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Analyzing and visualizing global research trends on COVID-19 linked to sustainable development goals

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Abstract
This study is intended to afford a comprehensive overview of the implications of COVID-19 on progress toward achieving the sustainable development goals (SDGs) set out in the United Nations (UN) 2030 Agenda and the state of related research activities on COVID-19 linked to the SDGs. Bibliometric techniques and visual mapping are proposed as methodological tools to better approach the objectives of the present work. This includes: retrieving related publications from Scopus database, investigating the trends and growth trajectories of research works, and analyzing the scenarios post-COVID-19 either optimistic or pessimistic outlooks. The national and international contributions and collaboration toward this theme of research are further analyzed at countries, institutions, and sources levels. This analysis indicates that research works conducted on the impacts of COVID-19 on the achievement of the SDGs are still in the immaturity level. The global research productivity on this topic was just 160 documents (0.19% of total global research productivity in all fields of science with relevance to COVID-19). The implications of COVID-19 on good health and well-being, SDG-3, have attracted considerable attention. It is followed by SDG-13 that concerned with climate changes. The post-COVID-19 scenarios showed deep and justified worries in relation to achieving the SDGs by 2030. This study figures the major issues debated in the literature with respect to COVID-19 and its implications on the SDGs. The study, furthermore, attempts to assess the required actions to advance the SDGs post-COVID-19.

Keywords COVID-19 · Sustainability · Visualization maps · Green recovery · Cleaner production · Climate change

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1 Introduction

Many cases of unexplained pneumonia outbreaks occurred in Wuhan City, Province of Hubei, China, in the latter half of 2019 (Wu et al., 2020). Subsequently, the arisen cases were associated with the newly emerging coronavirus. This virus is known as coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Worobey et al., 2020). It has caused what is renowned worldwide as Coronavirus Disease 2019 (COVID-19). With an exponential growth rate, COVID-19 pandemic has been associated with more than 2,894,010 confirmed deaths as of April, 9 2021 (World Health Organization, 2021). A total of 133,538,03 confirmed cases distributed across 223 countries, areas or territories has been recorded at the same time (World Health Organization, 2021). The World Health Organization (WHO) declared COVID-19 as a global pandemic and a public health emergency of global concern on January, 30 2020. Every aspect of human life is impacted by this pandemic. In addition, the pandemic has challenged healthcare systems around the world (Arora et al., 2020).

The scientific community working in epidemiology, virology, and medical sciences-related fields was being called to react promptly to COVID-19 pandemic. The development of preventive vaccines and curative medicines are being at the forefront of the global concerns associated with the outbreak of COVID-19 pandemic (Iyer et al., 2020). This is motivated by the fact that the pandemic has stroked the human existence core. Therefore, many ongoing efforts are being made to save lives. Furthermore, the developments of reliable tools for detecting and tracking the infection with SARS-CoV-2 are being essential for the effective diagnosis and treatment of COVID-19. Other concerns were related to understanding environmental conditions favorable to the development of the pandemic, especially climate change, ecosystem changes, and/or biodiversity loss (Zyoud & Zyoud, 2020).

The acceleration of research and development on COVID-19 was in line with different control measures and prevention strategies (i.e., lockdown, restrictions on transport activities, social distancing, self-isolation for patients, and self-quarantine for contacts) (Centers for Disease Control & Prevention, 2020). These critical measures were being imposed by governments at local and national levels responding to associated fears with the widespread COVID-19 outbreak. This, in turn, had a major impact on psychosocial, behavioral, governance, technological, and environmental issues (Zhang & Shaw, 2020). Accordingly, the risks associated with COVID 19 pandemic are not limited just to medical problems. This crisis has multiple dimensions with social and economic impacts that are much more far-reaching (Zyoud & Zyoud, 2020). In this regard, different multidisciplinary research activities are launched to look into the impacts of COVID-19 on economic, public health, environment, etc. aspects, which are fundamental to sustainable development, at different levels (i.e., global, regional, and national levels).

With regard to environmental challenges associated with this crisis, medical wastes management, municipal solid wastes management, and wastewater treatment policies were all impacted in one way or another. The use of medical supplies (i.e., masks and gloves), for example, in health care facilities and by people as a protective measure witnessed an exponential increase. The quarantine policies contributed to the increase of organic wastes produced by households. In the meanwhile, rates of municipal wastes recycling were in decline with the aim of protecting workers in this field from the pandemic. The health risks via waterborne resulting from detection of SARS-CoV-2 outbreaks in wastewater sources caused an increase in using disinfectants in wastewater. While these measures are efficient in preventing the spread of COVID-19, they can have

a negative impact on public health (Zambrano-Monserrate et al., 2020). Another environmental concern being raised during this crisis is the air pollution. It is found that people infected with COVID-19 who live in districts characterized by high levels of air pollution are at high risks of premature deaths (Wang et al., 2020).

In case of socioeconomic impacts, COVID-19 has caused negative or reduced growth of the economy at global levels due to containment measures (Nundy et al., 2021). A global economic recession accordingly has already been projected (Ogah et al., 2021). The major aspects of economic crisis encompass: human capital erosion due to loss of employment and schooling, lower investments, and disruption of supply chains and global trade (Ehrenberg et al., 2021). The lockdown, as a major protection measure, has affected economies all over the world. People have been forced to work from their homes, and closures of workplaces have lowered productivity and disrupted supply chains (Mofijur et al., 2021). The travel ban has affected the global travel industry, reducing this business by more than 90% (Mofijur et al., 2021). The social crisis brought about by COVID-19 pandemic led to increased discrimination, inequality rates, and medium- to long-term unemployment. The vulnerable social groups (e.g., elderly, poor, disabled and youth) are the most harmful ones (Nundy et al., 2021).

Though COVID-19 pandemic crisis has brought significant challenges to the globe, impacting all aspects of life, it has brought some positive impacts on the natural environment. Different research works have shown unprecedented improvements in the hydrosphere and atmosphere due to the significant cessation of human movement and economic activity during the lockdown (Roy et al., 2020). Due to the restrictions imposed on transportation activities, a considerable reduction in the consumption of energy required by this sector was clearly well observed (Muhammad et al., 2020). As most industrial activities are halted, a significant decline in oil demand has further occurred (Muhammad et al., 2020). Other positive environmental benefits of COVID19 are: noise level reduction and beach cleaning due to the suspension of tourism activities (Zambrano-Monserrate et al., 2020).

In conclusion, COVID-19 crisis is unprecedented in severity, its implications encompass public health, economics, politics, geopolitics, and social stability, and its trajectory is still very uncertain. The crisis will have profound implications on progress toward sustainable development goals (SDGs) adopted by all United Nations member states in 2015 and approved to be achieved by 2030 within The 2030 Agenda for Sustainable Development. The SDGs generally address major global challenges (i.e., poverty, climatic changes, inequality, degradation of environment, justice, and peace). Therefore, a strong debate in the scientific community, and among policymakers regarding whether it is realistic that the SDGs will be achieved by 2030. The Lancet Public Health (2020) warned of the regressive consequences of COVID-19 on the SDGs based on an international report (The Sustainable Development Goals Report 2020) prepared by the UN Department of Economic and Social Affairs in partnership with international scholars and experts. Some experts are even foreseeing a re-evaluation of the timeline for achieving the SDGs (Mukarram, 2020). The third "GlobalScan-SustainAbility Survey-2021" report conducted by GlobalScan and The SustainAbility Institute by ERM and in collaboration with about 500 sustainability professionals from Europe, Africa, North America, Latin America, and Asia-Pacific concluded that over 50% of experts believe COVID-19 and its economic impacts will slow the progress toward achieving the SDGs over the coming decade (The SustainAbility Institute by ERM, 2021). Around one-third of experts who participated in this survey believe that the COVID-19 crisis will serve to accelerate the SDGs advancement (The SustainAbility Institute by ERM, 2021).

The last statistics confirmed an enrichment in various fields of science aimed to disseminate and share contributions, findings, and advances of research on COVID-19 (Fraser et al., 2021). These scientific research activities are in link with endeavors devoted to combating COVID-19 crisis and mitigating the associated adverse impacts. In the meanwhile, more research is being done on the impacts in relation to this pandemic, either negative or positive (Zyoud & Zyoud, 2020). Despite that and to the best of our knowledge, there is a knowledge gap with respect to tracking and analyzing global research endeavors offered on the direct impacts of COVID-19 on the SDGs.

Motivated by providing an inclusive overview on the impacts of COVID-19 pandemic on advancing the SDGs, analyzing pessimistic and optimistic scenarios related to pandemic's impacts on the SDGs, and the exponential growth in research works on COVID-19, the present work is proposed to track and analyze research works on COVID-19 linked to the SDGs. The major objectives to be addressed include: investigating the trends and growth trajectories of research works on COVID-19 linked to the SDGs and vice versa; the topical foci of research works on this issue; the gaps and required improvements in research activities in this regard, and analyzing the scenarios post-COVID-19 either optimistic or pessimistic outlooks. The identification of national and international contributions toward this theme of research will be a further objective. This will be examined at the country, institution, and source levels. The present status of COVID-19-SDGs research will be analyzed with the aim of developing new proposals to steer research activities in the future. This will assist in suggesting novel avenues and locating research investments.

Bibliometric techniques and visualization mapping tools are proposed to better achieve the objectives of the present work. These methods offer a wide variety of mathematical and statistical tools to characterize the significant features, structures, and patterns of the underlying science (Du et al., 2014). Such techniques can be applied at various levels, from the micro-level (that is, institutions) to the macro-level (that is, countries and regions) for example. These methods are extensively utilized in various areas of science to recognize researches frontiers in terms of their quality and quantity (Del Giudice et al., 2021; Di Vaio et al., 2020; Di Vaio, Hasan, et al., 2021; Raman et al., 2021; Sweileh, 2020; Tao et al., 2020; Ye et al., 2020; Zheng et al., 2018; Zyoud & Zyoud, 2021). The present work is the first of its style in the literature that addressed COVID-19-The SDGs research works. It will act as a source that can help scholars in identifying the existing research priorities and other essential bibliometric information.

The current work is formulated as follows: Sect. 2 presents a theoretical background providing an overview on the SDGs, a brief literature review on the SDGs and COVID-19, and a comparative analysis with previous works. Section 3 displays the methodological approach used, while Sect. 4 analyzes and discusses the major findings. Section 5 analyzes pessimistic and optimistic outlooks on the effects of COVID-19 crisis on the SDGs. Section 6 is devoted to display the major implications of the work, while Sect. 7 illustrates the major limitations. The last section, Sect. 8, draws the major conclusions.

