Environmental Science: An Indian Journal

ISSN: 0974-7451

Research | Vol 17 Iss 6

A Comprehensive Review on COVID-19 Pandemic: Causes, Effects, and Concerns from Environmental Perspective

Shyam Thapa

Arkansas State University

***Corresponding Author:** Shyam Thapa, Arkansas State University, Jonesboro, United States of America; Tel: +91 8703512544; E-Mail: shyamsirsha@gmail.com

Received: June 14, 2021; **Accepted:** June 24, 2021; **Published:** June 30, 2021

Abstract

Severe acute respiratory syndrome coronavirus 2(SARS-CoV-2) and its variants are causing a humanitarian crisis globally. Zoonotic spillover followed by human to human transmission is to be blamed for the current pandemic and health crisis; however, it boils down to the long term environmental deterioration by anthropogenic activities to be the underlying cause of this predicament. Pandemic due to COVID-19 has several effects on social, economic, health and environmental fronts. There were some short-lived positive gains on environment due to COVID-19 imposed quarantines, lock downs, and shut downs; however these temporary gains couldn't be glorified in the wake of negative consequences of COVID-19 on environmental, social, economy, and health. Green investments post-pandemic through relief packages, recovery, and rebuilding plan will spur resilient and sustained growth. This review paper is an endeavor to decipher the bidirectional nexus between environment and COVID-19 and discusses various topics on effects of COVID-19 and environment both ways from different perspectives.

Keywords: COVID-19, Environmental effects; Disinfectant use; SARS-CoV-2; Zoonotic spillover; Sustainable Growth

Introduction

The name Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was given to the virus that causes coronavirus disease (COVID-19) by International Committee on Taxonomy of Viruses (ICTV) on 11 February 2020. COVID-19 is the new strain of coronavirus, belonging to a large family of viruses. The close relatives of COVID-19 are SARS and MERS-CoV which took a heavy toll in 2002/3 and 2012 respectively costing several hundreds of lives, and downturn the economy in certain regions of the world [1], [2]. The novel coronavirus was first detected among vendors and shoppers associated with one of wet markets in the Wuhan City of Hubei Province, China on December 31, 2019. Coronaviruses have crown like spiked surface structure and have propensity to infect both animals and humans. Seven coronaviruses belonging to alpha and beta genera, 229 E (α), NL63(α), OC43 (β), HKU1(β), MERS-CoV(β), SARS-CoV(β), and SARS-CoV-2(β) are known to infect humans.

Animals harboring coronaviruses may spread viruses to humans like in the case of SARS-CoV, and MERS-CoV, and 2019-nCoV [3]. SARS and MERS-CoV were found in the mammals of order chiroptera specifically bats and communicated the disease to humans from infected civets for SARS, and infected dromedary camels for MERS-CoV [4]. Recently published joint report by WHO [5] couldn't come up with a

Citation: Shyam Thapa. A Comprehensive Review on COVID-19 Pandemic: Causes, Effects, and Concerns From Environmental Perspective, J Environ Sci. 2021; 17(6):196

concrete conclusion on the origin of SARS-CoV-2. However, it recommended the need to sample large numbers of bats and pangolins in China and elsewhere. It also encouraged identifying potential intermediate hosts or wildlife reservoirs for SARSr-CoVs. Several modes of transmission of virus have been identified such as contact and droplet transmission, fomite or surface contamination, and air borne. The possibility of detection of SARS-CoV-2 in the feces or urine of an infected person is undeniable however there is no substantial study to support the transmission of the virus through them [6].

Coronavirus cases continue to surge even after a year WHO declared it a Pandemic. It has spread in 219 countries and territories [7] infecting more than 140.3 million, and causing deaths to over three millions globally. European region surpassed 1 million deaths as of April 15, 2021 [8]. Figure 1 shows the average weekly new cases and cumulative coronavirus cases observed between February 1, 2020 and February 10, 2021 in most affected countries in different regions of the world.

