Three pillars of sustainability in the wake of COVID-19: A systematic review and future research agenda for sustainable development

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Abstract

The economic, social, and environmental pillars of sustainability in human lives have been immensely impacted by the COVID-19 pandemic for the global economy and societies. Due to the scholars' increasing interest in responding to the urgent call for action against the pandemic, the literature of sustainability research considering the COVID-19 consequences is very fragmented. Therefore, a comprehensive review of the COVID-19 implications for sustainability practices is still lacking. This research aims to analyze the effects of COVID-19 on the triple bottom line (TBL) of sustainability to support the future sustainable development agenda. To do this, the following research questions are addressed by conducting a systematic literature review: (i) what is the current status of research on the TBL of sustainability considering COVID-19 implications?, (ii) how does COVID-19 affect the TBL of sustainability?, and (iii) what are the potential research gaps and future research avenues for sustainable development post COVID-19? The results manifest the major implications of the COVID-19 outbreak for the triple sustainability pillars and the sustainable development agenda from the economic, social and environmental points of view. The key findings provide inclusive insights for governments, authorities, practitioners, and policy-makers to alleviate the negative impacts of pandemic on sustainable development and catch the sustainability transition opportunities post COVID-19. Finally, five research directions for sustainable development corresponding to the UN's SDGs post COVID-19 are provided, as follows: (1) sustainability action plan considering COVID-19 implications: refining sustainability goals and targets and developing measurement framework; (2) making the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post COVID-19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding quantitative research to harmonize the COVID-19-related sustainability research.

Keywords: COVID-19; Environmental sustainability; Social sustainability; Economic sustainability; Sustainable development

1. Introduction

In the past two decades, sustainability concept has increasingly attracted both scholars and practitioners worldwide. Incorporating three interconnected pillars (Ranjbari et al., 2019), sustainability deals with a balanced integration of social, environmental, and economic performance of human lives within the society, environment, and economy to the benefit of current and future generations (Geissdoerfer et al., 2017). Given the ambiguous and challenging nature of sustainability for organizations, the Triple Bottom Line (TBL) concept was proposed by Elkington (1998) to support and operationalize sustainable development implementation. TBL simultaneously employs and balances the three pillars of sustainability from a microeconomic perspective (Gimenez et al., 2012). To put the sustainability essence into practice, the United Nations (UN) General Assembly launched the 2030 Agenda for Sustainable Development in September 2015 as a shared outline to address the TBL of sustainability. This Agenda introduces 17 Sustainable Development Goals (SDGs) and calls upon all governments and private businesses to support the achievement of the specified SDGs (Van der Waal and Thijssens, 2020).

The novel coronavirus-caused infectious disease 2019 (COVID-19) first emerged in December 2019 in China and spread worldwide in such a way that the World Health Organization (WHO) announced it as a pandemic in March 2020 (WHO, 2020a). As of December 19, 2020, a total number of 74,299,042 confirmed cases of COVID-19, including 1,669,982 deaths in 235 countries, areas, and territories, has been recorded by the WHO (2020b). The crisis's magnitude has marked the COVID-19 pandemic as the most severe health catastrophe of this century (Chakraborty and Maity, 2020).

The COVID-19 crisis has imposed immense pressure on the global economy and business activities with significant adverse financial consequences, increased GDP loss by countries, and raised poverty and hunger across the world (Iwuoha and Jude-Iwuoha, 2020). As a result, the global health crisis caused by this pandemic tremendously slows the international community's progress towards sustainability (Lee et al., 2020). Barbier and Burgess (2020) argued that the adverse impacts of COVID-19 could compromise our ability to achieve 12 out of the 17 UN’s SDGs within the 2030 Agenda for Sustainable Development. Moreover, Leal Filho et al. (2020) identified COVID-19 as a major threat to implementing sustainable development by reducing the

SDGs' priority. Hence, while significant global efforts are being put into controlling this pandemic, sustainability in the post-COVID-19 era should not be neglected (Lambert et al., 2020). As a matter of fact, sustainability and achieving the SDGs are even more critical now than before (Leal Filho et al., 2020).

Although the COVID-19 pandemic has not been around for too long, a massive amount of COVID-19-related research has been conducted due to its significant implications and consequences for society, the environment, and the economy worldwide. The effect of this pandemic on different dimensions of sustainability and sustainable development has been investigated by many sustainability scholars in a wide range of subject areas such as healthcare systems (Osingada and Porta, 2020; Sharma et al., 2020), tourism (Ioannides and Gyimóthy, 2020; Romagosa, 2020), food industry (Fleetwood, 2020), SDGs (Ashford et al., 2020; Paramashanti, 2020), sustainable transition (Bodenheimer and Leidenberger, 2020; Pirlone and Spadaro, 2020), education (Anholon et al., 2020; Tran et al., 2020), social media (AI-Youbi et al., 2020; La et al., 2020), strategic management (Barreiro-Gen et al., 2020; Hamilton, 2020), environmental pollution (Somani et al., 2020), energy (Kanda and Kivimaa, 2020; Kuzemko et al., 2020), climate change (Markard and Rosenbloom, 2020), and waste management (Kulkarni and Anantharama, 2020; Vanapalli et al., 2021).

Most previous research works have focused only on a specific subject area or considered just one dimension of sustainability in the light of the COVID-19 outbreak. Besides, due to the health emergency caused by COVID-19 and the increasingly widespread interest of scholars to respond to the urgent call for action in the context of sustainability within a short period, the literature in this area is very fragmented. Consequently, a comprehensive analysis of the COVID-19 implications for sustainability practices as a whole is lacking in the literature. Therefore, our research pays close attention to sustainability based on the TBL framework within the different subject areas, which have been impacted by the COVID-19 pandemic to provide a well-clarified overview of the COVID-19 effects, challenges, and opportunities for the TBL of sustainability. To the best of the authors' knowledge, no review has systematically addressed COVID-19 implications for integrating social, environmental, and economic pillars of sustainability research area. Hence, putting all sustainability research in the wake of the pandemic together can help governments, authorities, practitioners, and policy-makers to find out where to concentrate their

efforts to alleviate the negative impacts of the pandemic in moving towards sustainability, and also supports researchers to find the gaps, define future research directions, and derive new research interests in the area.

This paper aims to provide an inclusive insight into and a comprehensive overview of the sustainability perspectives, dynamics, and practices in the wake of the COVID-19 pandemic crisis. In this regard, the pandemic's potential effects on economic, social, and environmental pillars of sustainability are analyzed by conducting a systematic literature review to address the three research questions of our study as the following.

RQ1. What is the current status of research on the TBL of sustainability considering COVID-19 implications?

RQ2. How does COVID-19 affect the TBL of sustainability?

RQ3. What are the potential research gaps and future research avenues for sustainable development post-COVID-19?

The remainder of the paper is structured as follows. Section 2 explains the method adopted in this research. Section 3 presents the descriptive and thematic analysis of sustainability and COVID-19 implications and discusses the key findings. Section 4 offers the research gaps and different areas of sustainability disciplines affected by COVID-19, which need to be studied for further research post-COVID-19 in the future. Finally, section 5 summarizes the conclusions drawn from the research conducted for this paper

2. Methodology

To address the research questions and achieve the main aim of the paper, a systematic approach to review the literature adopted from Fink (2019) and Traxler et al. (2020) on the TBL of sustainability perspectives and practices in the context of the COVID-19 pandemic crisis is employed. The process of collecting papers was stopped on August 29, 2020, starting from December 2019. Besides, the sustainability literature before pandemic is also investigated separately in another systematic review process to have an update of the major sustainability challenges before COVID-19. This is done to provide a baseline of sustainability challenges

before COVID-19 to better analyze the effects of COVID-19 on the sustainability and sustainable development roadmap and see how COVID-19 has affected the current challenges. This helps more effectively identify the relevant research gaps and directions for future research post COVID-19. The search protocol and the review's overall process applied in our research to select the eligible papers through a screening process are described in the following subsections.

2.1. Database

Being a significant landscape shock, the COVID-19 pandemic and the consequent urgent call for action against the restrictions imposed by this crisis in various disciplines, a considerable number of COVID-19-related research has been conducted even before the pandemic was announced by the WHO in March 2020. To ensure sufficient coverage of published papers and enrich the reliability of the gathered publications, Web of Science (WoS) and Scopus were utilized as research databases for record identification and collecting the published papers.

The WoS core collection covers all publications indexed in Science Citation Index Expanded (SCIE-EXPANDED), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (AHCI), Conference Proceedings Citation Index- Science (CPCI-S), Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH), and Emerging Sources Citation Index (ESCI) (WoS, 2020). As a source-neutral abstract and citation database, Scopus provides a wide range of scholarly literature across many disciplines, including more than 75 million records, 24,600 active titles with more than 23,500 peer-reviewed journals, and 5,000 publishers (Elsevier, 2020).

2.2. Keywords definition

The initial selection of research and review papers was carried out through applying a structured keyword search. The main keyword of this paper is sustainability, and the COVID-19 pandemic is the context of the research. The combination of the keywords and operators were ("sustainability" OR "sustainable") AND ("COVID-19" OR "pandemic" OR "Coronavirus" OR "SARS-CoV-2"), limited to the article title, keywords, and abstract in WoS and Scopus databases. The "OR" operator means that the search will contain at least one of the keywords. This keywords selection limited the search scope to those research conducted on sustainability subject areas through the COVID-19 pandemic lens.

In addition, to catch the most recent challenges of sustainability and sustainable development before COVID-19, an initial query of ("sustainability" OR "sustainable development") limited to the article title AND ("challenges" OR "gaps") AND NOT ("COVID-19" OR "pandemic" OR "Coronavirus" OR "SARS-CoV-2") limited to the article title, keywords, and abstract was considered for data collection in WoS and Scopus.

2.3. Screening: Inclusion and exclusion criteria

A two-stage delimitation process was considered to select the most relevant articles before and after pandemic.

For the pre-COVID-19 articles, only the most recent review articles published in peer-reviewed journals (in English language) from 2018 to 2020 were included in the analysis. 355 reviews from WoS and 449 reviews from Scopus were collected after the first screening stage. Having removed 259 duplicated articles, a total of 545 reviews were included in the research. In the second screening stage, the content of the papers, which were filtered in the previous stage, was checked by first, reading the title, abstract, and conclusion and second, by reading the entire document to check the relevancy of the paper. The major challenges of sustainability literature before COVID-19 were extracted from the final sample of 38 reviews, which were found to be the most relevant articles after conducting the second stage of screening.

For the post-COVID-19 articles, which were the main target of our research, only scientific reviews and articles published in peer-reviewed journals in English language were considered in the first screening stage. The other document types, such as conference proceedings, book chapters, notes, and letters, were excluded from the database to enrich the study's validity and quality. Besides, due to the emergence of COVID-19 in December 2019, the search's period was limited to studies conducted as of December 2019. A total of 755 articles were excluded from 1436 items in the database during this stage. Afterward, 185 duplicated articles were eliminated, leaving 496 articles to be considered for the second screening stage. In the second screening stage, the content of the papers was checked to see whether there was a sufficient linkage between the TBL of sustainability perspectives, practices, and dynamics and the COVID-19 pandemic implications. Subsequently, 438 items were excluded, and finally, the

sample was composed of 49 articles for our review. Fig. 1 summarizes our search protocol and illustrates the overall process of the review.