2 Theoretical background

2.1 The SDGs: an overview

The SDGs adopted by the UN in 2015 provide a roadmap and ambitious plan for 17 key areas of international development and balancing the three pillars of sustainable

development: social, environmental, and economic (Di Vaio & Varriale, 2020; Verdejo Espinosa et al., 2021). The 17 SDGs are interlinked and consolidated recognizing that work in one field would impact others. They comprise 169 targets that can be measured against 247 distinctive indicators. These global goals include: SDG-1: Ending poverty; SDG-2: Ending hunger; SDG-3: Ensuring healthy lives and promoting well-being; SDG-4: Education characterized by good quality and equitable; SDG-5: Achieving equality in gender outcomes; SDG-6: Ensuring reliable access to water and sanitation for all; SDG-7: Give everyone access to affordable, modern, sustainable and reliable energy; SDG-8: Promote inclusive and sustainable economic growth, and decent work for all; SDG-9: Resilient infrastructure, sustainable industrialization, and innovation; SDG-10: Reduced inequality; SDG-11: Resilient and sustainable communities and cities; SDG-12: Ensuring sustainable production and consumption patterns; SDG-13: Combating climatic changes; SDG-14: Conserving oceans, seas, and marine resources and their lives; SDG-15: Life on land; Promote inclusive and peaceful societies, and provide access to justice; and SDG-17: Enhance global partnership for the SDGs.

These goals have considered the major global threats and provided an integrated vision for achieving a sustainable future (Walker, 2021). All UN member states have adopted these global goals, calling for actions to eliminate poverty, ensure peace and prosperity for all, and protect the planet (Sweileh, 2020). The SDGs are the result of decades of collaboration between governments and the UN, especially the UN Department of Economic and Social Affairs (United Nations, 2021). The historical evolution of the SDGs is depicted in Fig. 1, (information in Fig. 1 are based on data derived from United Nations (2021)). It is clear that the year 2015 was a milestone and historic for international policymaking with the endorsement of a number of important agreements such: Sendai Framework for Disaster Risk Reduction (March 2015), Addis Ababa Action Agenda on Financing for Development (July 2015), and Paris Agreement on Climate Change (December 2015) (United

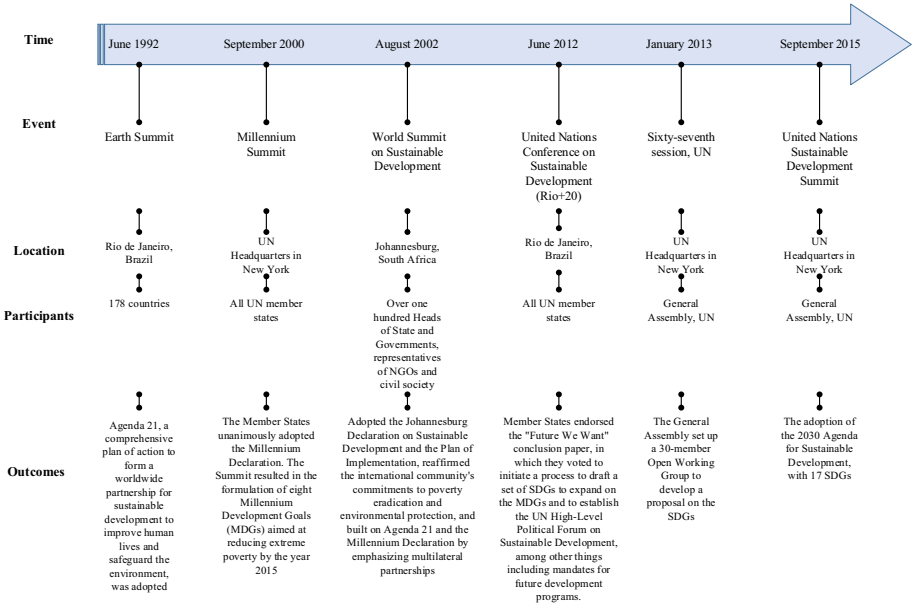

Fig. 1 Historical evolution of the sustainable development goals (SDGs)

Nations, 2021). These goals are applicable universally to all nations, aimed at providing guidelines for responsible and fair development and respecting ecosystems and humans (Anastas et al., 2021).

With respect to the economic pillars, the SDGs call for economically sustainable systems considering scarce resources. These systems should be able to provide goods and services based on the rules of continuity, and avoiding sectoral imbalances that could damage industrial and agricultural production, etc. (Kaymaz et al., 2021). The social pillars of the SDGs are human-oriented aspects that ensure fair and adequate distribution of social services including gender equality, education, health, participation, and political responsibility (Kaymaz et al., 2021). In case of the environmental pillars, the SDGs consider the balanced physical and biological systems. This includes maintaining biodiversity, other ecosystems, and atmospheric balance (Giddings et al., 2002).

Notably, the 17 SDGs represented a considerable advance from the eight UN Millennium Development Goals (MDGs). The SDGs have been adopted to replace the MDGs which range from containing HIV/AIDS to halving extreme poverty rates and affording universal elementary education, all by a target date of 2015 (Atukunda et al., 2021). The SDGs are differentiated from the MDGs on having a broader agenda that affects all countries and requires coordinated and sustainable global action (Atukunda et al., 2021). Furthermore, nations have led the processes toward the SDGs rather than international organizations as was the case related to the MDGs (Atukunda et al., 2021). The UN Member States guide the entire SDGs process, including the main discussions and selection of objectives, goals, and indicators (Sachs, 2012).

Since the launching of sustainable development agenda, there is a universal agreement and a broad consent regarding various challenges of achieving the SDGs by 2030. Most opinions affirm that unless the rate of progress increases, it will be difficult to achieve all the SDGs by 2030 (Fu et al., 2019). Along the global development course characterized by major progress in economic, energy, agricultural, environmental, infrastructure, education, demographic, governance, technology, and health, the world is not on the path for most SDGs by 2030 (Moyer & Hedden, 2020). The world will make limited progress toward some important human development SDGs, and the regional differences in performance are significant (Moyer & Hedden, 2020). Positive trends are seen in key areas including reduction of poverty and technological innovation, while negative trends in several of the other goals pose a significant risk to the realization of the SDGs (UNDP, 2017).

The low accomplishment of the SDGs in some regions across the globe, mainly developing countries, attributes to instability and conflicts, lacking programs that would fit the local context to facilitate the implementation of the SDGs; the political will to transform development programs into sustainable long-term practices through good governance; and better integrated economic and social policies (Tucho & Kumsa, 2020). Without breaking these barriers and challenges that are interrelated socioeconomic, cultural, and technical factors, achieving these global goals cannot be possible (Tucho & Kumsa, 2020).

Accordingly, different calls for developing action plans to enable full agenda implementation were being released (Fu et al., 2019). Such challenges cannot be resolved without a major switch in national and international aid priorities and policies. Resolving existing trade-offs between the SDGs, and maximizing synergies among them are crucial to achieving these global goals (Kroll et al., 2019). The adoption of alternative policy approaches for achieving the SDGs is among possible pathways to improve the course of human development. In this regard, Moyer and Bohl (2019) assessed decentralized governance, lifestyle change, and technology as three alternative pathways using integrated assessment models to determine the most successful one in improving human development. They concluded

that development strategies that attempt to harness efficient local governance and technology should be preferences toward achieving the SDGs Agenda (Moyer & Bohl, 2019). The local governments have a major role in localizing the SDGs and consequently contribute positively toward achieving the SDGs at the national level.

Given the devastating effects of COVID-19 on almost all aspects of life, it is clear that achieving the SDGs will be virtually impossible by 2030. This crisis could jeopardize our obligation to the 2030 Agenda (Shulla et al., 2021).

2.2 The SDGs and COVID-19: a brief literature review

As we have been already lagging behind on attaining the SDGs earlier than the COVID-19 pandemic crisis started, the COVID-19 hampers further the advancements of Agenda 2030 and exacerbates the existing challenges even more (Shulla et al., 2021). Due to this unexpected crisis, a major shift of priorities from reaching the SDGs by 2030 to recovering from the pandemic is witnessed at all levels (national governments, international organizations, etc.) (Leal Filho et al., 2020). Thus, it seems essential to analyze the impacts created by the pandemic on advancing the SDGs and the endeavors of the scientific community in this regard.

The research works conducted to track the impacts of COVID-19 on the achievement of the SDGs are still limited (Ranjbari et al., 2021a). This is due to the recentness of the pandemic and the increasing interests in responding to the pressing calls for actions against the COVID-19 crisis (Ranjbari et al., 2021a, b). Most research in this regard was devoted to analyzing the implications of COVID-19 on the major sustainable development dimensions including environmental, economic, and social aspects.

In this context, Ranjbari et al. (2021b) performed a systematic review to analyze the impacts of COVID-19 on the social, economic, and environmental aspects. They concluded the need to develop sustainability action plans considering COVID-19 impacts and introducing innovative solutions for economic resilience (Ranjbari et al., 2021b). Di Vaio, Trujillo, et al. (2021) conducted a structured literature review aiming at analyzing water governance models under the umbrella of sustainable development. They focused on SDG 6 which is concerned with clean water and sanitation and considered the uncertainty caused by COVID-19 on examining the capacity of these models to meet the SDGs (Di Vaio, Trujillo et al., 2021). To address the global challenges in the light of COVID-19 crisis, they found that coordination, collaboration, and stakeholder engagement are essential components to be considered in water governance models (Di Vaio, Trujillo et al., 2021). Shulla et al. (2021) analyzed the effects of COVID-19 crisis on the interconnectedness of the SDGs. They utilized moderated focus group discussions and concluded a distinctive pattern of interconnection between the SDGs that can be linked to COVID19 consequences (Shulla et al., 2021). Given the lack of funding to reach the SDGs post-pandemic, mainly in developing countries, Barbier and Burgess (2020) suggested cost-effective policies such: funding clean energy investments based on fossil fuel subsidy swap, redistribution of irrigation subsidies, and a tropical carbon tax.

