Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Sustainable development goals under threat? Multidimensional impact of COVID-19 on our planet and society outweigh short term global pollution reduction

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ABSTRACT

The Sustainable Development Goals (SDGs) call on all nations to accomplish 17 broad global development goals by 2030. However, the COVID-19 pandemic presents a challenging period in human history, causing large-scale impacts on society and the environment as governments shift priorities and divert funding in response to this pandemic. Through a literature survey and data acquirement from various international organizations (e.g. United Nations and European Space Agency), this manuscript is intended to provide critical insights into the impacts of the COVID-19 pandemic on the SDGs. We briefly describe this pandemic's positive and short-term effects on the environment, followed by a critical evaluation of its potential long-term impacts on the environment, society, and the SDGs. On the basis of COVID-19 effects, the SDGs are classified into three categories: directly-affected SDGs, indirectly-affected SDGs, and a stand-alone category. The COVID-19-induced lockdowns and restrictions resulted in a short-term decline in environmental pollution and greenhouse gases (GHG) emissions, providing valuable data for climate advocates and researchers. These positive impacts were essentially temporary due to the synchronized global response to the pandemic. The halted focus on the progress of the SDGs greatly impacts the global green transition to a healthy and sustainable world. COVID-19 threatens to impede the progress toward a prosperous, environment-friendly, and sustainable global development in multiple ways. These multi-dimensional threats have been critically evaluated, along with a description of potential solutions to curtail the adverse effects of COVID-19 on the SDGs. Considering the limited data regarding the impacts of the pandemic on the SDGs, diverse collaborative studies at the regional and global levels are recommended.

1. Introduction

The United Nations adopted the 2030 Agenda for Sustainable Development in 2015, which included 17 sustainable development goals (SDGs) (see Fig. 1). These 17 SDGs include no poverty (SDG1), zero hunger (SDG2), good health & well-being (SDG3), quality education (SDG4), gender quality (SDG5), clean water & sanitation (SDG6), affordable & clean energy (SDG7), decent work & economic growth (SDG8), industry, innovation & infrastructure (SDG9), reduced inequalities (SDG10), sustainable cities & communities (SDG11), responsible consumption & production (SDG12), climate action (SDG13), life below water (SDG14), life on land (SDG15), peace, justice & strong institutions (SDG16), and partnerships for the goals (SDG17). These goals aimed to set forth a global call to strive toward sustainable development

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for current and future generations by 2030 (Shulla et al., 2021a). However, with the onset and continued impact of the COVID-19 pandemic causing widespread health and economic disruptions, the achievement of the goals could be derailed or delayed due to shifts in governments' priorities, widespread restrictions, and spillover effects in response to COVID-19. An emerging trend in the literature has begun showcasing the impact of COVID-19 on one or multiple SDGs (Fenner & Cernev, 2021). For example, researchers highlighted the interdependencies of SDGs during COVID-19 (Shulla et al., 2021b), governments' policy aspects regarding SDGs in the post-COVID-19 era (Cheng et al., 2021), and challenges for SDGs in low-income countries (Nhamo et al., 2020). The potential impacts of COVID-19 on energy consumption (Nundy et al., 2021; Zhang et al., 2021), economy and transport (Nundy et al., 2021), and agriculture, environment and energy sectors were also described. Recent editorials and viewpoints also stressed the COVID-19 impact on SDGs and advocated for in-depth research (Barbier & Burgess, 2020; Lancet & Health, 2020; Naidoo & Fisher, 2020; Oldekop et al., 2020). However, a comprehensive and thorough look into the short- as well as long-term effects of COVID-19 on 17 SDGs seems necessary, which constitutes the main objective of this manuscript. This becomes crucial as even prior to the pandemic, countries were lagging behind in achieving the SDGs. It has been projected that 28 countries (generally developing) are likely to miss nine of the human development-related targets (SDGs 1–4, 6, and 7) set for 2030 (Moyer & Hedden, 2020), with global governments predicting a shortfall of $2.5 trillion prior to the COVID-19 pandemic (Shulla et al., 2021a). It stands to reason that the unprecedented and ongoing circumstances resulting from the global impact of COVID-19 (e.g., economic fallout, lockdown, and business shutdowns) will likely further affect the commitments and weaken the general strategy to accomplish the SDGs, such as health, education, zero poverty, sustainable growth, safe environment, and climate (conceptual diagram - Fig. 1). Here, we provide an impartial overview of both the adverse and beneficial outcomes of COVID-19 on the environment, society, and the SDGs, contrasting the predominantly positive narrative in the literature during the initial pandemic period (Fig. 1).

1.1. Literature survey on sustainable development goals

Although comprehensive and detailed studies of COVID-19's impact on SDGs are rare, efforts have been made to collect data from articles referring to the themes of the SDG. Google Scholar, Web of Science, ScienceDirect and websites of various international organizations, including but not limited to United Nations Development Programme (UNDP), World Meteorological Organization (WMO), Centers for Disease Control and Prevention (CDC), World Bank (WB), World Economic Forum (WEF), and European Space Agency (ESA) were searched to provide an extensive overview of published material on the subject matter. The following search parameters assisted in finding the required literature: "COVID-19 and sustainable development goals" during the initial survey, after which other combinations of keywords and synonyms for COVID-19 (i.e., coronavirus or pandemic or SARS-CoV-2) and sustainability (SDGs or sustainable) were utilized as also suggested in a previous study (Ranjbari et al., 2021). Every SDG (from 1 to 17) was individually searched to ascertain the impact on the SDG from COVID-19. Provided below is a brief description of the obtained findings.

