FUTURE AND EMERGING TECHNOLOGIES IN AI&ML

Open Journal

Future and Emerging Technologies in AI & ML

Review

Application of AI/ML Techniques in Achieving SDGs: A Bibliometric Study

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Article information
Received: March 20th, 2024; **Revised:** June 14th, 2024; **Accepted:** July 31st, 2024; **Published:** August 12th, 2024

Cite this article
A. Jiran Meitei, Pratibha Rai, S. S. Rajkishan. Application of AI/ML techniques in achieving SDGs: A bibliometric study. 2024; 3(2).
doi: https://doi.org/10.70705/ppp.fetaiml.2024.v03.i02.pp74-84

ABSTRACT

Based on research conducted between 2017 and 2022, this article summarizes the ways in which artificial intelligence and machine learning were used to accomplish the United Nations Sustainable Development Goals. Using Scopus and Web of Science, researchers conducted a systematic bibliometric review of 250 peer-reviewed journal articles. The goals of the review were threefold: (i) to identify current trends in publications about the use of innovative technologies like AI and ML to achieve the SDGs; (ii) to identify areas where AI is having a negative impact on sustainability; and (iii) to determine where research should go from here. China, the United States, Spain, the United Kingdom, and Australia were the top five countries from which research were sourced. Cooperation between nations and educational institutions is also clearly visible. Using Bradford's rule, the analysis determined that the journals Sustainability, Remote Sensing, IEEE Access, and Journal of Cleaner Production were the primary sources. Researchers have shown that AI has potential, but they worry that people are becoming too optimistic about its benefits. The report highlights the need of regulating AI and conducting frequent verification to maintain confidence, transparency, and adherence to universal ethical norms in order to fulfill the SDGs. The results may help point academics in the right direction about how to use AI and ML to accomplish the SDGs.

Keywords
Artificial intelligence (AI); Bibliometric coupling; Co-citation; Co-occurrence; Sustainable development goals (SDG).

INTRODUCTION

Environment & Development: "Our Common Future" (1987) proposed a comprehensive concept of sustainable development by the United Nations' World Commission. The goal of sustainable development is to provide for current needs and wants without sacrificing future capacity to do the same (Brundtland et al., 1987). According to Eustachio et al. (2019), the ecological, societal, and economic systems have been overwhelmed by the demands of the Anthropocene. The world is facing a lot of problems because of these overdos, like pollution, depletion of organic and inorganic resources, environmental degradation, natural disasters like famine and drought, and depletion of biodiversity, which has led to natural ruin (Mirakzadeh et al., 2012; Arora et al., 2019). The lessons learned from development efforts in the decades after World War II show that "developing countries must play a significant role and enjoy substantial benefits" because "the problems of poverty and underdevelopment cannot be solved unless we have a new era of growth." In the quest for innovative answers to the problem of sustainable development, technology plays a key role. Problems throughout the SDG spectrum have been addressed by the deployment of different technologies over the years. For example, GISs, MIFs, and remote sensing are employed to identify, map, and model vulnerability, hazard, and risk issues across geographical zones. The goal is to explore innovative and sustainable solutions (Roy et al., 2021, 2022a, 2022b).

IA lot of attention has been paid in recent years by both academics and professionals to the topic of the environmental impact of artificial intelligence (AI) and related technologies, which is considered a "mega-trend" and a game-changer in the green technology field (DFKI, 2020; Di Vaio et al., 2020; Loebbecke et al., 2020; Wanner et al., 2020). A number of technologies are already having a significant impact on people's daily lives. These include artificial intelligence (AI), big data analytics, the IoT, machine learning (ML), and deep learning (DL). In the last several years, they have made significant changes to systems and procedures (Palomares et al., 2021). How much the so-called sustainable technologies have slowed or sped up the achievement of the 17 SDGs is the subject of this investigation. According to the results, the main uses of these technologies and the tools that go along with them are data collection, prediction, mapping, and modeling.

The field of artificial intelligence (AI) focuses on the science and engineering of developing smart devices and software that can mimic human intellect. Learning and problem-solving are examples of human cognitive capabilities that are mimicked by McCarthy (2007). A primary focus of ML is the development of automated systems that can learn and improve their code over time (Mitchell, 1997). One way to teach a computer to think like a person is via a neural network, which is really just a bunch of algorithms designed to look like the brain. Through deep learning, the neural network aids the computer system in obtaining artificial intelligence. According to Goodfellow et al. (2016) and LeCun et al. (2015), deep learning has achieved impressive results in several fields. The neural network facilitates DL-based AI for computers. The controversy around the methods of interaction between AI and ML arises from their close proximity. These technologies rely heavily on data.

Views from global stakeholders are included in the accompanying figure, which follows the development of the Sustainable Development Agenda from the mid-1980s and the global acknowledgement of the importance of sustainable technologies by policymakers (Fig. 1).

The significance and role of new technologies in attaining the global goal for sustainable development gained quick currency and was adopted by the world community with the adoption and advancement of the sustainable development agenda.

