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Planetary health & COVID-19: A multi-perspective investigation

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ABSTRACT

COVID-19 can be characterized as an outcome of degraded planetary health drivers in complex systems and has wide-reaching implications in social, economic and environmental realms. To understand the drivers of planetary health that have influences of emergence and spread of COVID-19 and their implications for sustainability systems thinking and a narrative literature review are deployed. In particular, sixteen planetary health drivers are identified, i.e., population growth, climate change, agricultural intensification, urbanization, land use and land cover change, deforestation, biodiversity loss, globalization, wildlife trade, wet markets, non-planetary health diet, antimicrobial resistance, air pollution, water stress, poverty and weak governance. The implications of COVID-19 for planetary health are grouped in six categories: social, economic, environmental, technological, political, and public health. The implications for planetary health are then judged to see the impacts with respect to sustainable development goals (SDGs). The paper indicates that sustainable development goals are being hampered due to the planetary health implications of COVID-19.

1. Introduction

COVID-19 is a zoonotic disease [1,2] caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-Cov-2) [3], which is transmittable from animal to person and person to person [4–6]. In the short time since its presence has been observed, it has had an unprecedented impact on all aspects of the world's socio-ecological systems [7,8]. *All around the world, COVID-19 is being controlled and managed by guidelines such as those of the* World Health Organization (WHO) including identifying, testing, treating infected people and developing drugs, vaccines and treatment protocols [9,10]. Nevertheless, in the short time since its presence has been observed, it has had an unprecedented impact on all aspects of the world's socio-ecological systems.

Throughout its history, human civilization has observed a significant number of deaths due to zoonotic diseases [11–17]. Recent zoonotic diseases like Ebola (1976), Zika virus (1952), SARS (2002) and West Nile virus among others have caused significant death and socio-economic chaos [18,19]. The prime background factors of these zoonotic diseases are biological, environmental and lifestyle changes, among others [20].

Before COVID-19, the world was in vulnerable situations due to degradation of the socio-ecological systems [21–29]. COVID-19 has been amplifying these conditions. In this situation, COVID-19's unprecedented direct and indirect short- and long-term impacts raise serious concerns. The impacts are non-linear, interacting with each other in complex adaptive systems, defined as "a collection of individual agents with freedom to act in ways that are not always totally predictable, and whose actions are interconnected so that one agent's actions change the context for other agents" [30, p., 654]. The impacts can be viewed through the lens of social, political, economic, knowledge/technological and environmental realms which can be framed within the overarching concept of planetary health [31–33], defined as "characterizing the linkages between human-caused disruptions of Earth's natural systems and the resulting impacts on public health" [199, p., 1]. Multiple planetary health drivers which are causally connected are responsible for the emergence and spread of COVID-19. These planetary drivers and the implications of COVID-19 in social, economic and environmental realms can be understood by systematically employing the concept of complex adaptive systems [30,34]. Therefore, the objectives of this paper are to review and understand the drivers those have influenced of the emergence and spread of COVID-19 and their resulting consequences from planetary health perspectives.

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2. Methodology

Planetary health drivers related to COVID-19 as well as the planetary health consequences are considered as complex adaptive systems. This helped the authors to develop a cognitive map of the drivers and the consequences from a system thinking perspective [35]. Within this context, literature in a number of fields is reviewed to present a synthesis of the multiple drivers and implications of COVID-19. During literature identification and review, emphasis was given to articles that attempt to capture a timely and comprehensive cognitive picture of the relationship between the factors of planetary health and COVID-19 and COVID-19's planetary health impacts. A narrative review process was followed to identify the literature from peer-reviewed and non-peer reviewed articles, grey literature, blogs, commentaries, reports and news articles. Narrative reviews can be defined as comprehensive reviews which generally "cover a wide range of issues within a given topic, but they do not necessarily state or follow rules about the search for evidence" [36, p., 104]. Identified literature was verified and validated by the expertise and experience of the authors. Through the review process, 201 articles were selected by using both Google search and Google Scholar in diverse fields. The complex adaptive systems concept and findings of the identified literature guided us to categorize causally linked planetary health drivers (see Section 3) as well as consequences (see Section 4). The causally linked planetary health drivers were captured by a causal influence diagram developed by using Vensim software.