2. Short-term positive impacts of COVID-19 on the environment

One of the first and most prominent outcomes of the global restrictions was the distinguishable decline in hazardous greenhouse gases (GHG), including aerosols, nitrogen oxides, carbon dioxide, particulate matter, and various harmful chemicals (Gillingham et al., 2020; Mostafa et al., 2021; Singh & Mishra, 2021). Nitrogen dioxide (NO_2) data collected from the Sentinel-5 satellite of the European Space Agency (ESA) revealed substantial variations in pollution levels before, during, and after lockdowns were imposed during this pandemic. Concentrations are much higher in December 2019 than in February 2020 over China (Fig. 2a), while concentrations over Europe from March to April 2019 were higher than in the corresponding period in 2020 (Fig. 2b). Mean NO_2 levels decreased by approximately 54%, 48%, 47%, and 49%, in Paris, Madrid, Milan, and Rome, respectively (ESA, 2020) (Fig. 2b and S1). The Egyptian cities of Cairo and Alexandria experienced a decline of 15% and 33% in NO_2, respectively (Mostafa et al., 2021). In general, the restrictions reduced nitrous oxide emissions by 20–30% in China (Iman

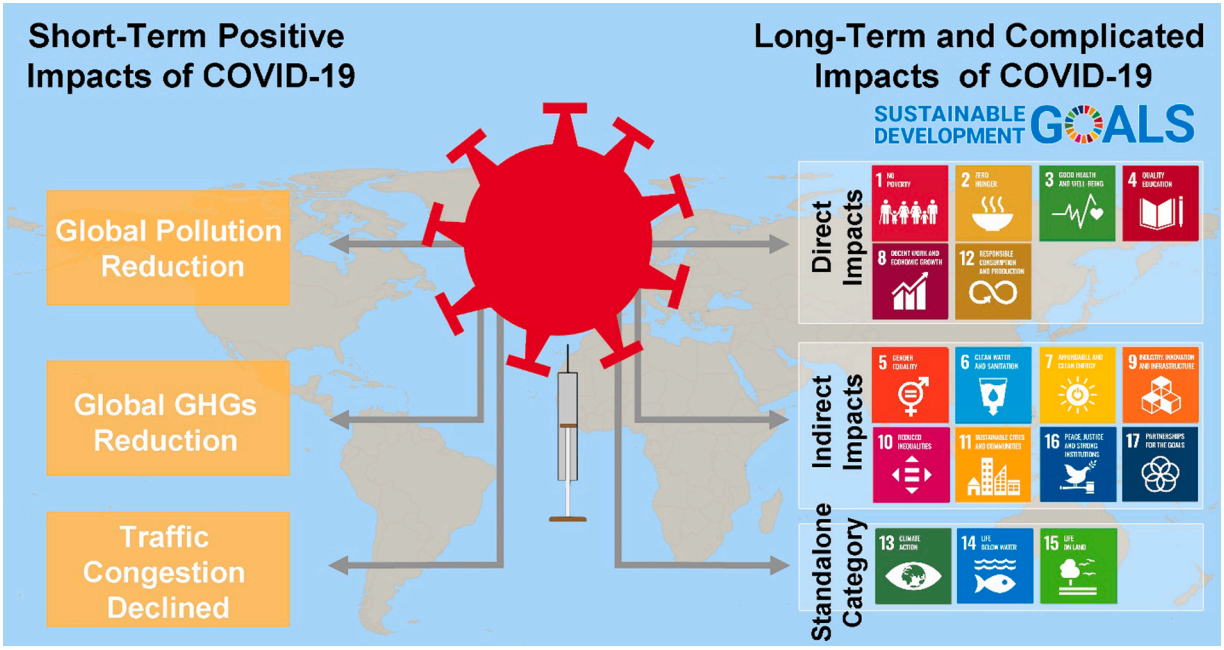

Fig. 1. Conceptualized diagram showing the 17 SDGs as impacted by the COVID-19 in three categories. SDGs-icons are reproduced from UN-website (UN-SDGs).

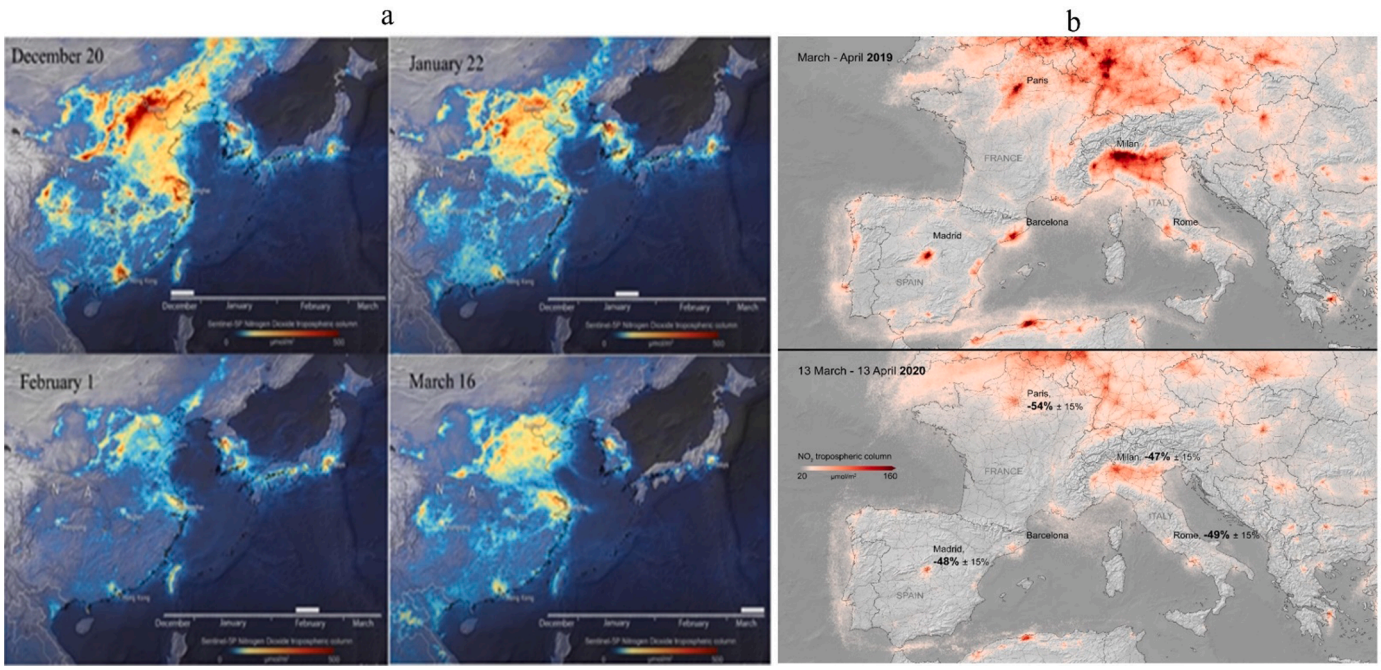

Fig. 2. Changes of NO_2 concentrations during COVID-19 in troposphere across (a) China and (b) European countries (bottom image shows lockdown and upper image shows pre COVID-19 scenario). Data from Sentinel-5 satellite of European Space Agency (European Space Agency, 2020). Pollution decreased during lockdown periods. Darker colors show higher pollution levels, and light colors show declining pollution notably during lockdown.