With the aim of achieving a sustainable future, the 17 Sustainable Development Goals (SDGs) were put in place (Nilsson et al., 2016; Bachmann, 2022; Arora & Mishra, 2019). Partnerships are the means to an end—the preservation of people, planet, prosperity, and peace (Filho et al., 2018). The above figure shows that the United Nations SDGs mark a turning point in the world's attitude toward the geopolitical and socioeconomic paradigm of "sustainable development. "Eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustain-able development," the 2015 "Transforming our World" proclamation acknowledged (United Nations, 2015). Management of sustainability within the context of the SDGs takes into account the interplay of monetary, ecological, and social factors. Employee or community benefit is at the heart of the sociological dimension. According to Palomares et al. (2021) and Schoormann et al. (2022), they are organized into six viewpoints, with a total of 169 objectives and 232 sub-objectives. Despite the importance of these interconnected webs for policymaking, the SDGs' political framework fails to do so. Because of this, SDGs are not very helpful in directing efforts to resolve the myriad of interconnected problems (Blanc, 2015). The SDG interconnections and complex trade-offs are being fine-tuned via international negotiations. Politicians strike a balance between competing interests and objectives (Nilsson et al., 2016). Interactions between the SDGs may lead to conflicting goals and interests among policymakers (Nilsson et al., 2016). outcomes (Pradhan et al., 2017) since no synergies were found (Kroll et al., 2019). When communicating the indicators to various audiences, such as decision-makers, policymakers, and non-specialists, Hak et al. (2016) stress the need of clarity and simplicity.

At the national, regional, and international levels, the 2030 Agenda must be conceived via a comprehensive, consistent, and coordinated process (UN, 2018). At least 101 economies, including both developed and developing nations, with a combined share of global GDP of over 90%, have adopted industrial development strategies in the past decade. This has opened up new possibilities for the creation of new systems to promote innovations that lead to sustainable development (UN, 2019). In order to achieve the United Nations Sustainable Development Goals by 2030, there are now several global activities and projects aimed at developing AI-based solutions (Cowls et al., 2021b; Vinuesa et al., 2020). As an example, according to Tomašev et al. (2020), the goal of the AI for Social Good movement is to form multidisciplinary alliances focused on using AI to achieve the SDGs. Technological advancements both present the greatest challenges of the 21st century (Palomares et al., 2021; Shiroishi et al., 2019) and play a crucial role in achieving the SDGs (Di Vaio et al., 2020). However, the agenda only offers limited direct relations between these goals and technology. According to Goralski and Tan (2020), the SDGs include artificial intelligence (AI) via experiments and, eventually, sustainable leadership and management initiatives. The significance of artificial intelligence (AI) in sustainable management was acknowledged by the United Nations (UN) and made clear in many reports and treaties, as seen in the right panel of flow diagram 1.

For the upcoming years, "a key enabler of sustainable development will be the digital revolution, constituted by ongoing advances in AI, connectivity, digitization of information, additive manufacturing, virtual reality, ML, blockchains, robotics, quantum computing, and synthetic biology," according to the Global Sustainable Development Report (GSDR, 2019). The use of AI has the potential to address some of humanity's most pressing problems and is essential to the attainment of the Sustainable Development Goals (SDGs) (ITU, 2017). Worldwide, people are working together to speed up and improve the "development and democratization" of AI solutions that can tackle several pressing global issues including hunger, poverty, health, education, equality (including gender equality), and the environment (ITU, 2017). The Age of Industry (IR)

Government, employment, conduct, recreation, and schooling are all being transformed by 4.0 technology. The United Nations (2019) reports that these contributions have the potential to increase the productivity of labor, energy, resources, and carbon while simultaneously decreasing production costs, increasing access to services, and dematerializing production. On a more positive note, in the digital Anthropocene, people will start to change themselves, improving their brainpower and cognitive capacities, as opposed to the Anthropocene, when people are major agents of environmental change (UN, 2019). Two primary research questions generated by the bibliometric analysis and two secondary research questions developed from the literature evaluation form the basis of the study. Both researchers and professionals in the field will get something from the search. Data collecting, forecasting, mapping, and modeling are the primary uses of these technologies and the tools that enable them, according to our research.

• Direct RQ1: Can you tell me how articles on SDGs and AI are trending in terms of publication time, journals, authors, associated countries, topics, and institutions?

The second direct research question is: which articles have had the most influence in terms of citations?

• Derived RQ3: How may AI affect economic, environmental, and social results, and what are the possible downsides to these areas?

• Derived RQ4: How can we mitigate the negative impacts of AI? What approaches have been proposed in the existing literature?
This is the outline of the paper. Part 2 delves further into the approach and seeks to address the primary research issues posed in Section 1. Section 3 provides a comprehensive overview of the most-cited publications, chosen using the normalized local citation ratings. The literature evaluation provides a satisfying response to the third research question, which concerned the benefits and drawbacks of using AI, ML, and other digital technologies to accomplish the SDGs. Finally, we answer the fourth research question posed by the literature review in the next section. Part 4 provides a brief overview of the research, while Part 5 details its limitations and offers suggestions for how to set priorities for the next decade that will allow data-driven methods to have the greatest possible beneficial influence on attaining the SDGs by 2030.