3. Planetary health drivers of COVID-19

Based on a literature review and using a complex adaptive systems framework, the possible drivers of the emergence and spread of COVID-19, can be broadly grouped in terms of sixteen planetary health issue related categories: (i) population growth, (ii) climate change, (iii) agricultural intensification, (iv) urbanization, (v) land use and land cover change, (vi) deforestation, (vii) biodiversity loss, (viii) globalization, (ix) wildlife trade, (x) wet markets, (xi) non-planetary health diet, (xii) antimicrobial resistance, (xiii) air pollution, (xiv) water stress, (xv) poverty and (xvi) weak governance. These attributes are causally connected as depicted in Fig. 1. All these drivers might link to pandemics in general, but COVID-19 brings them to the attention.

3.1. Population growth

At present, there are 7.8 billion people alive on Earth. This number could reach around 8.5 billion by 2030, 9.7 billion by 2050 and 10.9 billion by 2100 [25]. The current population uses resources equivalent to 1.75 Earths, which means they use more ecosystem services than nature can regenerate [37]. The growing population has created continuous pressure on earth's natural systems, and one consequence is that zoonotic disease rates have climbed [38]. The growing population is in continuous demographic change that makes humans vulnerable to zoonotic illnesses like COVID-19 [39]. This growing population is also more mobile, which has allowed COVID-19 to spread quickly around the world [40].