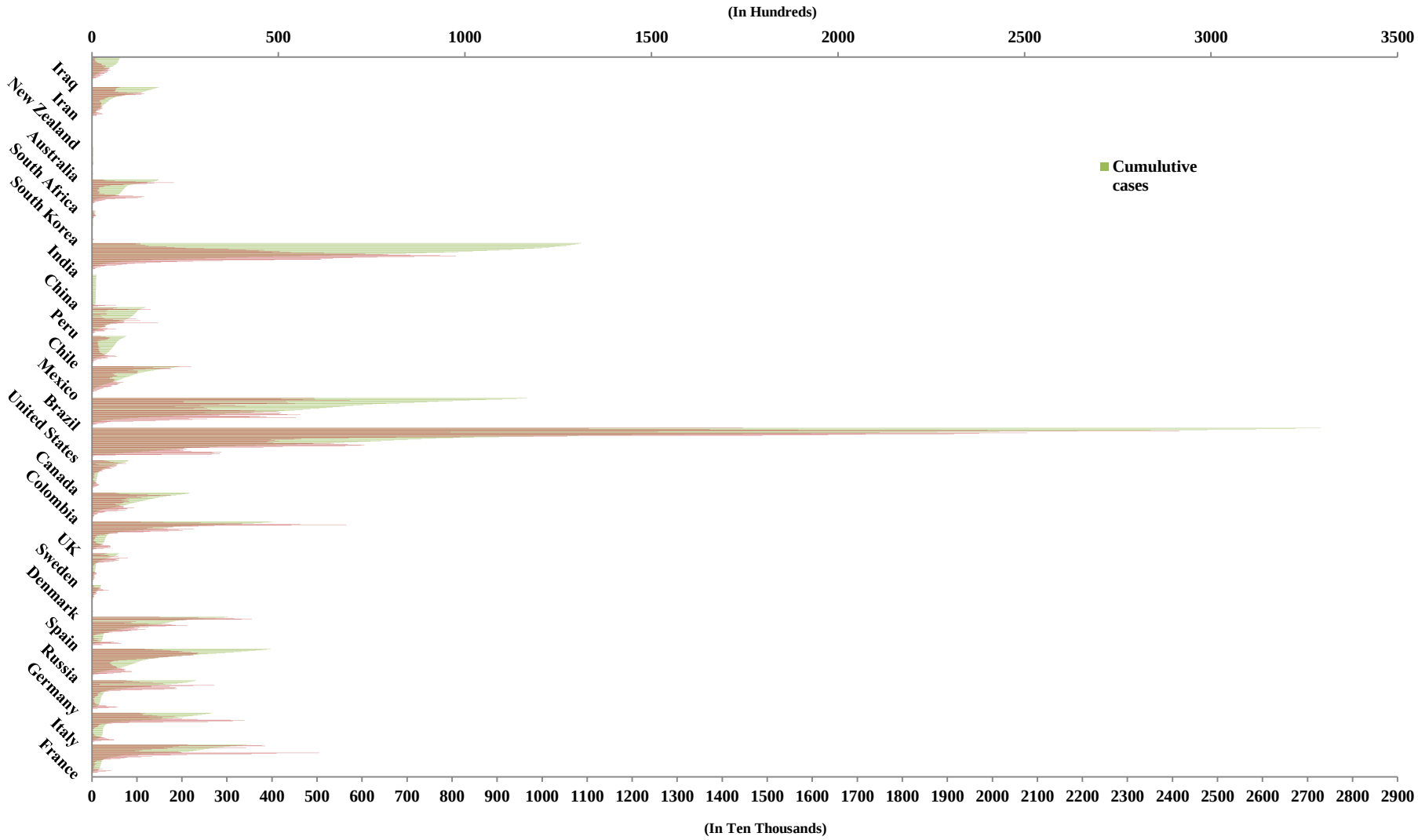


FIG 1: weekly new cases and total coronavirus cases observed between February 1. 2020 to February 10, 2021.

Method

Several credible sources of relevant literatures were accessed including books, journal articles, government documents, policy reports, and reputable news sources. Oxford COVID-19 Government Response tracker (OxCGRT) database, data from Bureau of Economic Analysis of U.S. Department of Commerce, trading economics GDP database, our world in data database were compiled and analyzed to elucidate the COVID effects. News briefs, short communications, bulletin of reputed news agencies and organizations were also considered.