2 Bibliometric methodology

Researchers now have a much harder time keeping up with topic trends, determining the keywords used, and investigating international or university collaborations due to the exponential increase in the number and variety of research publications (Aria & Cuccurullo, 2017). Disjointed and contradictory streams may emerge if empirical article deconstruction is the only criterion (Briner & Denyer, 2012). To solve these issues, researchers must use bibliometric analysis, which is a quantitative and systematic review of the bibliometric data of published papers (Boyce & Kraft, 1985). According to Crane (1972), it enables the researcher to record specifics about the subject being studied. Citation analysis, which uses citation counts to measure author, journal, and document similarity, is the most popular bibliometrics inquiry. Bibliographic coupling and co-citation analysis are the subjects of citation analysis. Numerous studies have examined various forms of author-citation relationships, including author-coupling (Zhao & Strotmann, 2008), author-journal coupling (Guan & Gao, 2008; Small & Koenig, 1977; Yan & Ding, 2012), and journal-journal co-citation (McCain, 1991). While writers whose works are examined acknowledge a bibliographic coupling connection, writers whose works are cited acknowledge a co-citation connection. The cited works are examined using bibliographic coupling (Kessler, 1963). According to Ma et al. (2022) and Small (1973), the referenced papers are examined by co-citation analysis. While bibliographic coupling is useful for identifying inter-research groupings, time-series co-citation analysis may reveal when paradigms and schools of thinking have shifted. According to Yang et al. (2016), the objectives of the analysis dictate the approach that is used.
Important bibliometric research measures for assessing the influence of writers and journals include citation metrics like the h-index (Hirsch, 2005) or the m-index (Gaviria-Marin et al., 2019). The h-index does not take the publication year into account; it just shows the frequency of citations for an author or journal. The m-index, on the other hand, is calculated by dividing the h-index by the total number of years beginning with the author's first printed work. In order to find out which keywords are most and least used in the articles being studied, the analysis of keywords counts them. The semantic network, which measures the knowledge structure of the articles, is based on the co-occurrence network of the keywords (Law et al., 1988; Radhakrishnan et al., 2017). Authors' keywords and keywords plus are the two categories of keywords used in bibliometric research (Zhang et al., 2016). Three authors use keywords to
Their publications are best described by five words, and the most prevalent terms in the article's references, which are not always in the article itself, are called keywords plus (Garfield, 1990). Given the lack of bibliometric analysis on the connection between AI and SDGs, the proposed review will help to unravel the evolving and emerging complexities of the research domain. It will also shed light on article trends, collaboration patterns, and research components (Verma & Gustafsson, 2020; Donthu et al., 2021). Finding influential and relevant sources and publications is the goal of the analysis, which also takes into account the frequency with which certain keywords and subjects appear in the text. Its interpretations are based on informed techniques that use both objective and subjective assessments, such as performance analysis and topic trend analysis and bibliometric coupling, respectively. We developed the study question that encompasses the whole topic. The process of bibliometric analysis, from data collection to visualization, is shown in the picture below (Fig. 2). This analysis follows the methodology put forward by Aria and Cuccurullo (2017) and Zupic and Čater (2015). The examination of the results section goes into further detail on these procedures. As seen in the procedure below, bibliometric technique includes data gathering, analysis, and visualization. Section 2.1 details the procedures used to get the data, whereas section The data analysis and visualization are presented in Sect. 2.2.

2.1 Data collection

We have collected published research articles from two databases, Web of Science (WoS) and Scopus. WoS is a powerful research engine that stores high-quality research publica- tions and citation records for confident discovery, access, and assessment. In WoS, the evaluation of publications is under three domains: Science Citation Index Expanded (SCI- EXPANDED), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (A&HCI). Scopus is one of the largest databases for published scientific research articles, conference proceedings, and books. Elsevier, launched in 2004, maintains the Sco- pus database.
Table 1 presents the gist of the process of selection of published documents adopted in the study. The documents were collected on 25th June 2022. We selected those rele- vant documents when words in the search criteria appeared in either the title, abstract, or keywords. The identified documents from the WoS and Scopus are 266 and 521 papers, respectively. We finally have 154 and 176 documents from Scopus and WoS, respectively,

after applying the filters of only published articles in the journals and written in English. After removing the duplicates and combining the two data sets, the final collection of documents has 250 documents published between 2017 to 2022. One hundred thirty-three sources published these documents with 1079 authors' keywords. Multiauthored docu- ments are 227 (90.8%), while the remaining are single-authored articles. The authors per document and collaboration index are 4.29 and 4.69, respectively. The references in the documents are 16,631, while the citations per document are 7.643.

2.2 Data analysis and visualization

Through statistical approaches like citation counts, bibliometric analysis examines sources, authors, documents, co-occurrence networks, and theme progression in an effort to statistically evaluate the scholarly quality of published publications on a certain subject. You can do this analysis using a lot of different programs. Our research relied on the R package "bibliometrix" (Aria & Cuccurullo, 2017). If you want to do bibliometric analysis using data from sources like "Clarivate Analytics Web of Science," "Digital Science Dimensions," "Cochrane Library," "Lens," "PubMed," and "SCOPUS," this program is to your liking.

The publishing analysis will be conducted in this research under many headings, such as source, author, and document. We will do bibliometric coupling analysis, clustering, co-occurrence, and co-citation. By analyzing normalized local citations, we will be able to find 20 papers that match our search criteria. We will next analyze these papers in depth to determine the current research trend.

From 2017 to 2022, the number of documents released is shown in Figure 3. From two papers in 2017 to 119 in 2021, the number of documents has grown at an exponential rate. Our document count reached 55 on May 25, 2022. Figure 4 is a three-field graphic that displays the top ten nations by publication count on the left, the ten most common author keywords in the middle, and the ten most referenced sources on the right. Spain, the United States of America, and China all contribute the most. The top cited sources are Sustainability, followed by Remote Sensing, Journal of Cleaner Production, and Remote Sensing of Environment. The most common keywords are sustainable development goals, artificial intelligence, sustainable development, big data, random forest, machine learning, and remote sensing. Additionally, the chart illustrates the correlation between nations, the kinds of crucial keywords being researched, and the leading journals that publish the results. For instance, the majority of the research published in Sustainability and the Journal of Cleaner Production that uses AI as a keyword originates from Spain.

2.2.1 Source information

A total of 133 journals contributed to the 250 papers retrieved from WoS and Scopus. According to Table 2 (sources with a minimum of three articles), the most abundant source is Sustainability with 50 documents (20%), followed by Remote Sensing with 21 documents (8.4%), IEEE Access and the Journal of Cleaner Production each with 6 documents (2.4%), Energies and Remote Sensing of Environment with 5 documents (2%) each.