At a country level, Ranjbari et al. (2021a) proposed a recovery agenda post-COVID-19 to achieve sustainable development in Iran. The reduction of poverty, job creation, end of pandemics and epidemics, and support of small-scale enterprises were identified as top priorities (Ranjbari et al., 2021a). In a qualitative study performed by Alibegovic et al. (2020) to assess the impacts of COVID-19 on the SDGs in Italy, the following global goals were found to be the most impacted ones: SDG-1 (ending poverty), SDG-4 (education characterized by good

quality and equitable), and SDG-8 (decent work and economic growth). As an outcome of their research on the adequacy of the SDGs to assess the readiness and resilience of countries facing global sustainability threats such as COVID-19 crisis, Kim and Kim (2021) concluded that countries with high SDG index scores were able to effectively control the catastrophic mortality from COVID-19, even though they were being unable to control the spread of infection. Accordingly, the impacts of COVID19 on the SDGs will vary in different communities, depending on the economic well-being, social structure, population density, resource availability, etc. (Bherwani et al., 2021).

Fenner and Cernev (2021) suggested that the large uncertainties associated with responses to COVID-19 at global level are having a strong effect on delivery of the SDGs by 2030. The work concluded that there is an opportunity to realign efforts to achieve the SDGs, but it may be hindered by new geopolitical conflicts of interest (Fenner & Cernev, 2021). Yoshino et al. (2021) in their theoretical work highlighted the importance of support given by governments toward achieving the SDGs in the post-COVID-19 era. At regional level, Odey et al. (2021) outlined the setbacks that the SDGs have encountered during COVID-19 crisis in Africa because of shifting to curbing the spread of COVID-19. In order for the African continent to realize sustainable development, relevant actors must take strategic measures, including innovation, evaluation and strong political implementation will, so that the African continent does not lag behind 2030 in achieving global goals (Odey et al., 2021). The same conclusion was reached by Ekwebelem et al. (2021) with respect to the devastating impacts of COVID-19 crisis on the SDGs in Africa. While these impacts have been aggravated in this region by hunger, poor health and educational and systems, lack of potable water, insufficient access to sanitation services, and poverty, the ability to meet the SDGs in the post-pandemic era has been questioned (Ekwebelem et al., 2021). Despite that, African governments should formulate policies that are affordable and able to achieve the SDGs in addition to adopting shared responsibility models (Ekwebelem et al., 2021).

2.3 A comparative analysis with previous studies

By reviewing major literature on COVID-19 linked to the SDGs, the features of scrutinized literature were concerned primarily with: analyzing the impacts of COVID-19 crisis on the SDGs considering a single goal or a group of goals, analyzing the setbacks the SDGs have encountered due to COVID-19 pandemic at regional or country levels, interconnections among the SDGs, the importance of digital sustainability, and resilience of communities. The present work will be concerned with revealing the state of research activities on COVID-19 linked to the SDGs in a more comprehensive approach considering: all SDGs, major contributors, collaboration links, major trends, etc. Categorizing and Clustering research works followed by deep analysis of each cluster to determine the core issues of high concern regarding the effects of COVID-19 crisis on the SDGs will be another characteristic of the present work. Analyzing the pessimistic and optimistic outlooks with respect to achieving the SDGs impacted by the pandemic crisis considering all arguments in this regard is a major distinction of the present analysis compared to previous studies.

3 Material and methods

3.1 Source of information

The data source for this analysis was the Scopus database (a well-known and an inclusive scientific literature database). Sufficient related information regarding the published works (i.e., authors, countries, affiliations, references, keywords, citations, date of publication, etc.) is also available (Romero & Portillo-Salido, 2019). Scopus database is one of four well-known scientific literature databases widely used to perform bibliometric studies (Zyoud & Al-Jabi, 2020). This set of literature databases involves Google Scholar, Web of Science, PubMed, and Scopus (Falagas et al., 2008). In terms of insertion of different sources (i.e., journals, proceedings, etc.), Scopus and Web of Science follow certain rigorous standards and measures (Martín-Martín et al., 2018). Scopus database characterized by its higher flexibility compared to other databases in terms of affording a comprehensive summary on the different fields of research. Furthermore, it is having potent tools of search that assist in conducting advanced assessments over the compiled data.

3.2 Search strategy

With the aim of compiling the required data, we considered all types of subject fields within Scopus database during the search phase. This included social, life, health, and physical sciences. In considering the terms to be used in the search query and in relevance to COVID-19, we availed from two recent bibliometric works by Zyoud and Al-Jabi (2020), and Zyoud and Zyoud (2020). These phrases, expressions and keywords were as follow: (COVID 19; nCoV-2019; COVID19; 2019 novel coronavirus; coronavirus disease 2019; coronavirus 2019; 2019-novel CoV; 2019 ncov; nCoV 2019; COVID 2019; corona virus 2019; Severe acute respiratory syndrome coronavirus 2nCoV2019; 2019-ncov; COVID-19; and SARS-CoV-2). While for the terms that are relevant to the SDGs, the most impact terms and keywords, in this regard, were: "sustainable development goals."

The two COVID-19 and "sustainable development goals" search queries were combined in one advanced search query. The final query string was concerned with searching for relevant COVID-19 and the SDGs terms in titles and abstracts of published works until March 24, 2021. Articles and reviews documents were considered for further analysis. While other types of published works (i.e., notes, editorial, conference papers, short communication, etc.) were eliminated. The resultant search query looks like this: TITLE-ABS ("COVID 19" OR "COVID-19" OR "2019 novel coronavirus" OR "corona virus 2019" OR "coronavirus disease 2019" OR "coronavirus 2019" OR "nCoV2019" OR "2019-novel CoV" OR "2019 ncov" OR "nCoV 2019" OR "COVID 2019" OR "COVID19" OR "nCoV-2019" OR "SARS-CoV-2") OR "2019-ncov" OR "Severe acute respiratory syndrome coronavirus 2" AND TITLE-ABS ("sustainable development goals") AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re")).

In search queries within Scopus database, terms and expressions that are bounded by double quotes are regarded as a one unity. They will appear in the precise order as considered in the search query. To merge the different elements of the search query, the Boolean operators OR and AND can be used to perform this duty. “ar” and “re” in the search query

refer to articles and reviews, respectively. The process of searching and collection of all required information were carried out all within 1 day, March 24, 2021. This is necessary in averting all possible biases as a consequence of the regular updating of Scopus database.

3.3 Data analysis

All compiled data from Scopus database are transferred to Excel files. These data comprise the following major information: title, authors, abstracts, keywords, type of document, authors, authors' affiliations, country/territory, year of publication, language of document, citation frequency, fields of interests, subject area, model of publication, source type, and funding sponsor. We used the performance analysis technique to assess the contribution and impact of different groups of scientific actors (i.e., countries, institutions, regions, sources, etc.). In this regard, the number of published documents by different scientific actors is being used as a quantitative index. This indicates the contribution and research productivity of the actors toward the scrutinized research field. While, various qualitative indexes (i.e., citations frequency, average, median, and interquartile range) are used to indicate the impact of published works. The aforementioned descriptive statistics were carried out using SPSS program. A Further assessment of the quality of published works was being proposed based on Hirsch index (*h*-index) (Hirsch, 2005). This index is vigorous enough in describing the impact and merit of cumulated research works (Meho & Rogers, 2008). By this index, it is possible to combine the productivity (i.e., number of published research works as a quantitative index) of either source, country, author, etc. and the frequency of citation (as a qualitative index). Its interpretation can be defined as the number of publications by scientific actors with a citation rate of h or greater (Hirsch, 2005). As an example, a journal with an h-index of 30 is owing 30 research works where each work has received at least 30 citations. The aforementioned example is a demonstration of the h-index concept while applied in evaluating the influence of a specific source. This is applicable in evaluating the impact of research works of other scientific research actors. In sorting different scientific research actors with prolific achievements in descending order, the formula of Standard Competition Ranking (SCR) was being utilized.

3.4 Science mapping techniques

Science mapping techniques aim at unveiling structural and dynamic features of different scientific research fields (Cobo et al., 2011). These techniques used, primarily, to quantify and visualize the revealed subfields by means of different approaches (i.e., co-authorship, co-citation, and co-word analyses) (Cobo et al., 2011). In this regard, different bibliometric tools have been developed with the aim of combining performance analysis techniques and science mapping techniques (Cobo et al., 2012). This helps, further, in generating knowledge maps, evaluating research advancements and frontiers, and recognizing research trends and hotspots (Chen, 2004). With regard to analysis of co-authorship links, it can be used to assess co-authorships' links between countries, or authors as an example. The shedding of light on collaboration links can be utilized constructively to stimulate research collaborations. By revealing collaboration links among countries, for example, it is straightforward to suggest that countries with frequent appearances are having strong research linkages compared to others (Zyoud & Zyoud, 2020). This helps in recognizing prospect collaborators in a certain area of science (Zyoud & Zyoud, 2020). Co-citation analysis reveals the co-citation links among two published works that are cited collectively

by another work. This helps in recognizing the intellectual principles of a certain area of science based on the links' strengths among various research works. In addition, this analysis can be utilized to identify research frontiers and trends, highly valuable researchers, and other pertinent bibliometric data (Chen, 2004).

We employed VOSviewer software in generating the visualization maps of co-authorships between countries and co-citation analysis of sources (van Eck & Waltman, 2010). This software utilizes similarity mapping and clustering techniques to display the contributions of sources, institutions, countries, etc. based on different bibliometric maps (van Eck & Waltman, 2010). With regard to countries' research collaboration, for example, VOSviewer is able to generate two dimensions' distance-based bibliometric map. The research collaboration strength between any two specific countries, for example, can be reflected by the distance on the map between these two countries (van Eck & Waltman, 2010). There will be a closer distance between countries having more joint research works (Bornmann, 2016). The items (objects of interest like sources, institutions, countries, etc.) can be demonstrated as nodes which will be normalized utilizing the formula of association strength normalization. Subsequently, these nodes will be assigned to distinct clusters that link closely related nodes. To differentiate clusters from each other, each cluster will acquire a specific color. The smart local moving algorithm is used by VOSviewer to clustering the different items (van Eck & Waltman, 2014). The links between objects on the bibliometric map which display the relationships between objects are represented by lines of positive values (higher values: stronger links; stronger links between two objects: thicker lines). With respect to co-authorship analysis, the link strength indicates the number of research works co-authored by two scholars for example (van Eck & Waltman, 2010). The distance on the map of co-citation between any two sources shows the relatedness of these sources (the closer two sources are located on the map: having stronger relatedness in terms of co-citation). The lines are also used to present the strong of co-citation links between sources (van Eck & Waltman, 2010).