Ghosh, 2020; Mousazadeh et al., 2021).

Daily global carbon dioxide (CO_2) emissions between April 2019 and 2020 declined by 17% (Le Quéré et al., 2020), while global CO_2 emissions dropped by 5.8% in total in 2020 according to the International Energy Agency (International Energy Agency: IEA, 2021). Levels of sulfur dioxide (SO_2) in the atmosphere were also reportedly reduced globally. For example, a study conducted in Salé City, Morocco, reported a 49% decline in the concentrations of SO_2 during lockdown (Otmani et al., 2020). Similarly, a decrease of up to 800–900 million metric tons in SO_2 concentrations was noticed during the lockdown in European countries (Shaikh et al., 2020). A similar trend was also reported in the Middle East, as depicted by the decrease in the concentration of SO_2 from 8.7 to 30% in the Eastern Provinces of Saudi Arabia (Anil & Alagha, 2021). Mega studies indicated a general drop in SO_2 levels across the globe including China, India, Europe and USA (Fu, Purvis-Roberts, & Williams, 2020; Sokhi et al., 2021). As determined by the absorbing aerosols index (AAI), elevated absorbing aerosols over Egypt declined by almost 30%, with GHG emissions dropping by at least 4% (Mostafa et al., 2021). Similarly, levels of $PM_{2.5}$ and PM_{10} were reduced by about 30% and 14%, respectively in Lublin, Poland (Polednik, 2021). About a 12% reduction in air pollution was noted across 50 capital cities (Rodríguez-Urrego & Rodríguez-Urrego, 2020). Several of the most polluted capitals, namely Dhaka, Kampala, Delhi, Kuwait City, and Bogotá, showed about 14%, 35%, 40%, 42%, and 57% reduction in $PM_{2.5}$, respectively (Rodríguez-Urrego & Rodríguez-Urrego, 2020). An Indian focused study also revealed a substantial reduction in $PM_{2.5}$ in Chennai (19–43%), Delhi (41–53%), Hyderabad (26–54%), Kolkata (24–36%), and Mumbai (10–39%) (Kumar et al., 2020).

This decrease in air pollution has been linked to COVID-19 triggered lockdowns. For example, in March and April 2020, global coal demand fell by 8% compared to 2019 due to lockdowns and shut down of economic activities (e.g., factories and workstations). Countries like Italy, India, Germany, and the United States (US) experienced a 30% drop in demand and a 12–20% drop in France, Germany, Spain, India, and the United Kingdom (Mousazadeh et al., 2021). In South Africa, the power utility Eskom experienced a break-in electricity demand due to stay-at-home regulations and economic slowdown (Andrade et al., 2020). Essentially, government policies and the economic downtown induced by COVID-19 during the initial first wave of the pandemic reduced the demand for fossil fuels and natural gas (Bertram et al., 2021; Le Quéré et al., 2020; Li et al., 2022). Additionally, traffic congestion improved globally, leading to positive outcomes in air quality (Chen et al., 2021; Polednik, 2021; Shakibaei et al., 2021). The reduction in traffic and economic activity translated to a 60% decline in noise pollution in Dublin, Ireland (Basu et al., 2021). Noise levels in three Boston, USA, urban protected areas were measured before, during, and after emerging from COVID-19 lockdown, which revealed lower noise levels occurred at two of the parks due to less traffic (Terry et al., 2021). Similar declines in urban noise levels have been reported in various locations globally, for example, in Stockholm, Sweden (Rumpler et al., 2020), Rio de Janeiro, Brazil (Gevú et al., 2021), and Barcelona, Spain (Bonet-Solà et al., 2021). COVID-19 also led to months-long reduction in seismic noise, providing a valuable window for researchers to detect subtle signals from subsurface seismic sources and make benchmark limits of anthropogenic sounds (Lecocq et al., 2020).

Global water pollution also declined, likely due to the decrease in industrial and agricultural activities as reported in heavily populated countries like China (Shen et al., 2021), India (Singh & Mishra, 2021), and Pakistan (Shafeeque et al., 2021). Globally, the period of COVID-19 restrictions also provided relief (reducing litter, and plastic pollution) to various water bodies, including the coastal areas of Ecuador (Ormaza--Gonzaìlez et al., 2021), Damodar River (Chakraborty et al., 2021), and Vembanad Lake, India (longest lake in India) (Yunus et al., 2020), Kenyan recreational beaches (Shafeeque et al., 2021), and the west coast of Tangier, Morocco (Cherif et al., 2020). Thus, as outlined above and showcased in recent research, many positive environmental impacts were recorded during the initial phase of strict government regulations.

3. The long-term impact of COVID-19 and how they relate to the SDGs

As shown in Fig. 1, the SDGs are categorized into three broad groups according to the impacts of COVID-19 on them including (i) SDGs that are directly affected (ii) SDGs that are indirectly affected and (iii)

standalone SDGs. Provided below is a brief description of these impacts and possible solutions and guidance for global government investment.

3.1. SDGs that are directly affected

The SDGs most likely to be directly affected by COVID-19 are SDG1 (no poverty), SDG2 (zero hunger), SDG3 (good health & wellbeing), SDG4 (quality education), SDG8 (decent work & economic growth) and SDG12 (responsible consumption & production) as illustrated below.