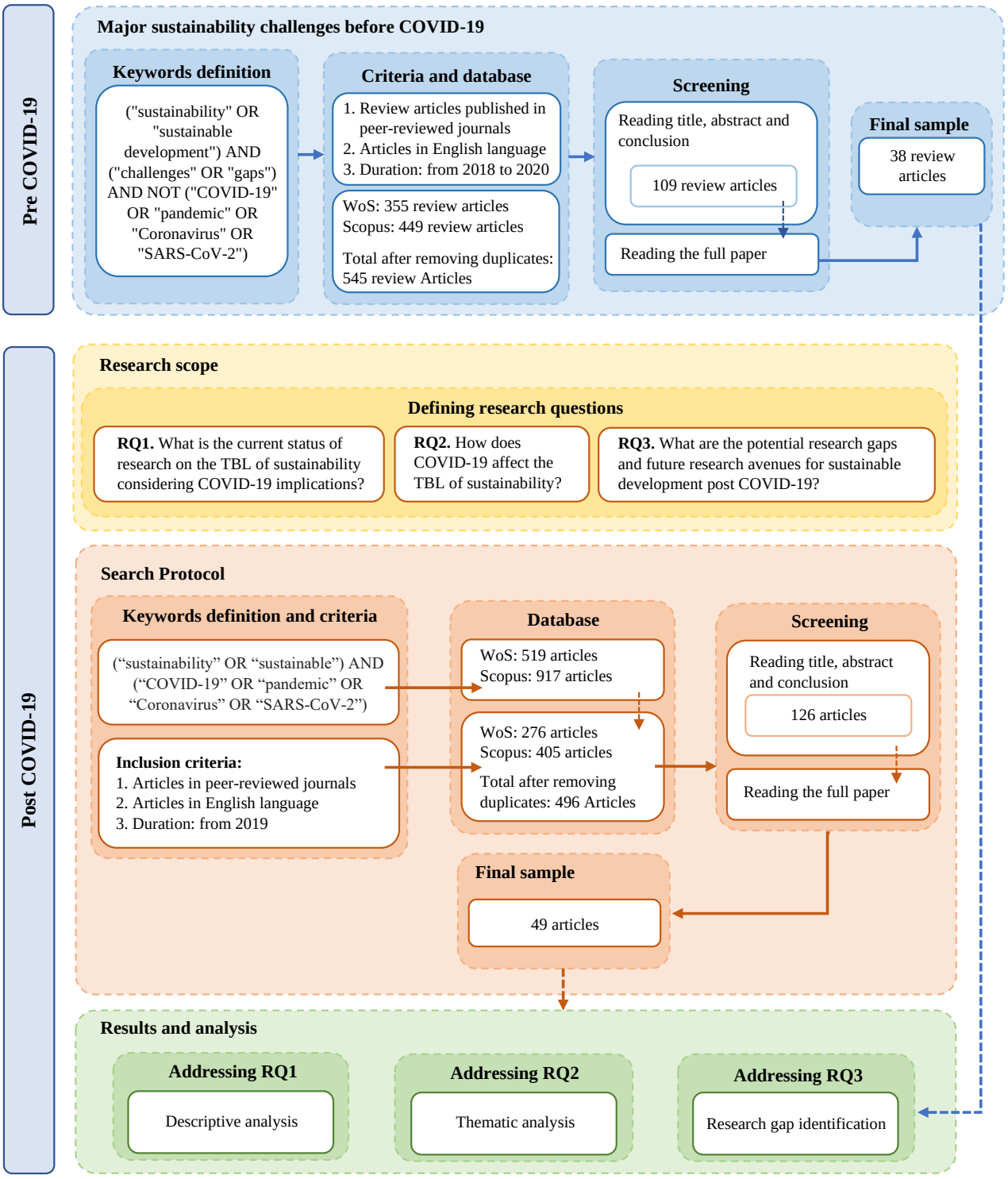

Fig. 1. *Overall search protocol and systematic literature review framework*

3. Results and Discussion

In order to clearly report the results to address the research questions, as a fundamental step in a systematic literature review (Milanesi et al., 2020), the results are analyzed in two sections including before COVID-19 (Sections 3.1) and after COVID-19 (Section 3.2 and Section 3.3) periods. Since the main focus of our research is COVID-19 implications for sustainability and sustainable development, in-depth descriptive and thematic analyses for sustainability research post COVID-19 are presented.

3.1. An overview of the major sustainability challenges before COVID-19

To have a general image of the challenges of sustainability and sustainable development before the COVID-19 pandemic crisis, the major challenges were extracted from the literature as shown in Fig. 2. The integration of education system as an important player of progressing towards sustainability agenda within the sustainable development practices has been highlighted as a significant multidisciplinary challenge in the social sustainability literature (Bascopé et al., 2019; Chen et al., 2020; Grosseck et al., 2019; Hermann and Bossle, 2020; Thürer et al., 2018). The need for convergence of social movements and civil society (El Bilali, 2019a), fostering cross-sectoral collaboration (El Bilali, 2019b), and behavioral change in the urban household consumption pattern (Shittu, 2020) are challenging the sustainability transition. Besides, social entrepreneurship as a path for social change and a driver of sustainable development is facing challenges due to the lack of a clear measurement framework for the different dimensions of sustainability (Bansal et al., 2019). Environmental sustainability roadmap urgently needs to be adapted with the challenges of climate change as one of the biggest environmental problem that human is facing with (Mauree et al., 2019). In this regard, policy-making, planning, and management of forest resources with the possibility of improving carbon capture and helping environment was presented by Nunes et al. (2019) as an important environmental sustainability challenge. In addition, combating the impacts of urban droughts, which have been magnified by climate change, has made serious challenges for policy-makers and city stakeholders towards environmental sustainability and SDGs achievement (Zhang et al., 2019). Public health crisis arising from healthcare pollution is another environmental sustainability concern, which highly needs to be addressed to achieve a sustainable healthcare system (Sherman et al., 2020).

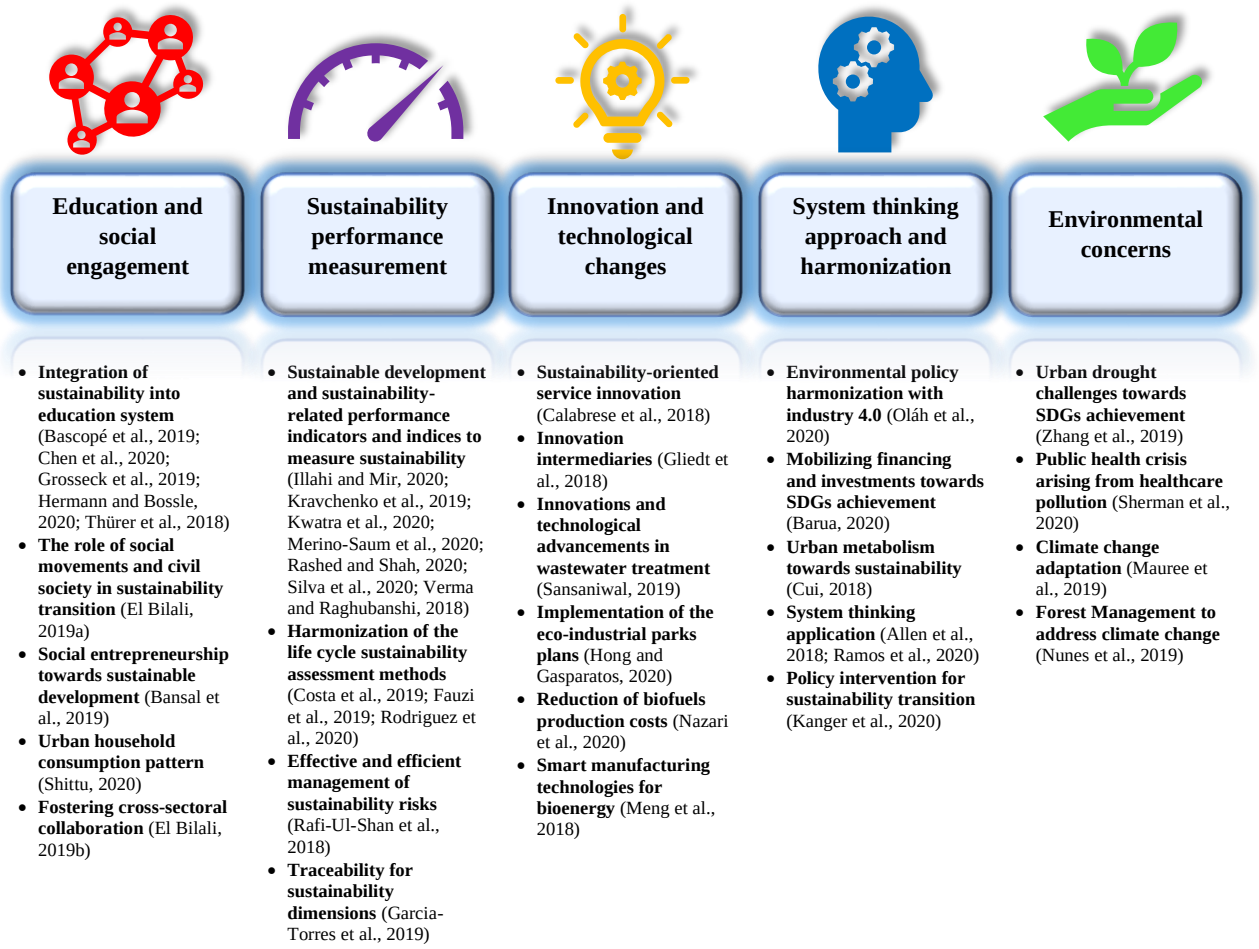

Fig. 2. *Major challenges in the sustainability literature before COVID-19*

Due to the complex and multi-dimensional concept of sustainability, which brings together discourses from different domains, sustainable development policy-makers and practitioners face the challenge of employing system thinking approach to consider sustainability dimensions as a whole (Allen et al., 2018; Ramos et al., 2020). In this regard, some challenges, such as environmental policy harmonization with industry 4.0 to create a sustainable Industry 4.0 (Oláh et al., 2020), mobilizing financing and investments towards SDGs achievement (Barua, 2020), urban metabolism of cities and their contribution towards sustainability (Cui, 2018), and innovative policy intervention for transformative systems change and sustainability transition (Kanger et al., 2020), have been highlighted as challenging approaches to support systems thinking and sustainability literacy.

Innovation is an essential factor for enabling industries and organizations to grasp sustainability transition opportunities and facilitating sustainable development agenda. However, transforming sustainability innovation from initial idea or laboratory scale to production or commercial scale is quite challenging in many areas. Instances include innovations and technological advancements in solar-powered wastewater treatment (Sansaniwal, 2019), smart manufacturing technologies for bioenergy (Meng et al., 2018), innovation intermediaries to accelerate environmental sustainability transitions (Gliedt et al., 2018), reduction of biofuels production costs (Nazari et al., 2020), sustainability-oriented service innovation as a new business model for companies to create value towards sustainability (Calabrese et al., 2018), and disjoint challenges between eco-industrial parks planning and implementation phases due to the lack of non-comprehensive assessment frameworks (Hong and Gasparatos, 2020). Moreover, measuring the progress towards sustainability in different subject areas is still challenging and needs developing specific adequate indicators (Illahi and Mir, 2020; Kravchenko et al., 2019; Kwatra et al., 2020; Merino-Saum et al., 2020; Rashed and Shah, 2020; Silva et al., 2020; Verma and Raghubanshi, 2018). To monitor the sustainability performance, indicators should be designed or customized based on the characteristics of any industry. In particular, harmonization of the life cycle sustainability assessment methods (Costa et al., 2019; Fauzi et al., 2019; Rodriguez et al., 2020), traceability for sustainability dimensions (Garcia-Torres et al., 2019), sustainability assessment of energy production (Turkson et al., 2020), and effective and efficient management of sustainability risks (Rafi-Ul-Shan et al., 2018) need more investigation.

3.2. Sustainability after COVID-19: Descriptive analysis

In the descriptive analysis, a statistical report on the TBL of sustainability perspectives and practices considering the COVID-19 crisis is presented to address the first research question (RQ1: What is the current status of research on the TBL of sustainability considering COVID-19 implications?). This report covers journal publications, distribution of the publications over time, countries which have contributed to the topic, citation ranking of the publications, and methodological approaches and research methods applied in the articles.

3.2.1. Journal publications

The distribution of journal papers within scientific journals in the WoS and Scopus is provided in Fig. 3. The 49 articles were published in 27 journals from different disciplines. As

shown in Fig. 3, 55% of the papers in the sample were published in five journals only. The leading journal to address the TBL of sustainability perspectives in the context of the COVID-19 pandemic crisis is *Sustainability*, with 12 articles out of 49 items, which constitute 25% of our sample. *Science of the Total Environment*, *Sustainability: Science, Practice and Policy*, and *Tourism Geographies*, each with 4 articles, and *Energy Research & Social science* with 3 papers stand in the next positions, respectively.

