towards these goals. It is important to note that this method has faced criticism from some scholars who argue that the outcomes can vary depending on the database used. For instance, different methods can lead to dissimilar results, with one institution achieving success in Gender Equality Goal 5 when using Scopus but receiving the lowest rating in the same goal when examining results from Dimensions, a different bibliometric suite.

There could be several reasons for this. For example, databases may use different methods for indexing publications and assigning keywords, as they may not all use the same controlled vocabulary and thesaurus. There have been criticisms about these techniques regarding the criteria for including documents in commercial databases, as well as concerns about transparency and diversity in the language included in these databases. This can limit the results of searches to only the publications available in these databases. Ensuring accessibility is crucial to upholding Open Research principles. These principles strive to make scientific discoveries more widely available, which also aligns with the Sustainable Development Goals. Prioritising equal access to knowledge supports the ideals of open research and contributes to a more equitable and fair society. According to Armitage, Lorenz, and Mikki, 2020, bibliometric services like Elsevier's SDGs mapping should be examined cautiously due to the difficult nature of understanding the SDGs. Other authors have put forth the idea that these search strings can lead to flawed outcomes, making it difficult for researchers to comprehend the influence of their works on the SDGs. Rafols declared in 2021 that bibliometrics analysts should not assume there is an accepted approach to correlating SDGs to publications. The evidence shows that specific components of these bibliometric mappings can be limited and should be managed cautiously while maintaining transparency.

Web of Science and Scopus have strict policies for selecting their indexed collection, ensuring high-quality standards. On the other hand, Dimensions indexes anything with a DOI identifier through Crossref using algorithms and machine learning. While this approach may seem fairer

and more inclusive, it has received criticism due to the lack of publication metadata quality. According to Guerrero-Bote et al., 2021, a significant percentage of Dimensions documents lack affiliation data, with almost half of them lacking country affiliation. In comparison, Scopus has a much lower percentage of documents without this information.

The purpose of this research is to present the results of Sustainable Development Goals using the three main bibliometric suites to analyse publications. To better understand the research contributions to the literature on the SDGs, this study evaluated the volume and trends of scientific publications on SDGs during the past decade (2011–2020). It is not intended to spark debates about database content however as an STI collective, we aim to work collaboratively with companies and data suppliers to provide better solutions that accurately represent the SDGs. We plan to converse with peers who still are not familiar with the SDGs and these methods to determine areas of collaboration, room for improvement and support for the community. Additionally, statistical methods have been used to simplify the excessive number of indicators and make the data more understandable.

In March 2017, the United Nations Statistical Commission held its 48th session where the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) created a global indicator framework for Sustainable Development Goals. This framework includes 231 unique indicators (SDG Indicators, 2022) that are categorized by income, gender, age, race, ethnicity, migratory status, disability, geographic location, and other indicators in accordance with the Fundamental Principles of Official Statistics.

Incorporating information about SDG Indicators from the UN would be beneficial in improving the bibliometric analysis and yielding valuable insights.

SDG Indicators - United Nations Statistics Division <https://unstats.un.org/sdgs/dataportal/>

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- Goal 3. Ensure healthy lives and promote well-being for all at all ages.
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- Goal 5. Achieve gender equality and empower all women and girls.
- Goal 6. Ensure availability and sustainable management of water and sanitation for all.
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
- Goal 10. Reduce inequality within and among countries.
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
- Goal 12. Ensure sustainable consumption and production patterns.
- Goal 13. Take urgent action to combat climate change and its impacts.
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.

- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
- Goal 17. Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development

By incorporating Sustainable Development Goals (SDGs) into the title, abstract, keywords, and the term bibliometrics, we found 118 documents in Scopus. Figure 1 illustrates the results of adding SDGs and bibliometrics. Only 118 publications related to the SDGs were produced using bibliometric methods.

(*TITLE-ABS-KEY* (“sustainable development goals”) *AND TITLE-ABS-KEY* (bibliometrics))

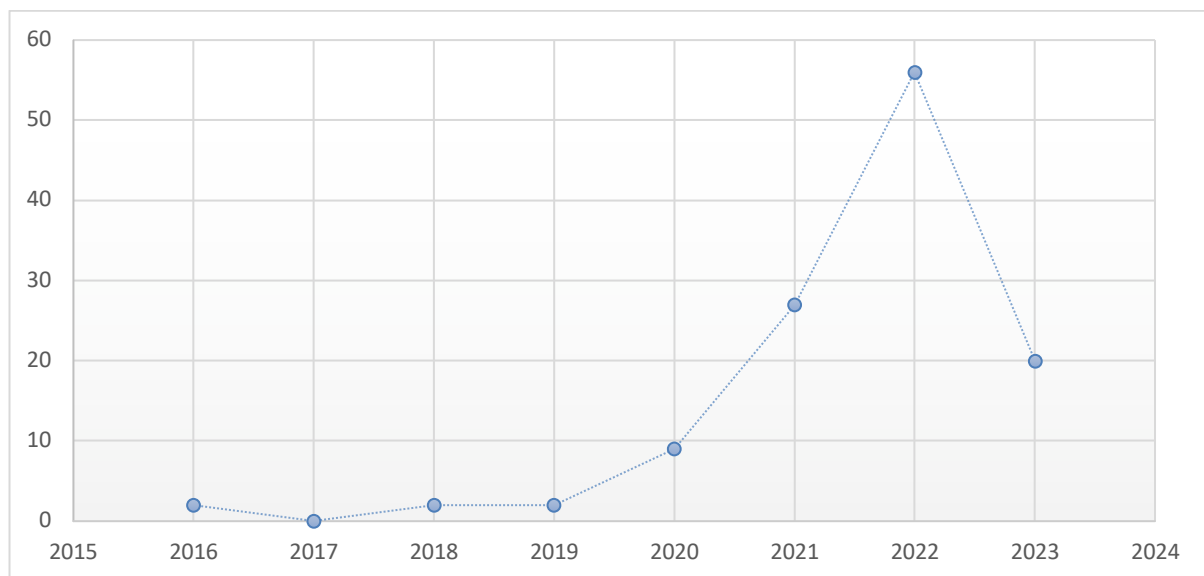


Figure 1. Publications produced using Sustainable Development Goals as a topic.

The figure above shows that there has been a rise in publication trends since 2015. In recent years, more publications have been incorporating bibliometrics and sustainable development goals, particularly in 2021 and 2022.

