

Resilience to flow rate variability in a green wall for greywater treatment

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

3

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## 35 Abstract

36 The economic, social, and environmental pillars of sustainability in human lives have been  
37 immensely impacted by the COVID-19 pandemic for the global economy and societies. Due to  
38 the scholars' increasing interest in responding to the urgent call for action against the pandemic,  
39 the literature of sustainability research considering the COVID-19 consequences is very  
40 fragmented. Therefore, a comprehensive review of the COVID-19 implications for sustainability  
41 practices is still lacking. This research aims to analyze the effects of COVID-19 on the triple  
42 bottom line (TBL) of sustainability to support the future sustainable development agenda. To do  
43 this, the following research questions are addressed by conducting a systematic literature review:  
44 (i) what is the current status of research on the TBL of sustainability considering COVID-19  
45 implications?, (ii) how does COVID-19 affect the TBL of sustainability?, and (iii) what are the  
46 potential research gaps and future research avenues for sustainable development post COVID-  
47 19? The results manifest the major implications of the COVID-19 outbreak for the triple  
48 sustainability pillars and the sustainable development agenda from the economic, social and  
49 environmental points of view. The key findings provide inclusive insights for governments,  
50 authorities, practitioners, and policy-makers to alleviate the negative impacts of pandemic on  
51 sustainable development and catch the sustainability transition opportunities post COVID-19.  
52 Finally, five research directions for sustainable development corresponding to the UN's SDGs  
53 post COVID-19 are provided, as follows: (1) sustainability action plan considering COVID-19  
54 implications: refining sustainability goals and targets and developing measurement framework;  
55 (2) making the most of sustainability transition opportunities in the wake of COVID-19: focus on  
56 SDG 12 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post  
57 COVID-19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-  
58 term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding  
59 quantitative research to harmonize the COVID-19-related sustainability research.

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

## 63 1. Introduction

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

78 The novel coronavirus-caused infectious disease 2019 (COVID-19) first emerged in  
79 December 2019 in China and spread worldwide in such a way that the World Health  
80 Organization (WHO) announced it as a pandemic in March 2020 (WHO, 2020a). As of  
81 December 19, 2020, a total number of 74,299,042 confirmed cases of COVID-19, including  
82 1,669,982 deaths in 235 countries, areas, and territories, has been recorded by the WHO (2020b).  
83 The crisis's magnitude has marked the COVID-19 pandemic as the most severe health  
84 catastrophe of this century (Chakraborty and Maity, 2020).

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

93 SDGs' priority. Hence, while significant global efforts are being put into controlling this  
94 pandemic, sustainability in the post-COVID-19 era should not be neglected (Lambert et al.,  
95 2020). As a matter of fact, sustainability and achieving the SDGs are even more critical now than  
96 before (Leal Filho et al., 2020).

97 Although the COVID-19 pandemic has not been around for too long, a massive amount of  
98 COVID-19-related research has been conducted due to its significant implications and  
99 consequences for society, the environment, and the economy worldwide. The effect of this  
100 pandemic on different dimensions of sustainability and sustainable development has been  
101 investigated by many sustainability scholars in a wide range of subject areas such as healthcare  
102 systems (Osingada and Porta, 2020; Sharma et al., 2020), tourism (Ioannides and Gyimóthy,  
103 2020; Romagosa, 2020), food industry (Fleetwood, 2020), SDGs (Ashford et al., 2020;  
104 Paramashanti, 2020), sustainable transition (Bodenheimer and Leidenberger, 2020; Pirlone and  
105 Spadaro, 2020), education (Anholon et al., 2020; Tran et al., 2020), social media (AI-Youbi et  
106 al., 2020; La et al., 2020), strategic management (Barreiro-Gen et al., 2020; Hamilton, 2020),  
107 environmental pollution (Somani et al., 2020), energy (Kanda and Kivimaa, 2020; Kuzemko et  
108 al., 2020), climate change (Markard and Rosenbloom, 2020), and waste management (Kulkarni  
109 and Anantharama, 2020; Vanapalli et al., 2021).

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

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

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

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

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

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

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

## 142 **2. Methodology**

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

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

## 155 **2.1. Database**

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

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

## 170 **2.2. Keywords definition**

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

179 In addition, to catch the most recent challenges of sustainability and sustainable  
180 development before COVID-19, an initial query of ("sustainability" OR "sustainable  
181 development") limited to the article title AND ("challenges" OR "gaps") AND NOT ("COVID-  
182 19" OR "pandemic" OR "Coronavirus" OR "SARS-CoV-2") limited to the article title,  
183 keywords, and abstract was considered for data collection in WoS and Scopus.