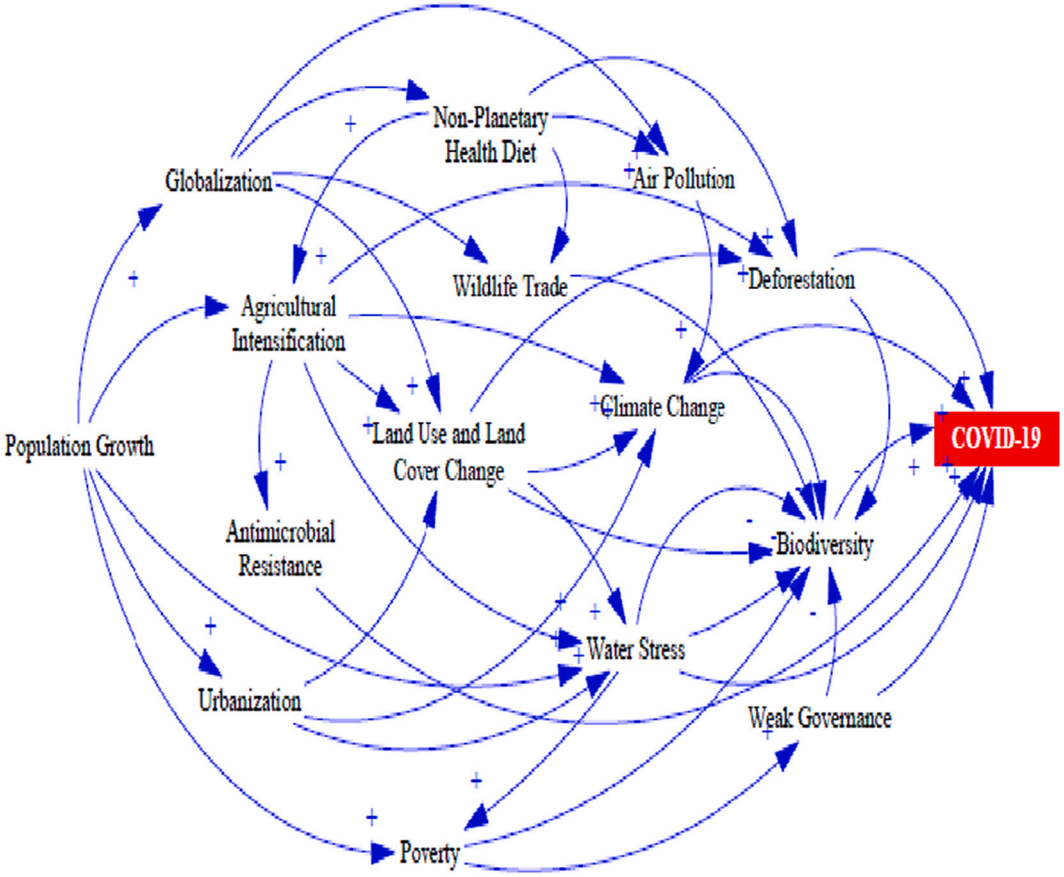

Fig. 1. Causal influence diagram of planetary heath drivers of COVID-19. Note: 16 planetary health drivers are responsible for the emergence and spread of COVID-19. These drivers interact and influence each other in a non-linear causal relationship as part of a complex adaptive system. In this diagram only the prime cause and effect relationships of the planetary health drivers that are responsible for emergence and spread of COVID-19 are shown. Perhaps, in reality all the drivers are non-linearly interconnected in complex adaptive systems. Different drivers, causally related to other drivers, are also possible. Here "+" indicates positive influence and "−" indicates negative influence.

3.2. Climate change

Climate change has resulted in warmer temperatures and increased precipitation, both of which create conditions for the survival and spread of many zoonotic pathogens [41]. There is no concrete evidence that climate change affects the spread of COVID-19 in particular. However, temperature variations and humidity may be important factors that affect COVID-19 mortality [42,43]. Climate change alters provisioning and regulating ecological services and accelerates species loss [44,45], which is a matter of risk to human health in terms of zoonotic diseases.

3.3. Agricultural intensification

Agricultural intensification is one of the prime drivers of zoonotic diseases [46,47] since agriculture interferes with the ecosystem's natural ability to defend against these diseases Thus, it increases the risks of human contact with zoonotic pathogens [48] through weakening the quantity and quality of biodiversity [49], fragmenting landscape heterogeneity, increased use of fertilizers and pesticides; eroding soil, destroying animal and plant habitats, and increasing the contact rate between humans and wild or domestic animals [50]. In this way, the emergence or re-emergence of zoonotic diseases is highly dependent on agri-food systems [47].

3.4. Urbanization

Global urban areas are the home of approximately 4 billion people [51], which is about 55% of the world's current population. This is expected to increase to 68% by 2050 [52]. Rapid urbanization causes major landscape disruption [53], which can have profound impacts on the epidemiology of infectious disease. Because of high population density, zoonotic diseases can spread in a more rapid manner and become worldwide threats [40,54] in megacities, as happened in the case of COVID-19 in New York City. Rapid urbanization without proper management and planning in developing countries can also contribute to the spread of zoonotic diseases [40,55].

3.5. Land use and land cover change

Land use and land cover change (LULC) directly and indirectly plays an important part in the spillover of zoonotic diseases [47] by changing pathogen ecology [56]. For instance, LULC causes land fragmentation [57] that facilitates the transmission of zoonotic infections [58].

3.6. Deforestation

Deforestation is responsible for ecological service degradation worldwide [59] and acts as a vehicle for transmitting zoonotic diseases like COVID-19 from animals to humans [58,60]. Deforestation has led to the loss of resilience of ecosystems against spreading zoonotic diseases such as COVID-19 [61].

3.7. Biodiversity loss

Ongoing biodiversity loss threatens human health by exacerbating the risk and distribution of infectious diseases [62,63] like COVID-19. Unprecedented loss of biodiversity is projected in the coming decades [28], which will further hamper biosphere integrity and planetary boundaries that are already at high risk [64]. Humans have caused the loss of 83% of all wild mammals and half of the plants [28]. Microbiodiversity loss is also of serious concern and, importantly, any impacts on microbial biodiversity which affect the resilience of all other organisms [65]. This loss will seriously affect ecological functions [66] that form an infrastructure to sustain all life on earth and support modern human society to exist and thrive [67]. Biodiversity loss brings humans in contact with previously isolated pathogens by removing buffers against pathogen abundance and spread [68,69].