Table 2 also includes the h-index (Hirsch, 2005), the total number of citations, and the publication start year. Both the h-index and the number of citations for sustainability are at their highest. Remote sensing has the second-highest h-index. Other top-notch journals with an impressive number of citations include Remote Sensing of Environment and the Journal of Business Research.

The two publications with the most citations are Nature Communications (262) and Cities (260), both of which contain just one article. Within the realm of organic

In the field of communications, one study (Vinuesa et al., 2020) discusses the use of AI to achieve 134 sub-targets across all SDGs. In the field of cities, another study (Allam & Dhunny, 2019) presents the potential of AI to manage smart cities while preserving existing urban fabrics or green fields and without ignoring cultural and human aspects.

In 1934, Bradford pioneered what is now known as Bradford law by systematically reviewing the primary literature on a certain topic (Leimkuhler, 1967). Sustainability, Remote Sensing, IEEE Access, and Journal of Cleaner Production are the four main journals that have been designated by this regulation as primary sources for papers pertaining to SDGs and AI (Fig. 5). Of the entire 250 papers, 83 (or around 33.3%) were published in these publications.

For local citations, the most relevant sources are included in the papers' references; Fig. 6 shows that they include Sustainability, Journal of Cleaner Production, Remote Sensing Environment, Science of the Total Environment, and Remote Sensing, respectively.

2.2.2 Authors information

One study found that 1.21% of authors (13 out of1073) had three documents, whereas 92.08% (988 out of1073) had only one. You may see the names of the top five writers, the institutions to which they were associated, and the country of publication in Table 3. With an h-index of 3, Arsanjani stands out as the most relevant author. A comparative study of five different ML techniques to detect invasive plant species using remote sensing data is included in Arsanjani's three publications (Jensen et al., 2020; Christensen & Arsanjani, 2020; Sulova & Arsanjani, 2021). Another study maps future land cover changes through simulation to provide a data-driven decision-making process. Lastly, an automated and cloud-based workflow is developed to help create a training dataset for fire events using openly accessible remote sensing data.

2.2.3 Country information

Table 4 shows the number of citations, average annual citations, and country-wise publication frequency for the 10 most important countries. The highest number of overall citations and average annual citations were recorded by Australia, with a mere 28 papers. With 10 publications, Sweden has the most citations overall with 282 and the highest average citation per year at 141. With 5 publications, Singapore ranks second with an average of 38 citations and a total of 76 citations. The United States of America (69), Spain (55), the United Kingdom (32), Australia (28), and India (27), in that order, have the most papers, followed by China (109).

Figure 7a depicts a network of countries working together, consisting of the most linked nations having at least two papers exchanged between them. From this network, four distinct clusters can be seen. Chinese, American, British, Australian, Indian, Malaysian, Iranian, Korean, and Saudi nationals make up Cluster I. Spain, Italy, France, and Colombia make up Cluster II. Cluster III: Argentina, Brazil, Canada, Japan, Germany, Hungary, the Netherlands, Belgium, and Sweden. Group IV: Russia, Ireland, Egypt, Turkey, Austria, Norway, and Denmark.

While the maximum number of documents for collaborations between China and the USA is five, for collaborations between the USA and the UK it is four, for collaborations between China and Australia it is three, for collaborations between Australia and Saudi Arabia it is four, for collaborations between Spain and Brazil it is three, between Spain and Ecuador it is two, between Turkey and Russia it is two, between the UK and India it is three, and between India and China it is two. An additional five partnerships include a single document, bringing the total number of collaborations to 32. Japan, China, the United States, Spain, the United Kingdom, Australia, India, Brazil, and Canada have the most collaborations out of all the nations. Countries' cooperation map, calculated using at least two papers between them (Figure 7b).

2.2.4 Affiliations information

Assessment of publications based on university affiliations shows that the University of Valencia has the maximum number of documents (11), followed by the University of Chi- nese Academy of Sciences and Polytechnic University of Madrid with seven documents each. The University of Granada and the University of Nottingham are amongst the top five educational institutions that have published six times simultaneously. According to the disclosed papers, the top 20 colleges are shown in Figure 8a. With at least two papers exchanged between each university, Figure 8b shows the network of cooperation between them. Six separate groups, denoted by various colors, can be seen. Within a given cluster, the university's contribution grows in proportion to the size of the nodes. Here are the clusters and the institutions that have collaborated, listed in decreasing order of contribution:

Group I: Sun Yat-sen University, Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai, the University of Chinese Academy of Sciences, Cairo University, the National Authority for Remote Sensing and Space Sciences, and the Aerospace Information Research Institute. Institutes of Technology in India and Queensland University of Technology make up Cluster II. University of Southern California, China Agricultural University, Griffith University, Peking University, Cornell University, and the Chinese Academy of Sciences make up Cluster III. Institutions in Cluster IV include Universidade Federal do Rio Grande do Sul, Oregon Institute of Technology, KTH Royal Institute of Technology, and Texas A&M University. Nisantasi University, Cyprus International University, Aswan University, Beni-Suef University, Technological University Dublin, and Ural Federal University make up Cluster V. University of Wollongong and Tenaga Nasional University make up Class VI.

2.2.5 Keywords analysis

There are a total of 1,346 keywords + 1079 author keywords in the 250 papers. Author keywords are a collection of terms and phrases chosen by the writers to best describe the papers' content. The keywords plus, on the other hand, are selected by WoS or Scopus and tend to show up in document titles and references but may not really be in the text itself. When investigating the knowledge structure of scientific domains and conducting bibliometric analyses, both the author's keywords and keywords plus are equally beneficial. The author's keywords, rather than keywords plus, are more useful when expressing the substance of the text (Zhang J et al., 2015).