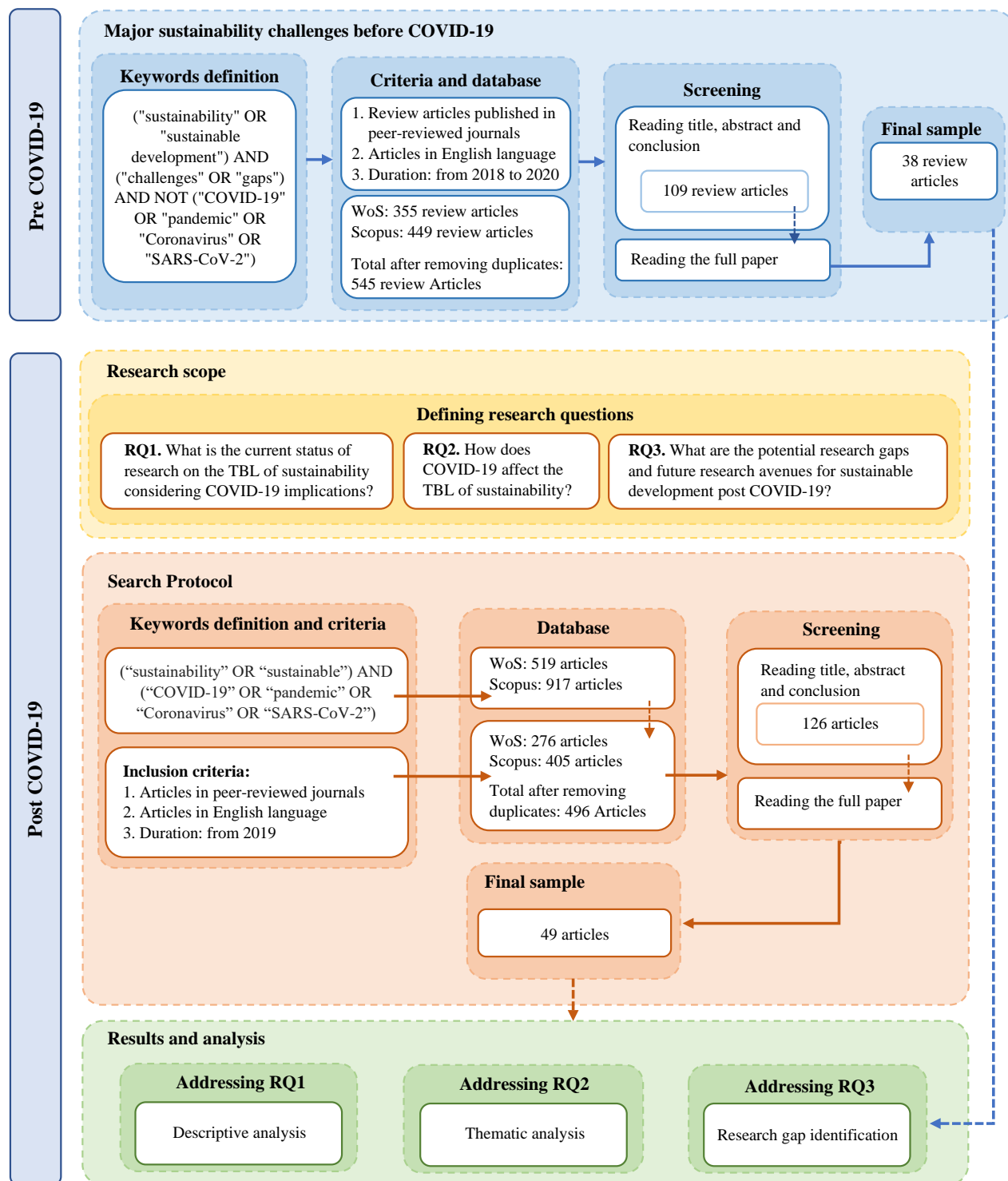
### 184 **2.3. Screening: Inclusion and exclusion criteria**

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

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

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

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



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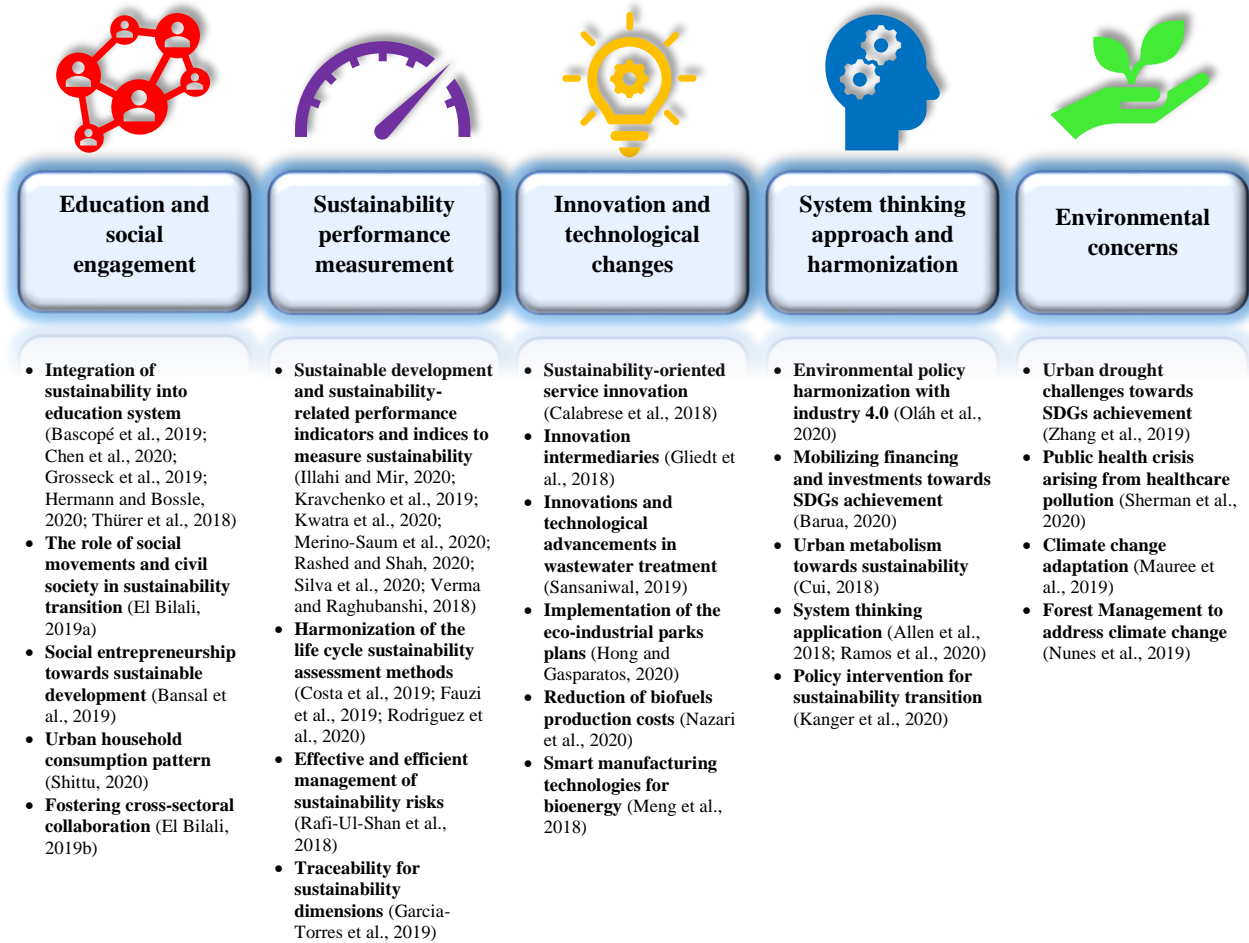
*Fig. 1. Overall search protocol and systematic literature review framework*