SDG1-No Poverty, SDG2-Zero Hunger, SDG3-Good Health & Well-being, SDG4-Quality Education: Different scenarios have been proposed in a recent study for COVID-19′s impact on global poverty. In the worst-case scenario, 251 million people may be forced into extreme poverty (Fig. S2) (United Nations Development Programme, 2021b). World poverty is expected to rise, from 17.1 to 25.9% for the first time since 1990 (Sumner, Hoy, & Ortiz-Juarez, 2020), as already noted in Indonesia, where poverty may reach 16.6% (Suryahadi et al., 2020). According to a recent World Bank Report, COVID-19 can push 150 million people to extreme poverty (The World Bank, 2021a). This trend will have a causal consequence in achieving zero hunger (SDG2), poverty coupled with the experienced disruptions in global food supply lines could push impoverished and conflict-affected countries into further distress, as witnessed in Yemen (United Nations Development Programme, 2021a).

The pandemic has directly impacted all aspects of human health (SDG3). Progress in the health sector was slowed or halted as the focus of governments shifted to alleviating COVID-19 and future precautionary measures. Awareness campaigns, control, and vaccinations against other diseases (e.g., HIV/AIDS, malaria, and polio in some countries) have also been disrupted (Din et al., 2020; Karim & Karim, 2020). In many instances, the global use of antibiotics, such as azithromycin, doxycycline, clarithromycineven, etc., is reaching new heights (Adebisi et al., 2021), even though antibiotics are ineffective against viral infection. According to a meta-analysis, antibiotics were given to about 75% of COVID-19 patients, although only 8% had a bacterial co-infection (Langford et al., 2020). Overuse and misuse of antibiotics are likely to increase the health burden in already struggling communities. Additionally, a study in Pakistan revealed that the lockdown-related economic recession and fear of infection were contributing factors to mental distress and suicides (Mamun & Ullah, 2020), which is likely to be a global trend.

A government's ability to prepare for the future is based on national census and data collection; however, delays have been experienced in 42% of countries (IISD-SDGs Knowledge Hub, 2021), adding further burdens in managing the economy, jobs, health, and diverse array of challenges. Globally, educational institutions, universities, and schools have been fully or partially closed (Fig. 3), with education (SDG4) being digitalized, ostracizing low-income families who are unable to afford digital devices or a stable internet connection. This situation could be worse in villages and remote areas where electricity or the internet is not stable. It is estimated that around 1.25 billion pupils are missing out on formal education (Shulla et al., 2021a).

SDG8, Decent Work & Economic Growth: The world economy has reportedly shrunk by 13–32% due to the pandemic (Mousazadeh et al., 2021). However, the country-specific impacts of COVID-19 is determined by regional economic resilience, government policies, and local characteristics. As the initial epicentre of the outbreak, China reported a 6.8% drop in GDP in the first quarter of 2020 (National Bureau of Statistics of China, 2022), while 2.2 million jobs were lost in the second quarter of 2020 in South Africa (Isilow, 2020). Pandemic-related job loss is expected to rise in the range of 255 million full-time employed personnel (IISD-SDGs Knowledge Hub, 2021), with developing countries likely to be more susceptible, as the daily-wager, immigrant workers, and underprivileged form a greater foundation of the population. COVID-19 related research and funding have seen an increasing trend (Chinnery et al., 2021), and oppositely, other research sectors suffered (Bailey et al., 2020).