3.8. Globalization

Globalization works as one of the drivers of the emergence, re-emergence and spread of infectious diseases [63,70]. Explosive international travel and transport of goods have increased under globalization and exposed people to different diseases [71–73]. In particular, global travel played an important role in spreading COVID-19 from Wuhan, China, to all around the world [74]. The travel connected with globalization also indirectly causes environmental damage [75] that is responsible for zoonotic diseases.

3.9. Wildlife trade

An unprecedented spike in both legal and illegal wildlife trade (through translocation, exotic pet trade, live animal and bush meat marketing and consumption, and ecotourism) has facilitated zoonotic disease transfer to humans [48,76,77]. It is estimated that 40,000 live primates, 4 million live birds, 640,000 live reptiles, and 350 million live tropical fish are traded globally each year [78]. The demand for exotic wild animals as raw food and medicine in China and other Southeast Asian and Pacific countries has played a huge role in the wildlife trade [79]. Trade in bats and pangolins is the prime suspect as the source of the virus responsible for the current COVID-19 pandemic [80,81].

3.10. Wet markets

Wet markets that offer live animals to consumers are a source of zoonotic diseases because they facilitate the transmission of viruses between neighbouring animals and humans [82–84]. It is believed that COVID-19 spread from the Huanan Seafood Wholesale Market, a wet market in Wuhan, Hubei, China [85].

3.11. Non-planetary-health diet

A non-planetary-health diet, one that is high in carbohydrates, meat, salt, saturated fats and/or sugars, causes obesity, cardiovascular disease, type 2 diabetes, malnutrition and weak immune systems. People with these health issues are more susceptible to COVID-19 [86,87]. On the other hand, a diversified diet that takes planetary health into consideration fights malnutrition, reduces non-communicable diseases and promotes strong immune systems [88,89] Present unhealthy diets are impacting health and environmental sustainability [86], but sustainable food systems have the capacity to provide a diet conducive to planetary health and also maintaining it [90] including preventing zoonotic diseases.

3.12. Antimicrobial resistance

Antimicrobial resistance (AMR) is a public health concern all over the world as it threatens the success of preventing and treating infections arising from pathogens [91,92]. AMR occurs due to misuse of antibiotics in human health treatment and also in agri-food sectors [93]. Excessive use of antibiotics in agri-food sectors exposes humans to antibiotics through food consumption and release into the environment [94]. Although there is no concrete evidence that COVID-19 has a relationship with AMR, it can be assumed that treatment of COVID-19 will be affected by AMR [95].

3.13. Air pollution

There is no direct relation between air pollution and zoonotic diseases like COVID-19, but air pollution makes people vulnerable to COVID-19 by weakening their lung function [42,96]. In addition, Wu

et al. [97] found that the quantity of lead particles in the air is related to increased COVID-19 death rate in the USA.

3.14. Water stress

Regular hand washing is advised to fight against COVID-19, but this is an issue in low- and middle-income countries where 75% of households do not have sufficient access to soap and clean water [98]. Apart from this, approximately 2 billion people are living in countries with high water stress [99]. The lack of clean water, water shortages and other effects of water stress leads to compromised health, and this can cause COVID-19 to have a disproportionate effect on these individuals.

3.15. Poverty

Poverty and the impacts of zoonoses are strongly correlated [100].

Fig. 2. A cognitive illustration of the implications of COVID-19 in different realms. In this figure, the inner circle indicates the drivers (PG = Population growth, CC = Climate change, AI = Agricultural intensification, UR = Urbanization, LULC = Land use and land cover change, De = Deforestation, BL = Biodiversity loss, Go = Globalization, WT = Wildlife trade, WM = Wet market, NPHD = Non-planetary health diet, AR = Antimicrobial resistance, AP = Air pollution, WS = Water stress, PO = Poverty and WG = Weak governance) of planetary health (PH) responsible for the emergence and spread of COVID-19 (C-19) as assumed in the outer red circle. Six red arrows indicate the implications (social, economic, environmental, technological, political, and public health) of COVID-19 from planetary health perspectives.