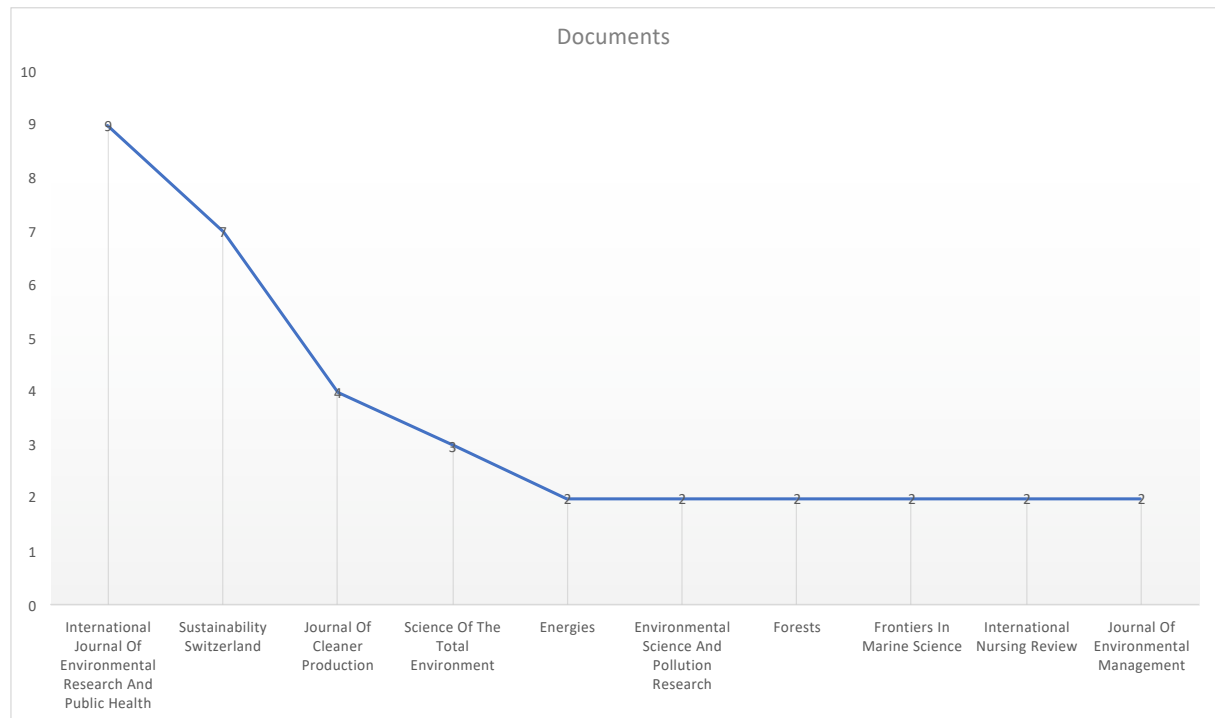


Figure 2. Journals publishing Sustainable Development Goals bibliometric analyses.

Figure 2 also indicates which journals have published the most papers on bibliometrics analysis related to Sustainable Development Goals. Interestingly, none of the top ten journals belong to the bibliometric field. Most of the works are related to the Environmental sciences, which explore the use of bibliometric methods to monitor SDG publications. The Sustainability journal is the second-highest producer of papers on SDGs and bibliometrics. I wanted to bring up a study published by Cabezas et al. in 2023 that investigated bibliometric papers published in the journal Sustainability. The study found that out of the 204 papers analysed, 181 of them (88.7%) had one or more methodological limitations that made it difficult to reproduce their findings. This suggested that there is a significant need to improve the methodological quality of papers published in Sustainability. (Cabezas et al., 2023)

The present study aims to compare the bibliometric methods used to map Sustainable Development Goals by the three major bibliometric databases, Dimensions, Scopus and Web of Science, by utilising the same publication windows to provide more information to the scientific community regarding the three mappings. This attempts to recognise which venues, and type of documents have been selected to communicate sustainable development goals and the scientific impact they have had.

Q1: How can the Sustainable Development Goals be seen in bibliometric databases?

Q2: Are there any discrepancies in the findings from the bibliometric suites?

Q3: Can the data describing the SDG results be reduced using EFA and PCA?

Data and methods

The publications were evaluated by using the three most prominent citation databases. Through the utilisation of keywords and machine learning, databases track publications related to the SDGs. Those responsible for the databases and experts in the relevant fields created search terms to identify publications regarding SDG topics. In order to develop a search strategy for each Sustainable Development Goal, data science teams collaborated with subject-matter specialists to provide a comprehensive overview of the studies associated with the SDGs.

To achieve these goals, it is crucial that funding agencies and research institutions provide their assistance in order to fund potential research projects on Sustainable Development Goals. An in-depth comprehension of the research that supports the SDGs can highlight any gaps and make it easier to assess how universities are assisting in the achievement of the goals, as shown by the Times Higher Education Impact Rankings.

The mappings were planned with the best of intentions to support in the visualisation of outcomes that come from combining awareness on content, data, and analytics with the networks and skill of the research community.

How do the citation databases present the SDGs?

Sustainable Development Goals in InCites – Web of Science

Clarivate uses bibliometric analysis and manual curation by analysts at the Institute of Scientific Information™ (ISI), to determine the most appropriate Micro Citation Topic for a publication of each SDG. It generated the Citation Topics from citation groupings that feature SDGs-related keywords. They ensure the pertinence by yearly re-aggregation of Citation Topics. Clarivate distributes the mapping document to promote a transparent and replicable technique for obtaining community input. They are open to receiving ideas for the refinement of SDG analysis. The Data is retrievable through the InCites API (SDGs InCites, 2022)

Citation Topics are clusters of citations which have been determined by an algorithm devised by CWTS, Leiden. This document-level classification system is structured in three hierarchical levels. According to the 2021 clustering, the three levels of the hierarchy and their respective content are as follows:

- Macro-topics (10)
- Meso-topics (326)
- Micro-topics (2444)

All documents from 1980 to the present were organised into groups, where possible, based on their references to one another within a Leiden algorithm. The algorithm contains parameters to ensure clustering and uphold the minimum cluster size; Macro- and meso-topics are manually labelled based on their contents. Micro-topics were categorised using the most relevant keyword algorithmically. Citation Topics are categorised through citation relationships rather than the content or subject of the documents, so the labels are determined through inference and may not accurately describe each document within the topic.

Individual goals of the UN Sustainable Development Goals were compared to Micro Citation Topics. Selected Micro Citation Topics and their associated publications were assigned to one or more of the 1 to 16 Sustainable Development Goals and indicators were calculated for the

Sustainable Development Goal entity. Every time the Micro Citation Topics are reviewed, the Sustainable Development Goals will be updated accordingly.

The SDG InCites method can be found here:

<https://incites.help.clarivate.com/Content/Research-Areas/sustainable-development-goals.htm>

SDG Research Mapping Initiative by SciVal – Scopus

The Data Science teams of Elsevier have produced three distinct sets of SDG mappings, one for each THE Impact Rankings (2019-2021). The versions of search queries and related documentation can be acquired from the Elsevier SDG hub:

<https://www.elsevier.com/about/partnerships/sdg-research-mapping-initiative>

In 2020, inspired by the earlier queries, Elsevier, through its Science-Metrix group, used a new approach to mapping publications to the SDGs. Taking into consideration customer input, they expanded the number of search terms utilised to describe each SDG. A machine learning model was used to increment the recall by approximately 10%, supplementing the queries. Thus, the 2021 iteration of “Elsevier 2021 SDG mapping” has, on average, twice the number of articles as the 2020 version, while still maintaining a precision rate of 80% or higher. The mapping has a greater affinity with SDG queries from other related projects. Times Higher Education is incorporating the 2021 mapping into their 2021 Impact Rankings. The 2021 SDG mappings from Elsevier have been integrated into SciVal as pre-defined Research Areas and can assist researchers and institutions in tracking and illustrating progress towards SDG targets (Elsevier, 2023)

Elsevier: SDG Queries

In an effort to identify research that supports the UN SDGs, Elsevier has generated a set of Scopus queries related to each of the SDGs. In this dataset, we can find documentation describing how each of the Scopus queries were created along with a collated list of the queries.

<https://elsevier.digitalcommonsdata.com/datasets/87txkw7khs/1>

Using Dimensions to explore the global landscape of research on Sustainable Development Goals

Together with Springer Nature, the Digital Science Consultancy and Dimensions teams created a way to classify research about the Sustainable Development Goals from the Dimensions publications. This work uses machine learning and semi-automatically generated training data. They recently launched an SDG classification system and filter on Dimensions. 4.9M of the 108.7M Dimensions publications were classified according to the 17 SDGs with the new system. They classify the SDGs using key phrases and terminology based on United Nations definitions of SDGs, including target and indicator definitions and narratives. The search strings take into account language differences (American English vs British English) and use nearby searches. They involved subject matter experts and added additional term phrases for quality assurance. They also eliminated false positives by improving the overall search string, not by manual intervention in the result list.