### 211 **3. Results and Discussion**

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

#### 218 **3.1. An overview of the major sustainability challenges before COVID-19**

219 To have a general image of the challenges of sustainability and sustainable development  
220 before the COVID-19 pandemic crisis, the major challenges were extracted from the literature as  
221 shown in Fig. 2. The integration of education system as an important player of progressing  
222 towards sustainability agenda within the sustainable development practices has been highlighted  
223 as a significant multidisciplinary challenge in the social sustainability literature (Bascopé et al.,  
224 2019; Chen et al., 2020; Grosseck et al., 2019; Hermann and Bossle, 2020; Thüerer et al., 2018).  
225 The need for convergence of social movements and civil society (El Bilali, 2019a), fostering  
226 cross-sectoral collaboration (El Bilali, 2019b), and behavioral change in the urban household  
227 consumption pattern (Shittu, 2020) are challenging the sustainability transition. Besides, social  
228 entrepreneurship as a path for social change and a driver of sustainable development is facing  
229 challenges due to the lack of a clear measurement framework for the different dimensions of  
230 sustainability (Bansal et al., 2019). Environmental sustainability roadmap urgently needs to be  
231 adapted with the challenges of climate change as one of the biggest environmental problem that  
232 human is facing with (Mauree et al., 2019). In this regard, policy-making, planning, and  
233 management of forest resources with the possibility of improving carbon capture and helping  
234 environment was presented by Nunes et al. (2019) as an important environmental sustainability  
235 challenge. In addition, combating the impacts of urban droughts, which have been magnified by  
236 climate change, has made serious challenges for policy-makers and city stakeholders towards  
237 environmental sustainability and SDGs achievement (Zhang et al., 2019). Public health crisis  
238 arising from healthcare pollution is another environmental sustainability concern, which highly  
239 needs to be addressed to achieve a sustainable healthcare system (Sherman et al., 2020).



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

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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.

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

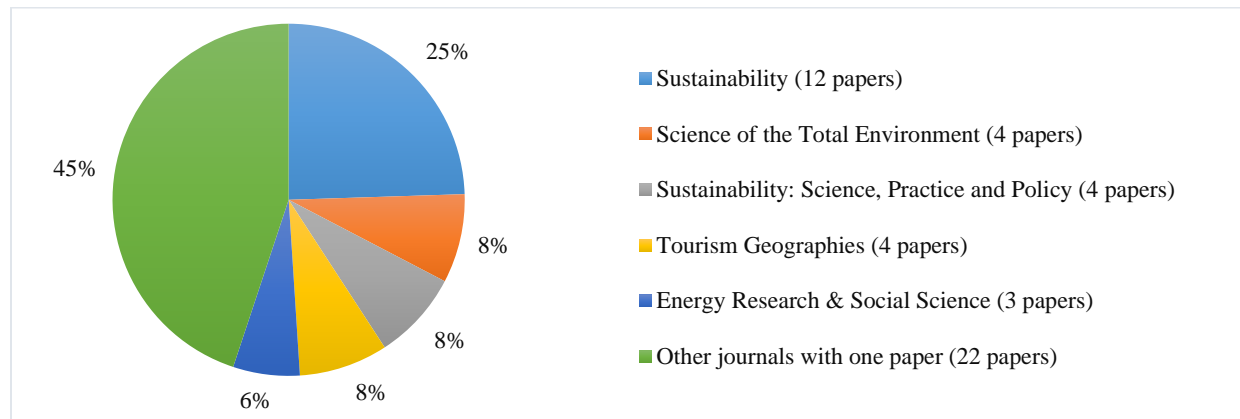
## 272 **3.2. Sustainability after COVID-19: Descriptive analysis**

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

### 279 **3.2.1. Journal publications**

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

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



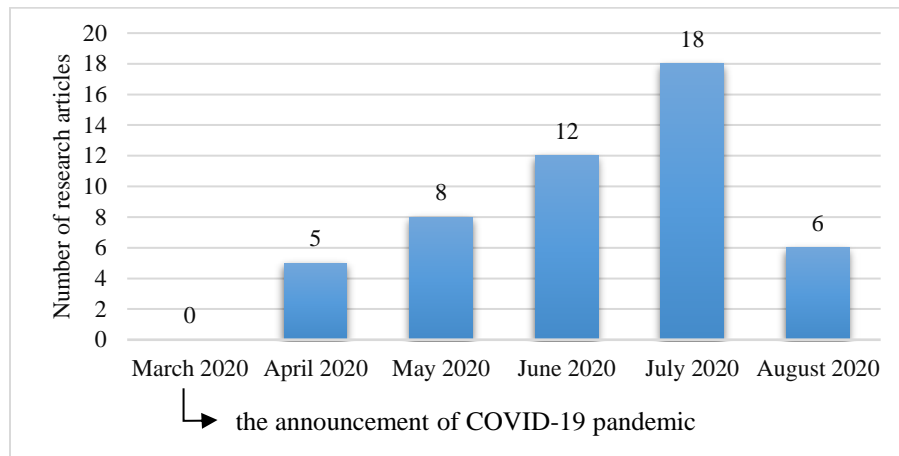
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289 **Fig. 3.** Distribution of the sample papers across journals in WoS and Scopus