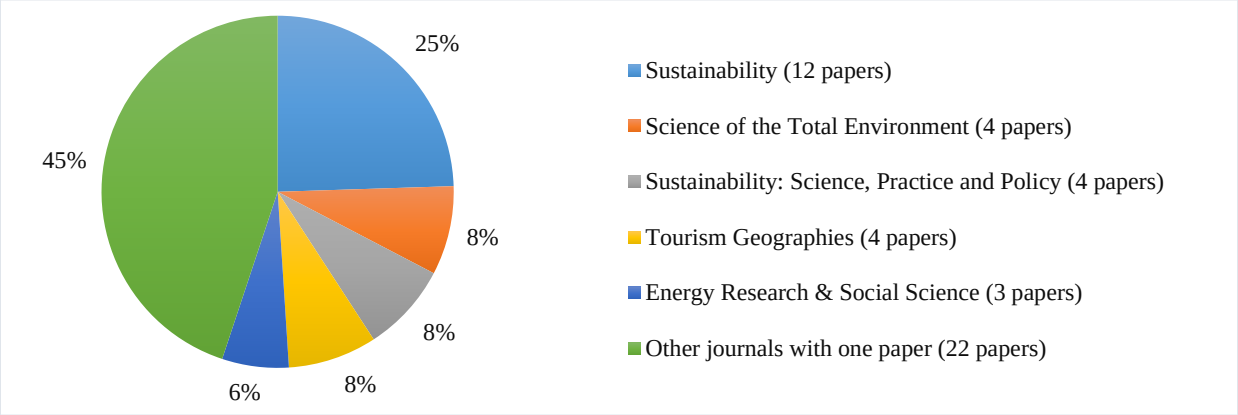

Fig. 3. *Distribution of the sample papers across journals in WoS and Scopus*

3.2.2. Distribution of the publications over time

The search process identified a total of 49 articles on the TBL dimensions of sustainability, taking COVID-19 effects into account, which were published from March 2020 to August 29, 2020, as shown in Fig. 4. Although the inclusion criteria in our search protocol allowed results with a publication date starting from December 2019, the content analysis showed that the first article investigating the sustainability effects of COVID-19 in our sample was published in April 2020. After the announcement of COVID-19 as a pandemic by the WHO on March 11, 2020, as observed in Fig. 4, the number of research conducted on the COVID-19 effects on the economic, social, and environmental sustainability in our sample has increased considerably. It is evident that due to the significant COVID-19 implications for global health and the concerns regarding sustainability for the economy, society, and the environment, academic interest to study the challenges caused by COVID-19 in the subject has rapidly increased. As the search process of our research stopped on August 29, 2020, the lower number of publications in August 2020 is due to the time that WoS and Scopus usually need to find the accepted articles online. Therefore,

some of the papers published in August 2020 may appear in WoS and Scopus databases in the next month(s).

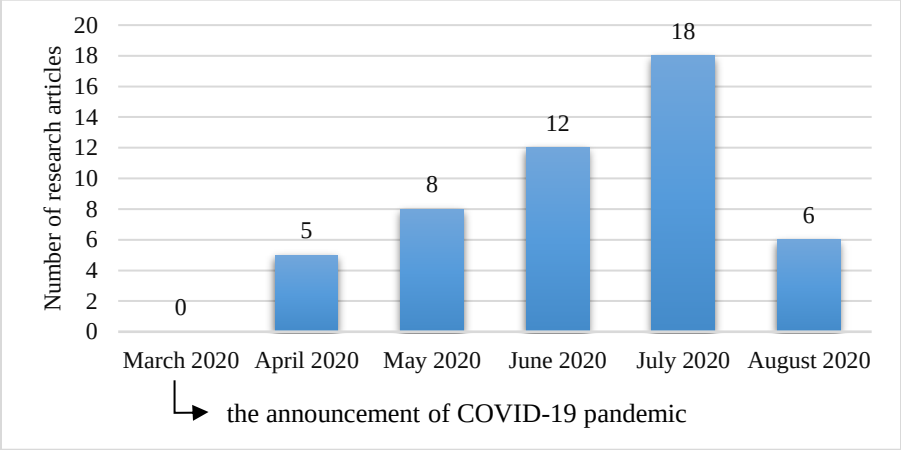

Fig. 4. *Distribution of the publications over time*

3.2.3. Contributing countries

The geographical distribution of the studied articles in our research for the top 10 contributing countries is presented in Fig. 5. Among the countries, the United States has the highest contribution in COVID-19 research, focusing on different sustainability dimensions through 11 research articles indexed in the WoS and Scopus. The second highest contribution comes from the United Kingdom with 8 articles, followed by Italy (5 papers) and Germany and Sweden (each 4 papers). As shown in Fig. 5, most of the countries listed in the top contributing nations to the COVID-19-related research have been dramatically affected by COVID-19, considering confirmed cases and death records. According to the report by the WHO (2020c), the United States is the most affected country by the COVID-19 in the world, with 7,206,769 confirmed cases and 206,558 death records, followed by India and Brazil by October 3, 2020. According to the same report, Spain is the second most infected country by COVID-19 in Europe, with 789,932 confirmed cases and 32,086 death records, followed by France, the United Kingdom, and Italy. The statistics of our sample shows that heavily infected countries by COVID-19 have intended to contribute more than the other countries in the world to the sustainability research, considering COVID-19 implications and future challenges.

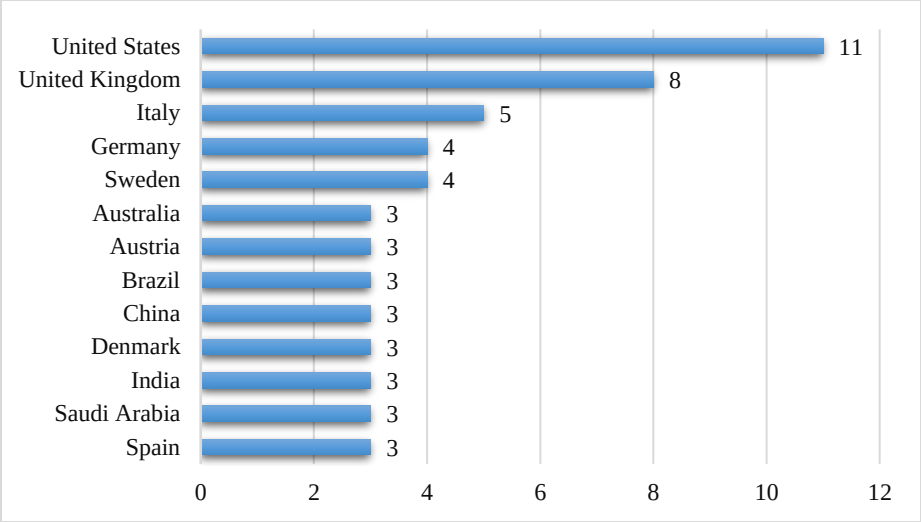

Fig. 5. *Number of publications in the top contributing countries*

3.2.4. Citation ranking

In order to provide a general overview of the influence of our sample papers on the subsequent scientific publications, the list of 10 most cited articles are presented in Table 1. As can be seen from this table, the first ranked article in terms of global citation score, which is written by Galanakis (2020), refers to the food system and has been 117 times cited in other scientific publications. The subject area of 3 out of the 10 listed articles is tourism industry and all of them are published in the journal *Tourism Geographies*. These articles, which are authored by Ioannides and Gyimóthy (2020), Romagosa (2020), and Galvani (2020), are ranked 3rd, 4th and 6th in the citation ranking list, respectively, and are cited 113 times in total. Although citation scores are not a proper measure to evaluate the quality of the articles (Nikulina et al., 2019), the presence of 3 tourism-related articles among the top 6 highly cited articles in the sample can point to the significant effects of COVID-19 on the sustainability of tourism industry that have attracted the attention of researchers. Tourism along with other subject areas which have been impacted by COVID-19 are discussed in the following sections of the paper.

Table 1. *The most influential sample papers*

Author(s) and year	Title of the paper	Citation score	Journal	Publisher
Galanakis (2020)	The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis	117	Foods	MDPI

La et al. (2020)	Policy Response, Social Media and Science Journalism for the Sustainability of the Public Health System Amid the COVID-19 Outbreak: The Vietnam Lessons	90	Sustainability	MDPI
Ioannides and Gyimóthy (2020)	The COVID-19 crisis as an opportunity for escaping the unsustainable global tourism path	46	Tourism Geographies	Taylor and Francis Group
Romagosa (2020)	The COVID-19 crisis: Opportunities for sustainable and proximity tourism	38	Tourism Geographies	Taylor and Francis Group
O'Connor et al. (2020)	Economic Recovery After the COVID-19 Pandemic: Resuming Elective Orthopedic Surgery and Total Joint Arthroplasty	35	The Journal of Arthroplasty	Elsevier
Galvani et al. (2020)	COVID-19 is expanding global consciousness and the sustainability of travel and tourism	29	Tourism Geographies	Taylor and Francis Group
Barbier and Burgess (2020)	Sustainability and development after COVID-19	22	World Development	Elsevier
Ryan et al. (2020)	COVID-19 Community Stabilization and Sustainability Framework: An Integration of the Maslow Hierarchy of Needs and Social Determinants of Health	22	Policy Analysis	Cambridge University Press
Kanda and Kivimaa (2020)	What opportunities could the COVID-19 outbreak offer for sustainability transitions research on electricity and mobility?	21	Energy Research & Social Science	Elsevier
Leal Filho et al. (2020)	COVID-19 and the UN Sustainable Development Goals: Threat to Solidarity or an Opportunity?	21	Sustainability	MDPI

3.2.5. Methodological approaches and research methods

Due to the recentness of the COVID-19 crisis and the lack of adequate and reliable quantitative data in many subject areas of sustainability research, most of the research in our sample was conducted by employing a qualitative approach. As shown in Fig. 6, 43 out of the 49 articles (i.e., 88% of the sample) applied a qualitative approach, while only 3 (i.e., 6% of the sample) used a quantitative approach. Moreover, 3 articles (i.e., 6% of the sample) employed a mix of quantitative and qualitative approaches. In terms of research methods, content analysis, as a qualitative research method, was the most frequently used method in our sample (applied in 39 research articles), followed by survey and case study applied in 4 and 3 research articles, respectively.

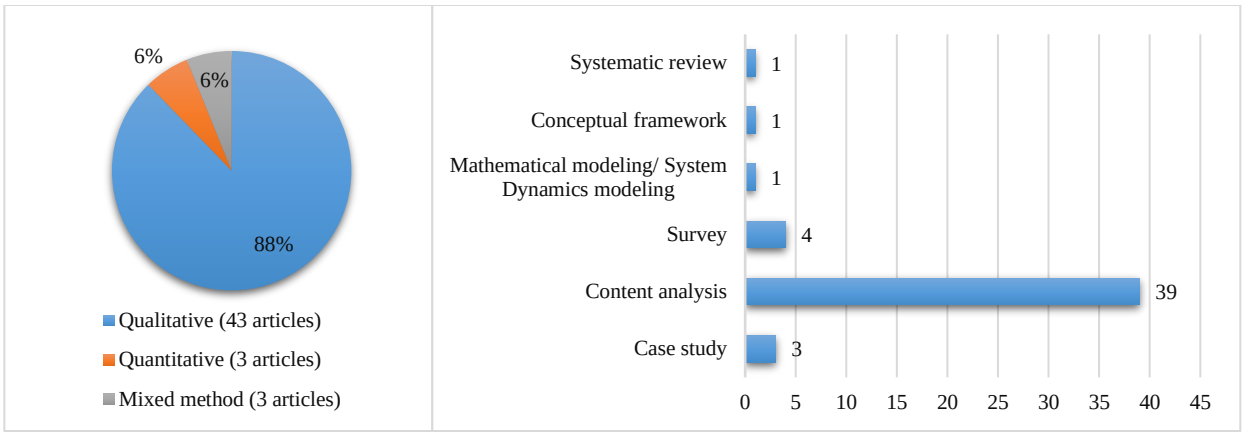

Fig. 6. *Methodological approaches and research methods*

3.3. Sustainability after COVID-19: Thematic analysis

The focus of thematic analysis is on the perspective to study sustainability, the main subject areas, and three main pillars of sustainability, including environmental, social, and economic, in the wake of the COVID-19 outbreak. The proposed analysis addresses both the first and second research questions of our study (RQ1: What is the current status of research on the TBL of sustainability considering COVID-19 implications? RQ2: How does COVID-19 affect the TBL of sustainability?). Fig. 7 demonstrates the distribution of articles within different sustainability dimensions, considering the COVID-19 crisis.