This paper aims to develop an understanding of the effects of COVID-19 pandemic on environment, health and economy and vice versa. Although prolific papers were published on COVID-19, very few review papers were available to decipher the bidirectional nexus between Environment and COVID-19. Most of the published papers used unidirectional approach attempted to establish positive effect of COVID-19 on Environment. This comprehensive review paper however discusses topics from different perspective to add to the body of knowledge.

Results and Discussion

Pandemic due to COVID-19 has several effects on social, economic, health and environmental fronts. We have observed that the countries that are globally engaged, open to trade and mobility were more vulnerable to pandemic. Although the pandemic is not the care to the environmental problems, it is deliberately buying time for environment to rejuvenate and recuperate. COVID-19 effect seems overwhelming right now, however, time will tell the effects of COVID-19 on the human health and environment. So far some positive gains of environmental amelioration, pollution abatement are happening due to SARS-CoV-2 virus insurgence. However there are many manifestations of human effects on the environment during this time as well.

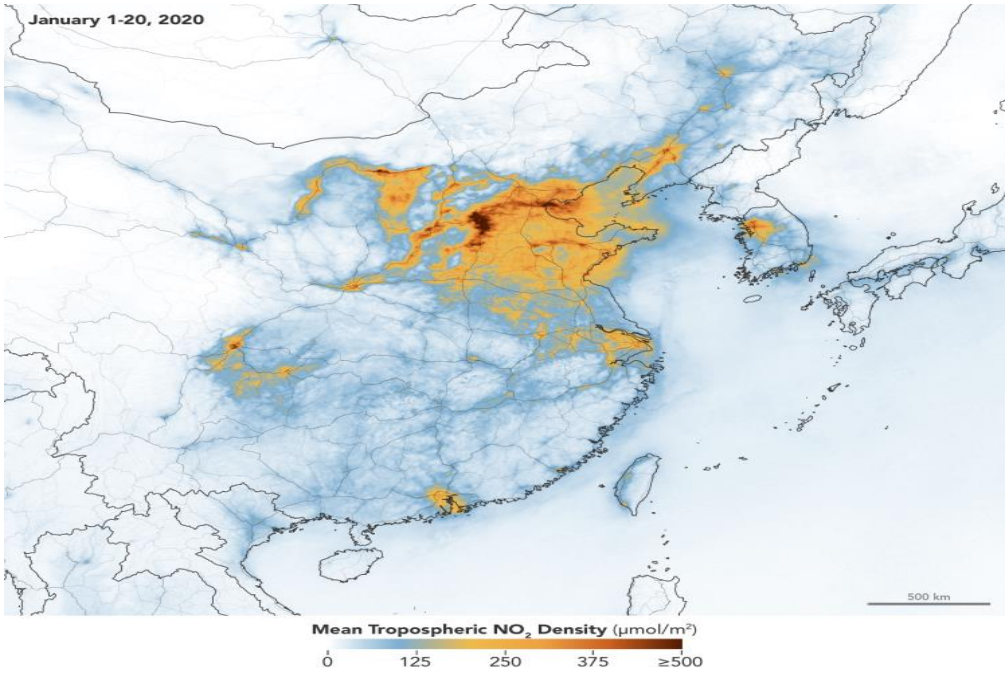
COVID-19 and Environmental Pollutions

Ambient air pollution is regarded as the cause of 4.2 million premature deaths annually with over 90% occurrences in low to middle income countries [9]. According to the European Environment Agency (EEA), air pollution possesses extreme threat to the human health and environment. In European Union (EU) alone over 400,000 premature deaths occur annually due to air pollution. Zhu et. al. [10] found the significant association between six air pollutants namely, $PM_{2.5}$, PM_{10}, SO_2, CO, NO_2, and O_3 with confirmed covid-19 cases.