### 290 3.2.2. Distribution of the publications over time

291 The search process identified a total of 49 articles on the TBL dimensions of sustainability,  
 292 taking COVID-19 effects into account, which were published from March 2020 to August 29,  
 293 2020, as shown in Fig. 4. Although the inclusion criteria in our search protocol allowed results  
 294 with a publication date starting from December 2019, the content analysis showed that the first  
 295 article investigating the sustainability effects of COVID-19 in our sample was published in April  
 296 2020. After the announcement of COVID-19 as a pandemic by the WHO on March 11, 2020, as  
 297 observed in Fig. 4, the number of research conducted on the COVID-19 effects on the economic,  
 298 social, and environmental sustainability in our sample has increased considerably. It is evident  
 299 that due to the significant COVID-19 implications for global health and the concerns regarding  
 300 sustainability for the economy, society, and the environment, academic interest to study the  
 301 challenges caused by COVID-19 in the subject has rapidly increased. As the search process of  
 302 our research stopped on August 29, 2020, the lower number of publications in August 2020 is  
 303 due to the time that WoS and Scopus usually need to find the accepted articles online. Therefore,

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



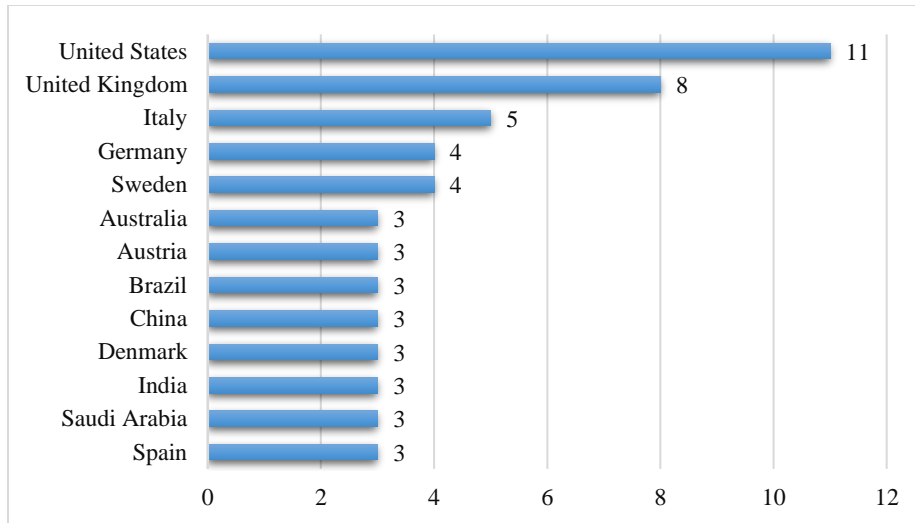
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*Fig. 4. Distribution of the publications over time*

### 308 3.2.3. Contributing countries

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



324

325

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

### 326 3.2.4. Citation ranking

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

340 *Table 1. The most influential sample papers*

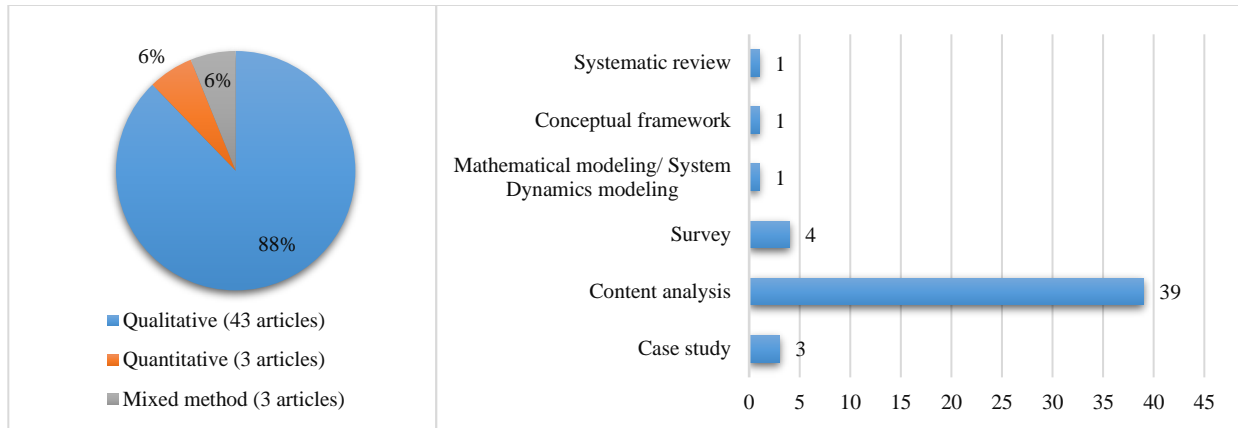
Author(s) and year	Title of the paper	Citation score	Journal	Publisher
Galanakis (2020)	The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis	117	Foods	MDPI

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

341

### 342 3.2.5. Methodological approaches and research methods

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



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*Fig. 6. Methodological approaches and research methods*

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### 3.3. Sustainability after COVID-19: Thematic analysis