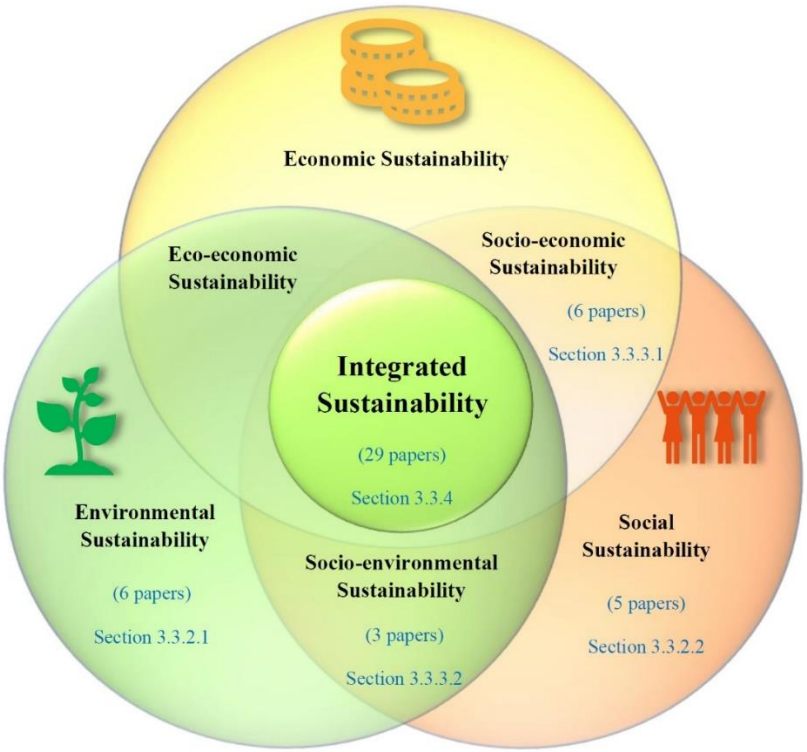

Fig. 7. *Distribution of the publications within the TBL dimensions of sustainability considering COVID-19*

According to Fig. 7, integrated sustainability is the most paid attention sustainability intersection considering the effects of COVID-19 by scholars with the total number of 29 research articles. The environmental sustainability section and socio-economic sustainability intersection come next, each with 6 research articles, followed by social sustainability section and socio-environmental intersection with 5 and 3 articles, respectively. On the contrary, there is no specific research on the economic sustainability section without involving the social and/or environmental pillars and also eco-economic sustainability intersection.

For the rest of the thematic analysis section, the key themes and subject areas studied in terms of sustainability perspectives in the aftermath of the COVID-19 outbreak are presented in Section 3.3.1. Then, the main research conducted on the COVID-19 implications for each pillar of sustainability, including environmental and social (Section 3.3.2), different pairwise intersections of pillars including socio-economic and socio-environmental (Section 3.3.3), and the integration of all three economic, social, and environmental pillars of sustainability, which refers to sustainable development (Section 3.3.4), are discussed.

3.3.1. Subject areas of sustainability amid COVID-19

The main subject areas in the literature within the different sustainability dimensions indicated in Fig. 7, considering the COVID-19 pandemic, are presented in Fig. 8. In terms of the overall number of research articles regardless of the sustainability dimension, as illustrated by Fig. 8, the healthcare industry with 8 research papers, the tourism industry with 6 research papers, the food industry with 5 research papers, and the SDGs and sustainable transition each with 4 research papers are the most frequent subject areas of sustainability research in the wake of COVID-19 pandemic, respectively. Environmental pollutions, the education industry, energy, waste management, and strategic management come next, equally with 4 articles.

As evident from Fig. 8, most of the studied subject areas in the literature belong to the integrated sustainability dimension in the wake of COVID-19 with 29 articles on the nine subject areas. In this regard, the tourism industry is the most frequent subject area, which has been addressed by sustainability researchers to investigate the COVID-19 implications, followed by the food industry and sustainable transition studies. On the contrary, socio-environmental sustainability and social sustainability dimensions have the fewest subject areas, including environmental pollution and healthcare sector, and education and healthcare industries, respectively. Environmental pollutions, waste management, and the airline industry are the main subject areas of environmental pillar of sustainability, while education, information system, SDGs, and social media subject areas come from socio-economic sustainability intersection.

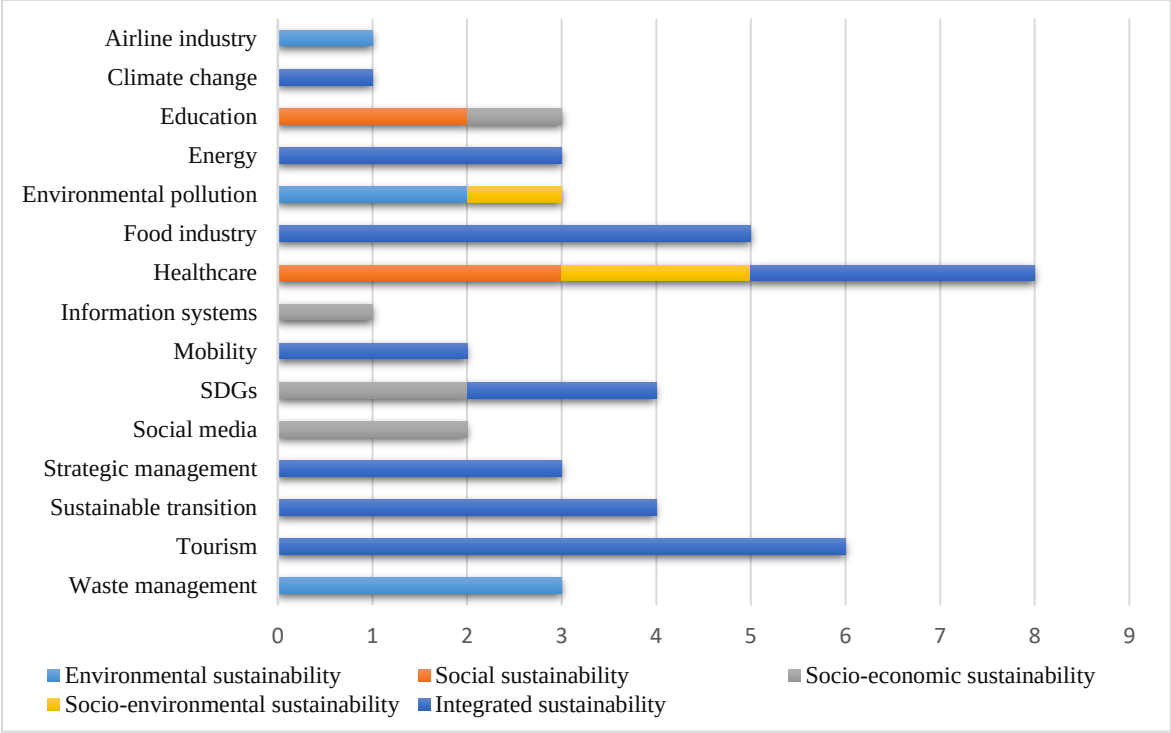

Fig. 8. *Distribution of the publications in terms of subject areas of sustainability amid COVID-19*

3.3.2. Main pillars of sustainability and COVID-19

As illustrated in Fig. 7, only 11 research articles among the 49 sample articles in our research have analyzed the COVID-19 implications for each pillar of sustainability separately, including 6 articles for the environmental pillar and 5 articles for the social pillar. Evidently, the number of research articles that have studied COVID-19 impacts on just one pillar of sustainability is considerably lower than those addressing all the three pillars at the same time. This may correspond with the complex and interconnected nature of the main pillars of sustainability (Ranjbari et al., 2019), which causes them to affect each other within the whole system. Table 2 summarizes these publications in terms of subject area (theme), research focus and objective, the scale of the study, geographical scope, methodological approach, and key results and findings.

The effects of the COVID-19 pandemic on each of the environmental and social pillars of sustainability are presented and discussed in the following sections.

Table 2. *Summary of the research conducted separately on the main pillars of sustainability and COVID-19*

Reference	Sustainability dimension			Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Methodological approach			Method	Findings
	Environment	Social	Economic					Quantitative	Qualitative	Mixed method		
(Somani et al., 2020)	✓			Environmental pollution	Studying the implications of COVID-19 towards a sustainable environment	Macro	India			✓	Case study	Analyzed the COVID-19 environmental implications for air quality, water quality, noise pollution, and emission of GHGs
(Adelodun et al., 2020)	✓			Wastewater management	Studying the potential snowballing transmission of COVID-19 through wastewater in low-income countries	Macro	Low-income countries		✓		Content analysis	Proposed sustainable preventive measures for the low-income countries against the potential outbreak of COVID-19 through wastewater
(Vanapalli et al., 2021)	✓			Waste management	Studying the challenges and strategies for effective plastic waste management during and after COVID-19	NA	NA		✓		Content analysis	Presented the disruption caused by COVID-19 on plastic waste generation and recommended policies to combat the rise in the use and disposal of single-use plastics post-COVID-19
(Kulkarni and Ananthara ma, 2020)	✓			Municipal solid waste management	Reviewing the consequences of the COVID-19 pandemic on municipal solid waste management	Macro	selected developed and developing countries		✓		Content analysis	Identified different types of waste generated during the COVID-19 outbreak that impact the existing municipal solid waste management practices
(Amankwah-Amoah, 2020)	✓			Airline industry	Examining the new challenges imposed by COVID-19 for adopting environmental sustainability policies in the global airline industry	Macro	Global		✓		Content analysis	Indicated that some airlines had to sidestep environmentally-friendly commitments to pass new restrictions in the wake of COVID-19 such as "cost pressures", "survival threat and deprioritizing environmental sustainability initiatives"
(Anholon et al., 2020)		✓		Education	Studying the need to insert sustainability into engineering education after the COVID-19 crisis	Macro	NA		✓		Content analysis	Denoted the importance of academic staff in the field of engineering education during the COVID-19 pandemic to pay attention more to

								sustainable development principles
(Christoffel et al., 2020)	✓	Healthcare	Examining the impact of the COVID-19 infection on vulnerable Brazilian children	Macro	Brazil	✓	Content analysis	Highlighted the critical role of the nursing field in monitoring children and their families in vulnerable social situations to prevent COVID-19 contamination
(Sharma et al., 2020)	✓	Healthcare	Analyzing the consequences of COVID-19 on the society for investments in family planning	Macro	NA	✓	Content analysis	Highlighted the need for support by governments and public-private partnerships for ensuring family planning services considering the newly emerged situation by COVID-19
(Ryan et al., 2020)	✓	Healthcare	Studying the effects of COVID-19 on the Maslow hierarchy of needs and social determinants of health to ensure community stabilization and sustainability	Macro	NA	✓	Content analysis	Proposed a sustainability framework to ensure community stabilization considering the hierarchy of needs and social determinants of health through providing baseline requirements, regulations and recommendations, and triggers
(Iyengar, 2020)	✓	Education	Studying the importance of education initiative in the post-COVID-19 recovery	Macro	NA	✓	Content analysis	Proposed three policies for education systems post-COVID-19, including using technology to overcome in learning, community-driven support systems, and focus on SDG 4.7
(Freire-González and Font Vivanco, 2020)	✓	Environmental pollution	Studying the environmental effects of the COVID-19 pandemic	Macro	NA	✓	Content analysis	Outlined the environmental rebound effect of COVID-19, referring to increase environmental burdens rather than decrease them

3.3.2.1. Environmental sustainability and COVID-19

As a major dimension of sustainability, environmental sustainability deals with managing limited resources to reduce the processing resources and minimize the waste generated to protect the environment and natural resources (Roy et al., 2020). Various environmental implications of the COVID-19 outbreak have created some challenges and opportunities for environmental

sustainability from different perspectives. Freire-González and Font Vivanco (2020) outlined the high risk of the environmental rebound effect of COVID-19, referring to the increase of environmental burdens rather than their decrease. As a response to the environmental rebound effect, they provided some recommendations for governments to put extra measures such as environmental taxation or limiting the use of resources, to support environmental sustainability in the post-COVID-19 era. Moreover, as a negative consequence of the COVID-19 restrictions for the environment, Amankwah-Amoah (2020) demonstrated that some airlines had to skip their commitment to environment-friendly and eco-friendly policies to survive and pass the economic pressure caused by COVID-19. In line with previous studies, Somani et al. (2020), in a case study in the Indian context, identified the positive environmental effects of COVID-19 on the ambient air quality, surface water quality, noise pollution, and greenhouse gas emission, while the negative impacts on the biomedical waste generation and mixed effect of carbon dioxide emission. However, the environmental impacts of the pandemic resulting in the changes to the access to clean and renewable energies, addressed in UN's SDG 7, and also wildlife below water and ecosystems and biodiversity on land, addressed by UN's SDGs 14 and 15, are other aspects of environmental sustainability that calls for more attention.