Due to poverty in middle- and low-income countries and even in developed countries, people struggle to maintain good living conditions and livelihoods. This may force them to violate advice against movement, leave lockdown and so forth in order to keep their jobs, where they have higher risk of exposure to COVID-19 [101]. In addition, poor populations lack access to health services, which leaves them vulnerable to be affected by the spread of COVID-19 [102].

3.16. Weak governance

The response to manage the impacts of COVD-19 requires a "whole-of-government" approach [103,104]. Failure to respond quickly and in a coordinated manner, political instability, resource limitations and poor governance will contribute to the spread of COVID-19 [104], as will failure to manage the environment.

4. Planetary health implications of COVID-19

Multidimensional implications of COVID-19 have been observed at local, national, and global levels. These implications can be categorized in six different subsystems: (i) social, (ii) economic, (iii) environmental, (iv) technological, (v) political and (f) public health. All these systems are being hampered directly or indirectly by COVID-19. Various multi-dimensional impacts under these subcategories are captured in Fig. 2 under the six categories of planetary health implications of COVID-19.

4.1. Social

Lockdown, social distance and restricted movement as norms have been imposed around the world to contain COVID-19, with adverse social impacts [105]. COVID-19 has put vulnerable people in developing and developed countries at great risk [106] and exposed social inequalities [107]. COVID-19 has forced changes in the lifestyles of billions of people around the world [108] and has exposed the inequalities of food systems [109]. Food and nutrition security is a priority to maintain good health and boost immune systems. Food production and food safety are of serious concern all around the world due to the halt of international and local food trades upon which millions of people depend for food security and livelihoods [110]. Before COVID-19, 135 million people around the world were experiencing acute food insecurity in 2019; this number is projected to rise to 265 million in 2020 due to the economic impacts of COVID-19 [111]. The pandemic's effect on world food system distribution can lead to famine [112]. Apart from this, many countries around the world face shortages of migrant workers in their industrial and agricultural sectors due to travel restrictions [113].

Domestic violence has risen worldwide during the pandemic [114]. Women and children are especially likely to be victims because of their restricted freedom of movement as well as pre-existing structural barriers of gender in societies [115]. Increasing social inequality due to COVID-19 in many societies will result in more and more social vulnerability [116] and social turmoil [117]. The negative effects of social distancing will cause difficulties in social networks and threaten the survival of many people [118]. However, in many countries new social networks have emerged mainly based on the internet.

Nationwide school closures implemented to contain COVID-19 are affecting the education of 80% of children worldwide [119]. Furthermore, in many parts of the world the justice systems have been shaken as governments have limited freedom of expression [120] and COVID-19 has provoked discriminatory acts targeting different groups [121] as seen in attacks on people of Chinese descent in the USA and African students in China. Healthcare services have been disrupted all around the world. Millions of unintended pregnancies may occur in the coming months, meaning that world population may grow even more [115]. The pandemic may impact existing disaster management systems by hindering safe evacuations in case of natural disasters or social unrest [122].

4.2. Economic

COVID-19 has brought economic activity to a near standstill [113]. It is estimated that its effects could cost $5.8 to $8.8 trillion globally [123]. Both operational and distribution aspects of the global supply chain of goods have been seriously disrupted [197]. The global supply chain is a key system in creating jobs and for maintaining efficient and competitive markets for stable growth of the global economy [124]. Moreover disruption of the local and global economy will push half a billion people (8% of the world population) into poverty in developing countries. This will be the first time that poverty will increase globally since 1990 [125].

Unprecedented global travel restrictions and stay-at-home orders disrupt different economic activities differently. Among many sectors, tourism, which employs 292 million people worldwide [198], has been hampered badly [126]. Demand from hotels and restaurants for agricultural commodities has dropped by 20% globally [127]. A massive pre-COVID-19 global unemployment crisis has been exacerbated by the pandemic [128]. The global economy will decline by 5.2% this year [129], the deepest recession since World War II [130].