Figure 9a shows the top 50 words employing the keywords plus in a word cloud format. Planning, China, the UN, big data, management, consumerism, productivity, farms, climate change, remote sensing, and productivity are among the most talked-about subjects.

topics such as population statistics, developing nations, water management, ecosystems, and human health. Meanwhile, there is coexistence of AI methods such as clustering, optimization, regression, decision trees, and classification.

Figure 9b shows a word cloud including the author's keywords together with the top fifty terms. Authors often use keywords related to topics like digitalization, smart cities, air pollution, urbanization, food security, developing nations, and circular economy. Popular artificial intelligence techniques include random forests, artificial neural networks, data mining, clustering, deep learning, optimization, decision support systems, and blockchain. The relative density of these terms indicates their level of development and assesses their relative power.

The cumulative word increase of the author's top five keywords is shown in Figure 9c. The rising use of AI and ML to address the SDGs is shown by this figure.

Using the bigrams approach with a minimum of three words frequency, the abstract analysis of the documents was conducted to examine the research patterns throughout the years. The results are shown in Figure 9d. The term "health care" was used three times in the published publication by Mollura et al. (2017), suggesting that SDG 3 was the main emphasis of the text. In order to meet the future need for health care capacity development in underprivileged regions of the globe, the writers of this paper emphasized the necessity of using cutting-edge technology in almost all fields of medicine and surgery. Even the next year, discussions about health continued to dominate. In 2018, the terms "humanitarian health," "health crisis," and "health crises" were used eight, five, and five times, respectively, in six published papers. The terms "broadband networks" and "multi-objective optimization" appeared three and four times, respectively, in these articles. Questions around "global health," "diabetic retinopathy," and "referable diabetic" continue to get attention in 2019's published papers. In the same year that these subjects were discovered, other ones concerning the economy and energy needs also emerged. By 2020, several AI-related subjects, such as "deep learning," "decision support," "neural networks," and "gmdh_type ann," had taken center stage. In the same year, the topic of "satellite images" also makes an appearance. In 2021, issues around "sustain-able development," "development goals," "machine learning," "artificial intelligence," and "goals SDGs" take center stage. "Soil salinity," "vegetation heterogeneity," "Landsat data," "information system," and "classification system" are some of the current themes. Twelve, ten, ten, and eight papers covering the aforementioned subjects were published by May 2022.

Fig. 7 a Collaboration relationship between countries, cluster formation is done using "Louvain", normali- zation using "jaccard," minimum item frequency is kept at two between the countries and the node size represents the number of contributions of the country, the larger the node size the more the contribution. Source: authors'. b. Collaboration Map of Most Connected Countries with a minimum of two documents between them. Source: authors'

2.2.6 Document analysis

A combination of global and local citation analysis is performed on the papers. Normalized citation counts, as opposed to plain citation counts (global and local), provide for a more accurate comparison of the citation effect across the documents. Both Appendix 2 and 3 include lists of the top 20 papers, with the former organized according to the normalized citation ratings and the latter in decreasing order. We are quite picky about the papers that pass muster in terms of our selection criteria, the SDGs, and AI/ML methods. According to Appendix 3, the highest number of normalized global citations is held by articles published in Nature Communications and Energy Reports by Vinuesa et al. (2020), Awosusi et al. (2022), and Adebayo et al. (2022). On the other hand, the top three positions in the list of normalized local citations are held by articles published in Artificial Intelligence, Nature Communications, and Remote Sensing of Environment by Palomares et al. (2021), Vinuesa et al. (2020), and Liu et al. (2021).

The tables (Appendix 2 and 3) include seven documents: Vinuesa et al., 2020; Liu H et al., 2021; Di Vaio et al., 2020; Truby, 2020; Braganza et al., 2021; Allam & Dhunny, 2019; and Shiroishi et al., 2018.

3 Discussion

Results from the literature review, survey, or case study that addressed one of the six viewpoints on the seventeen Sustainable Development Goals (SDGs) provided the basis for 28 of the top one hundred publications that were considered. Twelve pieces addressed SDG3, which is a state of optimal health and wellbeing. The provision of safe drinking water and sanitation was the subject of one article (SDG 6). Responsible production and consumption (SDG 12) were the only topics of two articles, while industry, innovation, and infrastructure (SDG 9) were addressed in three pieces. SDGs 11, 13, and 12 all dealt with sustainable cities and communities, but 34 of those publications also touched on climate action, living on land, and other related topics. Sustainable and affordable energy was the subject of four articles (SDG 7). Education quality (SDG4) and decent employment and economic development (SDG8) were the topics of eight pieces, respectively. According to research out of India, SDG 5 encompasses both gender equality and excellent education (SDG 4). Partnering for the objectives was the subject of one article (SDG17). No poverty, no hunger, and less inequality were the topics of five articles (SDGs 1, 2, and 10). A pair of articles addressed the topic of tranquility,

Equity, solid institutions, and justice (SDG 16). Out of 169 objectives, a wide variety of topics involving AI and ML were covered in these publications. Some of the topics were overlapping SDGs that covered a single target, while others covered several targets. Accordingly, a targeted analysis of twenty highly cited publications was chosen to address the third and fourth generated research topics.