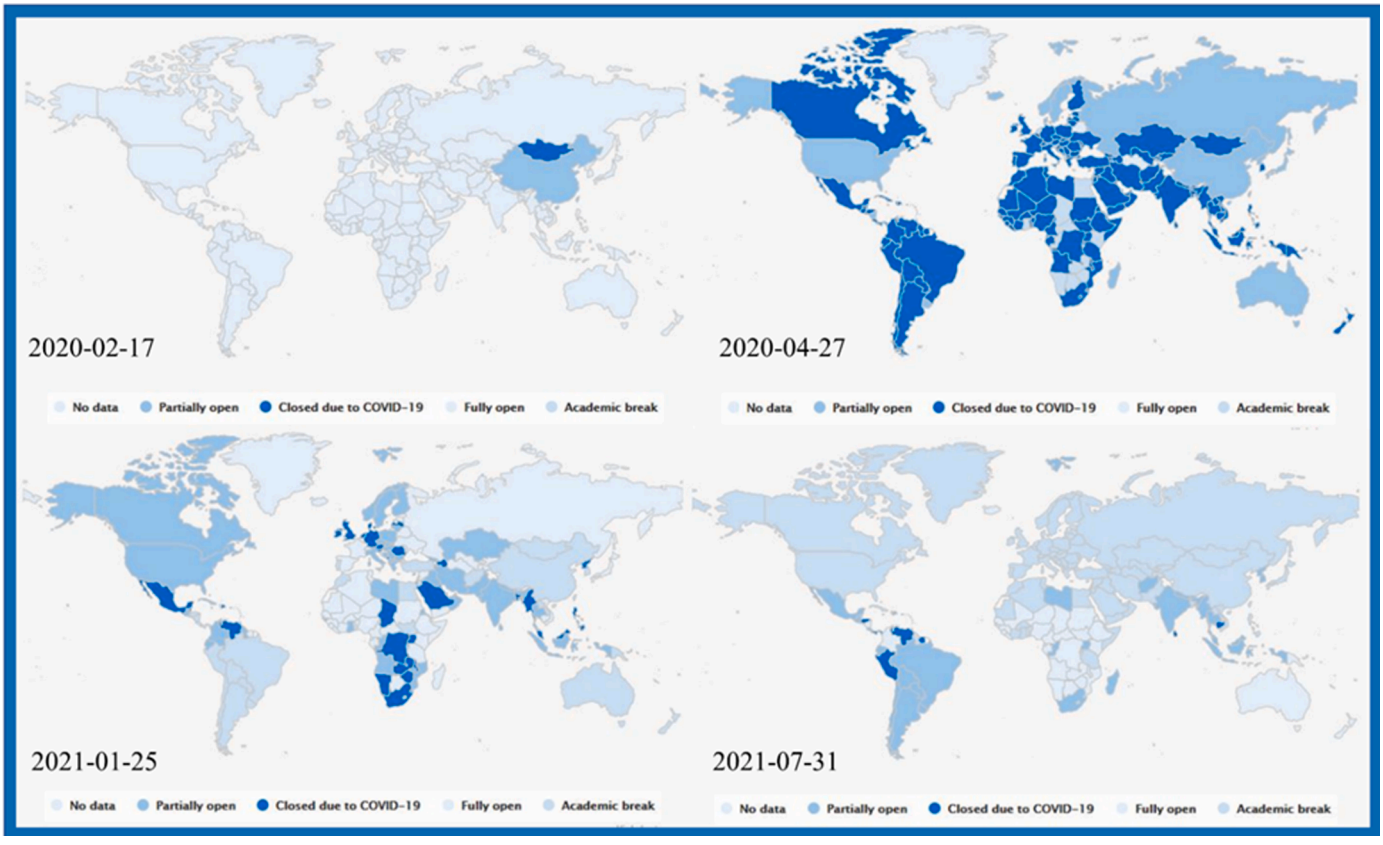

Fig. 3. Time series map of COVID-19 impact on school closures globally (UNESCO, 2022).

SDG12, Responsible Consumption & Production: Sustainable consumption and production are generally about achieving better with less. During the pandemic, SDG12 received mixed execution. Overseas travel declined dramatically, reducing consumption and decarbonizing the global economy (Perkins et al., 2021). Conversely, fear of illness and death fuelled panic buying and stockpiling, coupled with greater frequency in-home delivery, and thus packaging increased as a consequence of the stay-at-home policy. The pandemic also impacted product supply chains; for example, increased medical products led to a scarcity of medicine stockpiles. Contrarily, the greater need for personal protective wear and health sector paraphernalia resulted in a dramatic increase in the production and distribution of gloves, face masks, dressing materials, disposable PPE kits, and other biomedical materials (Zambrano-Monserrate et al., 2020). Sustainable consumption and production can be optimized by respecting the planet's biophysical boundaries and lowering global consumption rates.

3.2. SDGs that are indirectly affected

Some SDGs, including SDG5 (gender equality), SDG6 (clean water & sanitation), SDG7 (affordable & clean energy), SDG9 (Industry, Innovation & Infrastructure), SDG10 (reduced inequalities), SDG11 (sustainable cities & communities), SDG16 (peace, justice & strong institutions), and SDG17 (partnerships for the goals), are indirectly impacted of COVID-19.

SDG5-Gender Equality and SDG10-Reduced Inequalities: Data is still emerging on the impact of COVID-19 on gender equality (SDG5). A clear bias is shown in job loss, as women had to prioritize family responsibilities and childcare (Carli, 2020). About 740 million women are predicted to work in informal employment to escape extreme poverty and are now at risk of relapsing (Burki, 2020). In addition to the loss of education, girls lose a haven to avoid early marriage, female genital mutilation (Burki, 2020), and a sense of self-empowerment, due to school closures (Fig. 3), especially in developing countries. Gender-based violence has alarmingly increased during COVID-19 (Robinson, 2021).

The infectious nature of COVID-19 has led some to dub the pandemic a "great equalizer", a systemic disadvantage that prevents virtually everyone from participating in the economy regardless of social status (Qian & Fan, 2020). Conversely, evidence suggests that the COVID-19 pandemic has a greater impact on vulnerable populations, exacerbating pre-existing social inequalities (Bhaskar et al., 2020) and socio-economic conditions within and between countries (Qian & Fan, 2020). Therefore, instead of being a great equalizer, the pandemic may deepen the existing social and economic inequalities, which have disproportionately impacted vulnerable groups, such as daily wagers, immigrants, minorities, and ethnic groups.

SDG6-Clean Water and Sanitation: Safe drinking water is a basic human right; however, nearly 2 billion people do not have access to it, while 3.6 billion do not have access to safe sanitation (United Nations Report, 2021). Globally, progress on integrated management of water resources needs to be doubled as 129 countries may fail to attain sustainable management of water resources in the 2030 timeframe, although globally integrated water resource management increased from 49% in 2017 to 54% in 2020 (United Nations Report, 2021). The expenditures in this sector are likely to be postponed as governments prioritize the containment of the pandemic and rebuilding the economy (IISD-SDGs Knowledge Hub, 2021; United Nations Report, 2021).

SDG7-Affordable and Clean Energy: The indirect impact of COVID-19 on investments and shifts in priorities may hinder the progress of electricity distribution, an amenity 759 million people are currently without (United Nations Report, 2021). For example, the pandemic has left over 25 million people in Africa and Asia without power due to the rise in poverty and unemployment, with many unable to bear the cost of living (Yi, 2021). Gillingham reported that delayed investments in renewable electricity by even a year can outweigh the emissions reduction observed during COVID-19 (Gillingham et al., 2020), compelling the International Energy Agency and the International Renewable Energy Agency to urge for sustained funding into renewable energy.

SDG9-Industry, Innovation & Infrastructure; SDG11-Sustainable Cities & Communities: Investing in the green industry, technology, innovation, and resilient infrastructures are critical for economic growth, reducing pollution, combating climate change, creating jobs, ensuring social stability, and guaranteeing sustainable cities for current and future generations. Due to tariffs and trade tensions, global manufacturing growth slowed even prior to the pandemic. During the COVID-19 era, manufacturing enterprises were heavily hit and continue to be, causing value chains and product supply chain interruptions. Infrastructure needs will have to increase in response to rapid urbanization and COVID-linked homelessness, which may lead to slum dwellers, insufficient and overcrowded infrastructure, garbage overloads, sanitation, transportation, pollution, and unplanned urban sprawl. Implementing proposed measures in overcrowded areas is complicated, especially in developing countries. According to a UN-report, the number of researchers increased from 1022 (2010) to 1235 (2018) per million people globally (United Nations Report, 2021).