As reported by SMART WASTE (2020), among the environmental impacts of the COVID-19 pandemic, municipal waste management practices seem to be faced with more serious challenges. The role of local and regional authorities to adopt appropriate policies in municipal waste management, considering the current implications imposed by COVID-19, is essential in terms of managing waste generation, waste handling and separation, waste transportation, waste disposal, and landfilling. Besides, according to the research conducted by Mol and Caldas (2020), COVID-19 can spread through solid waste and inadequate waste transport and disposal, which can pose a risk to workers and environmental sustainability. Kulkarni and Anantharama (2020) proposed three policies for sustainable municipal solid waste management in the aftermath of the COVID-19 outbreak, including using decentralized waste management for waste collection and recycling, creating temporary waste storage and reduction site, and using thermal treatment with an energy recovery facility as a solution for processing a large amount of waste. The changes in consumption patterns caused by COVID-19, such as using personal protective equipment and increased demand for plastic-packaged food, have increased the complexity of

plastic waste management (Vanapalli et al., 2021). As a solution, applying circular technologies such as feedstock recycling, more investment in infrastructure, and using sealed bags to enhance the safety of contaminated plastic wastes disposal proposed by Vanapalli et al. (2021) are priorities in sustainable waste management during pandemic crisis. Another concern regarding the COVID-19 outbreak, especially in low-income countries that mainly rely on the surface and groundwater resources for water consumption, is the potential of community spread of COVID-19 through wastewater (Adelodun et al., 2020). Decentralization of wastewater treatment facilities, community-wide monitoring and testing of Coronavirus ribonucleic acid in wastewater, improved sanitation and water quality, development and use of the point-of-use device for virus decontamination, and policy intervention were suggested by Adelodun et al. (2020) as sustainable preventive measures for low-income countries against the potential outbreak of COVID-19 through wastewater. In this regard, monitoring COVID-19, as a tracer in wastewater, in order to single out the infected areas has also been highlighted and a feasibility assessment of a surveillance system is being conducted in Europe by the European Commission (EU, 2020).

3.3.2.2. Social sustainability and COVID-19

Social sustainability mainly deals with the supervision of social capital and human being by integrating human and civil rights, health and safety issues, social responsibility, and community (Cooper et al., 2018; Munny et al., 2019). The COVID-19 pandemic, as a global health emergency, has highly affected social sustainability by jeopardizing the life quality, human well-being, healthy and safe lives. Health and human well-being and education, basic social needs to achieve social sustainability, have been paid more attention than other social issues by sustainability researchers considering COVID-19 crisis effects. Based on a reflective study in Brazil, Christoffel et al. (2020) outlined the challenges of maternal, neonatal, and child health during COVID-19, especially for women who live in vulnerable situations, and called for public policy support and assistance. In line with SDG 3 for ensuring good health and well-being, the role of nursing professions, in particular, pediatric nursing for monitoring children and their families in vulnerable social situations is vital to prevent COVID-19 contamination by promoting prevention measures and detecting cases of COVID-19 (Christoffel et al., 2020). Therefore, it could be inferred that the focus among the social needs should be on the health and sanitation

efforts against the COVID-19 pandemic, putting older people, children, and pregnant women in vulnerable situations in priority towards social sustainability and its associated SDGs achievement. Due to the cloistering of individuals, couples, and families caused by the COVID-19 pandemic, ensuring rights-based family planning services, as a fundamental human right, is essential towards social sustainability and achieving the SDGs within the 2030 Agenda for Sustainable Development (Sharma et al., 2020). Community-based distribution, domestic investment in the health system, and collaboration with individual private health care providers were proposed by Sharma et al. (2020) to support the family planning service provision during the COVID-19 outbreak. Ryan et al. (2020) proposed a sustainability framework to ensure community stabilization considering the hierarchy of needs and social determinants of health through providing baseline requirements, regulations, and recommendations, triggers, and implementation. The authorities and decision-makers involved in the COVID-19 crisis management need to use a well-considered sustainable framework to balance lockdown and restrictive regulations and social needs to manage the crisis more sustainably.

SDG 4, referring to quality education as a fundamental enabler of social sustainability within the 2030 Agenda for Sustainable Development, aims to provide free, equitable, and quality primary and secondary education for all girls and boys worldwide by 2030 (General Assemly, 2015). Before the COVID-19 pandemic crisis, according to the report by the UN (2020a), 617 million youth worldwide lack basic mathematics and literacy skills, and more than 200 million children would be out of school. Based on this report, minimum proficiency standards in reading and mathematics are not met by more than half of children all around the world. COVID-19 lockdowns and closures have disrupted education systems worldwide by imposing some limitations and restrictions. Keeping social distancing and emerging new approaches to education and learning enabled by digitalization and online learning methods amid the COVID-19 outbreak has created new challenges to the education systems and the associated policy-makers worldwide. Therefore, more attention to sustainable development principles and inserting sustainability concepts into the education system structure in the wake of the COVID-19 crisis are urgently required (Anholon et al., 2020). Iyengar (2020), in response to the COVID-19 implications for education systems, proposed three policies, including using technology to overcome the learning difficulties caused by COVID-19, community-driven support systems,

and more investment in SDG 4, considering quality education to support sustainable development.

3.3.3. Sustainability pillars pairwise intersections and COVID-19

As stated in the previous section and shown in Fig. 7, due to the interconnected nature of the sustainability pillars, in most of our sample articles (38 out of 49), it is mentioned that the COVID-19 outbreak has affected two or even all three sustainability pillars. These intersections represent the common area between multiple pillars, which meet the requirement of those areas simultaneously. Among the three sustainability pairwise intersections, socio-economic sustainability with 6 research articles is the most frequently addressed intersection in the literature, followed by socio-environmental sustainability being the focus of 3 research articles (see Fig. 7). There are no research articles focusing on the eco-economic sustainability intersection. Table 3 summarizes the research conducted on the confluence of sustainability pillars, which have been affected by COVID-19, providing subject area, research focus and objective, the scale of the study, geographical scope, methodological approaches, and key results and findings.

COVID-19 implications for the pairwise intersections of sustainability pillars are provided and discussed in the following sections.

Table 3. *Summary of the research conducted on the sustainability pillars pairwise intersections and COVID-19*

Reference	Sustainability dimension			Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Methodological approach			Method	Findings
	Environment	Social	Economic					Quantitative	Qualitative	Mixed method		
(Pan and Zhang, 2020)		✓	✓	Information systems	Studying opportunities for responsible information systems research from fighting the COVID-19 pandemic to tackling SDGs	Macro	NA		✓		Content analysis	Identified six themes including 'expanding digital surveillance', 'tackling the infodemic', 'orchestrating data ecosystems', 'adapting information behaviors',

										'developing the digital workplace', and 'maintaining social distancing' to conduct responsible IS research to tackling sustainable development after COVID-19
(Yu et al., 2020)	✓	✓		Pharmaceutical supply chain	Studying the potentials of pharmaceutical supply chains to scale up the sustainability for the COVID-19 pandemic crisis	NA	NA	✓		Content analysis	Identified five urgent priority areas for pharmaceutical supply chains during COVID-19 regarding decision-making, optimal supply chain planning, game-theoretic analysis, life cycle sustainability assessment, and drug allocation strategies
(Paramashanti, 2020)		✓	✓	SDGs	Considering the challenges for Indonesia Zero Hunger Agenda in the context of the COVID-19 pandemic	Macro	Indonesia	✓		Content analysis	The COVID-19 pandemic could reverse Indonesia's progress towards SDG2 (zero hunger) from the 17 SDGs within the 2030 Agenda for Sustainable Development
(Chiang et al., 2020)	✓	✓		Healthcare	Studying the safety and practicality of elastomeric respirators from COVID-19	Micro	NA	✓		Content analysis	Highlighted the advantages of elastomeric face masks as a sustainable alternative over reusing disposable N-95 masks
(Pulimeno et al., 2020)	✓	✓		Air quality	Studying indoor air quality at school considering restrictions imposed by	Macro	Italy	✓		Content analysis	Presented recommendation in terms of indoor air quality at school after the COVID-19 crisis

				COVID-19 and students' performance							
(La et al., 2020)	✓	✓	Social media	Studying the policy response, social media, and science journalism amid the COVID-19 crisis in Vietnam	Macro	Vietnam		✓		Content analysis	Highlighted the importance of timely communication from the government and the media as a reliable source of information for society as a response to the public health crisis
(Tran et al., 2020)	✓	✓	Education	Studying the effects of COVID-19 on teaching and learning activities	Meso	Vietnam	✓			Survey	Presented the COVID-19 implications for students' learning habits with different socioeconomic statuses in Vietnam, which can be used by the local government to increase the sustainability of the education system towards SDG4
(AI-Youbi et al., 2020)	✓	✓	Social media	Strategy developing for social media awareness in the COVID-19 pandemic crisis towards a sustainable higher education	Micro	Saudi Arabia			✓	Survey	Presented a methodological approach to leverage social media focusing on official Twitter accounts in pandemic crisis for minimizing the negative impact of COVID-19 on education's sustainability

(Ashford et al., 2020)	✓	✓	SDGs	Studying inequality towards sustainability in the wake of COVID-19	Macro	NA	✓	Content analysis	Introduced the main interventions and strategies that should be considered after the COVID-19 crisis to achieve SDG10 (reduce inequality) towards sustainability

3.3.3.1. Socio-economic sustainability and COVID-19

The socio-economic impacts of the COVID-19 crisis on the global community have disrupted the path towards sustainability and achieving SDGs to implement sustainable development. According to the report by the UN (2020b) regarding hunger, the world is not on track to achieve SDG 2, which aims to end hunger and ensure access by all people, especially the poor people and those who live in vulnerable situations by 2030. Based on this report, nearly 690 million people are hungry, which constitute 8.9% of the world population. The serious pressure caused by the COVID-19 pandemic on the global economy has even worsened the situation towards achieving SDG 2. Paramashanti (2020) outlined the COVID-19 crisis as a shock for Indonesia's progress towards SDG 2 by affecting hunger, malnutrition, and food insecurity, and highlighted the importance of paying attention to the food and agriculture industry and social protection as well to prevent another humanitarian catastrophe, even though saving lives against COVID-19 is in priority. Moreover, the COVID-19 crisis has led to many social and economic inequalities, such as income, health, education, and safety inequalities for people worldwide. These emerging inequalities significantly threaten socio-economic sustainability and the achievement of SDG 10 within the 2030 Agenda for Sustainable Development, which aims to reduce inequality. In order to advance progress towards SDG 10 to reduce inequality, Ashford et al. (2020) proposed some policies to address the inequality issues amplified by the COVID-19 pandemic consisting of transferring income and wealth without increasing the deficit, focusing on workforce stabilization and safety, allocating government incentive and subsidies to support healthcare, food, and basic needs, and using debt suspension mechanisms for emerging and developing economies. Tran et al. (2020) identified the important role of students' perception of the necessity of self-learning, school type, and also grade level on their learning habits during the school suspension period caused by COVID-19, considering their different socioeconomic

552 statuses, through conducting a survey in Vietnam. The local governments need to reduce
553 inequality in education systems considering newly emerged limitations caused by COVID-19 to
554 make more sustainable education systems towards SDG 4, aiming to ensure quality education.

555 During a crisis, the policy response of governments and communications with social media and
556 the journalism community to control the crisis and its consequences are essential. For instance, in
557 the case of the COVID-19 crisis, the huge infodemic (i.e., the rapid and far-reaching spread of
558 both accurate and inaccurate information about an epidemic) and misinformation of COVID-19
559 news could cause panic within the society and threaten the socio-economic situation in many
560 sectors, such as downward trends in the stock markets and reduction of tourism activities. Timely
561 communications from the governments, authorities, and mainstream media, are reliable sources
562 of information for societies to avoid confusion and insecurity for the public and influence public
563 perception and build trust. These are collectively critical in combating COVID-19 spread (La et
564 al., 2020). Consistent with previous research, Pan and Zhang (2020) outlined the importance of
565 digital surveillance and data ecosystems orchestrating to help process and combine reliable data
566 and tackle the infodemic of COVID-19, which poses a serious challenge to sustainable public
567 health. Moreover, AI-Youbi et al. (2020) presented a framework to leverage a transparent
568 strategy for social media awareness focusing on official Twitter accounts for minimizing the
569 negative socio-economic impacts of COVID-19 on education's sustainability and support
570 strategic decision-making in social media plan deployment to deal with the crisis.