This section reviews the top 20 publications chosen based on normalized local citations; the main goal is to investigate the two research topics that were formed from them. The assessment did reveal certain blind spots, as previously stated. Six papers out of twenty examine the extent to which data-driven technologies have positively and negatively affected the attainment of SDGs and have warned against the careless use of AI technologies; these papers answer the derived research question (RQ3). The study conducted by Vinusea et al. (2020) using a consensus-based expert evaluation technique reveals that 134 subgoals were facilitated by AI adoption, whereas 59 subgoals were hindered. Artificial intelligence (AI) aided in the alleviation of poverty, as well as social protection and the accumulation of benefits. Simultaneously, the expansion of digital technology has exacerbated economic and social disparities in many instances, particularly in poor and rising nations. A word of warning, though: unchecked AI might impede SDG advancement due to potential safety, ethical standard, and transparency gaps. Following a comprehensive literature review, Palomares et al. (2021) provide a strengths, weaknesses, opportunities, and threat assessment of the connection between SDGs and AI technology. The results show that big, computationally expensive deep learning models will be required for future AI advancements. A potential downside to AI's beneficial contributions to SDGs is its potential overuse, according to the research. There is mounting evidence that we need to move away from traditional AI and toward greener alternatives, and this research provides crucial guidance for reaching our sustainability targets by 2030. Similarly, Truby (2020) contends that data-driven technologies and AI have a substantial impact on inequality. Since artificial intelligence (AI) destroys markets in developing and emerging nations while enriching industrialized nations, some have compared the proliferation of digital start-ups to "tech colonialism" (Müller, 2016). Job prospects in the field of artificial intelligence are both fascinating and professional. Still, the results imply that AI programmers should prevent a "black box" scenario by continuously auditing their code to guarantee trust in ethical decision-making.

In a descriptive research, Saetra (2021) demonstrates how the SDGs provide a helpful framework for analyzing and classifying the pros and cons of AI. An AI hype cycle may be upon us, according to the research. A number of AI-related initiatives have a detrimental effect on the SDGs, despite early evidence of perhaps favorable outcomes. Therefore, further study is needed to fully comprehend the consequences of AI in order to have a balanced perspective. A total of 108 non-commercial SDG initiatives that meet the requirements of AI'SDGs of five constituents were identified for assessment and analysis in the research by Cowls J et al. (2021a). According to the findings, it is far from the case that projects are distributed evenly among SDGs. Goal 3 ("Good Health and Well Being") is well ahead of the pack, with less than five initiatives addressing Goals 5, 16, and 17. Though it won't fix every issue, well-designed AI has the potential to greatly improve society while producing results on a scale never seen before. Findings from the study indicate that a multidisciplinary strategy, including deeper community and place-based research, is necessary for the development and deployment of AI and other digital technologies to achieve the SDGs. Using a case study technique, Goralski and Tan (2020) find out whether AI will speed up the UNSDGs' development or cause more economic instability, environmental catastrophe, and social chaos. Both current and future company leaders may benefit from the study's recommendations about how to educate themselves. Companies and nations that embrace AI have the potential to make significant in a "winner-take-all" competition. Lawmakers, CEOs, and government officials must exercise caution when dealing with artificial intelligence (AI) because of the potential privacy and security risks it poses.

The next four articles, which stress the need of an integrated strategy, are more upbeat in their assessment of the potential of digital technology to accomplish the SDGs. An integrated framework for comprehensively comprehending AI for decision-making by Knowledge Management System and Sustainable Business Model (SBM) is emphasized in the study of Di Vaio et al. (2020). According to the research, it's crucial to comprehend various cultures, user traits, knowledge-based AI ergonomic design, and the synergies that exist between AI and SBM. The societal changes brought about by digital transformation may be better anticipated and managed if scientists, specialists, and institutions collaborate to establish a public-private partnership (PPP). In order to help firms enhance their GOIE, a research conducted by Ogbeibu et al. (2021) looked at how LSC (Leader Smart Competence), AI, Robotics, and Algorithms Competence may promote green creativity components and environmental dynamism. New avenues for discussion of GOIE may be explored in light of this study, which confirms the need for more research and calls for a combination of qualitative and quantitative methods to better understand how companies might spread the concept.

In a similar vein, Alonso et al. (2021) provide a hopeful prediction, arguing that AI and related technologies will play a significant role in many domains as they help to achieve the SDGs. The authors see a bright future for data infrastructure investments that make it easier to gather, store, convert, and retrieve high-quality data sets. According to Shiroishi et al. (2018), a collaborative ecosystem including industry, academics, and people is essential to develop a society of high sustainability. This groundbreaking development lends credence to Keidanrenis, Japan's vital business association. By bridging previously inaccessible areas, cyber-physical systems (CPS) have the potential to bring previously isolated communities closer together. Sharing and tackling difficulties collectively via the potential of CPS is essential for the implementation of Society 5.0/SDGs among the many stakeholders from business, academia, and people.

Some researchers, including Khamis et al. (2021) and Włodarczyk et al. (2021), are worried that AI might affect nations at various stages of development differently. In the first research, which aims to achieve SDG 3, the ethical implications of Robotics & Automation (R&A) during and after a pandemic are examined, taking into account the IEEE Global Initiative. While AI and robotics are crucial, they can only serve humans if they are well-managed and controlled. Włodarczyk et al.'s research is centered on SDG 7, which is relevant to countries in the EU. Using hierarchical clustering, the member states are grouped into five categories according to their performance in renewable energy sources, as per Eurostat's available statistics. A number of nations have made great strides in increasing their use of renewable energy, but there are still large gaps across the member states. To become climate neutral and eliminate inequities in renewable energy consumption, governments must implement enormous investment programs, particularly in the trailing areas. This is the key strategy for their upward progression. Private sector funding and the implementation of circular economy principles (for conserving, generating, and recreating) to reduce disparities between established and developing regions and urban and rural areas are essential initiatives for minimizing renewable energy consumption inequities.