More information about the methodology can be found:

https://digitalscience.figshare.com/articles/report/Contextualizing_Sustainable_Development_Research/12200081

Bibliometric databases: Web of Science, Scopus, and Dimensions

For bibliometric analyses, Web of Science and Scopus have traditionally been the most widely used databases. WoS core collection (which includes its main citation indexes) covers over 75 million records. It has been reported that Scopus encompasses around 76 million records (Baas et al. 2020). Dimensions surpasses Web of Science and Scopus in coverage, reaching 82.22% and 48.17% more respectively and providing the most thorough journal coverage. There is a significant difference between the coverage of journal articles in the databases, with Web of Science being the most selective and Dimensions being the most extensive. The rate of journals indexed in Web of Science which are also indexed in Scopus is 99.11%, and the rate of journals indexed in Web of Science which are indexed in Dimensions is 96.61%. Scopus has a journal index coverage of 96.42% which is also featured in Dimensions (Singh et al., 2021). Expert editors use a set of criteria to decide which journals, conference proceedings, and books should be included in Web of Science and Scopus databases. By utilising a more comprehensive approach, Dimensions indexes a vast majority of their publication database from open sources such as CrossRef and PubMed. If journal articles, proceedings, books or book chapters have DOIs and are indexed in Crossref, they will be featured in Dimensions as well (Martin Martin et al., 2021; Dimensions, 2023)

It is essential to remember that the three databases are not only unique in their indexing methods of content but also in the countries, languages and topics they cover. English is the most popular language in both WoS and Scopus, with 92.64% of the documents indexed in Scopus being in English and an even higher percentage of 95.37% in the WoS. Chinese is the second most widely used language in Scopus, with a total of 2.76% of documents being indexed, while Spanish is second in terms of popularity in WoS with 1.26% (Vera-Baceta, Thelwall & Kousha, 2019). Multiple studies have found that Scopus and Web of Science have very limited coverage of research in Africa, South America, and some parts of Asia. Scopus is usually larger and covers a wider range of geographical locations than the Web of Science. Despite this, only a limited amount of journal publishing is addressed outside of Europe and North America. (Tennant, 2020).

The dissimilarities in the indexing procedures and the publication coverage among different databases may have an effect on the outcomes we get concerning the Sustainable Development Goals publications. It is important to assess the results cautiously to identify which database holds the most data related to SDGs publications. It is possible that the varying outcomes of the SDGs are caused by the discrepancies in indexing between databases.

Scopus does not include the SDG 17 (Partnerships for the Goals) therefore it is not possible to make a comparison using the publications of this goal. According to Scopus, SDG 17 is very difficult to quantify, there is no satisfactory search query to define it at this time. This is why SDG 17 is not included in this analysis.

Bibliometric indicators used in this study

InCites indicators

- Documents: Total number of Web of Science documents
- Times Cited: Number of times a set of publications has been cited.
- Citation Impact: The average number of citations that a document has received.

- Documents in Top 10%: The top ten percent most cited documents in a given subject category, year and publication type divided by the total number of documents in each set of documents, displayed as a percentage.
- Category Normalized Citation Impact (CNCI): This indicator is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area.
- International Collaborations: Percentage of publications that have international co-authors.
- Highly Cited Papers: Percentage of publications that are assigned as Highly Cited in Essential Science Indicators (ESI) (top 1% by citations for field and year)
- Hot Papers: Percentage of publications that are assigned as Hot Papers in ESI (top 1% by citations for field and age)
- Documents in Q1: Number of documents that appear in a journal in the 1 Journal Impact Factor Quartile in a given year.
- All open access documents: Percentage of documents published in open access (Gold, Green).
- Industry collaborations: Percentage of publications that have co-authors from industry.
- Domestic Collaborations: Percentage of publications that have national co-authors.
- Gold documents: Percentage of articles published in journals listed on the Directory of Open Access Journals (DOAJ).
- Gold Hybrid documents: Percentage of other Gold open access articles are identified as having a Creative Commons (CC) license by Our Research but are not in journals listed on the DOAJ.
- Free to read documents: Articles in the Web of Science identified as Bronze are labelled Free to Read in the Journal Citation Reports (JCR). Bronze is a relatively recent term, used by Our Research to describe content that is free to read on the publisher site, but not published under an OA license.

SciVal indicators

- Scholarly Output: number of publications produced in a data range.
- Citations per publication: indicates the average citation impact of each of an entity's publications: how many citations have this entity's publications received on average.
- Field-Weighted Citation Impact: the ratio of citations received in relation to the expected world average for a specific subject field, publication type and publication year. Note: FWCI is less stable on small data sets.
- Outputs in Top Citation Percentiles (top 10%): publications in the top 10% most cited publications worldwide.
- Publications in Top Journal Percentiles (top 10%): publications in the top 10% journals by CiteScore. CiteScore calculates the average number of citations received in a year by articles published in a journal in the previous four years, while JIF is calculated over a two-year period.
- Collaboration: Collaboration indicators indicate the extent to which a researcher's output have international, national or institutional co-authorship, and single authorship.

Dimensions indicators

- Publications: It is the number of publications related to the search in Dimensions.
- Citations mean: it is the number of times that a publication has been cited by other publications in the database. Citing publications can be of any publication type, such as articles, chapters, preprints, or monographs.

- Publications with citations: it is the number of publications with at least x citations or publications which have not been cited yet.
- The Field Citation Ratio (FCR): it indicates the relative citation performance of a publication when compared to similarly aged articles in its subject area. A value of more than 1.0-1.5 indicates higher than average citation, when defined by Field of Research (FoR) subject code, and publication year. The FCR is calculated for all publications in Dimensions which are at least 2 years old and were published in 2000 or later.
- The Relative Citation Ratio (RCR): it indicates the relative citation performance of a publication when comparing its citation rate to that of other publications in its area of research. A value of more than 1.0 shows a citation rate above average. The article's area of research is defined by the articles that have been cited alongside it. The RCR is calculated for all PubMed publications which are at least 2 years old.
- The Altmetric Attention Score: is a weighted count of all the online attention Altmetric have found for an individual research output. This includes mentions in public policy documents and references in Wikipedia, mainstream news, social networks, blogs and more.
- Publications with attention: it is the number of publications with Altmetric attention.

Exploratory factor analysis and principal components analysis

Exploratory factor analysis (EFA) and principal components analysis (PCA) are two techniques that can be employed by researchers to represent a multitude of relationships between normally distributed or scale variables with greater simplicity and efficiency. These two methods determine which items, from an extensive set, are related. For factor analysis and principal components analysis to be successful, two main conditions must be fulfilled. First, the variables must be related. Further, the larger the sample size, particularly in relation to the number of variables, the more reliable the results. In factor analysis, sample size is less crucial if there are high or relatively high communalities among the items. Utilising exploratory factor analysis techniques can be very beneficial when we want to work with variables that show relatively high correlation coefficients and desire to create new variables that reflect the collective behaviour of the original variables.

A ten-year publication window 2011-2020 was selected to compare the data from the three bibliometric suites. The data was downloaded in December 2021. The statistical software SPSS was used for the statistical analysis of the data. The visualisations were produced with the software Power BI.

Results

The data in Figure 3 represents the number of publications on Sustainable Development Goals from different databases. According to the data, SciVal collects the most significant number of publications, followed by Dimensions, and Incites.