The analysis of keyword co-occurrence and word frequency was carried out utilizing the powerful features of VOSviewer software. Such analyses are important as central keywords display literature core and research hub in a particular field of science (Wang et al., 2017). The keyword co-occurrence analysis helps in recognizing the interconnections between the notions of various research works. This helps in identifying hot subjects which will continue to be energetic in the future. Thresholds have been applied to properly visualize the bibliometric networks (i.e., minimum occurrences of a term) (Aleixandre-Benavent et al., 2017). Figure 2 summarizes the methodological approach of the search strategies and inclusion criteria employed to retrieve research works in relation to COVID-19 and the SDGs. It further illustrates the roadmap that outlines the entire analysis procedure including data collection, bibliometric analysis, and major outcomes.

4 Results and discussion

4.1 The scientific research productivity on COVID-19 linked to the SDGs

In response to COVID-19 crisis and as recorded in Scopus database, researchers across the globe yielded 123,377 documents in all fields of science at the time of data collection March 24, 2021. Medicine subject area topping these research works (82,270 documents; 66.7%). It is followed by Social Sciences (14,090 documents; 11.4%), Biochemistry,

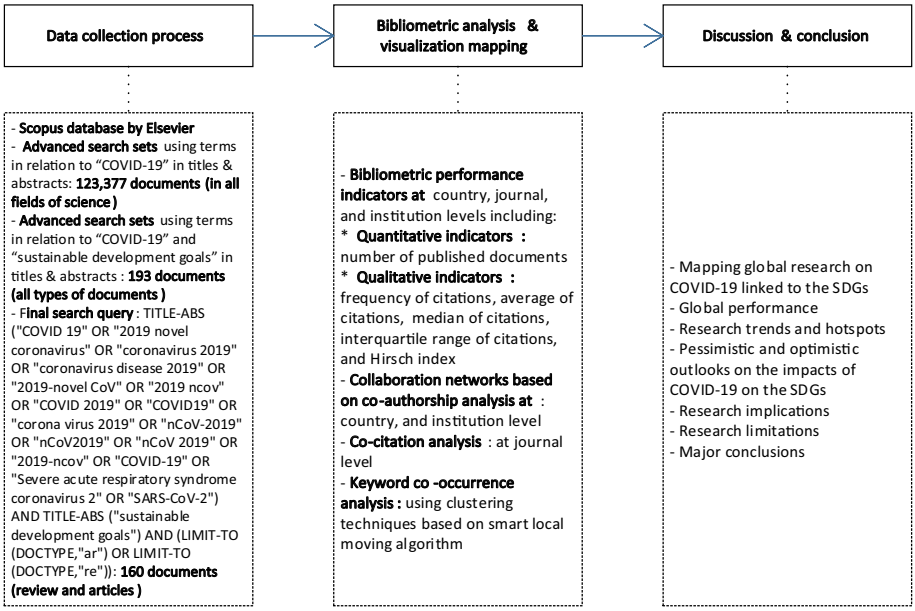

Fig. 2 The roadmap outlines the entire analysis procedure including data collection, bibliometric analysis, and major outcomes

Genetics and Molecular Biology (13,511 documents; 11.0%), Immunology and Microbiology (8365 documents; 6.8%), Computer Science (8944 documents; 4.8%), Environmental Science (5664 documents; 4.6%), Nursing (5287 documents; 4.3%), Pharmacology, Toxicology and Pharmaceutics (5,058 documents; 4.1%), etc. The breakthrough in research fields related to understanding the structural and functional properties of SARS-CoV-2, realization of infection and transmission mechanisms, and development of vaccines and curative medicines was an intuitive matter. These issues were a top priority identified by policymakers, health agencies, and researchers aiming at saving human existence. Subsequently, the interest in the effects triggered by COVID-19 on the social and environmental aspects has grown considerably. That was in association with the deep realization of the impacts of COVID-19 affecting social, economic, and environmental aspects. All of this has entailed the expanding of COVID-19 -related activities to a variety of disciplines (i.e., economy, socioeconomics, environment, etc.). When the search is limited to COVID-19 linked to the SDGs, the global research productivity was 193 documents (0.16% out of total global research productivity in all fields). This figure decreases to 160 documents when limiting the search to just article and review document types (138 articles; 86.3%, 22 reviews; 13.7%) representing 0.19% of total global research productivity. Despite this modest rate, it is anticipated that research activities on COVID-19 linked to the SDGs will attract much attention and will continue as a dynamic and flourishing field. The endeavors toward counteracting the adverse impacts of this crisis that hinder the reaching of the SDGs by 2030 will accelerate at a high pace. The shift toward these issues will be driven by the remarkable progress on developing vaccines against COVID-19. Furthermore, the advances on these issues will lead to the development of different global strategies for managing future global risks.

4.2 Leading countries with prolific contributions and patterns of collaboration on COVID-19 Linked to the SDGs

The geographic distribution of research works on COVID-19 linked to the SDGs is displayed in Fig. 3. Seventy-two countries across the globe have made dissimilar research contributions ranging from 33 documents (21.0% out of total global research productivity) as the case of the USA to simply 1 document/ country as the case of 28 countries. Most productive countries, Fig. 3 and Table 1, are, in general, developed countries from Northern America (i.e., USA, Canada), Western Europe (i.e., UK, Spain, Germany, the Netherlands), Asiatic region (i.e., Japan), and Pacific region (i.e., Australia). The achievements of some developing countries (i.e., India, China, Nigeria, and South Africa) were being clear. It is clear that these countries are among the most impacted countries by the COVID-19 pandemic, and having high economic and scientific research capabilities. Because of launching scientific research activities on COVID-19 linked to the SDGs late compared to other research activities in relation to COVID-19, the figures of h-index and collected citations for published works by different countries were relatively small. The UK was the country of the highest: *h*-index (4), number of citations (65), and the most collaborated country with other countries.

Collaboration among countries, Fig. 4, is displayed using two dimensions' space. This space is instituted using co-authorships linkages between different countries. The importance of research collaboration is stemmed from its potential in producing research works with high impacts based on integration of different skills, experiences and complementary practices. The teaming up of researchers, research institutions, and countries across the globe during COVID-19 crisis is an intuitive manner aiming at reaching potential solutions in combating the impacts of this pandemic. The visualization maps show countries with high levels of cooperation adjacently. Countries with persistent collaborations are assigned to unified clusters with distinctive colors. Moreover, countries with larger nodes do much better than others with respect to collaboration and co-authorship. The least number of research works of a country was defined as 5 documents. Of 87 countries, 18 countries matched the set threshold with 99 links of collaboration and a total strength of 182. The USA and the UK had the highest number of links (16 links/country). The strongest link

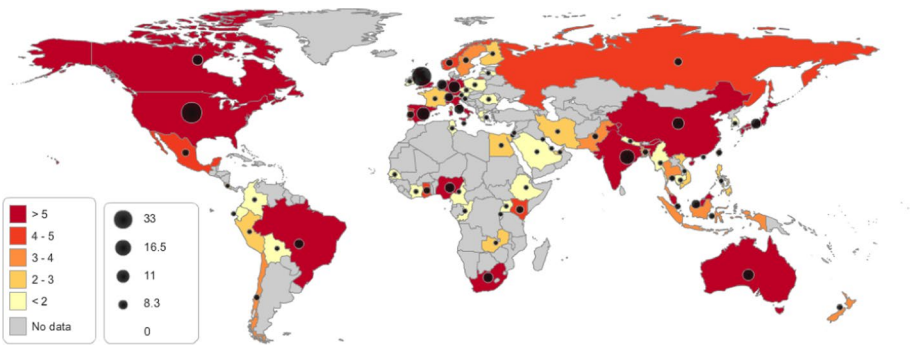

Fig. 3 Nation-level production on COVID-19 linked to sustainable development goals (SDGs); worldwide view of the research output of countries. The color intensity represents the number of publications. The volume of black circles indicates the productivity of each country (i.e., the larger the circle, the higher contribution of country in terms of number of published documents). Global map was generated by Statplanet Interactive Mapping and Visualization Software, www.statsilk.com, free license

Table 1 Countries' major bibliometric performance indicators associated with research on COVID-19 linked to Sustainable Development Goals (SDGs), top 10 most productive countries

SCR[a]	Country	No. of documents (%)[b]	*h*-index	No. of citations	Collaboration with other countries -No. of collaborated countries	No. of documents form collaboration (%)[c]	Most collaborated country	No. of documents with most collaborated country (%)[d]
1st	USA	33 (20.6)	3	40	35	22 (66.7)	India UK	6 (18.2) 6 (18.2)
2nd	UK	29 (18.1)	4	65	40	21 (72.4)	India	7 (24.1)
3rd	India	17 (10.6)	3	29	29	11 (64.7)	UK	7 (41.2)
4th	Spain	13 (8.1)	2	12	21	4 (30.8)	USA	3 (23.1)
5th	China	11 (6.9)	2	20	23	8 (72.7)	Australia UK USA	3 (27.3) 3 (27.3) 3 (27.3)
5th	Germany	11 (6.9)	2	35	26	8 (72.7)	UK	5 (45.5)
7th	Australia	10 (6.3)	1	18	23	5 (50.0)	China USA	3 (30.0) 3 (30.0)
8th	Canada	9 (5.6)	2	16	24	6 (66.7)	USA	5 (55.6)
9th	Japan ara>	8 (5.0)	3	29	9	3 (37.5)	UK	2 (25.0)
9th	The Netherlands	8 (5.0)	1	5	23	6 (75.0)	Canada USA	4 (50.0) 4 (50.0)
9th	Nigeria	8 (5.0)	2	19	24	6 (75.0)	UK	4 (50.0)
9th	South Africa	8 (5.0)	2	9	21	5 (62.5)	Nigeria USA	3 (37.5) 3 (37.5)

SCR Standard Competition Ranking

[a]Equal countries have the same ranking number, and then a gap is left in the ranking numbers

[b]Percentage of documents/ country out of the total published research

[c]Percentage of documents with international authors out of the total number of documents for each country

[d]Percentage of documents with most collaborated country out of the total number of documents for each country