Generally, the Research and Development (R&D) budget represented ~1.7% and ~1% of the GDP for developed and developing countries, respectively, prior pandemic (IISD-SDGs Knowledge Hub, 2021; The World Bank, 2021b); hence investments in SDG9 and SDG11 may be considerably impacted due to the economic downturn and shifting of priorities.

SDG16, Peace, Justice, and Strong Institutions: Global reports suggest that COVID-19 has accelerated human rights violations (Aborisade, 2021; Heimer et al., 2020; Odigbo et al., 2021), injustice (Bhaskar et al., 2020), interpersonal violence and sexual abuse (Mazza et al., 2020), food insecurity, and social injustice (Odunitan-Wayas et al., 2021). The pandemic has put enormous strain on the relationship between the state and citizens owing to the introduction of strict regulations (e.g., lockdowns, masks, and social distancing) to prevent the spread of COVID-19. Justice systems worldwide were unprepared and ill-equipped to deal with the situation. Global calls for restriction and lockdowns ultimately led to court closures and the suspension of legal aid, resulting in many legal issues (Castelliano et al., 2021; Hotopf et al., 2020). In an attempt to overcome these issues, courts are being convened virtually to meet with current needs (Rossner et al., 2021). According to descriptive data, levels of violence remained either unchanged or increased during the first five months of the pandemic, and COVID-19-related societal unrest extended outside conflict-affected regions (Polo, 2020). Democracy and human rights in 80 countries have deteriorated since the outbreak of COVID-19 (Parry et al., 2021; Sarah Repucci, 2020). In many cases, governments have reacted by abusing their power, intimidating critics, and weakening or closing critical institutions (Sarah Repucci, 2020). The excessive use of force, police surveillance, and limited economic opportunities may have subjected the less privileged communities, minorities, and individuals to greater consequences. COVID-19 is likely to disrupt global governance structures and processes, which may lead to increasing economic nationalism and authoritarianism (Levy, 2020).

SDG17, Partnerships for The Goals: The success of the SDGs is dependant on collective global human efforts. Consequently, active international collaboration and partnership are essential for the inclusive achievement of the SDGs to which SDG17 is based. The pandemic has had an impact on how international collaboration is realized. An enhancement in anti-globalization sentiment is comprehensible in the midst of a pandemic in which every country is focused on national interests to contain the virus spread (Norma et al., 2020). Notwithstanding, the contraction of the global economy makes strong international cooperation more important than ever. Most developing countries lack the required domestic resources and fiscal liberty to implement adequate COVID-19 response and recovery measures. Therefore, developing countries need assistance in dealing with

pandemics and managing their economies.

3.3. Standalone category of SDGs

The standalone or independent SDGs benefitted from government implemented COVID-19 regulations (see Section 2), namely SDG13 (climate action), SDG14 (life below water), and SDG15 (life on land). The short-term positive relief does not invalidate sustainable development and a safe environment on a larger scale or bigger picture.

SDG13-Climate Action: Lockdowns and restrictions lead to reduced pollution (including GHGs emissions), which positively impacts climate change (Figs. 2 and Fig. S1). On the other hand, data collection for climate prediction and observations was temporarily suspended. The World Meteorological Organization (WMO) reported that the COVID-19 epidemic had a major impact on land-based, marine, and air observing systems, compromising forecasting and climate services quality (World Meteorological Organization, 2021). Post-COVID, it is highly probable that the workforce and related activities will resume or escalate their pace to balance or compensate for the losses experienced during the pandemic season. As indicated in Fig. 4, the potentially elevated recovery pace and high production rates will negate or likely outweigh the pollution and GHGs reduction achieved during the initial stages of lockdown. The sudden drop in air pollutants (Fig. 4), energy use (material uses), and greenhouse gaseous emission (GHGs) in 2020 provided valuable data for future recovery projections. Environmental indicators, primarily related to energy use (GHGs, air pollutants, and fossil fuels), experienced a 7–8% drop in 2020, followed by a slow rebound of 2–3% below the pre-COVID baseline. The agricultural sector or land use showed minimal change (Fig. 4). CO_2 emissions will start to rise as the global economy gains momentum, e.g., CO_2 concentration rose by about 2% in December 2020 as compared to 2019 (Organisation for Economic Co-operation and Development 2021).

Undoubtedly, we are already in a climate emergency and striving to reduce global GHG emissions by adhering to the SDGs and the Paris Climate Agreement. In the last century, sufficient GHG emissions have locked the planet into a certain future of global warming (Park et al., 2018). The US National Oceanic and Atmospheric Administration report indicated a surge in methane (CH_4) concentration (14.7 ppb per annum) in the atmosphere despite the global economic slowdown in 2020 (Climate & Clean Air Coalition, 2021; National Oceanic and Atmospheric Administration, N 2021. The latest Emissions Gap Report 2021 (United Nations-Environment Programme, 2021) warned that new