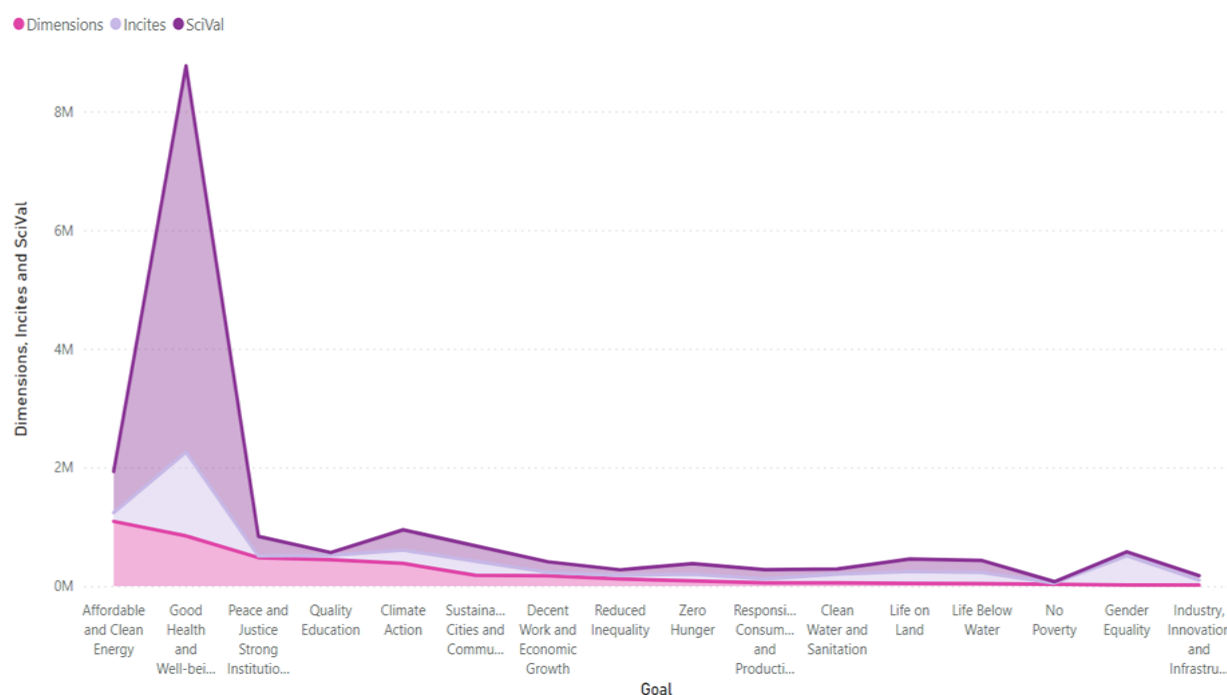


Figure 3. Publications on SDGs from Incites, SciVal and Dimensions.

We can see how the publication distributions differ between the goals. In relation to Goal 3, there is a significantly larger quantity of publications in SciVal than in Incites and Dimensions. Even though Dimensions mostly obtains its publication data from open sources such as Crossref and PubMed. What could account for such a significant variance in data? To ascertain the source of these discrepancies, we could take one objective and evaluate a sample of publications across all of them to determine how the various databases are indexing these publications.

In table 1 below it is showed the Pearson correlation among the distribution of publications across the years in each Sustainable Development Goals comparing the different bibliometric suites.

Table 1. Correlation among publications classifications

Incites vs Scival (0.93)
Incites vs Dimensions (0.42)
SciVal vs Dimensions (0.56)

A pearson correlation was conducted between the different outcomes per year. We can clearly see that there is a powerful relationship between the production from Incites and Scival (0.93), which is not unexpected because of their extensive traditional coverage and comparable indexing methods. Nevertheless, when comparing the outcomes of Dimensions, the Pearson correlation between Dimensions and Incites was 0.42 and Dimensions and SciVal was 0.56. Thelwall (2018) suggested that Dimensions could be compared to Scopus, however, not the Web of Science, as Scopus has been confirmed to include a broader selection of academic journals and so it is more comprehensive (Mongeon & Paul-Hus, 2016; Waltman, 2016; Thelwall, 2018)

Scientific impact across data sources

It is important to remember that the same indicator might have different names depending on the database. Such as Incites: Citation Impact, Dimensions: Citations Mean, and SciVal: Citations per Publication. But all of them measure the same an average of citations per publication. The figure 4 below represents the three impact indicators per SDG in each bibliometric suite.

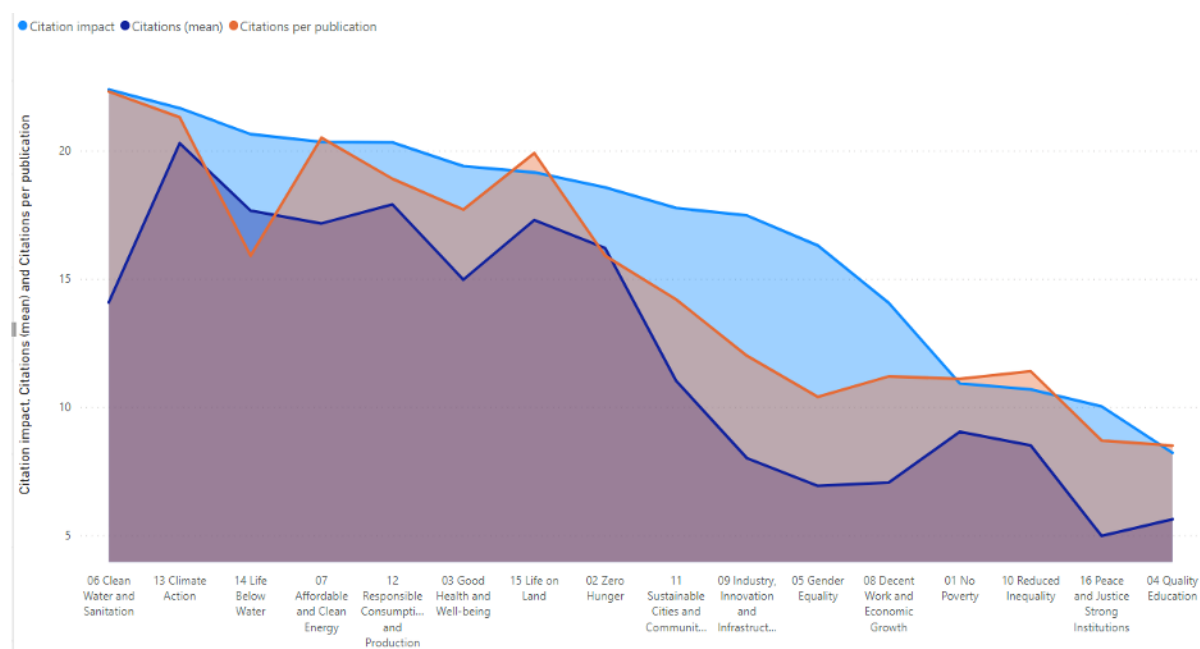


Figure 4. Scientific impact across data sources

Table 2. Correlation among citations per publications in classifications

Incites vs SciVal (0.88)
Incites vs Dimensions (0.83)
SciVal vs Dimensions (0.90)

Observing figure 4 it is evident to admit that the publications included in InCites received the highest citation average i.e., except in the SDG 15 Life on Land or SDG 10 Reduced Inequality. The three databases are showing the publication on SDG 13 Climate Action received the highest citation average. In contrast, the publications around SDG 04 Quality Education received the lowest citation impact in the three databases. The SDG 6 Clean Water and Sanitation publications in SciVal and InCites had the highest number of citations per publication. Dimension publications concerning SDG 12 Responsible Consumption and Production acquired a considerable number of citations. SDG 4 Quality Education publications had the least number of citations per publication among all databases when compared.

In general, regarding citation average, all bibliometric suites showed a strong correlation in this indicator as observed in Table 2. The strongest one is between Scival and Dimensions (0.90).

Open Access is key to achieving the United Nations' Sustainable Development Goals. The Sustainable Development Goals are reliant on improved access to information and knowledge, therefore creating a clear link between Open Access, access to information, and sustainable

development. The number of SDG-related papers that are open access is presented across the three databases in the Figure 5, which illustrates the link between SDGs publications and open access.