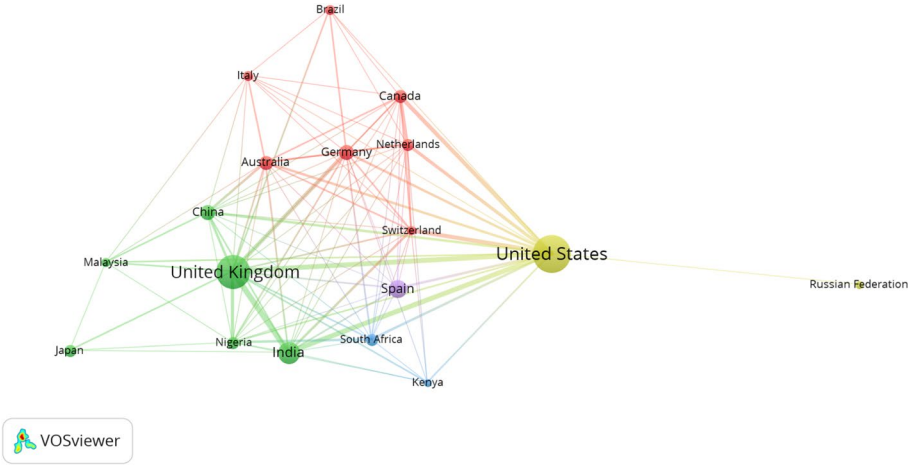

Fig. 4 Network visualization map of country collaboration. A minimum of 5 documents per the country was set as a threshold and 18 countries met the threshold. The thickness of the link between any two countries is an indicator of the strength of collaboration between the two countries. The volume of the circle around the item is an indicator of the contribution of the item (i.e., the larger the circle, the higher the contribution of country in terms of co-authorship). The items with same color indicate that these items are related to each other (i.e., within the same cluster)

was recorded to the benefit of the USA (50), followed by the UK (44). The strongest links (total link strength: 6) were between the USA and the UK, and between the USA and India. The frequently cooperating countries were grouped into 5 clusters. Cluster 1 of red color includes 7 countries with Germany and the Netherlands in the core. Cluster 2 of green color includes 6 countries with the UK in the core. Cluster 3 of blue color includes two countries with South Africa in the core. Cluster 4 of yellow color includes two countries with the USA in the core. The latest cluster, cluster 5, of purple color includes 1 country; Spain.

4.3 Leading journals with prolific contributions on COVID-19 linked to the SDGs

Researchers around the world published their research on COVID-19 linked to the SDGs in 120 journals. Most journals, 111, published only 1 document/journal. The other journals with productivity more than or equal to 2 documents/journal are shown in Table 2. Sustainability Switzerland journal with IF, 2019 = 2.576, published the largest number of documents on COVID-19 linked to the SDGs ($n = 26$; 16.3%), followed distantly by International Journal of Environmental Research and Public Health ($n = 4$; 2.5%, IF = 2.849), and Agricultural Systems ($n = 3$; 1.9%, IF = 4.212). The present analysis indicated that most published works were published in reputable sources with impact factors. In general, many journals, including major journals, allocated special issues as means of disseminating COVID-19-related research works more swiftly. Moreover, research related to COVID 19 was considered a top preference and was published primarily as open access. In the present analysis, for example, 122 documents (76.0% of total published works) are published as open-access works. The highest

Table 2 Ranking of top 10 most productive journals on COVID-19 Linked to Sustainable Development Goals (SDGs)

SRC[a]	Name of the Journal	No. of Documents (%)[b]	*h*-index	No. of citations	Impact Factor (IF)[c]
1st	Sustainability Switzerland	26 (16.3)	5	85	2.576
2nd	International Journal of Environmental Research and Public Health	4 (2.5)	1	3	2.849
3rd	Agricultural Systems	3 (1.9)	1	1	4.212
4th	Globalization and Health	2 (1.3)	1	1	2.525
4th	Journal of Global Health	2 (1.3)	–	–	2.899
4th	Journal of Public Health Research	2 (1.3)	–	–	NA
4th	One Earth	2 (1.3)	1	4	NA
4th	Prospects	2 (1.3)	1	4	NA
4th	Renewable and Sustainable Energy Reviews	2 (1.3)	–	–	12.11
4th	World Development	2 (1.3)	–	–	3.869

SCR Standard Competition Ranking; *IF* impact factor

[a]Equal journals have the same number of ranking, and then a gap is left in the numbers of rankings

[b]Percentage of documents/ source out of the total published research

[c]Impact factors of journals were documented from Journal Citation Reports (JCR): released in 2020 by Thomson Reuters for 2019 citations data

number of citations was collected by Sustainability Switzerland journal (85), followed by One Earth journal and Prospects journal (4 citations/journal).

The visualization maps of most co-cited journals are displayed in Fig. 5a: Map of network visualization, and Fig. 5b: Map of density visualization. The least citations number of a journal was set as 20 citations. Out of 5221 journals, only 9 journals met the threshold. A total of 23 links having a total strength of 1090 was recorded between the most co-cited journals. The strongest link strength (425) was recorded to the benefit of Lancet journal, followed by Nature journal (387), and Science journal (382). The strongest link (123) was between Lancet journal and Health Research Policy and Systems journal (Fig. 5a). It is followed by the link between Nature and Science journals (117). This mapping demonstrates the significance of topics addressed on COVID-19 linked to the SDGs as they are cited by well-reputable and prestigious sources in fields of natural sciences, public health, science, medicine, environment, and technology. This includes Lancet, Science, Nature, Journal of Cleaner Production, Science of the Total Environment, Plos One, Health Research Policy and Systems journal, Sustainability, and World Development journals. Four clusters of journals have been recognized in the present study. Cluster 1 of red color includes 3 journals that are very close to each other in terms of scope. The Sustainability journal at the core of cluster 1. Cluster 2 of green color includes 3 journals where Nature journal is at the core. Cluster 3 of blue color includes 2 journals where Lancet journal is at the core. The latest cluster, cluster 4, of yellow color includes 1 journal; Science of the Total Environment journal. In Fig. 5b, regions with red colors indicate prolific journals with the highest rates of citations (i.e., Sustainability, Lancet, Science, and Nature journals).

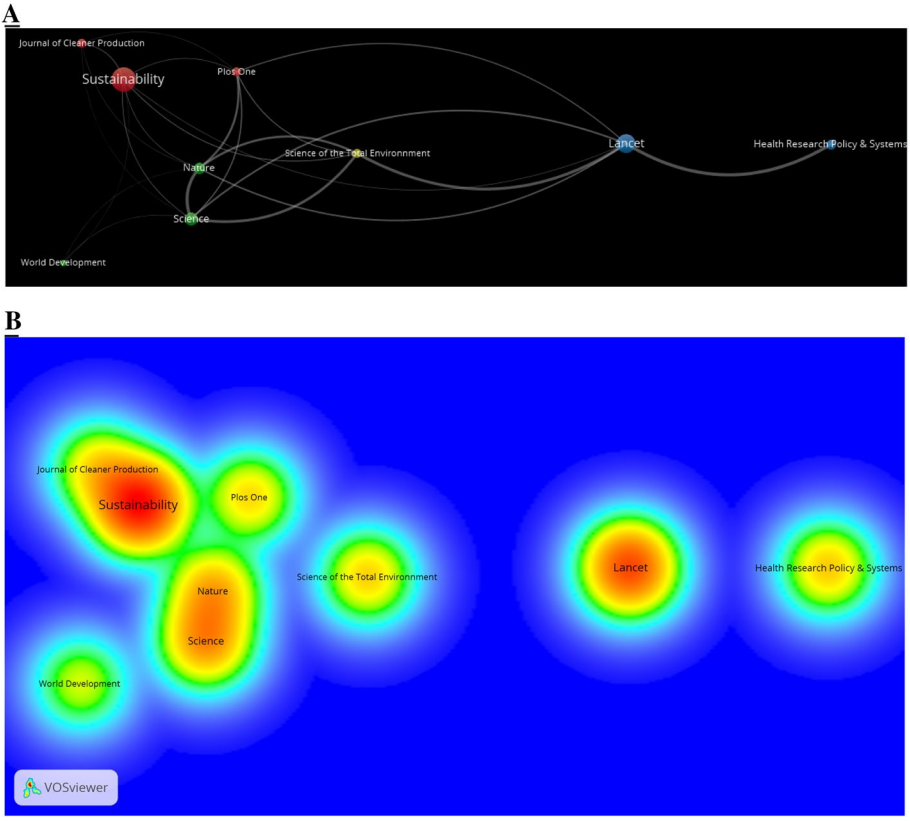

Fig. 5 Visualization maps of top journals based on co-citation analysis; **a** Network visualization map; **b** Density visualization map. A minimum number of citations of a source: 20. Of the 5221 sources, 9 met the threshold. For each of the 9 sources, the total strength of co-citation links with other sources was calculated. The sources with the greatest total link strength are selected

4.4 Top cited works on COVID-19 linked to the SDGs

The research works on COVID-19 linked to the SDGs collected 291 citations. The average was 1.82, and the median (interquartile ranges): 0 (0–2). The h-index was 9. This indicates that 9 research works had collected at least 9 citations/document. The top 10 most cited documents on COVID-19 linked to the SDGs are demonstrated in Table 3 (Chiaramonti & Maniatis, 2020; Filho et al., 2020; Fleetwood, 2020; Haywood, 2020; Ibn-Mohammed et al., 2021; Khetrapal & Bhatia, 2020; Pan & Zhang, 2020; Shammi et al., 2020; Tran et al., 2020; Yeasmin et al., 2020; Yoshino et al., 2021). Three documents out of 11 documents in this list were published by Sustainability journal. The most cited work discussed the major threats posed by COVID-19 toward the reaching of the SDGs mainly in developing regions (Filho et al., 2020). The study concluded that while COVID-19 crisis has become a preference on the agenda of most health organizations and frameworks, other disease prevention programs were disrupted. The other works discussed issues like the need to adjust the development plans, the importance of digital sustainability, mental health of children, impacts of COVID-19 on learning and

Table 3 Top 10 most cited documents on COVID-19 linked to Sustainable Development Goals (SDGs)