Particulate Matter Pollution: Particulate matter pollution refers to the particle pollution with inhalable particles (PM_{10}) and fine inhalable particles ($PM_{2.5}$) in the air. The subscript indicate aerodynamic diameter of particles in microns. $PM_{2.5}$ is more harmful than PM_{10} due to its smaller size, longer residence time in air, and long range of transport. It is accountable for some health risks as these can penetrate into lungs, corrode alveolar wall, and give rise to severe respiratory diseases [11]. Poor air quality leads to premature deaths in humans, while reduces visibility, influences local climate based on dominant aerosol species in the mixture. For example, black carbon has warming effect while nitrate & sulfate have cooling effect [12]. Karagulian et. al. [13] analyzed the sources of $PM_{2.5}$ and their respective share in urban air pollution, found that vehicular pollution followed by industrial activities, domestic fuel burning, human induced PM from unspecified sources, and natural sources such as dust storms and

salt spray accounted 25%, 15%, 20%, 22%, and 18% to urban air pollution respectively in low and mid income countries. World Health Organization (WHO) recommended maximum permissible annual average of ≤ 50µg/m^3 for PM_{10} and ≤ 10µg/m^3 for $PM_{2.5}$. According to Helfand et al. [14], high concentration of $PM_{2.5}$ may result in high morbidity and mortality mainly from cardiovascular system. EPA [15] identified five important pollutants that together account above 50% of the total respiratory hazard index. These are formaldehyde, acetaldehyde, acrolein, naphthalene, and diesel PM. The study conducted to find the association between COVID-19 and hazardous air pollutants concluded that COVID-19 mortality rates increased even with a chronic exposure of a small concentration of diesel PM and acetyldehyde as they inhibit the body's immune system [16]. Several studies previously had reported diesel PM effect on respiratory and cardiovascular systems [17, 18]. Chronic exposure to $PM_{2.5}$ is related to the incidence of COVID-19 [16], [19, 20]. Places with higher PM concentration increase the susceptible to COVID 19 infections [21, 22]. Particulate pollution damages cilial lining in airways increasing chances of viral infections [23, 24]. In contrast to the PM supporting COVID-19 cases, COVID-19 related lockdowns and restrictions reduced $PM_{2.5}$ in many cities and countries [25-27].

NO_x Pollution: Nitric oxide and nitrogen dioxide commonly known as NO_x are produced from natural and anthropogenic sources. Anthropogenic sources include emissions from combustion of fossil fuels especially coal and gasoline in power plants, factories, industries, burning of gasoline and diesel in motor vehicle and aviation fuel in planes for transportation, and combustion of oil and gas in other machineries and equipment (farm machinery, construction equipment).



(a)