571 #### 3.3.3.2. Socio-environmental sustainability and COVID-19

572 As shown in **Fig. 7**, the socio-environmental sustainability intersection includes 3 research
573 articles focusing on the healthcare industry and environmental pollution topics. The healthcare
574 industry is an important subject area, which can significantly affect the social and environmental
575 dimensions of human lives towards sustainability. COVID-19 has imposed immense pressure on
576 the healthcare systems, not only to deal with COVID-19 confirmed cases but also for the
577 provision of medical services and care for patients with other diseases that require
578 hospitalization. In such a situation, healthcare systems need to manage their resources and
579 capacities effectively for increasing the sustainability of medical services and the healthcare
580 system, on the whole, saving human lives. In this regard, Yu et al. (2020) identified five urgent
581 priority areas for pharmaceutical supply chains during COVID-19 regarding decision-making,

582 optimal supply chain planning, game-theoretic analysis, life-cycle sustainability assessment, and
583 drug allocation strategies to help the pharmaceutical industry scale up sustainably for the
584 COVID-19 crisis. Due to the shortage of personal protective equipment against COVID-19,
585 Chiang et al. (2020) outlined the advantages of elastomeric face masks as a safer and sustainable
586 alternative over reusing disposable N-95 masks during the COVID-19 outbreak. This can lead to
587 enhanced socio-environmental sustainability by saving lives and reducing material and resource
588 use and disposal because, as Chiang et al. (2020) claim, a single elastomeric respirator can
589 replace hundreds to thousands of new disposable N-95 masks, which significantly benefits the
590 environment and society.

591 The health and also learning efficiency of 64 million students and 4.5 million teachers across
592 Europe has been affected by the issue of indoor air quality of the school classrooms, which is
593 still a neglected topic impacted by ventilation, temperature, and humidity rate (Pulimeno et al.,
594 2020). Therefore, efforts to ensure a healthy microclimate in schools seem to be fundamental to
595 achieve SDG 3, aiming to ensure good health and well-being, and SDG 4 to increase the quality
596 education towards sustainable development. Due to COVID-19 restrictions and the high need for
597 hygiene, the issue of indoor air quality has become more relevant. Regarding the indoor air
598 quality issue at schools after COVID-19, Pulimeno et al. (2020) highlighted the importance of
599 installing air decontamination filters in schools, ventilating classrooms before the beginning of
600 the lessons during the pandemic, and installing thermostats in classrooms to monitor the
601 temperature and humidity to avoid overheating or dry air, which decreases indoor air quality.

602 ### 3.3.4. Integrated sustainability and COVID-19

603 Integrated sustainability brings together environmental, social, and economic responsibilities
604 (Gimenez et al., 2012) to attain a proper balance between the objectives of these dimensions at
605 different levels (Janjua et al., 2020). As shown in Fig. 7, among the 49 sample articles of our
606 study, 29 research articles have addressed all three sustainability dimensions in the wake of the
607 COVID-19 pandemic crisis. Table 4 presents a summary of these publications in terms of the
608 subject area, research focus and objective, the scale of the study, geographical scope,
609 methodological approaches, and key results and findings.

610 ***Table 4.*** *Summary of the research conducted on integrated sustainability and COVID-19*

Reference	Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Methodological approach			Method	Findings
					Quantitative	Qualitative	Mixed method		
(Barbier and Burgess, 2020)	Energy	Identifying affordable progress policies towards several SDGs together considering the COVID-19 implications	Macro	Developing countries		✓		Content analysis	Presented three policies to achieve several SDGs together considering the COVID-19 implication, including: - Fossil fuel subsidy swap to fund clean energy investments - Reallocating irrigation subsidies to improve water supply - Tropical carbon tax
(Sovacool et al., 2020)	Energy	Providing insights on the COVID-19 effects on the supply, demand, and governance of energy and "future low-carbon transitions" and social justice	Macro	NA		✓		Content analysis	Provided some recommendation for policy-makers in terms of energy and climate planning considering the opportunity to transform social practices
(Rowan and Galanakis, 2020)	Agri-food industry	Unlocking challenges and opportunities presented by the COVID-19 pandemic for cross-cutting disruption in agri-food and green deal innovations	Macro	64 selected European startups and SMEs and 43 Irish disruptive technology projects		✓		Case study	Highlighted trends in the innovation ecosystem and potential technology, product, and business service disruptors in the agri-food industry to support transitioning beyond COVID-19
(Markard and Rosenbloom, 2020)	Climate change	Studying the COVID-19 effects on climate change	Macro	NA		✓		Content analysis	Proposed to use the disruptive force of the COVID-19 pandemic to support the transition to "more sustainable" and "low-carbon systems"
(Kanda and Kivimaa, 2020)	Electricity and mobility	Identifying the sustainability transitions opportunities in the electricity and mobility sectors after COVID-19	Meso	Finland and Sweden		✓		Content analysis	The long-term implications of COVID-19 lead more changes towards "digitalization of work" and reducing "mobility needs" and overall "fossil-energy consumption"

(Kuzemko et al., 2020)	Energy	Investigating the implications of COVID-19 for the politics of sustainable energy transitions	Macro	Emphasis on the OECD countries		✓	Content analysis	Identified the effects of COVID-19 on sustainable and fossil sources of energy and how social and economic support can shape "energy demand, the carbon-intensity of the energy system, and the speed of transitions" in a sustainable manner
(Zhu and Krikke, 2020)	Food supply chain	Studying how to manage a sustainable perishable food supply chain considering the COVID-19 restrictions	Macro	NA	✓		Mathematical modeling/ system dynamics modeling	Tested different scenarios of product shortages using a system dynamics simulation and identified four dominant loops that facilitate the generation of endogenous demand to manage a sustainable perishable food supply chain after the COVID-19 crisis
(Galanakis, 2020)	Food Systems	Studying the COVID-19 implications for food systems	Macro	NA		✓	Content analysis	Denoted the need for a sustainable food chain to reduce the frequency of relevant food and health crises in the future and avoiding "business as usual" practices
(Barcaccia et al., 2020)	Agri-food industry	Analyzing the impacts of the COVID-19 pandemic on the Italian agri-food sector	Macro	Italy		✓	Content analysis	Highlighted the role of research networks for an "efficient socio-economic and territorial restart", and a faster transition to sustainability in the frame of a "circular bio-economy" management
(Wells et al., 2020)	Sustainability transition	Assessing future sustainability in the age of COVID-19 following a socio-technical transitions perspective	NA	NA		✓	Content analysis	Analyzed four scenarios for a post-COVID-19 socio-economic future, including business, as usual, managed transition, chaotic transition, and managed degrowth
(Pierantoni et al., 2020)	Sustainability transition	Examining the COVID-19 opportunities for reorganizing and sustainable transition of human living environments	Micro	NA		✓	Content analysis	Examined how COVID-19 has spread in the air and different urban contexts and provided some recommendations in terms of design and space for the future resilient cities and urban areas
(Pirlone and Spadaro, 2020)	Mobility	Adapting to the health emergency caused by COVID-19 towards sustainable	Micro	Italy	✓		Survey	Promoted the sustainable mobility practice for students when traveling between home and university as a solution to return to normality after

		university mobility for students					COVID-19
(Obrenovic et al., 2020)	Strategic management	Studying main factors influencing enterprise operational sustainability in the wake of the COVID-19 crisis implications	Macro	NA	✓	Conceptual framework	Conceptualized enterprise effectiveness and sustainability model as an innovative response to COVID-19 for enterprises, which ensures survival during the COVID-19 crisis
(Cooper and Alderman, 2020)	Sport tourism	Studying the COVID-19 effects on the sport tourism economy	Macro	US	✓	Content analysis	Analyzed the economic, socio-cultural, and environmental impacts of sport tourism and identified COVID-19 as an opportunity to make a more sustainable sports tourism economy
(Galvani et al., 2020)	Travel and tourism	Studying the impact of COVID-19 on the expanding global consciousness and the sustainability of travel and tourism	Macro	NA	✓	Content analysis	Highlighted the role of COVID-19 in shifting human beliefs, desires, knowledge, and experiences towards positive directions and sustainable tourism
(Rydzewski, 2020)	Health and security	Studying the hierarchy of needs within social, economic, and environmental pillars of sustainability amid the COVID-19 crisis	Macro	UK	✓	Content analysis	Denoted that in instability caused by COVID-19, social pillar dominates and pushes the environment and economy back with the environment being less important than the economy
(Goffman, 2020)	Sustainability transition	Studying the relationship between glocalization and sustainable future after COVID-19	NA	NA	✓	Content analysis	Highlighted the significant role of innovation and local leadership within the context of glocalization to overcome the COVID-19 challenges and make future more sustainable
(Osingada and Porta, 2020)	Healthcare	Studying the challenges of nursing in the age of COVID-19 towards the achievement of the SDGs	Macro	NA	✓	Systematic review	Highlighted the important role of nursing to contribute to micro and macro-level efforts toward achieving the SDGs in the post-COVID-19 era
(Bodenheimer and Leidenberger, 2020)	Sustainability transition	Seeking sustainability transitions opportunities in the	Macro	Western Europe	✓	Content analysis	Showed that continuing unsustainable behavior could lead to more crises during the pandemic and proposed some

		wake of COVID-19						post-COVID-19 communication strategies
(O'Connor et al., 2020)	Healthcare	Proposing economic recovery for healthcare systems after the COVID-19 pandemic	Macro	US	✓		Content analysis	Highlighted the need to plan the sustainable resumption of elective procedures putting the safety of patients and surgical staff in priority within the healthcare systems to reduce expenses and survive economically
(Fleetwood, 2020)	Food industry	Studying the interrelationship between social justice, food loss, and the SDGs during the COVID-19 crisis	Macro	NA	✓		Content analysis	Highlighted the impact of the COVID-19 implications on the commitment to social justice and the achievement of SDGs focusing on food loss
(Barreiro-Gen et al., 2020)	Organization policy	Studying the effects of COVID-19 on the organizations' sustainability priorities	Macro	Global		✓	Survey	Denoted that the main sustainability priority for organizations is on the social pillar in the wake of the COVID-19 outbreak
(Sakamoto et al., 2020)	Vulnerability	Investigating Bangladesh's vulnerabilities concerning the COVID-19 implications	Macro	Bangladesh	✓		Content analysis	Demonstrated that a considerable part of Bangladesh's people would not be able to tolerate the current situation
(Leal Filho et al., 2020)	SDGs	Studying the impact of the COVID-19 pandemic on the achievement of the SDGs	Macro	NA	✓		Content analysis	Showed that strong focus on fighting the COVID-19 outbreak is disrupting other disease prevention programs
(Hamilton, 2020)	Strategic marketing	Studying business sustainability during the COVID-19 pandemic in the digital marketing industry	Meso	Australia	✓		Case study	Analyzed the strategic change matrix to adjust the business considering restrictions imposed by COVID-19 on the traditional client as an enabler of sustainable competitive business position
(Ioannides and Gyimóthy, 2020)	Tourism industry	Studying COVID-19 opportunities for the sustainable tourism industry	Macro	NA	✓		Content analysis	Highlighted COVID-19 opportunities for public and private sectors to rethink and redesign towards a greener and more sustainable tourism

(Romagosa, 2020)	Tourism industry	Investigating the COVID-19 opportunities for sustainable and proximity tourism	Macro	NA	✓	Content analysis	Highlighted the importance of the commitment of the companies involved in the tourism industry to the principles of sustainable tourism for being able to well position post-COVID-19
(Higgins-Desbiolles, 2020)	Tourism industry	Studying the challenges of sustainable tourism in the wake of the COVID-19 outbreak	Macro	NA	✓	Content analysis	Analyzed different opportunities and threats regarding the future of tourism post-COVID-19 and highlighted the task of the members of the tourism academy to contribute to the sustainable tourism post-COVID-19 not as combatants but as scholars
(Weed, 2020)	Sport tourism	Analyzing the interconnections between sport and tourism in response to the COVID-19 crisis	Macro	NA	✓	Content analysis	The interface of sport and tourism considering the COVID-19 crisis were discussed under two main concepts of sports fixtures and events and activity, movement and travel to recommend policies for well-being, physical and mental health, green space, and sustainable travel

As can be seen from Table 4, a wide variety of subject areas, including tourism and travel, food and agriculture, healthcare, strategic management, and organizational policy, SDGs within the 2030 Agenda for Sustainable Development by the UN, climate change, energy and mobility, and sustainability transition opportunities caused by COVID-19, have been investigated in details in terms of the implications of the COVID-19 pandemic crisis on their path towards sustainability.