Results for SDGs 11, 13, and 15 are shown here. In previous studies (Liu et al., 2019; Peng et al., 2021; Holloway et al., 2019; Lui et al., 2021; Allam & Dhunny, 2019; Kim & Huh, 2020), etc. After reviewing the contributions of geographers to China's growth, Lui et al. (2019) laid forth the path for future study. In order to facilitate the work of researchers and geographers from across the world, they noted that practical and scientific solutions are required.

in relevant fields of study to target the United Nations Sustainable Development Goals. The rapid advancement of ground-based observational capabilities and the knowledge of remote sensing should take into account the integration of many disciplines and the provision of real-time decision-making assistance. In order to forecast the Foliage Projective Cover (FPC) of the subtropical location in Australia, Holloway et al. (2019) used two machine learning methods—the gradient boosted algorithm and the random forest—to simulate missing pixels in satellite photos. The ML algorithms were used to predict Foliage Projective Cover (FPC), a continuous biophysical quantity. With 90% accuracy, both ML methods—specifically random forest—can quickly and accurately classify both visible and invisible pixels. The authors suggest extending the two approaches to further SDGs, such SDGs 2 and 6, to achieve their goals. To help with future urban planning and reach SDG 15.9, Peng et al. (2021) investigated the changes in eco-system service value (ESV) in China's Wuhan metropolitan area under several future scenarios. The results point to the need for further research into a spatially explicit model called Inte- grated Valuation of Ecosystem Services and Trade-offs (InVEST) in order to properly assess the ESV (ecosystem service value) in light of the effects of climate change. As part of the Natural Capital Project, the World Wildlife Fund (WWF) and the universities of Stanford and Minnesota developed the Geographic Information System (INSTANT) to aid in environmental preservation efforts.

In order to address basic issues with remote sensing, Liu et al. (2021) suggest a new framework for mapping the worldwide land cover from year to season. This research compiles the first 30 million worldwide comprehensive daily seamless data cubes (SDC) for a mech-anized, end-to-end serverless data production chain and accompanying mapping system from 1985 to 2020. According to the data, the average annual rate of change in the world's land cover is 0.36%. From 1985 to 2020, there was a drop of 1.47 million km2 in worldwide forest cover, a gain of 0.84 million km2 in cropland, and a decrease of 0.48 million km2 in impervious surface. There is a 10% improvement in map accuracy compared to other global land cover datasets. The i-Map architecture is shown to be viable and successful by the objective validation sample of FLUXNET sites. Since the SDC construction has a mean error of less than 2.14%, the results demonstrate that it is desirable to do additional study in the subject. Data gap management has been highlighted by the results of Vinusea et al. (2020) and Olteanu et al. (2019).

In their 2019 article, Allam and Dhunny examine AI's potential in cities and propose a new framework that would bring together AI and cities, ensuring that important factors like culture, metabolism, and governance are internalized. Goal 11 serves as the basis for the research. Using new large data from a variety of smart city service providers, the authors demonstrate a plethora of AI applications. For urban ethical governance that supports all life forms and provides a more inclusive and safer environment, a successful smart city framework must use big data and AI. Kim and Huh's (2020) research focuses on SDG 7 and tries to demonstrate how blockchain technology may make carbon emission rights trades more trustworthy. Still, SDGs 11 and 13 cover similar ground. The research suggests (i) a hybrid Governance Protocol, (ii) dApps (decentralized applications), and (iii) blockchain technology for MRV (Measurement, Reporting, and Verification) purposes in greenhouse gas reduction efforts. Due to the inefficiency of centralized carbon transaction verification, the research suggests including decentralized services and dApps into blockchain AI architecture.

Most notably, SDG 8 and SDG 4 are the primary subjects of the research conducted by Buenaño-Fernández et al. (2019) and Braganza et al. (2021). The first research proposes using ML approach to track and forecast students' grades in the classroom using their previous performance. The goal is to use the best predictions to create a personalized learning system that groups students according to predetermined criteria. (i) A system for predicting academic performance and keeping tabs on those people. This approach has three main goals: (i) improving the accuracy of predictions; (ii) creating a personalized learning system for a set of students who share some common criteria; and (iii) analyzing and planning a big data architecture to process the massive amounts of academic data generated by the university on a regular basis. The student learning evaluation system may be enhanced by including personal and socioeconomic information with academic data. First and foremost, we need to plan how to scale out our current big data architecture so that it can handle the massive amounts of academic data that our institution produces on a regular basis. Then, we can take that blueprint and apply it to other schools. Using a study of 232 surveys from West London-based businesses, Braganza et al. (2021) examine how the adoption of AI affects the engagement of workers in the psychological contract. The results demonstrate that as AI became more widely accepted, the beneficial effects of psychological contracts diminished significantly. Existing research (rooted in structural equation modeling) suggests that the use of AI led to a third kind of psychological contract known as "Alienation," in contrast to SDG 8, which places an emphasis on strengthening relationship contracts between firms and their workers. To achieve the UN SDGs goal via effective implementation, further large-scale research is needed to investigate how AI changes in response to worker demands; this would allow for comparisons across regions.

Outcomes of AI applications might be multi-faceted, ever-changing, and intricate in the social, economic, and environmental sectors, according to a rapid analysis of the sub-themes arising in the twenty articles chosen (from normalized local citations). The following analysis lists the possible benefits and areas where it might be improved. Unintentional abuse may occur because to a lack of access to vital knowledge and AI-skilled talents that create, execute, and enhance algorithms and machines. We may deduce that AI does not provide a miraculous solution because of these known bottlenecks and many more that are still undiscovered. Facilitating the development of AI applications is important, but so is encouraging their responsible and considerate usage at all levels if we are to harness AI's potential to achieve the SDGs (Goralski & Tan, 2020; Palomares et al., 2021).