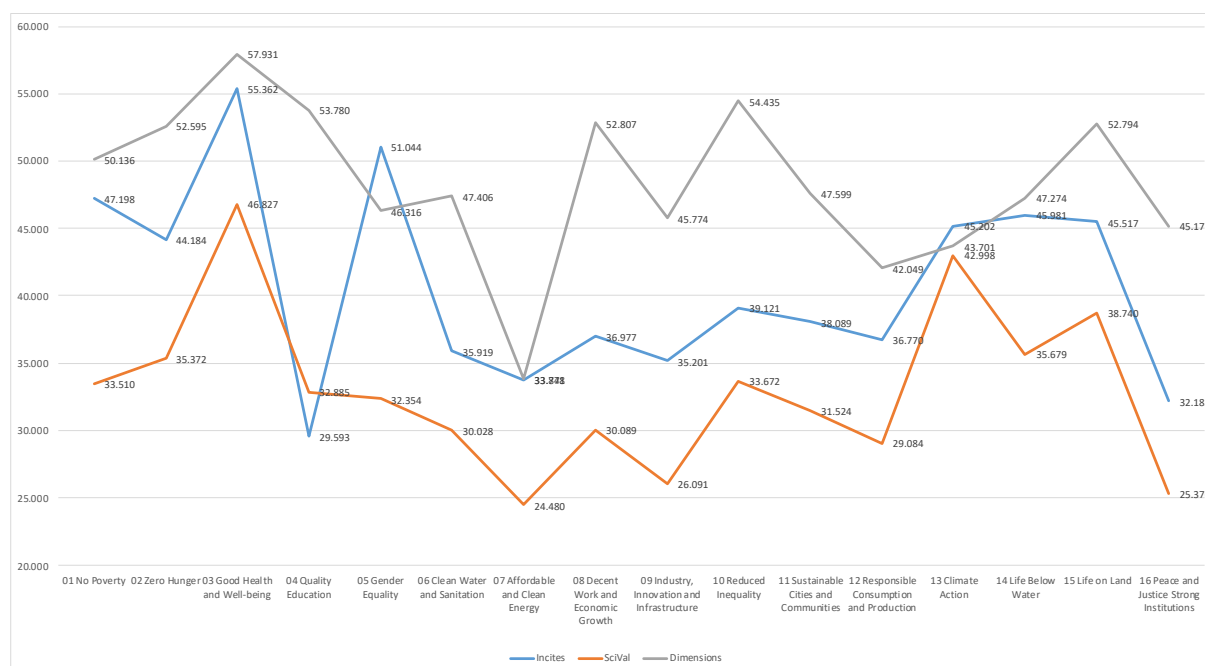


Figure 5. Open Access publications per SDG across data sources

Despite the efforts to make Open Access a fundamental part of the Sustainable Development Goals (SDGs), less than 50% of the SDG publications included in the three bibliometric suites were published in Open Access (on average). Dimensions has the largest number of documents in Open Access (48,35% on average), followed by Incites (40,75%) and SciVal (33,04%). The SDG 03 Good Health and Well-being has highest percentage of OA documents in the three databases. However, the SDG publications with less percentage of open access are SDG 7 Affordable and Clean Energy.

As Dimensions has the highest percentage of OA publications, in the figure 6 it shows the publications in Dimensions divided by different OA to analyse them in more detail.

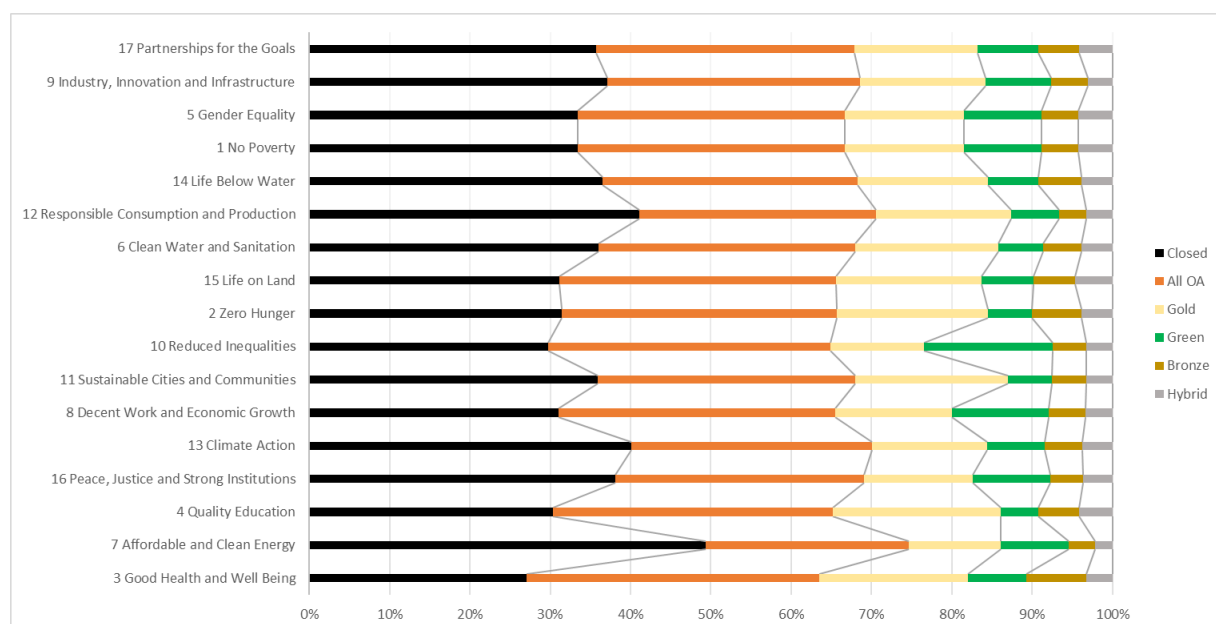


Figure 6. OA Dimensions publications per SDG

Comparing publications in Dimensions per different types of availability. Dimensions revealed most SDG publications were Closed publications on average. The total number of Closed publications is 2,167,815 and the total number of Open Access publications is 1,872,102. Nevertheless, with regards to SDG 13 Good Health and Well Being, SDG 4 Quality Education, and SDG 10 Reduced Inequalities, the number of open access publications was greater than that of closed access publications.

Web of Science is one of the well-known bibliometric databases that gathers a large number of publications about the SDGs, and also provides a variety of indicators through its bibliometric suite InCites that are not offered by other databases. Consequently, the figure below serves as a context to further explore the indicators related to these publications.

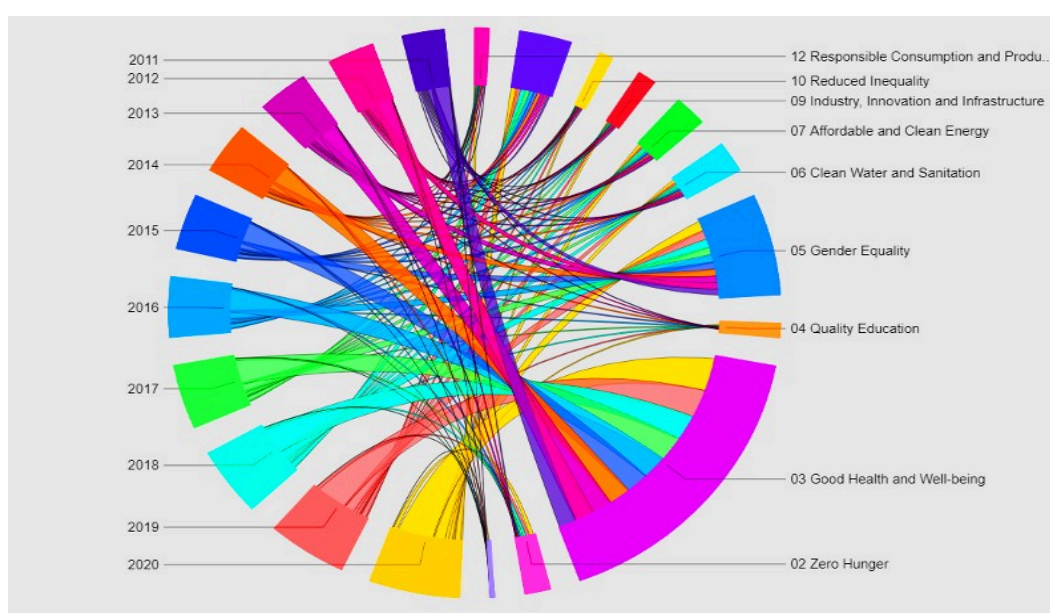


Figure 7. Web of Science publications around SDGs across different years.

In the Figure 7 above, we observe the publications in InCites in the different SDGs, and per year, it looks like the SDG 3 has the largest number of publications, and the year 2020 grouped the most considerable number of publications around SDGs. This figure demonstrates that despite the SDGs being launched in 2015, we can see captured publications in previous years.

All the three databases provide a selection of indicators that can be applied to analyse the publications on SDGs. However, InCites has the largest number of indicators, approximately 60 indicators per each SDG. Consequently, it was decided to utilise the indicators of this database to apply the Exploratory Factor Analysis and Principal component. In InCites, we can find indicators as a total, percentage of the total, and averages. In order to avoid any duplications, it was decided to use percentages and average indicators instead of the totals. In the future, it could be used with other indicators in on other databases and the outcomes could be compared.