These economic influences will have a major impact on globalization [131]. Consumer spending on goods and services has been substantially affected by the impacts of COVID-19 all around the world [132]. Worldwide remittance, which is a vehicle of socio-economic development in many countries, will decline by about 20% [133]. *E*-commerce has emerged as a major method of doing business and keeping economies alive [134]. Besides, around the world economic models for the post-COVID future [135], impacts on big transnational corporations as well as also small and medium enterprises and the impacts of the economic stimulus packages by the countries are being discussed.

4.3. Environmental

COVID-19 is having both positive and negative impacts on the environment. As a majority of people are staying at home, their patterns of activities (e.g., more in-house cooking, use of cleaning materials) which might deteriorate indoor air quality (IAQ) have changed greatly. IAQ has a profound impact on human health [136]. Lockdown has reduced human transportation and many industries have shut down, which to some extent has led to cleaner air but will do little to address the issue of air pollution in the long run [137]. For example, NASA reported that air pollution such as NO_2 dropped in China with the coronavirus quarantine [138]. GHG emissions have dropped 6 %, but this is not enough to have a major impact on climate change [139]. Commercial aircraft are being used for taking meteorological measurements, but due to fewer flights, the quantity and quality of weather observations and forecasts along with atmospheric and climate monitoring have declined [140]. Thousands of infected masks, gloves, protective equipment and other hazardous items along with waste from cleaning materials such as hand sanitizer are being generated everyday. The unsound management of these wastes could create serious health problems as well as environmental problems [141,142]. Around the world, 40% of people have insufficient access to basic hand-washing facilities and clean water, so the frequent hand washing necessary to reduce the spread of COVID-19 will lead to greater water stress for those people [143]. However, because COVID-19 has manifested as a problem of environmental degradation, this can help to develop a positive mindset and awareness for biodiversity preservation, climate change, ecosystem services, adaptation, and mitigation. Many Asian and African countries [144] are promoting traditional medicine as treatment for COVID-19, which has created tremendous curiosity about medicinal plants that may help to save traditional medicinal plant diversity in many countries.

4.4. Technological

The world has observed the emergence and extensive use of epidemiological models as guiding and planning tools for policymakers and health practitioners as part of COVID-19 interventions [145,146]. For example, an online interactive dashboard to visualize and track reported COVID-19 cases in real-time was designed and hosted by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University [147, p., 533]. Transdisciplinary techniques are employed to develop these models for different purposes such as public health forecasting [146] and decision making based on "what-if" scenarios [148].

Digital technologies are being extensively applied to deliver online education, offer health services through telemedicine and facilitate COVID-19 screening apps to help people to stay at home. Big data analysis [149] using artificial intelligence and analytics for epidemiological modelling, vaccine invention, patterning mobility and contact tracing, has become a new norm all around the world for people, institutions, business and government [150]. The World Bank has identified more than 300 government and private sector organizations that are using digital technology to deliver e-health services, e-payment and other e-services [150,151]. Video gaming has flourished, but it poses the danger of solidifying unhealthy lifestyle patterns and requires a balanced approach of mental enjoyment and physical health to support physical and psychological wellbeing [152]. Many companies and institutions all around the world have adapted online meeting software, collaboration platforms and location-based services (LBS) technology to help employees work and stay at home [153].

4.5. Political

Global food insecurity due to COVID-19 is a huge concern among all nations [154], as reflected in the overwhelming increase in demand for food aid among the world's food-related organizations [155]. Food aid will be an even more significant issue in future international politics if countries adopt trade barriers or export bans on food [156]. In response to the economic impacts on developing countries, a $2.5 trillion coronavirus crisis package has been called for by the United Nations [157]. Official development assistance (ODA) is important for Least Developed Countries (LDCs) [158], and increased ODA is an immediate solution to lessen some of the short-term effects in the poorest countries [159]. The effect of COVID-19 is expected to peak in the world's poorest countries within the next three to six months. The United Nations reports that $7 billion is being sought by humanitarian organizations to halt the spread of COVID-19 so as to protect the lives of millions of vulnerable people in the world's most fragile countries [160, p., 1]. However, both ODA and humanitarian aid flow could be seriously disrupted due to the ongoing effects of COVID-19 on OECD countries. Existing geopolitical stress could be worsened, as exemplified by the deteriorating relationship between the US and China [161].