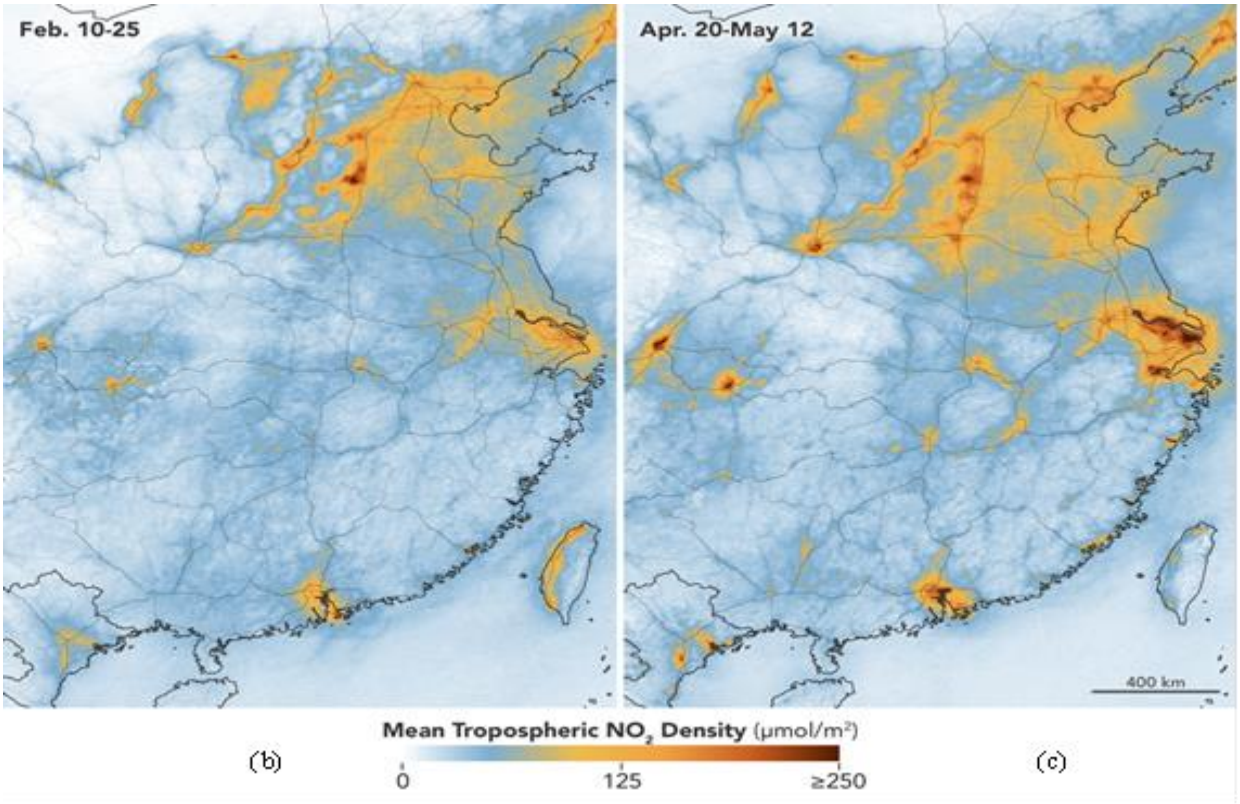


FIG.2.Comparisons of the amounts of NO_2 before quarantine, during quarantine, and after restrictions lifted

Source: NEO, NASA [28].

The maps above show the changes in tropospheric NO_2 levels before quarantine, during lockdown/quarantine, and after restrictions were lifted in China from data collected by the TROPOMI (tropospheric monitoring instrument) on Copernicus Sentinel-5P satellite of the European Space Agency. The impact of lockdown is evident from figure 2(a), 2(b), and 2(c). The mean NO_2 density levels in the coronavirus hit areas stayed low until the restrictions were lifted, FIG. 2(b). The world was able to witness unprecedented improvements in the air quality during the quarantine period in China as a result of lockdowns in some industrial cities of China. However, these improvements were short lived as NO_2 levels rebound back to normal levels [FIG.2(c)] after 70 days due to restoration of economic activities following lockdowns [28]. Eastern and central China has significantly lower NO_2 levels during this period. Several studies reported reductions in ground-level NO_2 due to lockdowns, and temporary pause in industrial activities in response to COVID 19 [27]. Conversely, some studies concluded that NO_2 among others is also responsible for higher infections and mortalities [22], [29].

Carbon dioxide Emissions: Carbon dioxide is one of the greenhouse gases that have the higher global warming potential by trapping shortwave radiation (heat) going from earth to the atmosphere. According to International Energy Agency [30], the global CO_2 emission declined a historic 2 billion tons in 2020, with 5.8% contribution from

energy sector alone. Over half of the global CO_2 emissions reduction is explained by dwindling oil use owing to the pandemic related effects predominantly on ground and air transportation [30]. Analyses of carbon monitor dataset for CO_2 emissions showed an annual decline of 6.4% or 2.3 billion Global CO_2 emissions in 2020 compared with that of 2019 [31] which is slightly higher than IEA analyses. This reduction was much higher, 8.8% or 1.551 billion CO_2 in the first half of 2020 [32] largely contributed by China due to 10% reductions in its greenhouse gas emissions until the beginning of April, 2020 compared to the same period in 2019 [33]. The soaring of economic activities in China following lockdown and relaxed restrictions in European countries and others in the 2^{nd} half of 2020 diminished the gains in CO_2 emission decline. Large reductions between 10% [31] to 12.5% [31] of the 5246.4 million metric tons from previous year was observed in the United States in 2020. To put into perspective, the United States which had one-quarter of global COVID-19 cases accounted for over one-quarter of global CO_2 reductions in 2020. Similarly, with high incidence of coronavirus India's reductions in CO_2 emission was over 200 million tons in 2020 which is second highest reductions after the United States followed by Europe with 7.7% reductions from its own 2019 emissions. The 10% reductions in GHG in China was short lived due to rebound of economy in the second half of 2020 with 5% CO_2 emissions above 2019 levels that resulted in the minor overall decrease of 1.4% compared to last year [31]. The large cuts in CO_2 emission were seen in transportation sector, followed by power sector/energy sector.