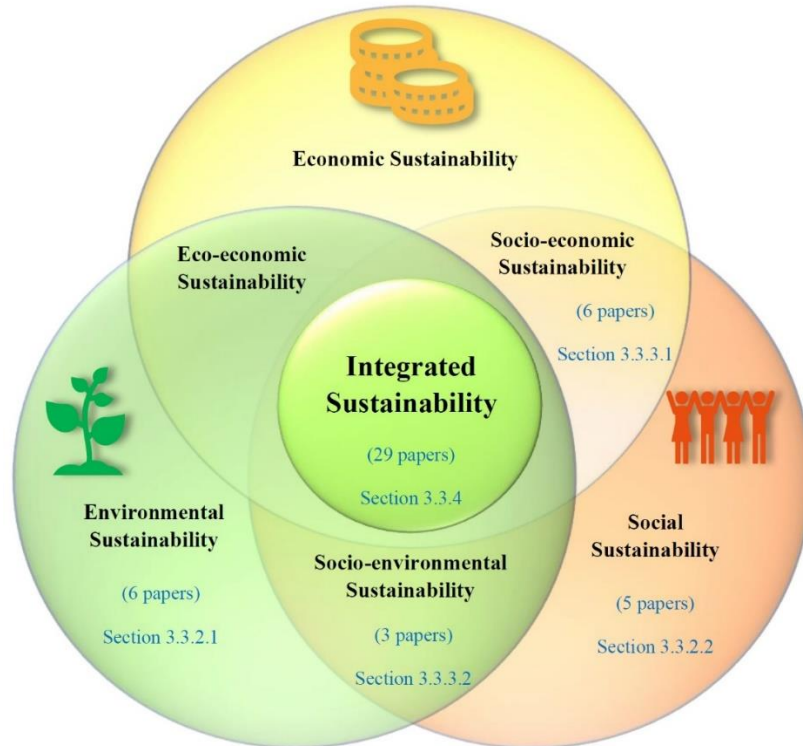
355

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.

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

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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.

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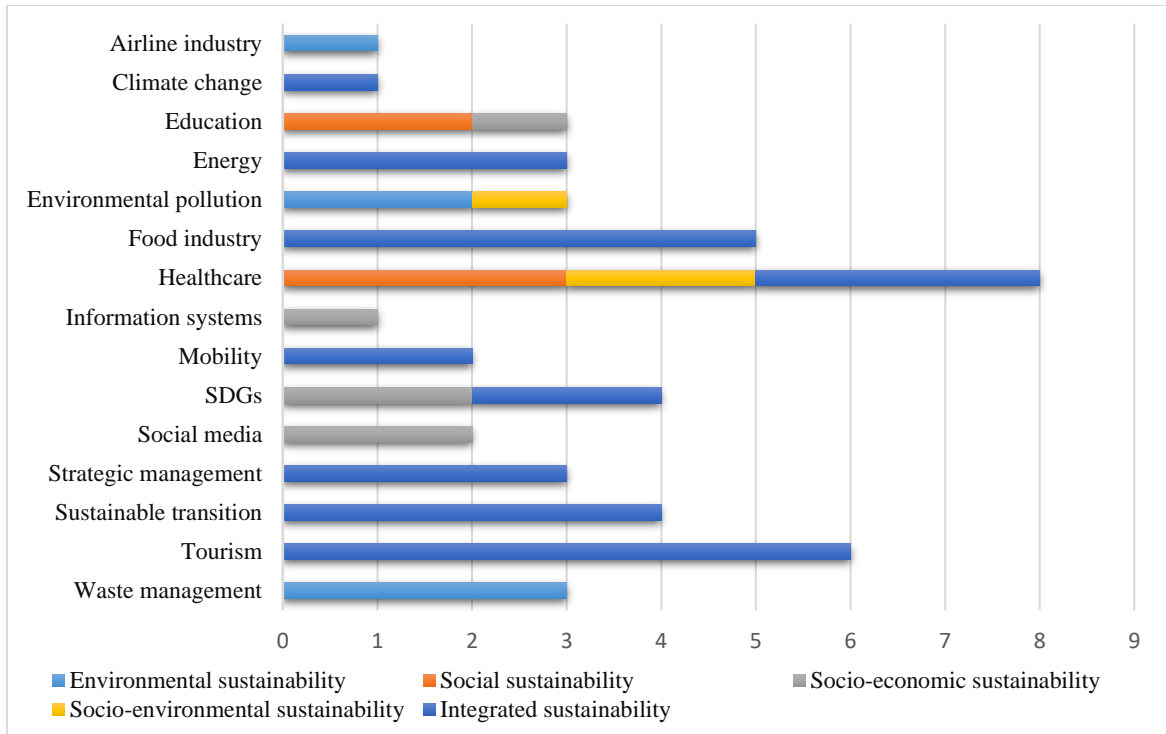
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For the rest of the thematic analysis section, the key themes and subject areas studied in terms of sustainability perspectives in the aftermath of the COVID-19 outbreak are presented in Section 3.3.1. Then, the main research conducted on the COVID-19 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.

### 378 **3.3.1. Subject areas of sustainability amid COVID-19**

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

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



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

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### 3.3.2. Main pillars of sustainability and COVID-19

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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.

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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.

412

*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 Anantharama, 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

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### 414 3.3.2.1. Environmental sustainability and COVID-19

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

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

435 As reported by SMART WASTE (2020), among the environmental impacts of the COVID-  
436 19 pandemic, municipal waste management practices seem to be faced with more serious  
437 challenges. The role of local and regional authorities to adopt appropriate policies in municipal  
438 waste management, considering the current implications imposed by COVID-19, is essential in  
439 terms of managing waste generation, waste handling and separation, waste transportation, waste  
440 disposal, and landfilling. Besides, according to the research conducted by Mol and Caldas  
441 (2020), COVID-19 can spread through solid waste and inadequate waste transport and disposal,  
442 which can pose a risk to workers and environmental sustainability. Kulkarni and Anantharama  
443 (2020) proposed three policies for sustainable municipal solid waste management in the  
444 aftermath of the COVID-19 outbreak, including using decentralized waste management for waste  
445 collection and recycling, creating temporary waste storage and reduction site, and using thermal  
446 treatment with an energy recovery facility as a solution for processing a large amount of waste.  
447 The changes in consumption patterns caused by COVID-19, such as using personal protective  
448 equipment and increased demand for plastic-packaged food, have increased the complexity of