The tourism industry has been dramatically affected due to the pandemic restrictions on the traveling of people worldwide. Stay-at-home orders by official authorities and partial lockdown by many countries during the COVID-19 crisis have created different opportunities and threats regarding the future of sustainable tourism. Cooper and Alderman (2020) considered COVID-19 as an opportunity to make the sport tourism more sustainable from economic, socio-cultural, and environmental points of view. Galvani et al. (2020) analyzed the COVID-19 effects on the knowledge and experience of people and their beliefs to expand the global consciousness

in terms of positive movements towards a sustainable travel and tourism industry. The importance of rethinking and restructuring strategies for greener and more sustainable tourism after COVID-19 was highlighted by Ioannides and Gyimóthy (2020) for public and private sectors involved in the tourism industry. Romagosa (2020) proposed the commitment to the principles of sustainable tourism as a solution for tourism companies to survive in the uncertain future after the COVID-19 era, and Higgins-Desbiolles (2020) identified the COVID-19 pandemic even as a "game-changer" for the tourism industry and called the tourism academy members to support and contribute to the sustainable tourism after COVID-19 not as competitors, but as scholars.

The outbreak of the COVID-19 pandemic has affected the stability of food industry supply chains globally. Galanakis (2020) indicated the need for the food industry to avoid a "business as usual" strategy post-COVID-19 and to follow sustainable food system principles to ensure food safety and security with less food waste. Managing the perishable food supply chain during the COVID-19 crisis has been challenging due to the short lifetime of the food products, demand uncertainty, and product shortage caused by customers who possibly buy a larger amount of food in the wake of the COVID-19 lockdowns and mobility restrictions (Zhu and Krikke, 2020). According to the simulation model for testing different scenarios of product shortages during the COVID-19 outbreak built by Zhu and Krikke (2020), applying a loosely coupled policy for decision-making and stopping the information sharing that causes endogenous demand are the best policies for managing a sustainable perishable food supply chain post-COVID-19. An enhanced innovation ecosystem and new sustainability multi-actor innovation hubs in the agri-food sector can support the COVID-19 recovery agenda for sustainable food industry supply chains (Rowan and Galanakis, 2020). The role of research and development sectors within the industries to deal with COVID-19 restrictions in an innovative sustainable manner has become more critical than in the past. Barcaccia et al. (2020), in their study on the Italian agri-food sector post-COVID-19, outlined the importance of investment in research networks to accelerate the sustainability transition in the context of circular bio-economy. The commitment to social justice and the SDGs principles were mentioned by Fleetwood (2020) as a response to the food loss and waste in the food industry supply chains during the COVID-19 crisis towards ending hunger for people in vulnerable situations.

As mentioned before, the COVID-19 pandemic is the most serious threat to global health in 2020, which has substantially imposed pressure on the healthcare systems globally. This pressure threatens the sustainability of healthcare systems and highlights the urgent need for plans and actions. Based on a study conducted by Osingada and Porta (2020), to achieve the SDGs post-COVID-19, the responsive and proactive nursing efforts and policies in healthcare systems at micro and macro levels need to be in line with the 2030 Agenda for Sustainable Development. Besides, the healthcare system decision-makers need to plan the sustainable resumption of elective procedures, putting the safety of patients and surgical staff in priority during COVID-19, to reduce expenses and survive economically (O'Connor et al., 2020). To sustain the healthcare system fighting the COVID-19 pandemic, detecting the positive cases as soon as possible is crucial. Moreover, the application of smartphone-based healthcare monitoring systems could be a solution to support the sustainability of the healthcare system during the COVID-19 pandemic crisis.

Strategic planning and management are fundamental to control and timely prevent the COVID-19 pandemic and its negative implications. Authorities and policy-makers need to establish a well-clarified strategic plan to detect the confirmed cases, measure indicators, sustain the healthcare systems, and manage resources effectively beyond the COVID-19 crisis considering economic, social, and environmental perspectives. Hamilton (2020) analyzed the strategic change matrix to adjust the business considering restrictions imposed by COVID-19 on the traditional clients as an enabler of sustainable competitive business position. Moreover, as an attempt towards business sustainability post-COVID-19, Obrenovic et al. (2020) denoted that companies with networked structure and distributed leadership, which effectively use internet and communication technologies and have a resilient supply chain and organizational culture, can sustain their business operations during and after the COVID-19 pandemic. Due to the financial burden imposed on the societies by COVID-19, strategic prioritizing activities towards sustainability seems to be inevitable. As outlined in a survey conducted by Barreiro-Gen et al. (2020) on the 11,657 organizations worldwide, the main sustainability priority for organizations in the wake of COVID-19 is the social pillar rather than the economic and environmental pillars. Besides, consistent with their study, Rydzewski (2020) denoted that in the instability caused by COVID-19, the environmental and economic pillars of sustainability are pushed back by the

social pillar based on the "hierarchy of needs", which should be considered as a guideline for social policy-making and strategic planning after the COVID-19 instability.

The achievement of the 17 SDGs within the 2030 Agenda for Sustainable Development by the UN has faced serious challenges due to the COVID-19 outbreak. Among the 17 SDGs, SDG 1 ("no poverty"), SDG 2 ("zero hunger"), SDG 3 ("good health and well-being"), and SDG 8 ("decent work and economic growth") seem to be the most affected in the wake of the COVID-19 crisis. However, SDG 1, SDG 4 ("quality education"), and SDG 8 were identified by Alibegovic et al. (2020) as the most impacted SDGs by COVID-19 in Italy. Moreover, Barbier and Burgess (2020) outlined the notable effects of COVID-19 on the SDGs 1-8, SDG 11 ("sustainable cities and communities"), SDG 13 ("climate action"), SDG 16 ("peace, justice, and strong institutions"), and SDG 17 (which aims to collaborate for achievement of the other 16 SDGs). They proposed three policies for developing countries to achieve several SDGs together, considering the COVID-19 implication, including fossil fuel subsidy swap to fund clean energy investments, reallocating irrigation subsidies to improve water supply, and tropical carbon tax. Sakamoto et al. (2020), in a qualitative study on the most vulnerable populations to COVID-19, including the garment workers, urban slums dwellers, social exclusion, and pre-existing health conditions in Bangladesh, demonstrated that a considerable part of Bangladesh's people would not be able to tolerate the current situation. They highlighted the need for a tolerance capacity for Bangladesh to deal with the COVID-19 implications and reconsideration of the SDGs towards implementing the 2030 Agenda for Sustainable Development post-COVID-19. From a different angle of analysis, Leal Filho et al. (2020) warned about the strong focus of the healthcare systems on fighting the COVID-19 pandemic, which is disrupting other diseases prevention programs such as malaria, yellow fever, and others that imperils the achievement of the SDGs, in particular SDG 3, to ensure the health and human well-being globally. Therefore, there is a need to balance healthcare system capacities and priorities to allocate available resources more efficiently.

3.3.4.1. Sustainability transition opportunities in the wake of COVID-19

The COVID-19 pandemic and its disruptive change over the established urban systems may offer some promising sustainability transition opportunities for the societies, which require to be supported by economic and societal actors, policy-makers, and governments. Wells et al. (2020),

through analyzing four post-COVID-19 scenarios including "business as usual", "managed transition", "chaotic transition", and "managed degrowth" to assess the future sustainability, identified COVID-19 as a meta-transition for socio-technical regimes and a catalytic event which can redefine the ecological burdens of human activities. Markard and Rosenbloom (2020) proposed using the potential disruptive force of COVID-19 to reduce the carbon-intensive industries, technologies, and practices and drive low-carbon innovation as an opportunity to support the climate change and sustainable development agenda. As discussed in the research conducted by Kanda and Kivimaa (2020), expanding the digitalization of work to prevent the COVID-19 outbreak and, consequently, reducing the need for mobility and fossil energy consumption leads to more sustainable cities and urbanization. Besides, low-carbon transport through "mobility as a service" concept enabled by electrification and biogas use was proposed by Kanda and Kivimaa (2020) as a sustainable transition opportunity after COVID-19 in urban transport systems. Promoting sustainable mobility practice for students traveling between home and university during the COVID-19 pandemic, using different incentives, was proposed by Pirlone and Spadaro (Pirlone and Spadaro, 2020) to the public authorities as a solution to sustain and return to normality after COVID-19 in Italy.

The COVID-19 pandemic implications deserve to be addressed as a subject of sustainable energy transition policy by energy policy-makers. Kuzemko et al. (2020) outlined the potential of COVID-19, as a driver of the sustainable energy transition, to shape the sustainable energy demand, the carbon-intensity of the energy system, and the sustainable transition speed considering the investment in the clean-tech in the energy sector. The emerging situation caused by COVID-19 as a "post-disaster window of opportunity" for developing new urban and territorial planning towards sustainability transition was addressed by Pierantoni et al. (2020) to highlight the need for rethinking and reorganizing the living environment of cities employing a network of open spaces and greenery to make cities more secure and sustainable for dealing with potential future health crises. Moreover, Sovacool et al. (2020) pointed to the "Christmas" effect of the COVID-19 pandemic by harnessing the social response to the pandemic in terms of energy and climate planning and policy, including informing people how to reduce their carbon footprints, creating a capacity to deal with emergency measures, and providing support for vulnerable people in term of energy and mobility. Goffman (2020) highlighted the significant

role of innovation and local leadership from glocalization (i.e., a combination of the words "globalization" and "localization.") lens, which refers to local movements with globally cooperative ethics, as an opportunity to overcome the COVID-19 challenges, support the sustainability transition, and make a more sustainable future. Although Bodenheimer and Leidenberger (2020) addressed COVID-19 as a "window of opportunity" for sustainability transitions in the future, they emphasized using the word "opportunity" with caution and highlighted the importance of designing appropriate communication strategies to make it happen. Based on their study in the Western Europe context, crisis communication strategies should address different target groups of the population through appropriate channels in a truthful and cautious, understandable, fast, consistent, and explanatory manner to deliver the narrative between unsustainable behavior and the COVID-19 crisis and support a sustainability transition in the society.

4. Research gaps and directions for a sustainability research agenda after COVID-19

Our systematic review showed the need for an update of the sustainability research agenda after COVID-19. Based on the results of the present review, considering the challenges to sustainability before COVID-19 and also the recently created challenges by COVID-19, research gaps are identified and summarized in this section, and the research avenues to fill them are proposed. Although sustainability before COVID-19 was facing challenges such as environmental concerns, the education system involvement in sustainability practices, mobilizing financing and investments towards SDGs achievement, and public health crisis arising from healthcare pollution, the COVID-19 pandemic has intensified those challenges. In the other hand, COVID-19 restrictions have led to new challenges for different dimensions of sustainability practices and sustainable development in the future. The research avenues identified herein call for: (1) sustainability action plan considering COVID-19 implications: refining sustainability goals and targets and developing a measurement framework; (2) making the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post COVID-19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding quantitative research to harmonize the COVID-19-related sustainability research. Fig. 9

summarizes the sustainability research avenues corresponding to the SDGs for further research post COVID-19 towards sustainable development.