In Table 3 we can observe the indicators chosen to employ the Exploratory Factor Analysis and Principal Component. The aim is to simplify the information available about the research contributions to the SDGs to extract the most insights. It is important to mention that the analysis has taken only 22 bibliometric indicators from InCites (from Highly Cited Papers to Green Submitted Documents) as observed in the next table.

Table 3. InCites indicators chosen for the analysis

Name	Web of Science Documents	Times Cited	Category Normalized Citation Impact	% Highly Cited Papers	% Hot Papers	% Documents in Q1 Journals	% Documents in Q2 Journals	% Documents in Q3 Journals	% Documents in Q4 Journals	Citation Impact	% International Collaborations	% All Open Access	% Industry Collaborations	% Domestic Collaborations	Journal Normalized Citation Impact	Impact Relative to World	Documents in JIF Journals	% Gold - Hybrid Documents	% Free to Read Documents	% Green Submitted Documents	% Green Accepted Documents	% Green Published Documents
01 No Poverty	20323	221991	0.99	0.50	0.01	36.44	32.01	17.97	13.58	10.92	29.77	47.20	0.41	23.22	1.04	0.99	13687	6.45	7.20	13.80	8.33	23.49
02 Zero Hunger	117604	2183470	1.00	1.44	0.03	49.43	26.05	13.58	10.94	18.57	31.79	44.18	0.66	32.06	1.20	1.68	91546	5.71	6.41	13.06	5.37	19.96
03 Good Health and Well-being	1414623	27495847	1.00	1.20	0.02	43.70	27.72	16.69	11.90	19.39	24.38	55.36	2.10	41.96	1.13	1.76	1194909	5.24	10.99	12.73	10.43	34.56
04 Quality Education	70629	580561	0.99	0.23	0.00	29.02	28.76	24.70	17.52	8.22	13.61	29.59	0.18	22.46	1.12	0.74	30494	3.07	3.51	10.51	5.22	8.08
05 Gender Equality	493895	8049241	1.00	0.81	0.01	41.67	28.55	17.41	12.38	16.30	23.61	51.04	1.29	40.35	1.11	1.48	402401	4.56	9.49	11.78	11.81	29.04
06 Clean Water and Sanitation	149467	3344721	1.00	1.75	0.03	51.63	23.94	14.54	9.88	22.38	29.13	35.92	1.09	34.20	1.20	2.03	123819	4.46	5.89	11.08	4.03	12.82
07 Affordable and Clean Energy	148993	3030486	1.00	2.00	0.04	61.93	19.61	12.41	6.04	20.34	25.20	33.78	2.04	26.92	1.13	1.84	100044	4.01	3.22	11.00	4.00	10.46
08 Decent Work and Economic Growth	58737	825704	1.00	1.54	0.04	42.08	25.53	19.24	13.14	14.06	24.25	36.98	0.69	22.22	1.13	1.27	38224	3.89	3.39	16.80	5.36	10.91
09 Industry, Innovation and Infrastructure	84909	1472987	1.00	1.87	0.03	53.66	24.20	13.88	8.26	17.47	25.29	35.20	0.97	23.90	1.18	1.58	51721	4.50	2.55	13.18	5.56	10.22
10 Reduced Inequality	62785	671155	0.99	0.56	0.01	34.85	29.36	21.24	14.56	10.69	20.00	39.12	0.42	24.38	1.04	0.97	40049	4.07	4.74	14.92	8.51	14.91
11 Sustainable Cities and Communities	237189	4212428	1.00	1.52	0.03	52.82	23.86	14.08	9.24	17.76	26.01	38.09	1.24	27.60	1.17	1.61	163632	4.53	3.70	12.91	5.23	12.54
12 Responsible Consumption and Production	65361	1328105	1.00	2.22	0.04	56.98	22.58	12.64	7.80	20.32	25.90	36.77	1.08	27.63	1.26	1.84	47514	4.87	3.30	11.91	4.37	12.44
13 Climate Action	225413	4881490	1.00	1.83	0.03	58.02	22.96	10.84	8.18	21.66	34.22	45.20	0.92	30.82	1.17	1.96	182617	6.49	7.48	15.26	6.31	17.08
14 Life Below Water	188150	3883365	1.00	1.49	0.02	52.79	25.81	11.91	9.48	20.64	35.81	45.98	0.81	33.89	1.16	1.87	159742	6.02	8.43	15.39	6.18	19.09
15 Life on Land	198558	3802022	1.00	1.16	0.02	51.94	25.86	12.62	9.58	19.15	36.30	45.52	0.60	34.03	1.08	1.73	172135	5.38	8.58	15.13	5.67	19.94
16 Peace and Justice Strong Institutions	33309	334053	0.99	0.37	0.00	35.61	29.32	22.80	12.28	10.03	13.92	32.18	0.11	28.49	1.07	0.91	21832	3.22	3.81	8.66	9.33	11.94

The data from InCites was extracted to apply the exploratory factor analysis and principal component analysis to group the indicators related to SDG. After choosing the indicators, the technique was applied using SPSS. This analysis is conducted to determine if an exploratory factor analysis could reduce the number of indicators associated with the goals and take only several dimensions which accurately represent them. A correlation between them was

determined. The analysis showed that it would be possible to group the variables into three separate clusters.

The table 4 indicates a matrix was applied to assess if the variables chosen had a moderate or strong relationship with other variables. If the correlation values are not significant, it would be inadvisable to generate the correlation matrix with factor analysis or principal components analysis.

The selected technique for rotation is Oblimin with Kaiser-Meyer-Olkin (KMO). After 9 iterations, the rotation had reached its convergence. The items cluster into these three groups defined by the highest loading on each item.

Table 4. Pattern matrix

	Component		
	1	2	3
% Highly Cited Papers	,975		
% Documents in Q2 Journals	-,968		
% Documents in Q1 Journals	,945		
% Documents in Q4 Journals	-,886		
% Hot Papers	,885		
Category Normalized Citation Impact	,884		
Citation Impact	,873		
Impact Relative to World	,873		
% Documents in Q3 Journals	-,818		
Journal Normalized Citation Impact	,809		
% Green Accepted Documents	-,655		
Documents in JIF Journals		,988	
Web of Science Documents		,988	
Times Cited		,978	
% Domestic Collaborations		,837	
% Green Published Documents		,817	
% Free to Read Documents		,715	
% All Open Access Documents		,688	
% Industry Collaborations		,670	
% Gold - Hybrid Documents			,860
% International Collaborations			,817
% Green Submitted Documents			,750

After applying Exploratory Factor Analysis (EFA), the indicators were grouped into three factors depending on the strong associations among them. The Factor 1 comprises 11 indicators showed in descending order of loading. Highly Cited Papers has the highest loading with .975, while Green accepted documents have the smallest loading at .655. After evaluating the items for each factor, they could be combined conceptually, providing a title to them. The first factor

is associated with productivity, a set of measures related to scientific production. The second factor includes indicators related to Open access, so it would be suitable to call it Open Access. The name of the third factor could be international collaborations and visibility, as it has indicators related to research international collaborations.

In order to establish a link between EFA results and the Sustainable Development Goals. The indicators that are strongly loaded in the same factor were Highly cited papers, Documents in Q1 and Q2 Journals. It gives us an important insight into the type of venue and productivity of publications on SDGs in relation to this component. Furthermore, as a means of assessing the impact of publications on their area of research, Category Normalised Citation Impact (CNCI) has been applied but it is highly associated with Productivity factor. CNCI is a measure for assessing the progress and performance at all levels of an organisation, from individual institutions to group of institutions or countries.

The second factor, which appears to be related to Open Access and Impact, had a higher loading rate for documents in JIF Journals, number of documents and citations received as well as % All Open Access Documents. It was found that the third factor in the table were strongly correlated with the final 3 items, all relating to international collaboration, and this correlation could be attributable to visibility and cooperation.