SRC[a]	Authors	Title	Journal name	Times cited[b]	Document type
1st	Filho et al. (2020)	COVID-19 and the UN sustainable development goals: Threat to solidarity or an opportunity?	Sustainability (Switzerland)	26	Article
2nd	Shammi et al. (2020)	Strategic assessment of COVID-19 pandemic in Bangladesh: comparative lockdown scenario analysis, public perception, and management for sustainability	Environment, Development and Sustainability	18	Article
3rd	Tran et al. (2020)	Toward sustainable learning during school suspension: Socioeconomic, occupational aspirations, and learning behavior of vietnamese students during COVID-19	Sustainability (Switzerland)	17	Article
4th	Pan and Zhang (2020)	From fighting COVID-19 pandemic to tackling sustainable development goals: An opportunity for responsible information systems research	International Journal of Information Management	16	Article
4th	Yeasmin et al. (2020)	Impact of COVID-19 pandemic on the mental health of children in Bangladesh: A cross-sectional study	Children and Youth Services Review	16	Review
6th	Ibn-Mohammed et al. (2021)	A critical analysis of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies	Resources, Conservation and Recycling	14	Article
6th	Khetrapal and Bhatia (2020)	Impact of COVID-19 pandemic on health system & Sustainable Development Goal 3	Indian Journal of Medical Research	14	Article
8th	Chiaramonti and Maniatis (2020)	Security of supply, strategic storage and Covid19: Which lessons learnt for renewable and recycled carbon fuels, and their future role in decarbonizing transport?	Applied Energy	13	Article
9th	Haywood (2020)	A post-COVID-19 future—tourism re-imagined and re-enabled	Tourism Geographies	12	Article
10th	Yoshino et al. (2021)	Covid-19 and Optimal Portfolio Selection for Investment in Sustainable Development Goals	Finance Research Letters	9	Article

Table 3 (continued)

SRC[a]	Authors	Title	Journal name	Times cited[b]	Document type
10th	Fleetwood (2020)	Social justice, food loss, and the sustainable development goals in the era of COVID-19	Sustainability (Switzerland)	9	Article

SCR Standard Competition Ranking

[a]Documents with equal number of citations have the same number of ranking, then a gap is left in the numbers of ranking

[b]Total citations have been collected from Scopus database, and could be differ when using other research database

teaching activities, quality of education in fanciful situations, the importance of circular economy-related options as a catalyst essential for the growth of the global economy in a resilient post-COVID-19, cleaner transport fuels in the post-COVID-19 recovery plans, future of tourism, global taxation on pollution, and food loss challenges within global food supply systems caused by COVID-19.

4.5 Institutions with prolific contributions on COVID-19 linked to the SDGs

One hundred sixty institutions, globally, have dissimilar contributions toward COVID-19 linked to the SDGs. In the table of most prolific institutions, Table 4, University of Toronto, Canada topping the list (5 documents; 3.1%). There were 4 institutions from the UK, 3 institutions from the USA, 2 from Canada, 1 from Italy, and 1 from Japan. Collaboration among institutions and organizations across the globe is displayed in Fig. 6. This map shows the largest set of connected organizations only that consists of 15 institutions. The map categorized all institutions in one cluster, red color. Each institution has 14 links with the other institutions. This set of institutions had collaborated on a research work entitled "*Goals in Nutrition Science 2020-2025*," published in *Frontiers in Nutrition* journal as a review article. In this work, authors from 15 different institutions explored the function of the microbiome in providing insights on the interrelations between nutrition, immune systems, and diseases (Bassaganya-Riera et al., 2021). They confirmed the importance of considering lessons learned from COVID-19 in relation to the weakness of food systems at the global level in ensuring the security of global food systems (Bassaganya-Riera et al., 2021).

Table 4 Top 10 most productive institutions on COVID-19 linked to Sustainable Development Goals (SDGs)

SRC[a]	Name of the Institution	No. of Documents (%)[b]
1st	University of Toronto, Canada	5 (3.1)
2nd	Harvard University, USA	3 (1.9)
3rd	Politecnico di Torino, Italy	3 (1.9)
4th	University of Nottingham, UK	3 (1.9)
5th	University of Guelph, Canada	3 (1.9)
5th	University of Sussex, UK	3 (1.9)
5th	Keio University, Japan	3 (1.9)
8th	The University of Edinburgh, UK	3 (1.9)
8th	London South Bank University, UK	3 (1.9)
8th	Michigan State University, USA	3 (1.9)
8th	United Nations, USA	3 (1.9)

SCR Standard Competition Ranking

[a]Equal institutions have the same number of ranking and then a gap is left in the number of rankings

[b]Percentage of documents/ institution out of the total published research

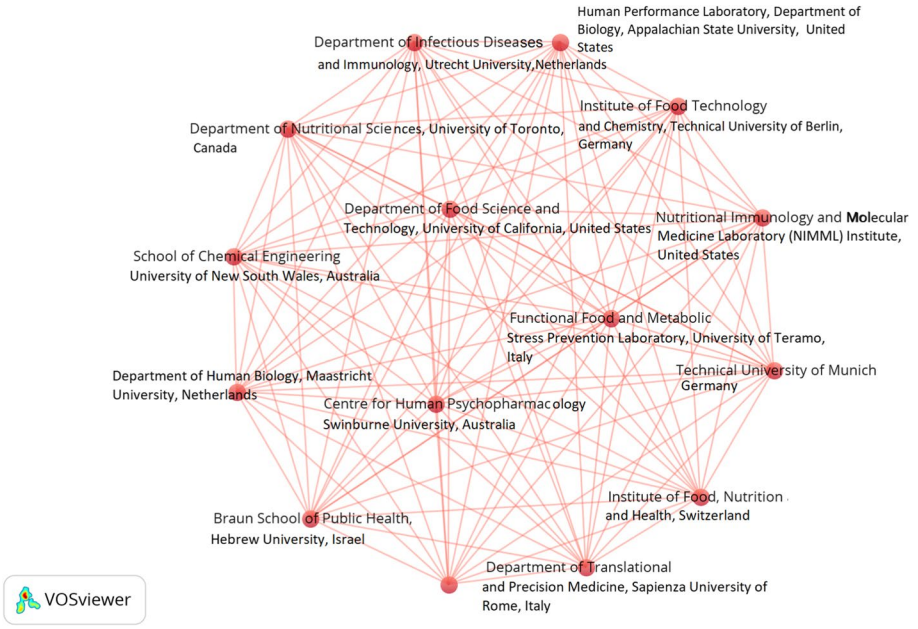

Fig. 6 Network visualization map of institutions collaboration. A minimum of 1 document per the institution was set as a threshold and 15 institutions met the threshold. The thickness of the link between any two institutions is an indicator of the strength of collaboration between the two institutions. The volume of the circle around the item is an indicator of the contribution of the item (i.e., the larger the circle, the higher the contribution of institution in terms of co-authorship). The items with same color indicate that these items are related to each other (i.e., within the same cluster). The map shows the largest set of connected institutions and organizations which consists of 15 items

4.6 Word frequency and co-occurrence keywords analysis

The map of network visualization, Fig. 7, based on keywords co-occurrence (all keywords) categorized these keywords into five major clusters with 556 links (the total links strength was 1647). The strongest links were between sustainability, sustainable development, the SDGs and the pandemic/COVID-19 (total links strength: 85), followed by the links between human and the pandemic/COVID-19 (total links strength: 51). A detailed explanation of clusters and their relevance to different SDGs is given as follow:

– *Cluster 1*, red color includes the following major terms: (public health: 16 occurrences, health care delivery: 11 occurrences, poverty: 8 occurrences, female: 7 occurrences, health care policy: 7 occurrences, global health: 7, health insurance: 7 occurrences, leadership: 7 occurrences, organization and management: 6 occurrences, developing countries: 6 occurrences, vulnerable population: 6 occurrences, disease burden: 5 occurrences, and health promotion: 5 occurrences). Public health had the strongest links strength (109). Health issues were in the core of this cluster. In this regard, these works concluded that achieving sustainable health systems and investments in national health care capital coupled with resilience health care systems are essential measures to overcome the gaps in pandemic preparedness at present as in the case of COVID-19 and in the future (Eissa, 2020). Socially sustainable care systems that contribute better

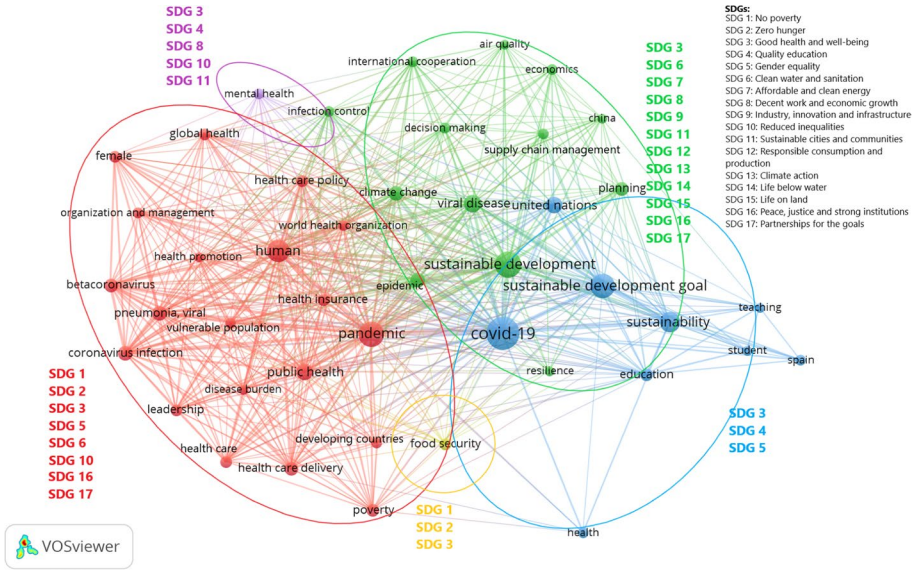

Fig. 7 Network visualization map, analysis of co-occurrence of terms, all keywords. Minimum number of occurrences of a term was set to 5, Of the 1339 terms, 60 terms have met the specified threshold. For each of the 60 terms, the total strength of the co-occurrence links with other keywords was calculated. The keywords with the greatest total link strength were selected. The map categorized keywords in 5 major clusters

to fair using of health care in a post-COVID-19 era are of paramount significance due to the possible increase of chronic diseases in the future (Macassa & Tomaselli, 2020). In the case of developing countries, the priorities were concerned with: restructuring of public health systems to decrease the burden of infectious diseases, the establishment of sustainable financing programs for new vaccines, modifying vaccine delivery models mainly to remote zones, and the insurance mandate (Fonjungo et al., 2020). A further issue with concern in developing countries was related to investigating the threats of the pandemic on some SDGs, particularly poverty. Moreover, the investigation of the most impacted persons by the pandemic. Bukari et al. (2021), for example, concluded that the pandemic had significantly deteriorated standards of living, increased poverty rates, and impacted mostly female class in Ghana. A major issue of interest that arose in association with COVID-19 pandemic is the need to better coordinate the efforts of global health actors to attain health-related SDGs (Spicer et al., 2020). This entails a primary commitment to reducing the causes of fragmentation that undermine the effectiveness of health programs (i.e., problems of global leadership; divergent interests, etc.) (Spicer et al., 2020). In general, the topics addressed in this cluster were in relevance to SDG-1, SDG-2, SDG-3, SDG-5, SDG-6, SDG-10, SDG-16, and SDG-17.