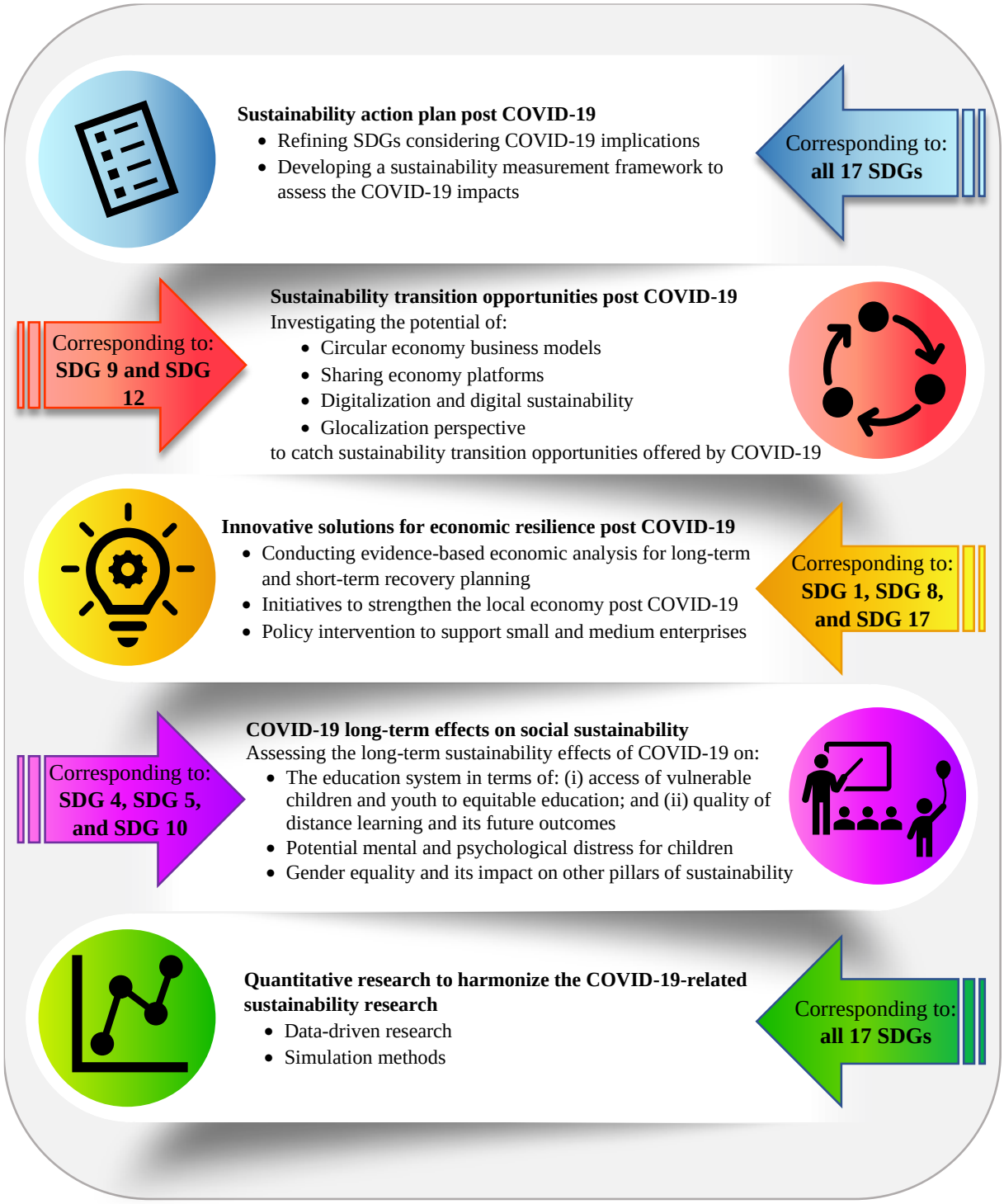

Fig. 9. *Future research avenues for sustainability and sustainable development post COVID-19*

4.1. Sustainability action plan considering COVID-19 implications: refining sustainability goals and targets and developing a measurement framework

Consistent with the suggestions made by Elliott et al. (2020), we believe that rethinking sustainability should take place in a more quickly manner, before the pandemic disaster is overcome and people return to their normal lives, forgetting about the possible future challenges resulting from the next pandemic. Therefore, a highly recommended research avenue for scholars is developing a modified solid action plan including COVID-19 consideration for sustainability to support governments, authorities, and practitioners of sustainable development.

To do this, revisiting the two following factors in the wake of COVID-19 are critical. First, a well-scrutinized review of the COVID-19 effects on the 17 SDGs and their relevant targets to prepare a well-defined description of the goals and targets based on the COVID-19 implication for any area of study is crucial. Rethinking sustainability is necessary for the current SDGs of the UN 2030 Agenda for Sustainable Development since they are not resilient enough towards the shocks resulting from the pandemic (Ibn-Mohammed et al., 2021). And second, developing a measurement framework to efficiently assess the impacts of COVID-19 on the progress towards sustainability pillars and sustainable development is highly required. Due to the recentness of COVID-19, the lack of an adequate and effective measurement tool for sustainability monitoring and assessment calls for conducting more research and investigations in the future.

4.2. Making the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12 and SDG 9

As mentioned in previous sections, COVID-19 has provided some opportunities for sustainability transition and rethinking sustainability to create a more sustainable future in different subject areas, such as urban transport system (Kanda and Kivimaa, 2020), and sustainable energy transition (Kuzemko et al., 2020). In our opinion, there is no better time than now to promote innovative sustainable consumption and production patterns within the sociotechnical regimes. In particular, the sustainability opportunities offered by COVID-19 to SDG 12 (responsible consumption and production patterns), which ensure using the natural environment and resources in a sustainable manner, need to be addressed for further research. In this regard, we highly recommend carrying out empirical research on the potential of circular economy business models (Elliott et al., 2020), sharing economy platforms (Ranjbari et al.,

2018), digitalization and digital sustainability (Pan and Zhang, 2020), and glocalization perspectives (Goffman, 2020) in increasing the resilience of the communities and mitigating the COVID-19 disruptive effects on sustainability in future. Moreover, the role of innovation and initiatives is significantly important to help sustainability policy-makers post COVID-19. Therefore, we recommend to seek new insight into fostering innovation processes and research and development units in a real world for building a resilient infrastructure and domestic technology development to support SDG 9 achievement.

4.3. Innovative solutions for economic resilience towards sustainability post COVID-19: focus on SDG 1, SDG 8, and SDG 17

COVID-19 has led the world to face the worst economic recession since the great depression, as it has caused 400 million job losses in the second quarter of 2020, and the GDP per capita is expected to decline by 4.2% in 2020 (UN, 2020c). Due to the severe economic problems caused by this pandemic for societies, there is an urgent need for innovative proposals to make economic resilience and support sustainable economic growth and decent work for all according to SDG 8. In this regard, contributing in the development of an economic recovery plan is highly urgent, particularly with the focus on the following research avenues; (1) conducting evidence-based economic analysis for long-term and short-term recovery planning; (2) initiatives to strengthen the local economy post COVID-19; and (3) policy intervention to support small and medium enterprises.

This challenge is even more critical in developing and specially less developed countries, which are more financially vulnerable. The achievement of SDG 8 and also SDG 1 (no poverty) has hardly been influenced by the COVID-19 implications. The global partnership among the countries (SDG 17) to achieve UN's SDGs was taking place among various countries before the pandemic, and the aid to least-developed countries and Africa in 2019 experienced an increase of 2.6% and 1.3%, respectively, compared with the year 2018 (UN, 2020d). However, it is estimated that the 554 billion dollars of remittances to low- and middle-income countries in 2019 would decrease to 445 billion dollars in 2020, and the global foreign investment falls by up to 40% in 2020 due to the pandemic (UN, 2020d). Therefore, although almost all countries are facing serious health and economic challenges in their own territories because of the pandemic, investigating practical solutions to support the partnerships specified in SDG 17 post COVID-19

is extremely encouraged to be the focus of future research to support less-developed and developing countries move towards sustainable development.

4.4. In-depth analysis of the COVID-19 long-term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10

In general, social sustainability has not been paid as much attention as economic and environmental sustainability (Govindan et al., 2021; Yawar and Seuring, 2017). Besides, according to the research conducted by Anisul Huq et al. (2014), most social sustainability research has been conducted within the developed countries context rather than less-developed or even developing countries. However, the social pillar was identified by Barreiro-Gen et al. (2020) as the main sustainability priority for organizations among three sustainability pillars aftermath of the COVID-19 pandemic crisis. Additionally, in the instability caused by COVID-19, social pillar pushes environmental and economic pillars back based on the hierarchy of needs (Rydzewski, 2020).

It is apparent that COVID-19, with its catastrophic implications for the global economy and business activities across the globe, has made social sustainability issues even more challenging. Based on the results of our research, the literature lacks a comprehensive study to investigate the long-term effects of COVID-19 on the social dimensions of sustainability towards sustainable development specially in developing and less-developed countries. In particular, the following three research gaps corresponding to SDG 4, SDG 5, and SDG 10 of the UN's SDGs need more research in the future. First, in line with SDG 4, the long-term sustainability effects of the pandemic situation on the education system should be assessed in terms of (1) access of vulnerable children and youth to equitable education; and (2) quality of distance learning and its future outcomes and challenges. Second, examining the potential mental distress and also the psychological aspects of keeping away from many of regular social activities for children, as one of the most vulnerable groups in societies, needs further research to evaluate the possible future impacts on different dimensions of social sustainability and SDG 10 achievement. And finally, although gender inequalities and violence against women post COVID-19 have been highlighted in some research (Gulati and Kelly, 2020; Vora et al., 2020), not many studies have addressed the achievement of SDG 5 and its impact on other pillars of sustainability towards sustainable development. While women represent only 25% of the national parliament and 36% of the local

government in pandemic-related leadership roles, they are at the front lines of fighting COVID-19 and represent 70% of the health and social workers during the pandemic period (UN, 2020e). Such inequality requires extensive studies to evaluate its outcomes and the prospective effect on the sustainability of societies.

4.5. Expanding quantitative research to harmonize COVID-19-related sustainability research

As shown in **Fig. 6**, 88% of the research articles reviewed in our study adopted a qualitative rather than a quantitative approach to provide analysis regarding the implications of COVID-19 for sustainability. As a result, the lack of quantitative methods in examining the COVID-19 crisis and its impact on the environmental, social, and economic dimensions of human lives and making projections on the future of world sustainability aftermath of COVID-19 are highly visible. Employing quantitative methods to conduct more data-driven research and using real data to provide an adequate and reliable assessment of the changes made to various aspects of sustainability due to the pandemic is highly recommended for future research. In this regard, mathematical and statistical analysis and simulation models informed by real data can harmonize the results of the research in this area.

In the other hand, referring to the WHO Director-General speech on 22 April 2020, COVID-19 will remain with us for a long time (UN, 2020f). Therefore, applying simulation models to illustrate the consequences of various scenarios for a long period of time (Shams Esfandabadi et al., 2020) is of high importance. Examples of such simulation methods are System Dynamics and agent-based modeling, the former based on the systems thinking approach, capturing causalities, and the latter based on the idea of modeling individuals and their interactions, to derive patterns of behaviors. These models can simulate the future outcomes of taking different managerial actions and changes over time, which supports decision making towards sustainability challenges post COVID-19. Such simulation methods provide a ground for interdisciplinary analysis on the pandemic effects, to which researchers must pay more attention in future research of the sustainability context.

5. Conclusion

The COVID-19 pandemic crisis, as the most serious health threat for the global community in 2020, has become the central issue of international concerns these days. A wide range of businesses and industries such as healthcare systems, travel and tourism industry, food and agriculture sectors, education system, energy, and mobility have been hardly hit by the restrictions of this crisis worldwide. A tremendous amount of research has been conducted within various subject areas to respond to the urgent call for action against the unprecedented situation caused by the COVID-19 crisis for the global economy and societies during a short period of time, leading to a fragmented literature. Our research has revisited and reviewed the pandemic crisis implications for the sustainability of human lives, considering social, environmental, and economic dimensions based on the TBL framework. A systematic approach to review the literature adopted from Fink (2019) and Traxler et al. (2020) was employed to provide an inclusive insight into the three environmental, social, and economic pillars of sustainability in the wake of COVID-19. The effects, challenges, and potential solutions based on the TBL framework, for each pillar of sustainability including environmental and social, different pairwise intersections of pillars including socio-economic and socio-environmental, and finally, the integration of all three pillars of sustainability, which refers to sustainable development, were analyzed. As a result, an update of the current status of research on the TBL of sustainability considering the COVID-19 pandemic implications was presented through the descriptive analysis of 49 research articles on the subject. Moreover, to highlight the COVID-19 effects on sustainability, the impacts of the pandemic outbreak on the sustainability dimensions in different subject areas were synthesized and mapped for different intersections of the triple pillars through a thematic analysis. Consequently, some potential sustainability transition opportunities post-COVID-19 for societies, such as low-carbon innovations to support the climate change, promoting digitalization of the work, and sustainable mobility and energy transition were discussed. The results support governments, authorities, practitioners, and policy-makers to alleviate the negative impacts of the pandemic on the sustainable development and catch the potential sustainability transition opportunities post COVID-19. At the end, future research directions for sustainable development corresponding to the UN's SDGs considering COVID-19 were proposed.

Our study had two limitations. Firstly, the present research focused on the academic literature limited to WoS and Scopus as the main databases of the systematic literature review. The research could be enriched by including approaches from grey literature, such as using government reports, policy statements, and organizational deliverables. Due to the recentness of the COVID-19 crisis and the fragmented academic literature in its implications, conducting grey literature to cover more insights on the sustainability practices is suggested to address this limitation and contribute to shape a more balanced picture of the available evidence. And secondly, our analysis was conducted at the level of the TBL dimensions of sustainability including environmental, social and economic pillars. More in-depth research on each one of these dimensions are required to investigate the cultural, operational, political, and technical aspects of the sustainability in the wake of COVID-19, as well.

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