In multivariate statistics, a scree plot is a line plot of the eigenvalues of factors or principal components in an analysis. The scree plot is used to determine the number of factors to retain in an exploratory factor analysis (FA) or principal components to keep in a principal component analysis (PCA).

In figure 8 it is shown the scree plot of the EFA of the indicators of the SDGs. The eigenvalues are always displayed in the downward curve in the scree plot, and the eigenvalues are ordered from the largest to the smallest. According to the scree test, the "elbow" of the graph where the eigenvalues seem to be decreasing should be found, and the factors or components to the left of this point should be retained as significant. The scree plot illustrates that the differences between the eigenvalues decrease and become less than 1.0 after the first three components. This serves to reinforce the idea that a three-factor solution is likely to be accurate.

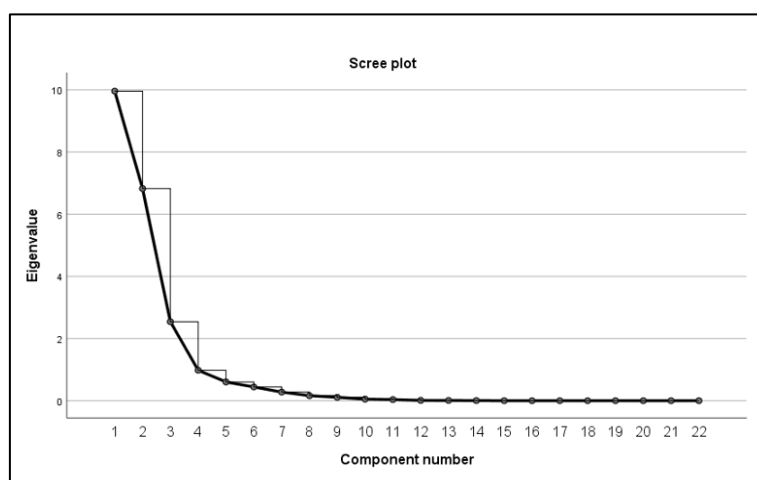


Figure 8. Scree plot for principal component analysis (PCA)

The Scree plot shows that there are three components which have initial Eigenvalues that are greater than 2.0, with the second component being just barely above the 2.0 mark at 2.20. Fifty per cent of the variance can be explained by the First Factor.

The Scree Plot is a way to show the Eigenvalues graphically. The scree plot and the eigenvalues both indicate that it may be possible to reduce the 22 variables down to three components. It is evident that the scree plot declines after the third factor. Despite this, the third component is still undefined, related to only three variables.

Open Research has enabled us to look at Sustainable Development Goals (SDGs) from a fresh perspective, allowing us to publish innovative ways of communicating research findings, thus contributing to a quicker resolution of global issues. Dimensions have been employed to analyse the published datasets and preprints related to the Sustainable Development Goals. In the future, we can compare the data from all the indicators to determine if there is any correlation between them. Using this technique, we can conclude that the number of variables involved in contributing to Sustainable Development Goals can be reduced. These methods would reduce variables through statistical analysis to explore latent dimensions that illustrate the relationships between multiple variables.

Table 6 provides information on the number of Datasets and Grants that have been linked to Sustainable Development Goals (SDGs) using data from the Dimensions.

Table 6. Publications, citations, datasets and grants associated to SDGs in Dimensions

	Publications	Citations	Citations means	Datasets	Grants
3 Good Health and Well Being	837,558	11,616,141	13.87	39,093	69,614
7 Affordable and Clean Energy	1,070,478	17,041,635	15.92	19,287	110,513
13 Climate Action	372,132	6,947,031	18.67	19,246	57,515
16 Peace, Justice and Strong Institutions	476,305	2,164,446	5	10,013	28,353
4 Quality Education	440,904	2,264,116	5.14	8,900	49,542
14 Life Below Water	42,729	693,618	16.23	8,514	5,834
15 Life on Land	47,041	744,544	15.83	7154	6,854
8 Decent Work and Economic Growth	173,104	1,094,005	6.32	6922	11,847
11 Sustainable Cities and Communities	179,473	1,792,046	9.99	4851	24,599
2 Zero Hunger	85,780	1,261,267	14.7	3075	12,027
10 Reduced Inequalities	119,292	922,620	7.73	2,328	8,722
6 Clean Water and Sanitation	52,414	668,495	12.75	1,794	5,438
1 No Poverty	31,304	257,822	8.24	902	2,311
12 Responsible Consumption and Production	55,176	887,601	16.09	774	9,601
5 Gender Equality	17,630	110,839	6.29	502	1,345
9 Industry, Innovation and Infrastructure	16,375	118,067	7.21	271	2,956
17 Partnerships for the Goals	8,548	51,422	6.02	94	1,092

Sharing research data has been shown to increase visibility and impact of scientific publications (Colavizza ET AL., 2020) The table above suggests that SDG 3 Good health and well-being, SDG 7 Affordable and clean energy and SDG 13 Climate Action are the SDGs where most datasets have been collected. Not surprisingly, the publications related to these SDGs received the highest impact. Despite to be one of the lowest SDGs in Datasets, the publications on SDG 12 Responsible consumption and production obtained one of the highest Citations means.

SDG 7 Affordable and Clean Energy, SDG 3 Good Health and Well-being and SDG 13 Climate Action, are the SDGs where most grants were received linked to publications.

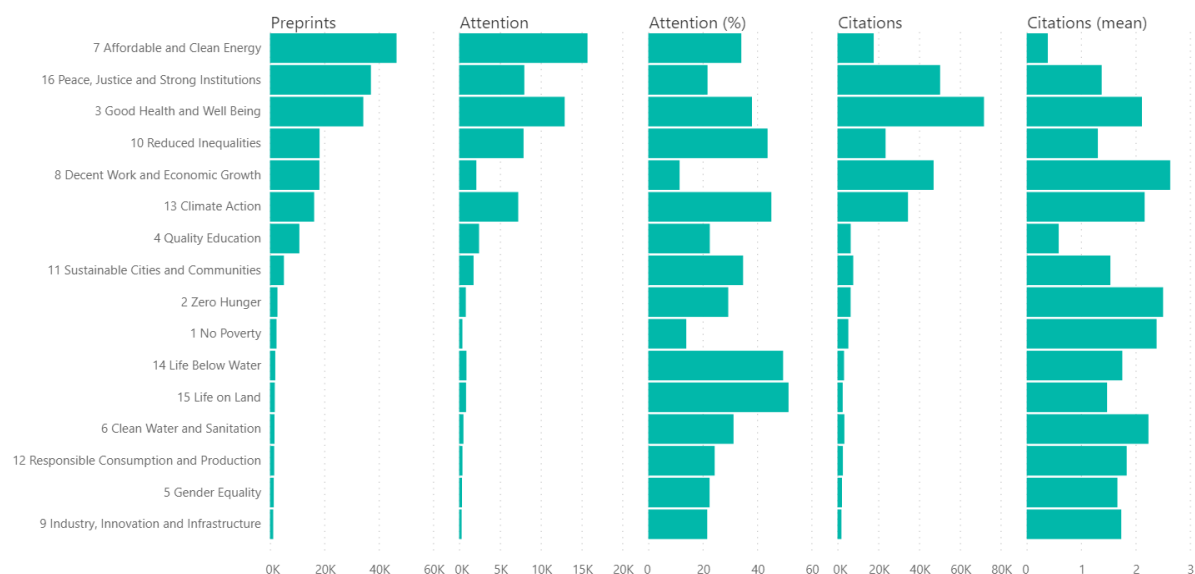


Figure 9. Number of preprints produced around SDGs

Figure 9 shows the number of preprints that have been produced related to Sustainable Development Goals. The SDGs with the highest number of preprints were: SDG 7 Affordable and Clean Energy (46,173), SDG 16 Peace, Justice and Strong Institutions (36,738), and SDG 3 Good Health and Well Being (33,948). The preprints with the highest citation mean were SDG 8 Decent Work and Economic Growth (2.62), SDG 2 Zero Hunger (2.49) and SDG 1 No Poverty (2.37). Publications that received the attention (Altmetric) were those in the SDG 7 Affordable and Clean Energy (33.81), followed by SDG 3 Good Health and Well Being (37.73), and SDG 16 Peace, Justice and Strong Institutions (21.4). There is no relation (-0.20) between the attention received (Altmetrics) and the citations means in the preprints regarding SDGs. Although there is an obvious correlation between the number of preprints produced for each goal and the attention they receive, this indicates the preprints are associated with attention, visibility and not necessarily with scientific impact (citations).