Nevertheless, COVID-19 has attracted people from transdisciplinary fields of knowledge under an umbrella for an unprecedented spirit of collaboration to face the crisis [162] through connectedness and interdependencies [163]. For instance, to accelerate the development of a vaccine to combat COVID-19, Chinese and Australian researchers have made the SARS-CoV-2 genome freely available [162, p., 1]. COVID-19 is bringing to the foreground the importance of collaboration and purposeful partnership at the transnational level.

4.6. Public health

COVID-19 is disrupting public health systems all around the world, especially the fragile health systems of LDCs. In particular, it is seriously affecting world vaccination programmes. UNICEF reports that "[o]ver 13 million children did not receive any vaccines, even the basic ones, even before COVID-19 disrupted global immunization" and that "[m]ass measles immunization campaigns have been suspended in 25 largely high-burden countries due to the pandemic" [164, p., 1]. Millions of children will be at risk due to suspended immunizations for measles, diphtheria and polio [165].

In addition, eating healthy fresh fruits and vegetables is important, but lockdown can lead to consumption of higher quantities of carbohydrates and protein [166], which can lead to malnutrition and other health issues. Prior to COVID-19, hundreds of millions of people were already suffering from hunger and malnutrition, and the pandemic can worsen this situation [167]. The fragile livelihoods along with nutrition and food security of vulnerable people have been devastated. Past experiences show that outbreaks of infectious diseases bring hunger and malnutrition [168]. Safe water, sanitation and hygienic (WASH) conditions are essential to face COVID-19. Limited WASH services will contribute to greater vulnerability to COVID in many underserved areas [169].

Under-resourced hospitals and weakened health systems are facing mounting pressure, which hinders the proper treatment of communicable and non-communicable diseases, especially in resource-scarce situations [170]. For example, refugee camps, which already have inadequate medical resources, will face even more serious health problems due to lack of medical supplies [171]. Mental health and psycho-social consequences such as harmful alcohol and drug use, anxiety, insomnia, depression, loneliness and self-harm or suicidal behavior are emerging in many societies as consequences of COVID-19 [172,173]. Hospital management and occupational health services in health care facilities and personnel are also facing serious threats; it is vital to protect infrastructure and health workers to ensure continuous services from healthcare systems [174]. While the stress caused by COVID-19 makes public health systems more vulnerable there are investigations to determine options to face it. For example, repurposing drugs, traditional medicines and developing new therapies are welcomed by WHO in the search for potential treatments for COVID-19 [175]. In addition, according to the UNDP, "[t]he proliferation of dangerous disinformation and misinformation threaten national COVID-19 pandemic responses, which not only undermines the effectiveness of public health measures, but also leads to real life violence and discrimination, confusion, fear and, arguably, long-term societal harm" [176, p., 1].

5. Planetary health implications of COVID-19 and sustainable development goals (SDGs)

The planetary health implications of COVID-19 as captured in Sections 3.1 to 3.6 have deep consequences for halting progress on the United Nations' Sustainable Development Goals (SDGs, see Fig. 3), especially in the resource-limited settings in LDCs [157,177,178]. SDGs are "a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030" [179, p., 1] across nations for an equitable future [180]. Checking the planetary health implications of COVID-19 on SDGs, as shown in Fig. 3., reveals that out of 17 SDGs, 7 goals will have some sort of increasing positive impacts, whereas the other 10 goals will possibly be negatively impacted. Overall, the entire SDGs will be hampered.

The foundations of human wellbeing and survival ultimately depend on planetary resources, but these resources are under great pressure in the way the present planetary resources are used. For example, the biodiversity on which planetary health depends [181,182] is at a "tipping point," meaning that small alterations in environmental situations can lead to huge changes [183]. If the present rate of using planetary resources continues, global wildlife populations will drop significantly in coming decades [184].