– *Cluster 2*, green color with the following major terms: (climate change: 13 occurrences, international cooperation: 6 occurrences, decision making: 6 occurrences, economics: 6 occurrences, infection control: 6 occurrences, supply chain management: 6 occurrences, air quality: 5 occurrences, and resilience: 5 occurrences). Climate change issues had the strongest links strength (78), followed by international cooperation (44). The pandemic has impacted the sustainability dimensions (economic, environmental, and social) immensely (Ranjbari et al., 2021b). It was clear that health systems, food and agricultural systems, tourism and travel industry, energy, education, and mobility

all impacted by COVID-19 pandemic (Ranjbari et al., 2021b). Accordingly, different research works proposed sustainable transition interventions post-pandemic include: energy transition (i.e., promotion of investments in clean technology in the energy sector), low-carbon innovations, digitization of works, and sustainable mobility schemes (Ranjbari et al., 2021b). Rethinking, reassessment, and restructuring the environments of living of cities using networks of greenery and open spaces are essential toward sustainable transition and making cities more secure against potential future health crises (Pierantoni et al., 2020). The impacts of the pandemic crisis on health–energy–environment nexus under the different constraints of climate changes were of high concern in this cluster. Jiang et al. (2021), for example, concluded that the point views and attention of decision and policymakers toward this issue is important in guiding sustainable future planning. Other authors raised their worries in relation to losing renewable energy projects their competitiveness. This is a consequence of collapsing the prices of fossil fuels in association with the shrinking of global energy demand during the present crisis. They concluded that will impact some SDGs and the Paris agreement on climate changes (Yoshino et al., 2021). Mukherjee et al. (2020) concluded that the pandemic crisis provided a real occasion to evaluate the impacts of human developments on water, air, and health of humans. The implications of the COVID-19 pandemic crisis on the air quality were perceived as positive due to decreasing industrial activities and car traffic and. The improvements in the air quality caused decreases in mortality rates (Karuppasamy et al., 2020). If this trend of improvements in air quality will continue after the pandemic, this will positively impact the climate in the long run. While economic and mobility activities are expected to recover after the pandemic, the reductions in emissions in the short run cannot be considered as a sustainable solution toward the cleaning up of the environment (Zambrano-Monserrate et al., 2020). The green recovery and the sector of transportation paths are areas of sustainable interventions. The smart mobility models based on utilizing flexible programs of working with minimal commuting, advanced transportation systems, and cars and bike sharing models are examples of such sustainable approaches (Zyoud & Zyoud, 2020). Other issue of concern was related to supply chains and the importance of utilizing lean, agile, and leagile strategies to improve the global sourcing practices during difficult times (Rashad & Nedelko, 2020). This is important because of disruptions occurred in food supply chains at local and global levels. Moreover, sustainable supply chain management that considered different challenges (i.e., climate changes, poverty, and pandemics) is important in this regard. López-Santos et al. (2020) utilized Analytic Hierarchy Process (AHP), a well-known decision-making model, to develop long-term resilience in supply chains of small- to medium-sized companies, a Mexican agri-food company was taken as a case study. Digitization of supply chain systems is important to achieving business resilience amidst COVID-19 pandemic. Benefiting from disruptive digital technologies that support smart manufacturing (i.e., 3D printing, cloud computing, big data analysis, internet of things, and artificial intelligence) is important for companies to mitigate the disruptions in economic sectors (Ibn-Mohammed et al., 2021). Most discussed topics in this cluster are relevant to SDG-3, SDG-6, SDG-7, SDG-8, SDG-9, SDG-11, SDG-12, SDG-13, SDG-14, SDG-15, SDG-16, and SDG-17.

– *Cluster 3*, blue color includes the following major terms: (education: 9 occurrences, teaching: 5 occurrences, and student: 5 occurrences). The strongest links strength was recorded by education (49), followed by teaching (23), and student (21). Some major implications of COVID-19 crisis on education include: negative impacts of educational financing because of economic recession, and reduction in the enrollment rates of new

students (Liu, 2020). Spiteri (2021) concluded that children will experience psychological and emotional stresses in the future due to associated social, health, and economic crises with the pandemic. In this regard, considering the social and emotional needs of this group is an essential matter to be adopted by their educators (Spiteri, 2021). In less developed countries, students are found to be more likely to face difficulties to access educational resources during the pandemic (Liu, 2020). Reducing digital learning inequalities is important toward achieving the targets of the SDGs in relation to education (Liu, 2020). Portillo et al. (2020) found in their study to assess the performance of teachers who are performing remote teaching activities during the pandemic the following shortcomings: deficiencies in digital skills, negative emotions, and low technological competence at lower educational levels. The quality and the progress of education based on distant learning and the efficiency of virtual learning due to the pandemic have been tested and found to be impacted negatively to some minor extent (Al-Jaber & Al-Ghamdi, 2020). As regular schools' operation has been disrupted globally to limit the spread of the pandemic, different research works were devoted to assess students' manners of teaching and studying at homes (Tran et al., 2020). Such works aimed to promote students' learning habits during difficult times toward achieving SDG-4 (quality of education) (Tran et al., 2020). As most SDGs impacted by COVID-19 pandemic, prioritization is essential to allocate the available resources toward achieving these goals effectively. Different research works concluded that quality education (SDG-4) in addition to good health and well-being (SDG-3), and clean and affordable energy (SDG-7) are synergetic goals of high priority during the difficult times (Asadikia et al., 2021). The current pandemic promotes the investments to enhance the digital literacy among students mainly in developing countries (Tran et al., 2020). The most relevant SDGs addressed in this cluster were: SDG-3, SDG-4, and SDG-5.

– *Cluster 4*, yellow color includes food security term as core with 7 occurrences and a total links strength of 28. The food security issue in relation to COVID-19 has been tackled from two sides. The first concerned with the food safety issues and if there is an association between food, packaging of foods and the transmission of the viruses caused COVID-19. In this regard, current pieces of evidence confirmed that COVID-19 is not a food safety issue (Mardones et al., 2020). The second side concerned with the impacts of the crisis on food security because of the disruption of food systems at local and global scales. This food insecurity could lead to severe consequences related to public health (Mardones et al., 2020). It is expected that a starvation crisis could follow COVID-19 crisis. This is primarily related to the unprecedented challenges of food loss and waste in food supply systems imposed by the COVID 19 pandemic. imposed by COVID-19 crisis (Fleetwood, 2020). Accordingly, "One Health" concepts, that cover the emergence of diseases and the food–health-related consequences, become a priority to prepare for future outbreaks that could threaten food systems (Mardones et al., 2020). Moreover, the adoption of more adaptive and responsive food supply systems (i.e., regionalized food supply chains (RFSCs)) is essential in supporting resilient and socially sustainable food systems (Marusak et al., 2021). In the case of the USA, RFSCs proved to be more efficient than vertically integrated food supply chains (FSCs) during the pandemic crisis which caused failures in production and distribution systems (Marusak et al., 2021). Other studies proposed decision-making models to identify the most appropriate risk mitigation strategies associated with perishable food supply chains (PFSC) as they struggle against, operational, logistics, greater wastage, and health risks during the pandemic (Kumar et al., 2021). These strategies include financial sustainability, collaborative management, and proactive business continuity plan-

ning (Kumar et al., 2021). SDG-1, SDG-2, and SDG-3 were the most SDGs discussed in this cluster.

– *Cluster 5*, purple color includes mental health term as core with 6 occurrences and a total links strength of 22. Mental health is a top priority in the world, as the cost of mental illness is more than 4% of GDP (Izutsu et al., 2015). Its importance stemmed from the intersection of mental health issues with all SDGs, and the rights of people with mental health disorders are denoted mainly in SDG-4, SDG-8, SDG-10, and SDG-11(Warmate et al., 2021). Achdut and Refaeli (2020) in a study to assess the unemployment and psychological distresses during the crisis of the COVID-19 pandemic concluded that the pandemic and the associated economic crisis posed significant threats to young people mental health. They utilized hierarchical linear models to investigate the links between unemployment, psychological distress, risk factors, and psychological resources (Achdut & Refaeli, 2020). To alleviate the mental health consequences of the pandemic, they have induced policymakers to develop appropriate health initiatives and to promote market interventions that help young people to integrate in employment (Achdut & Refaeli, 2020). At children's and adolescents' levels in Germany, Ravens-Sieberer et al. (2021) analyzed the impacts of the pandemic crisis on mental health of this group based on the perspectives of children themselves. They used online survey that included internationally accepted and tested instruments (i.e., KIDSCREEN-10: health-related quality of life, SDQ: mental health problems, SCARED: anxiety, and CES-DC: depression) (Ravens-Sieberer et al., 2021). The majority of participated children and adolescents, two-thirds, reported being highly burdened by the pandemic (Ravens-Sieberer et al., 2021). In Bangladesh, Yeasmin et al. (2020) utilized online cross-sectional study among parents who are having at least one child to analyze the effects of the pandemic crisis on children. The children were classified benefiting from mental health scores and confirmatory factor analysis. The aim was to recognize the links between parental behaviors and their child mental health. The outcomes of this study showed a large proportion of children had suffered mental health issues during the quarantine and lockdown (Yeasmin et al., 2020). The work of Maalla M'jid (2020) to analyze the impacts of violence and the pandemic crisis on the mental health of children concluded that the risks of violence against children had increased. Furthermore, the pandemic affected mental health services and child protection capabilities (Maalla M'jid, 2020). The most relevant SDGs addressed in this cluster were: SDG-3, SDG-4, SDG-8, SDG-10, and SDG-11.

5 Pessimistic and optimistic outlooks on the impacts of COVID-19 on the SDGs

There is much heated debate among researchers and policymakers on the possible implications of COVID-19 toward advancing the SDGs by 2030. Many SDGs were not on the track of achievement even before COVID-19 pandemic came into view. Despite that, COVID-19 pandemic represents enormous challenges and tremendous opportunities at the same time to reach the Agenda of 2030 and the SDGs. In this regard, there are two possible scenarios post-COVID-19 linked to achieving the SDGs (i.e., pessimistic and optimistic scenarios). The ability of communities across the globe to: diminish the damages caused by the pandemic; swift recovery; build on the improvements introduced during COVID-19 pandemic crisis to social protection, healthcare, and governance systems; and reenergize

the efforts toward sustainable developments will determine the prevalent scenario (United Nations, 2020).