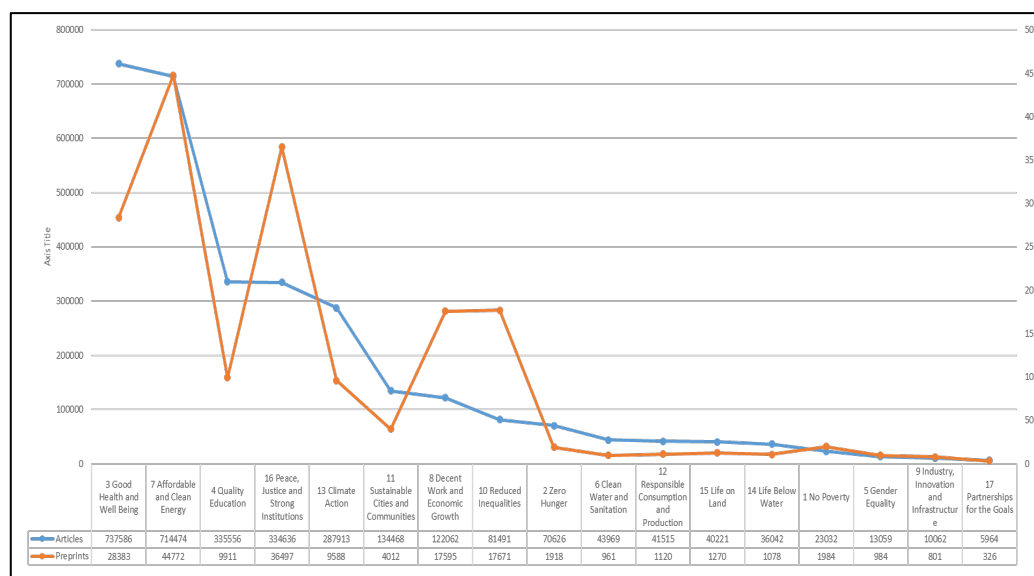


Figure 10. Comparison between preprints and articles per SDG in Dimensions.

The results from figure 10 shows the comparison between number of preprints and articles. We can observe that the SDG with the highest number of papers is not always the one with the highest number of preprints. Except in the SDG 7: Affordable and Clean Energy, SDG 3: Good health and well-being.

Discussion and conclusions

Citation databases use author keywords as well as indexed keywords with controlled vocabulary to identify publications. The method of indexing could have a significant impact on how publications concerning the SDGs are ultimately retrieved.

We were able to gain a deeper understanding of Sustainable Development Goals publications through the analysis of the SciVal, InCites, and Dimensions bibliometric suites. SciVal has the most publications regarding SDGs, followed by Dimensions and InCites. There is a high correlation coefficient of 0.93 between SciVal and InCites results. Due to their traditional bibliometric nature and comparable coverage, this is not surprising.

There is a large collection of publications about SDG 3 Good health and wellbeing in all three databases. SciVal and Dimensions have collected a large number of publications in relation to SDG 7 Affordable and Clean Energy. InCites has the most comprehensive collection of publications dedicated to SDG 5 Gender Equality. InCites and SciVal databases both show the lowest quantity of publications on SDG 1 No Poverty.

Calculating the correlation of the same indicator (average citation per publication) in all three databases, strong correlation values were revealed. SDG 13 Climate Action publications had the highest citation impact in all databases. SDG 04 Quality Education received the lowest citation impact in the three bibliometric suites. Are the publications associated with SDG 4: Quality Education indexed in journals from the Arts and Humanities or Social Sciences disciplines? Art and Humanities and Social Sciences related disciplines can exhibit differences in publications and citation patterns, as well as in database coverage, compared to STEM disciplines. Arts and Humanities and Social Sciences scholars feel are still underrepresented in citation databases where the reasons could be the insufficiency books coverage and the limited

coverage of non-English publications in mainstream databases. It is obvious that these differences will have an impact on the indicators related to SDGs as well as their interpretation. In addition, every subject area has its own unique particularities, so this should be considered when comparing the results using bibliometric suites. Consider the data sources' limitations, the data's reliability, and the discipline's attributes before attempting to evaluate or interpret SDG results without putting them into context.

Open Access is a key factor in the attainment of the UN Sustainable Development Goals. Nevertheless, the three main databases demonstrate that the average of OA publications on SDGs is not more than 48%. Analysis of the Dimensions results demonstrated that most publications are closed Access, with scholars, their corresponding institutions and academic libraries having to invest heavily for Access to the articles. For example, there are over 2,167,815 closed publications (52%). The average does not apply to all the SDGs. The majority of publications on SDG 03 Good Health and Well-being and SDG 05 Gender Equality and SDG 01 No Poverty were published in Open Access.

Preprints have been an essential part of the recent advances in scholarly communications by providing a quick way to share research findings. Despite this, there is a clear disparity between the number of articles and preprints that have been published regarding the SDGs. Articles have been the preferred method of spreading the contributions to the SDGs.

Through the use of exploratory factor analysis (EFA) and principal component analysis (PCA), it is possible to reduce the number of indicators on SDGs into a few key dimensions that can be more easily comprehended. We could reorganise the indicators into clusters, referred to as factors or components. This reorganisation is based on the similarities among multiple indicators.

Certain pieces of information may be omitted when employing the technique. We need to find the equilibrium between decreasing the number of dimensions and losing information. We are required to accept a compromise through the application of this statistical technique. The Principal Component Analysis changes the original indicators into data that is related to the main components of the data, meaning that the new data variables cannot be interpreted in the same way as the original. Principal component and factor analysis could merge the indicators that define the SDGs. It is crucial to assess the results carefully and always with the advice of specialists in the field.

Limitations

The present study is not free from certain limitations. In order to conduct the study, the three main citation databases, Dimensions, Scopus and Web of Science were utilised; therefore, any publications not indexed in these databases were not considered in the analysis. The number of publications retrieved from countries or regions with local or regional journals that are not listed in mainstream databases could be significantly lower due to this issue.

This research particularly concentrated on peer-reviewed literature and did not include any policy reports from government departments or other sources of grey literature. Grey literature can be a useful resource for assessing the progress of a nation's efforts to achieve the Sustainable Development Goals. All types of SciVal publications, e.g. Letters, Notes, Reviews and Editorials, were included in the analysis. Although these forms of contributions may not always be seen as an original research element.

The Lancet journal is well-known for its editorial work on SDGs. Its publications then may inflate the journal's contribution to the Sustainable Development Goals when we compare. The present study did not differentiate between articles that focus primarily on SDGs and those that mention the term. A document could bring up a challenge, such as sanitation, making no explicit references to the Sustainable Development Goals. There might be literature that mentions the term "Sustainable Development Goals" or "SDGs" and they were not captured by the search strings pre-configured.

False positives are documents collected that are unrelated to the Sustainable Development Goals (SDG) but they are picked up because of the keywords used. False negatives, on the other hand, are documents that are actually contributing to the SDGs but are not collected because of unmatched keywords. Both of these scenarios can take place. These cases, however, may not be very common.

When looking at the results, it is important to keep in mind the limitations that may exist. This research presents an in-depth examination of SDGs with an international focus, which have been of great interest to the research community.

As a potential future project

- Comparing the results to other open databases, such as OpenAlex, Overton and BMJ Analytics.
- Through comparing data from various sources, such as statistical databases like SDG Indicators - UN Statistics Division, in addition to citation databases.
- Examining the gender representation in publications related to the Sustainable Development Goals is one issue that needs to be analysed.
- It is important to identify the countries that are making the greatest contributions to achieving the sustainable development goals (SDGs).

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