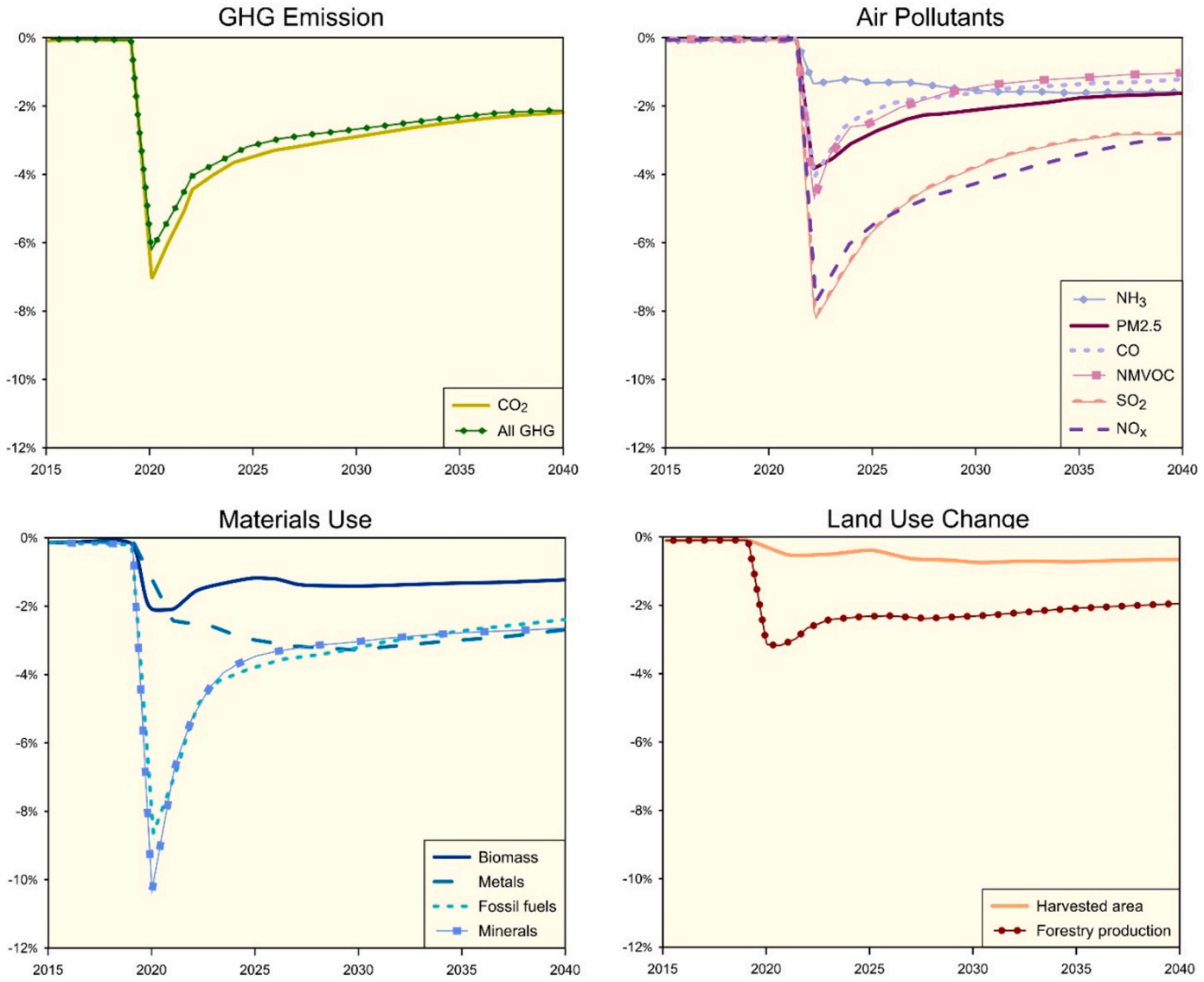

Fig. 4. . Projections of greenhouse gases (GHGs) emission, air pollutants, material use and land-use changes from 2020 to 2040, Env-Linkage Model (OECD, 2021). Data indicate a sudden drop in GHGs, energy use, and air pollutants in 2020 and potentially bounce back to the pre- COVID-19 level. Change in land use was minimal.

national climate pledges and mitigation strategies will lead to a global temperature rise of 2.7 °C by the end of the century. This is well beyond the Paris Climate Agreement goal and may lead to disastrous changes to the earth's natural systems (United Nations Environment Programme, 2021). Moreover, several recent studies indicate that the short-lived COVID-19 environmental effects are unlikely to provide a lasting impact on climate change (Forster et al., 2020; Weber et al., 2020). All above-stated reports and studies show that the world is running out of time to stop the global temperature rise from reaching a catastrophic level.

Efforts are needed to reduce GHG emissions, this can be achieved by implementing the SDGs, ultimately keeping global warming to below 1.5 °C. Therefore, the short-term lockdowns aimed at controlling COVID-19 are of no substitute for the long-term climate action required to accomplish the Paris Agreement while concurrently encouraging global economic growth (IISD-SDGs Knowledge Hub, 2021).

SDG14, Life Below Water, and SDG15-Life on Land: Similar to climate change, an indirect positive influence was observed on the SDG14 and SDG15 during the first few months into the pandemic. Globally, an apparent reduction in air, water, soil, and noise pollution occurred, as outlined in Section 2 (Lokhandwala & Gautam, 2020; Mousazadeh et al., 2021). However, production rates of key items (see SDG12) resulted in millions of discarded single-use plastics (e.g., PPE and sanitizer bottles) most of which entered the environment, due in part to waste management and recycling facilities being partially shut down or operating at reduced capacity (Benson, Bassey, & Palanisami, 2021; Zambrano-Monserrate et al., 2020). Waste generated due to the pandemic, particularly plastics, will have detrimental effects on the environment and humans for many years to come. The slow degradation of plastic into micro (nano) plastic may lead to land, water, and air pollution, posing ecological and health risks. Thus, the short-term improvements in environmental conditions should be seen as temporary and may rapidly be offset by the negative environmental trends previously documented.

3.3.1. Biological consequences

Disinfectants and sanitizers, which had increased distribution to act as a safeguard against the spread, have entered the environment through such methods as surface runoff. Antibiotics, which were widely administered (per Section 3.1), are only partially metabolized, resulting in a greater degree of antibiotic-infused sewerage effluent. Only about 20–30% of this infused effluent is removed by conventional wastewater treatment plants (Kovalova et al., 2012). The increased solvent load can lead to a higher release of antibiotics and disinfectants into terrestrial and aquatic environments. Antibiotics are prone to bioaccumulation and transfer in the food web, threatening ecological and human health (Zhou et al., 2020). Antibiotics in the environment will not only impact the health and normal function of indigenous flora and fauna, but will also accelerate antibiotic-resistant genes (ARGs) or antibiotic-resistant bacteria (ARBs) (Kovalakova et al., 2020; Usman et al., 2020). Before COVID-19, ARGs infected at least 2.8 million people in the US each year, with more than 35,000 deaths (Centers for Disease Control and Prevention, 2021). Antibiotics, disinfectants, and consequently ARGs or ARBs, will threaten ecological and human health for many years to come.