449 plastic waste management (Vanapalli et al., 2021). As a solution, applying circular technologies  
450 such as feedstock recycling, more investment in infrastructure, and using sealed bags to enhance  
451 the safety of contaminated plastic wastes disposal proposed by Vanapalli et al. (2021) are  
452 priorities in sustainable waste management during pandemic crisis. Another concern regarding  
453 the COVID-19 outbreak, especially in low-income countries that mainly rely on the surface and  
454 groundwater resources for water consumption, is the potential of community spread of COVID-  
455 19 through wastewater (Adelodun et al., 2020). Decentralization of wastewater treatment  
456 facilities, community-wide monitoring and testing of Coronavirus ribonucleic acid in  
457 wastewater, improved sanitation and water quality, development and use of the point-of-use  
458 device for virus decontamination, and policy intervention were suggested by Adelodun et al.  
459 (2020) as sustainable preventive measures for low-income countries against the potential  
460 outbreak of COVID-19 through wastewater. In this regard, monitoring COVID-19, as a tracer in  
461 wastewater, in order to single out the infected areas has also been highlighted and a feasibility  
462 assessment of a surveillance system is being conducted in Europe by the European Commission  
463 (EU, 2020).

#### 464 **3.3.2.2. Social sustainability and COVID-19**

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

479 efforts against the COVID-19 pandemic, putting older people, children, and pregnant women in  
480 vulnerable situations in priority towards social sustainability and its associated SDGs  
481 achievement. Due to the cloistering of individuals, couples, and families caused by the COVID-  
482 19 pandemic, ensuring rights-based family planning services, as a fundamental human right, is  
483 essential towards social sustainability and achieving the SDGs within the 2030 Agenda for  
484 Sustainable Development (Sharma et al., 2020). Community-based distribution, domestic  
485 investment in the health system, and collaboration with individual private health care providers  
486 were proposed by Sharma et al. (2020) to support the family planning service provision during  
487 the COVID-19 outbreak. Ryan et al. (2020) proposed a sustainability framework to ensure  
488 community stabilization considering the hierarchy of needs and social determinants of health  
489 through providing baseline requirements, regulations, and recommendations, triggers, and  
490 implementation. The authorities and decision-makers involved in the COVID-19 crisis  
491 management need to use a well-considered sustainable framework to balance lockdown and  
492 restrictive regulations and social needs to manage the crisis more sustainably.

493 SDG 4, referring to quality education as a fundamental enabler of social sustainability  
494 within the 2030 Agenda for Sustainable Development, aims to provide free, equitable, and  
495 quality primary and secondary education for all girls and boys worldwide by 2030 (General  
496 Assembly, 2015). Before the COVID-19 pandemic crisis, according to the report by the UN  
497 (2020a), 617 million youth worldwide lack basic mathematics and literacy skills, and more than  
498 200 million children would be out of school. Based on this report, minimum proficiency  
499 standards in reading and mathematics are not met by more than half of children all around the  
500 world. COVID-19 lockdowns and closures have disrupted education systems worldwide by  
501 imposing some limitations and restrictions. Keeping social distancing and emerging new  
502 approaches to education and learning enabled by digitalization and online learning methods amid  
503 the COVID-19 outbreak has created new challenges to the education systems and the associated  
504 policy-makers worldwide. Therefore, more attention to sustainable development principles and  
505 inserting sustainability concepts into the education system structure in the wake of the COVID-  
506 19 crisis are urgently required (Anholon et al., 2020). Iyengar (2020), in response to the COVID-  
507 19 implications for education systems, proposed three policies, including using technology to  
508 overcome the learning difficulties caused by COVID-19, community-driven support systems,

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

### 511 3.3.3. Sustainability pillars pairwise intersections and COVID-19

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

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

526 *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
(Al-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
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528 **3.3.3.1. Socio-economic sustainability and COVID-19**

529 The socio-economic impacts of the COVID-19 crisis on the global community have  
530 disrupted the path towards sustainability and achieving SDGs to implement sustainable  
531 development. According to the report by the UN (2020b) regarding hunger, the world is not on  
532 track to achieve SDG 2, which aims to end hunger and ensure access by all people, especially the  
533 poor people and those who live in vulnerable situations by 2030. Based on this report, nearly 690  
534 million people are hungry, which constitute 8.9% of the world population. The serious pressure  
535 caused by the COVID-19 pandemic on the global economy has even worsened the situation  
536 towards achieving SDG 2. Paramashanti (2020) outlined the COVID-19 crisis as a shock for  
537 Indonesia’s progress towards SDG 2 by affecting hunger, malnutrition, and food insecurity, and  
538 highlighted the importance of paying attention to the food and agriculture industry and social  
539 protection as well to prevent another humanitarian catastrophe, even though saving lives against  
540 COVID-19 is in priority. Moreover, the COVID-19 crisis has led to many social and economic  
541 inequalities, such as income, health, education, and safety inequalities for people worldwide.  
542 These emerging inequalities significantly threaten socio-economic sustainability and the  
543 achievement of SDG 10 within the 2030 Agenda for Sustainable Development, which aims to  
544 reduce inequality. In order to advance progress towards SDG 10 to reduce inequality, Ashford et  
545 al. (2020) proposed some policies to address the inequality issues amplified by the COVID-19  
546 pandemic consisting of transferring income and wealth without increasing the deficit, focusing  
547 on workforce stabilization and safety, allocating government incentive and subsidies to support  
548 healthcare, food, and basic needs, and using debt suspension mechanisms for emerging and  
549 developing economies. Tran et al. (2020) identified the important role of students’ perception of  
550 the necessity of self-learning, school type, and also grade level on their learning habits during the  
551 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