Most pessimistic outlooks suggested that in light of COVID-19 pandemic, the SDGs have become unachievable and called instead for lowering the ambition of these goals (Schmidt-Traub, 2020). Naidoo and Fisher (2020) in their work "*Reset Sustainable Development Goals for a pandemic world*" revealed that COVID-19 pandemic had exposed the fragility of the SDGs and expected that two-thirds of these goals are now unlikely to be met. Their argument based on the fact that the success of the SDGs depends mainly on sustained economic development and globalization. The global economy is anticipated to shrink by at least 5% at the present time and the timeframe of recovery is years from now. Furthermore, developed and industrialized countries are struggling to assist their communities and will not pay much attention to others (Naidoo & Fisher, 2020). In a report performed by the United Nations Development Programme (UNDP) and the University of Denver to analyze the impacts of COVID-19 pandemic crisis on the SDGs, the worst scenario expected that more than 1 billion people could be living in extremist poverty by 2030 (United Nations Development Programme, 2021). The pessimistic outlook linked primarily to the major uncertainties regarding the economic recovery as a result of the pandemic's long-term impacts (United Nations Development Programme, 2021). On the other hand, the report concluded that by adopting a focused set of the SDGs investments in governance, digitization, green economy, and social protection programs, and "SDG push" scenarios, the trajectory of development will be accelerated (United Nations Development Programme, 2021). Shulla et al. (2021) suggested that in light of COVID-19 pandemic, the present decade that has been recognized as the decade of action toward the implementation of the SDGs until 2030 should instead be turned as recovery and action decade. In this regard, the SDGs should be utilized as a shared global framework to meet all essential economic, environmental and social targets that can be enabled through global partnerships (Schmidt-Traub, 2020). With respect to health services, the pandemic had disrupted essential health services across the globe. This disruption could cause large number of additional deaths from communicable diseases in the next few years because most resources are freed up for COVID-19 patients (United Nations, 2020). The social protection programs will be impacted over the next 10 years due to deficiencies in the economic growth impacted by the pandemic. Under this pessimistic scenario, children, orphan, older people, and people with disabilities will not receive enough social security services (United Nations, 2020). With respect to planet protection and climate actions, the pessimistic scenario takes lessons from the global financial crisis in 2008. During the crisis in 2008, there was a large decline in emissions. However, the emissions are rebounded after the crisis (Fatih Birol, 2020b). In the case of COVID-19 crisis, the significant reduction in emissions due to reducing industrial and commercial activities and reduction in travel will fade as the world will get back to pre-COVID-19 tracks (Fatih Birol, 2020b). If the trends of land using, loss of freshwater bodies and biodiversity loss that are predominant pre-COVID-19 crisis will continue after the crisis, the improvements that seen during the crisis will rapidly vanish (United Nations, 2020). In relation to the previous issue, the rising pressures on land, water, and biodiversity caused an increase in material production and consumption at global levels surpassed the biophysical capacity of the planet. Plastic products are among the most produced material. These products, in general, are non-biodegradable, major contaminants to water, air, and land, and can enter the human food chain causing many carcinogenic consequences (Global Footprint Network, 2016). Despite the fact that the pandemic caused some reductions in material production and consumption (i.e., plastic products), the pessimistic scenario could happen if the global community failing in noticing and appreciating

the opportunities of reduction of consumption and instead comes back to pre-COVID-19 trends (United Nations, 2020).

The strong argument of the optimistic outlook relies on the fact that the SDGs can be financed at a relatively modest cost (2% - 3% of total world gross product) (Schmidt-Traub, 2020). Furthermore, the technical details for most SDGs display that the SDGs are still be achieved if policymakers and governments stay focused on them (Schmidt-Traub, 2020). Ottersen and Engebretsen (2020) argued that COVID-19 pandemic may support stimulate efforts to achieve the SDGs and 2030 Agenda. They emphasized that the SDGs should not be revised but should be considered as a catalyst toward progress. They called for the development of a universal preparedness for health considering anticipatory approaches to health which is essential in addressing the future health challenges (Ottersen & Engebretsen, 2020). Building on the emergency health services steps adopted by governments during the crisis (i.e., increasing physical capacities, support healthcare personnel, and eliminate the gaps in health financing and insurance systems) and making these measures more durable will achieve more robust healthcare systems (United Nations, 2020). Moreover, the use of emergency measures to set the basis for sustainable and long-term social protection programs and the optimistic scenario of rebounding the economic growth will increase the capacity of investments in social protection systems (United Nations, 2020). With regard to climate actions, the promotion of green energy investments and decoupling economic growth from the increase in emissions are the core of post-COVID-19 optimistic outlook (Fatih Birol, 2020a). The active policy measures toward achieving Aichi Biodiversity targets that intended at reducing the rates of loss of all-natural habitats and much attention to the zoonotic nature of COVID-19 can give an optimistic scenario in more protection of land, water, and biodiversity post-COVID-19 (Gannon et al., 2019). With respect to sustainable production and consumption, the optimistic scenario suggested that it is possible to achieve this issue by making the increase in consumption patterns as less resource- and waste-intensive as possible and by adopting new digital technologies (United Nations, 2020). The key players in fostering progress on all SDGs are the governments. Better governance including effective communication, transparency, participation, stakeholder engagement, accountability, smart use of technology, etc. is essential in strengthen resilience and accelerate actions to achieve the SDGs (United Nations, 2020). Furthermore, greater partnerships among countries across the globe are needed so as to deal more efficiently against pandemics.

6 Major implications of the study

The present analysis has various theoretical and practical implications. It contributes to the existing literature as it sheds the light on the existing knowledge on COVID-19 linked to the SDGs and the literature gap concerning this vital topic. Research hotspots derived from relevant literature would provide sufficient information to help researchers and decision makers identify future trends and guide research investments. Identification possible variations in research interests and tendencies in comparison to current ones is another significant implication of this study. The analysis of pessimistic and optimistic outlooks would benefit policymakers and researchers in identifying areas of opportunities that benefit from positive feedbacks to reenergize the efforts toward achieving 2030 Agenda. It reveals the importance of adopting in practice good governance, green economy, and social protection programs to lessen the impacts of COVID-19. Developing universal preparedness health

programs and greater partnerships should be a policy priority as mainly supporting vulnerable communities and developing countries in fighting against the pandemic and future crises. This analysis, from a practical perspective, highlights the importance of supporting local governments which have a primary part in the localizing the SDGs and actively contribute to the achievement of the SDGs at the national level. The analysis, further, provides policy recommendation with respect to investing more in digital transformation, participatory approaches and decision making, establishment of clear guidelines at national levels concerning with fostering 2030 Agenda, supporting resilience and recovery agenda, and efficient financial resources' allocation.

7 Limitations of the study

In retrieving the related works, only Scopus database has been adopted as a source of data. The database of Scopus does not contain an online version of the published research works for most indexed journals before the inclusion of these works in an issue (Falagas et al., 2008). While other literature databases as PubMed, online versions are available (Falagas et al., 2008). Therefore, some related works published in other databases may be excluded. In the present analysis, reviews and articles were considered only. The exception of other kinds of published works (i.e., letters, comments, editorials, etc.) could neglect invaluable related contributions and information and contributions. With respect to citations figures, the citation rates determined from Scopus database may differ from other databases. Still, database of Scopus is widely accepted by scholars for high-quality bibliometric studies because it includes plentiful features and offers more flexible tools compared to other literature databases (Zyoud & Zyoud, 2020). Lastly, the keywords used are based on our analysis of the present literature. As indicated by Del Giudice et al. (2021), other related keywords could emerge in the future.

8 Conclusions

The present analysis provides insights into the implications of COVID-19 crisis on progress toward reaching the SDGs benefiting from bibliometric techniques and visualization mapping. Different quantitative and qualitative bibliometric indicators were revealed and analyzed to demonstrate the contribution and performance of countries, institutions, sources, etc. toward the progress of the SDGs. Collaboration among countries and institutions on this topic based on co-authorship analysis was analyzed and assessed. To identify the intellectual basis among research works, analysis of co-citation links has been conducted. While keyword co-occurrence analysis was done to reveal the core topics and future trends of research works in relation to COVID-19 and the SDGs. As most endeavors were devoted to developing vaccines and curative medicines aiming at saving human existence, substantial research works in this regard were begun early and extensively. Therefore, other research activities to assess and mitigate the impacts of the pandemic including works on COVID-19 linked to the SDGs were very modest. A promising launch and increased interests on this issue will be witnessed in the near future mainly after successes in developing vaccines against viruses causing COVID-19. This path is inevitable toward resilience post-COVID-19 aiming at achieving the SDGs by 2030. The post-COVID-19 pandemic era should focus on rebuilding the economy and the society. A strong integration

of the scientific community, policymakers, health care professionals and global community is essential to deal with the impacts of the crisis. The outcomes revealed that there is a need to develop integrated methodologies aiming at lessening the impacts of COVID-19 through collaboration, participation, and commitment. The supporting of more vulnerable communities which utilized major resources to deal with the crisis should be a priority at the agenda of high-income countries. This includes investments in a better health infrastructure, effective poverty-oriented programs, and green projects.

As the present analysis reveals major concerns and deficiencies regarding existing health care systems and their preparedness, sustainable mobility schemes, resilient cities and communities, sustainable supply chain management, digital literacy, responsible decision making in difficult times, collaboration and coordination, etc., this would lead to much work and yield new research avenues on these issues. The need for further research in this regard is essential to complementing and broadening the existing understanding since this field of research is under-explored till now. Advancing research activities on previous issues will guide developing resilient and more dynamic global strategies to control future global risks (e.g., climate changes, future pandemics, etc.). In turn, this will promote plans of recovery and action toward achieving the 2030 Agenda more swiftly. As a recommendation, this study suggests further research on sustainable decision-making models for successful risk management caused by different crises (e.g., pandemics, climate changes, air pollution, food insecurity, etc.). Such models are essential to identify the most appropriate risk mitigation strategies through scenarios analyses that merge social, economic, and environmental dimensions at all decision-making levels.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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