3.3.2. Ecological consequences linked with economic burden

The unintended consequence on the global economy will heighten alternative methods for vulnerable communities to provide for themselves and their family. One option would be an urban outflux as people may seek opportunities away from cities, another may be the need to resort to criminal activities. A recent study showed that illegal forest resource extraction has increased globally (Brancalion et al., 2020). Deforestation increased by 63% in the America, 136% in Africa, and 63% in Asia-Pacific since COVID-19 started (Brancalion et al., 2020). The Global Land Analysis and Discovery (GLAD) laboratory recorded a total area loss of 9583 km^2 possibly linked to deforestation across the global tropics during the first months of the COVID-19 restrictions - approximately double the 4732 km^2 reported in 2019 (Brancalion et al., 2020). This trend of deforestation is also impacting the achievement of SDG15.

4. Solutions

The global investment required to recover from COVID-19 is estimated to be $20 trillion (Shulla et al., 2021a). The decisions made on how this money is invested will have long-term impacts on future generations and will determine whether communities, some already struggling, become more sustainable, environmentally friendly, and resilient to future pandemics. Even before the pandemic, the world was off-track in achieving the SDGs within the 2030 timeframe. Therefore, attempts to tackle negative impacts on the climate, environment, and SDGs must be presented as a multifold solution varying from region to region according to local characteristics. The most heavily impacted SDGs should be prioritized for government concerns and investments such as health and well-being, poverty, hunger, quality education, and employment. Interdependence and interconnection of SDGs are noteworthy; investments in key areas of SDGs can provide relief to other related goals, too. Therefore, investments in clean energy, green industries, innovations, and sustainable cities are important, which can help generate employment, economic growth, revenue and ensure a safe environment for future generations. Global efforts to revive and recover economic growth is fundamental and rational, however not at the expense of the SDGs. Although cooperation between all nations is necessary to achieve common human goals, developing countries (especially Asia and Africa) are in serious need of cooperation and partnership in science, technology, education, green industries, and economy to assist in meeting the SDGs within the 2030 agenda. Some researchers have noted, that low- and middle-income countries may face a lack of international funding to achieve SDGs due to COVID-19 related economic loss, therefore developing nations also need to find innovative and smart ways to achieve multiple SDGs simultaneously (Barbier & Burgess, 2020). For example, governments need to form synergies across multiple SDGs concurrently, such as boosting economic activity, job creation, poverty reduction, environmental improvement, and health outcomes (Barbier & Burgess, 2020). Vulnerable communities, such as minorities, daily wagers, refugees, immigrants, and disadvantaged sectors of society, need special aid and a sensitive approach or a pro-poor strategy from government bodies. Societal issues aggravated by COVID-19 need reconsideration from relevant departments, including interpersonal violence, mental health, sexual abuse, social injustice, and human rights. As the development of SDGs is reinstated, global realignment of national priorities and commitments are essential toward the SDGs' long-term achievement.

5. Conclusion

The world's commitment in following and implementing the 17 SDGs for sustainable development and ensuring a safe environment for future generations has been significantly impacted by the unprecedented consequences of the pandemic. The initial global efforts of COVID-19 containment resulted in a sudden decrease in environmental pollution which has been explosively reported worldwide. The appeal of pollution reduction as presented by the COVID-19 era is likely a short-term environmental response, which is expected to diminish once economies return to normal activity post-COVID-19. The global vaccination campaign, being driven to achieve herd immunity, is inclined to hasten the economic recovery.

In this study, the 17 SDGs were divided into 3 categories based on the effects of COVID-19. Six SDGs (namely SDG 1, 2, 3, 4, 8, and 12) are directly impacted by COVID-19 due to direct economic fallout, loss of jobs, and closure of schools, whereas eight SDGs are indirectly impacted due to the spillover effect (namely SDG 5, 6, 7, 9, 10, 11, 16, and 17). An

independent or "stand-alone" category (included SDG 13, 14 and 15) experienced mixed outcomes from COVID-19. Here, the initial short-term positive impacts on climate change and pollution reduction (SDG 13–15) are considered as a brief respite with negative impacts on the spirit of achieving these goals being beyond the measure of view, as government priorities changed under the pressure of the pandemic. Brief episodes of relief in GHGs reduction are of no use to avert future catastrophic climate change (limit below 1.5 °C), and some gases, especially CH_4, have also seen a record surge despite the economic slowdown. It is important to note that CH_4 is considered about 28 times stronger than CO_2 in trapping heat in a 100-years time span (US EPA, 2021). Ultimately, SDG progress and investment have been slowed or reversed as global governments are already short of the necessary budget.

The world will likely see a greater acceleration in hunger, poverty, unemployment, health issues, exploitation of natural resources, deforestation, conflicts, human rights violations, injustice, authoritarianism, violence, and social unrest due to COVID-19. Investments and progress in climate change, environmental safety, clean energy, smart and sustainable cities, and green industries and technologies have either slowed or been suspended. Women's empowerment, education, and economic independence are disproportionately impacted compared to their male counterparts. The epidemic severely influenced the job market, with the most vulnerable communities being highly susceptible to hunger, social injustices, and inequality, especially in developing countries (e.g., South Africa, India, and Pakistan). Overall, COVID-19 has likely halted or delayed achieving SDGs by 2030. On a positive note, the pandemic taught us that no one is safe until everyone is safe; thus, the world should foster strong international partnerships to synchronously achieve the SDGs. Finally, this manuscript highlights that the negative impact of COVID-19 on the environment, society, and SDGs offsets the short-term reduction in environmental pollution.

6. Limitations of the study

The spread of COVID-19 is still ongoing despite the widespread vaccine campaign and relaxing restrictions. Therefore, scientific data on the global and regional scale and its impact on SDGs is limited and may not be fully revealed until years later. We suggest that future research should include more diverse data (global and regional) to provide the full spectrum of COVID-19 impacts on the SDGs, environment, and climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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