The second derived research question, RQ4, considers potential responses to the negative impacts of AI on the SDGs. Artificial intelligence (AI) must be considered in the perspective of a bigger superstructure in order to be understood. Ignoring this fact and asserting that AI is a detached and impartial technology that can save the world is deceiving and absurd, since a thorough investigation shows its inseparable connection to certain dangers to most of the SDGs. (Study by Palao-Mares and colleagues, 2021). The significance of doing thorough study on the ethical implications and sustainability of AI is highlighted by these challenges (Bachman et al., 2022). It is imperative that the communities and locations chosen for the development and implementation of SDG projects undergo thorough examination using a multidisciplinary approach. Disparities and gaps in the use of AI to meet different SDGs and indicators must be understood, therefore it is crucial to look at what makes SDG initiatives succeed or fail from a "on the ground" perspective. The discrepancies between the project's operational status and the correct location for its launch are equally important to understand. In addition to resolving critical gaps and inconsistencies, it is critical to choose the appropriate location for the SDG-related project and to define the roles and responsibilities of the key stakeholders. The efficient development of AI and related technologies can be achieved through the following measures: increasing funding for IT infrastructure and training and education (Alonso et al., 2019), promoting international and interdisciplinary collaboration (United Nations, 2015), improving data collection (Santos & Villatoro, 2016), sharing digital knowledge through open-source software (Buenaño-Fernández et al., 2019), and rigorously testing critical data models. Disaggregated data (by gender and location, for example) is necessary, and the democratization of artificial intelligence (Liu to guarantee balanced growth (e.g., Vinuesa et al., 2020), new methods for evaluating ML models (et al., 2019), and an emphasis on developing environmentally friendly technology. Global standards for ethical data usage (Allam & Dhunny, 2019; Levin et al., 2020) and proper cyber security & management plans (Goralski & Tan, 2020) are important measures that the international community should take to encourage the application of safeguards. There is a trade-off between the energy needed to utilize AI data to promote the creation of climate-friendly efficiency and solutions and the energy saved in the long run. The increasing urgency of a paradigm change toward green AI is further emphasized by this research. A comprehensive knowledge of deep learning with an emphasis on energy efficiency to decrease emissions is essential for the goal of creating green AI, which in turn requires enhanced collaborative technical advancements. The importance of environmentally friendly sensing and communication has recently grown (Gupta et al. 2020). The need for technological robustness, respect for human rights, equality, data privacy, transparency, and auditability is further emphasized by the responsible use of AI. To guarantee a fair, secure, and advantageous way to adopt AI in the future, good governance will need to stay up with AI developments. To help achieve the 17 SDGs, an interdisciplinary, multi-stakeholder approach is needed to deal with ethical dilemmas (Benaich & Hogarth 2020).

4 Conclusion

Two parts of analysis made up this research. In Section 2, we examine the results of the bibliometric analysis of the 250 research publications chosen from WoS and Scopus to investigate the first two research issues. In Section 3, we look at the top 20 publications chosen using normalized local citations to try to address the two research questions that were generated from the first section.

According to Bradford law's bibliometric study, the four primary sources are Sustainability, Remote Sensing, IEEE Access, and the Journal of Cleaner Production. Out of a total of 250 documents, 83 (or around 33.2%) were published in these publications. China, the United States, Spain, the United Kingdom, and Australia have all contributed more articles than any other country. Meanwhile, the top universities in this field include the Polytechnic University of Madrid, the University of Valencia, and the University of the Chinese Academy of Sciences. Abstracts analyzed using bigrams reveal that "soil salin-ity," "vegetation heterogeneity," "Landsat data," "information system," and "classification system" are hot subjects right now.

The study goes on to say that AI is promising, but that people should be wary of its constant exaggeration. Following this course of action with great moral obligation toward both humans and the physical environment is essential (Sun & Medaglia, 2019). In order to tackle the most recent advancements in AI, deep learning models are becoming larger and more computationally intensive, but they work in tandem with AI and other interconnected digital technologies. This has undoubtedly led to new paradigms that drive the SDGs. Recognizing the critical role that data infrastructures and high-quality data play in the majority of AI-based solutions is essential for pursuing the SDGs (Alonso et al., 2021). The high computational cost is preventing practitioners, project managers, and organizations from adopting them, but the potential benefit more than makes up for it (Palomares et al., 2021). In order to overcome the challenge of limited resources, which necessitates solutions that are inexpensive, inclusive, and environmentally sustainable, it is crucial to create technologies that are frugal (Ebolor et al., 2022). Investigating and classifying the effects of digitization has low impact on sustainable development. Gupta and Rhyner's (2022) research presents the Digitainability Assessment Framework (DAF) as a novel approach to filling this knowledge gap. In order to reduce the environmental cost-benefit gap and help achieve the SDGs, the AI field should carefully think about creating efficient and logical AI algorithms (Spelda & Stritecky, 2020). Academic institutions have a responsibility to train the next generation of corporate executives and policymakers to deal with the possibilities and threats presented by artificial intelligence. To reach the SDGs, management learning and leadership development are crucial, as pointed out by Goralski and Tan (2020). Being prepared for a future driven by AI is a community priority in light of the pressing need to achieve global objectives. To achieve the SDGs in an ethically responsible manner, AI must be subject to rigorous testing to guarantee its reliability, openness, and compliance with applicable regulations (Ng & Kwok, 2017). While good regulation won't eliminate all dangers posed by experimental AI, it will ensure that those working on AI designs exercise caution while keeping the SDGs in mind. It is worth noting that half of the publications that were referenced in this research have warned against the careless use of AI and have investigated the impacts of data-driven technologies on the SDGs. The research that were analyzed shed light on the sometimes blind spots that arise while using AI to accomplish the SDGs.

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