611

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

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

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

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

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

668 Strategic planning and management are fundamental to control and timely prevent the  
669 COVID-19 pandemic and its negative implications. Authorities and policy-makers need to  
670 establish a well-clarified strategic plan to detect the confirmed cases, measure indicators, sustain  
671 the healthcare systems, and manage resources effectively beyond the COVID-19 crisis  
672 considering economic, social, and environmental perspectives. Hamilton (2020) analyzed the  
673 strategic change matrix to adjust the business considering restrictions imposed by COVID-19 on  
674 the traditional clients as an enabler of sustainable competitive business position. Moreover, as an  
675 attempt towards business sustainability post-COVID-19, Obrenovic et al. (2020) denoted that  
676 companies with networked structure and distributed leadership, which effectively use internet  
677 and communication technologies and have a resilient supply chain and organizational culture,  
678 can sustain their business operations during and after the COVID-19 pandemic. Due to the  
679 financial burden imposed on the societies by COVID-19, strategic prioritizing activities towards  
680 sustainability seems to be inevitable. As outlined in a survey conducted by Barreiro-Gen et al.  
681 (2020) on the 11,657 organizations worldwide, the main sustainability priority for organizations  
682 in the wake of COVID-19 is the social pillar rather than the economic and environmental pillars.  
683 Besides, consistent with their study, Rydzewski (2020) denoted that in the instability caused by  
684 COVID-19, the environmental and economic pillars of sustainability are pushed back by the

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

687 The achievement of the 17 SDGs within the 2030 Agenda for Sustainable Development  
688 by the UN has faced serious challenges due to the COVID-19 outbreak. Among the 17 SDGs,  
689 SDG 1 ("no poverty"), SDG 2 ("zero hunger"), SDG 3 ("good health and well-being"), and SDG  
690 8 ("decent work and economic growth") seem to be the most affected in the wake of the COVID-  
691 19 crisis. However, SDG 1, SDG 4 ("quality education"), and SDG 8 were identified by  
692 Alibegovic et al. (2020) as the most impacted SDGs by COVID-19 in Italy. Moreover, Barbier  
693 and Burgess (2020) outlined the notable effects of COVID-19 on the SDGs 1-8, SDG 11  
694 ("sustainable cities and communities"), SDG 13 ("climate action"), SDG 16 ("peace, justice, and  
695 strong institutions"), and SDG 17 (which aims to collaborate for achievement of the other 16  
696 SDGs). They proposed three policies for developing countries to achieve several SDGs together,  
697 considering the COVID-19 implication, including fossil fuel subsidy swap to fund clean energy  
698 investments, reallocating irrigation subsidies to improve water supply, and tropical carbon tax.  
699 Sakamoto et al. (2020), in a qualitative study on the most vulnerable populations to COVID-19,  
700 including the garment workers, urban slums dwellers, social exclusion, and pre-existing health  
701 conditions in Bangladesh, demonstrated that a considerable part of Bangladesh's people would  
702 not be able to tolerate the current situation. They highlighted the need for a tolerance capacity for  
703 Bangladesh to deal with the COVID-19 implications and reconsideration of the SDGs towards  
704 implementing the 2030 Agenda for Sustainable Development post-COVID-19. From a different  
705 angle of analysis, Leal Filho et al. (2020) warned about the strong focus of the healthcare  
706 systems on fighting the COVID-19 pandemic, which is disrupting other diseases prevention  
707 programs such as malaria, yellow fever, and others that imperils the achievement of the SDGs, in  
708 particular SDG 3, to ensure the health and human well-being globally. Therefore, there is a need  
709 to balance healthcare system capacities and priorities to allocate available resources more  
710 efficiently.

#### 711 **3.3.4.1. Sustainability transition opportunities in the wake of COVID-19**

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

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

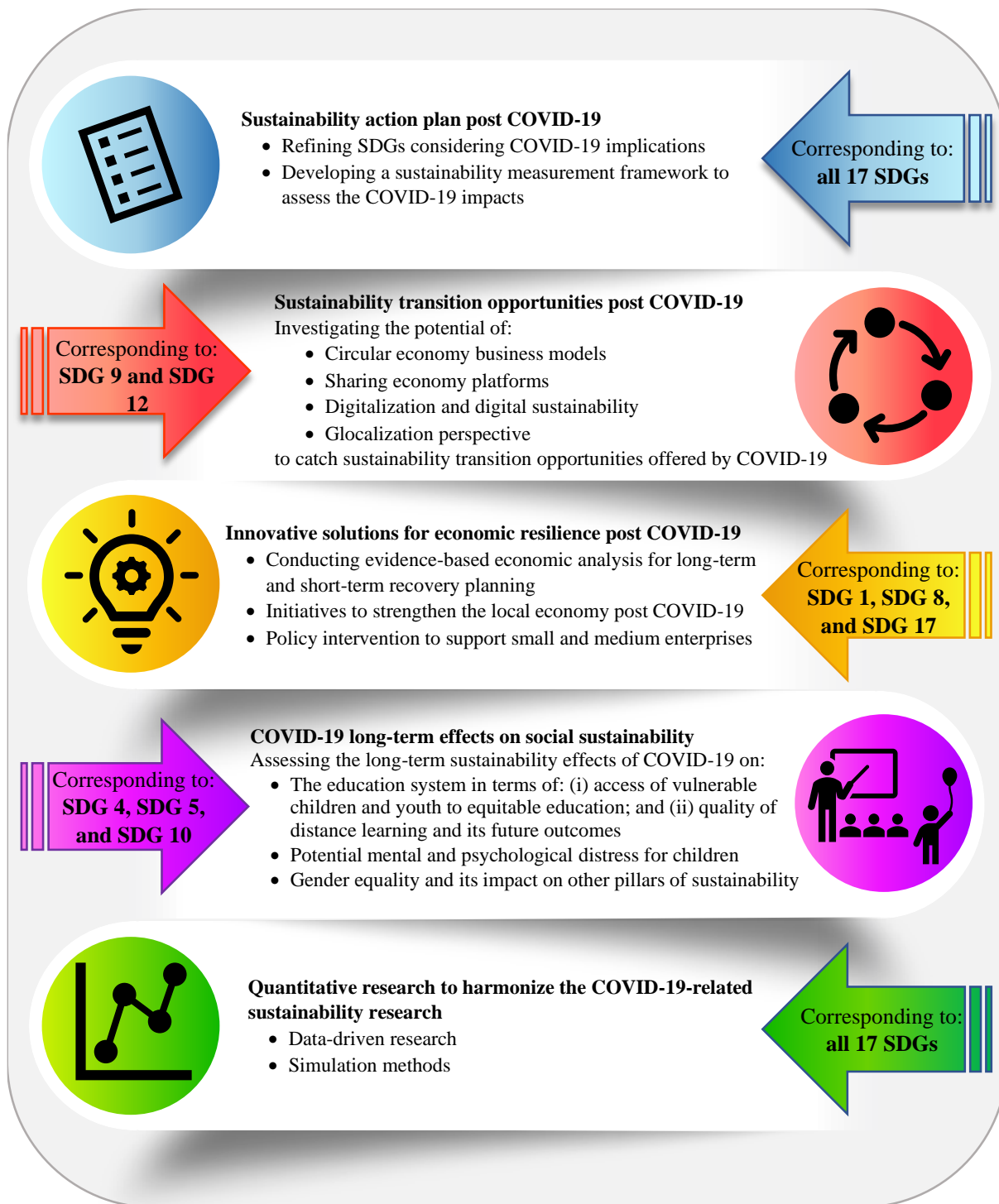
731 The COVID-19 pandemic implications deserve to be addressed as a subject of sustainable  
732 energy transition policy by energy policy-makers. Kuzemko et al. (2020) outlined the potential  
733 of COVID-19, as a driver of the sustainable energy transition, to shape the sustainable energy  
734 demand,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