Some 60% of emerging infectious diseases that are reported globally are zoonoses [4]. For example, the ILRI reported that "[o]f 12 major pandemics since the 1980s, 9 were due to zoonoses—like SARS, AIDS, MERS and now COVID-19" [185, p., 1]. Also, the WHO [186, p., 1] points out that more than three quarters of the 30 new human pathogens

Fig. 3. Impacts of COVID-19 on SDGs. Note: Up arrow indicates increasing and down arrow indicates decreasing, "+" = positive and "−" = negatives. *** Positive impacts [] on Goal 6: Clean water and sanitation, Goal 7: Affordable and clean energy, Goal 11: Sustainable cities and communities, Goal 12: Responsible consumption and production, Goal 14: Life below water, Goal 15: Life on land, and Goal 17: Partnerships for the goals. ***Negative impacts [] on Goal 1: No poverty, Goal 2: Zero hunger, Goal 3: Good health and well-being for people, Goal 4: Quality education, Goal 5: Gender equality, Goal 8: Decent work and economic growth, Goal 9: Industry, Innovation, and Infrastructure, Goal 10: Reducing inequalities, Goal 13: Climate action, and 16: Peace, justice and strong institutions.

discovered in the last 30 years originated from animals, and that every year such zoonoses account for about one billion illnesses and millions of deaths. The release of new viruses from the melting of glaciers/permafrost is another potential threat [187] since these viruses are new to our immune systems and unfamiliar to public health experts. In addition, antimicrobial resistance, food safety and climate change-related communicable and non-communicable diseases are huge concerns for human civilization.

Planetary health foundation-level actions are required to manage zoonotic disease and other emerging health issues. If the world keeps using ecosystems in a business-as-usual model, zoonotic diseases will keep emerging. Therefore, we need to flatten the curve of using the planet's ecosystem capacity. Hence, understanding the causal relationship of planetary health perspectives, zoonotic disease and its implications are very important to identify risk and then to model, forecast and make decisions for risk-informed planetary heath management and sustainable development [188]. Under the present scenario of use of planetary resources, achieving SDGs will not be possible by 2030 and beyond. To ensure planetary health and SDGs, transformation is needed in "(1) education, gender and inequality; (2) health, well-being and demography; (3) energy decarbonization and sustainable industry; (4) sustainable food, land, water and oceans; (5) sustainable cities and communities; and (6) digital revolution" [200, p., 805]. Existing frameworks, such as green growth [189], low-carbon society [190], climate-smart agriculture [191], agroecology [192], ecosystem-based adaptation [193], circular economy [194], doughnut economics [195], regenerative economics [196] and so forth, can be tools for this transformation to flattening the curve, managing zoonotic diseases and achieving SDGs.

6. Conclusion

COVID-19 is a reminder of how human health is interconnected with that of the planet and is an early warning to show how the collapse of planetary systems can lead to cascading effects on interlinked global, regional and local health. Understanding the drivers and implications of COVID-19 in the context of planetary health is important in order to manage and take multisectoral, collaborative, holistic action against the social, economic, environmental, technological, political and public health ramifications associated with COVID-19.

The world has been unprepared in facing the COVID-19 pandemic, so it is a great learning opportunity for human civilization in terms of preparedness, policy formulation and integrated research for future pandemics that can be incorporated into public health and global health planning and study. Therefore, a framework needs to be developed to predict, prevent, detect and respond to future pandemics. The concept of planetary health can be such a framework since it allows to take transdisciplinary actions.

Only recently have people started to put high value on the interconnection of health and the environment in terms of one-health, environmental-health, geo-heath, eco-health and planetary health concepts. However, scholars in various disciplines are studying and doing research unconnected with public health experts and medical science. The time has come to remedy this disconnection and work together from the same platform for better-informed management of pandemics like COVID-19 and other upcoming infectious disease.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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