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

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

758 Our systematic review showed the need for an update of the sustainability research agenda  
759 after COVID-19. Based on the results of the present review, considering the challenges to  
760 sustainability before COVID-19 and also the recently created challenges by COVID-19, research  
761 gaps are identified and summarized in this section, and the research avenues to fill them are  
762 proposed. Although sustainability before COVID-19 was facing challenges such as  
763 environmental concerns, the education system involvement in sustainability practices, mobilizing  
764 financing and investments towards SDGs achievement, and public health crisis arising from  
765 healthcare pollution, the COVID-19 pandemic has intensified those challenges. In the other  
766 hand, COVID-19 restrictions have led to new challenges for different dimensions of  
767 sustainability practices and sustainable development in the future. The research avenues  
768 identified herein call for: (1) sustainability action plan considering COVID-19 implications:  
769 refining sustainability goals and targets and developing a measurement framework; (2) making  
770 the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12  
771 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post COVID-  
772 19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-term  
773 effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding  
774 quantitative research to harmonize the COVID-19-related sustainability research. Fig. 9

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



777

778

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

779 **4.1. Sustainability action plan considering COVID-19 implications: refining sustainability**  
780 **goals and targets and developing a measurement framework**

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

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

797 **4.2. Making the most of sustainability transition opportunities in the wake of COVID-19:**  
798 **focus on SDG 12 and SDG 9**

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

809 2018), digitalization and digital sustainability (Pan and Zhang, 2020), and glocalization  
810 perspectives (Goffman, 2020) in increasing the resilience of the communities and mitigating the  
811 COVID-19 disruptive effects on sustainability in future. Moreover, the role of innovation and  
812 initiatives is significantly important to help sustainability policy-makers post COVID-19.  
813 Therefore, we recommend to seek new insight into fostering innovation processes and research  
814 and development units in a real world for building a resilient infrastructure and domestic  
815 technology development to support SDG 9 achievement.

#### 816 **4.3. Innovative solutions for economic resilience towards sustainability post COVID-19:** 817 **focus on SDG 1, SDG 8, and SDG 17**

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

828 This challenge is even more critical in developing and specially less developed countries,  
829 which are more financially vulnerable. The achievement of SDG 8 and also SDG 1 (no poverty)  
830 has hardly been influenced by the COVID-19 implications. The global partnership among the  
831 countries (SDG 17) to achieve UN's SDGs was taking place among various countries before the  
832 pandemic, and the aid to least-developed countries and Africa in 2019 experienced an increase of  
833 2.6% and 1.3%, respectively, compared with the year 2018 (UN, 2020d). However, it is  
834 estimated that the 554 billion dollars of remittances to low- and middle-income countries in 2019  
835 would decrease to 445 billion dollars in 2020, and the global foreign investment falls by up to  
836 40% in 2020 due to the pandemic (UN, 2020d). Therefore, although almost all countries are  
837 facing serious health and economic challenges in their own territories because of the pandemic,  
838 investigating practical solutions to support the partnerships specified in SDG 17 post COVID-19

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

#### 841 **4.4. In-depth analysis of the COVID-19 long-term effects on social sustainability: focus on** 842 **SDG 4, SDG 5, and SDG 10**

843 In general, social sustainability has not been paid as much attention as economic and  
844 environmental sustainability (Govindan et al., 2021; Yawar and Seuring, 2017). Besides,  
845 according to the research conducted by Anisul Huq et al. (2014), most social sustainability  
846 research has been conducted within the developed countries context rather than less-developed or  
847 even developing countries. However, the social pillar was identified by Barreiro-Gen et al.  
848 (2020) as the main sustainability priority for organizations among three sustainability pillars  
849 aftermath of the COVID-19 pandemic crisis. Additionally, in the instability caused by COVID-  
850 19, social pillar pushes environmental and economic pillars back based on the hierarchy of needs  
851 (Rydzewski, 2020).

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

869 government in pandemic-related leadership roles, they are at the front lines of fighting COVID-  
870 19 and represent 70% of the health and social workers during the pandemic period (UN, 2020e).  
871 Such inequality requires extensive studies to evaluate its outcomes and the prospective effect on  
872 the sustainability of societies.

#### 873 **4.5. Expanding quantitative research to harmonize COVID-19-related sustainability** 874 **research**

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

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

## 896 5. Conclusion

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

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

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