Ozone pollution: During COVID-19 pandemic when mobility was temporarily halted due to lockdowns and pause in economic activities, many studies reported increase in ground level ozone in polluted urban areas [34-37]. According to Sicard et. al. [37] in highly polluted areas with NO_x concentration above 1ppb, if reduced abruptly, can increase ozone as ozone titrant nitric oxide is reduced. In contrast, a 7% drop in ozone at lower atmosphere (1km - 8kms) between April and August of 2020 was recorded in the Northern Hemisphere due to interruption of photochemical ozone production owing to the reduced nitrogen oxides in clean and mildly polluted environments during COVID-pandemic [38]. In polluted cities, ozone formed near the ground not only reduces the visibility causing hazy conditions but also poses threat to sensitive groups (people suffering from asthma and lung diseases, senior citizens, and infants and children) of respiratory and cardiovascular problems. Therefore, tropospheric ozone is harmful air pollutant [39].

COVID-19 Effect on Deforestation and Land Degradation

Biologists, ecologists and conservationists pointed out some human actions such as destroying animals' natural habitats among others are predominantly responsible for the transfer of diseases. In other word, traditional buffer zones which serve to separate humans from animals were obliterated by humans through encroachment into their natural habitats for agriculture, industry and settlements. Risks associated with emergence of zoonotic pathogens and its transmission is enhanced with human invasion of wilderness areas and the destruction and devastation of ecosystem [40, 41]. Coronavirus is likely the result of zoonotic spillover [5], which is; either bat virus carried into humans through handling and consumption or may have leaped into another species and mutated into a variant that has the ability to infect humans. Therefore, the significance of the forest as a buffer between human and animal

interaction needs to be maintained in order to prevent this kind of zoonosis in the future. Environmental degradation, large scale deforestation, biodiversity loss, and climate change are the imminent causes of new infectious diseases.

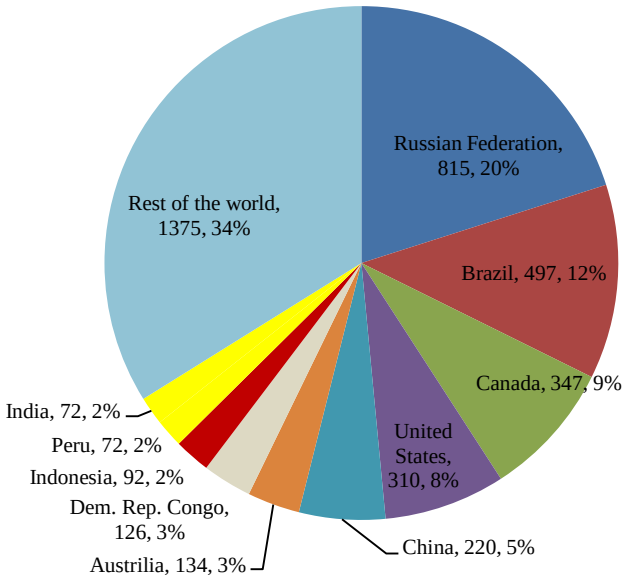


FIG.3.Global distribution of forests

Source: FAO & UNEP[42].

FIG.3. shows that 66% of the world's forest is located in just these ten countries. The current forest coverage is 30.8% globally, a loss of 2.5% since 1990 [42]. These forests are also referred to as "lungs of the earth" as they sequester CO2, release O2, excels hydrological cycle, provides water provisioning services, inhabits diverse life forms, regulates climate, and most importantly intervene "the species jump in humans" along with other ecosystem services.

However these forests were at stake long before the inception of pandemic, and even more so during pandamic. An increse in land clearing, illegal logging, discontinued community empowerment activities, halted forest patrolling by authorities due to pandemic, and income loss during pandamic all imparted to the crippling forest and its resources [43]. Above half of the once lush tropical forests is destroyed or degraded since 1960 [44], and that trend is continued in Amazon rain forest [40]. Deforestation and land fragmentation trigger zoonoses by enhancing human-animal interaction [45]. Pathogen spillover can be steered by the alarming rate of deforestation/ fragmentation happening in tropical forests, accompanied by global wildlife trade [46].

Imperiled Forests by Human Greed and Forest Fires: Brazil's Amazonian biome deforestation is exceeding at an unprecedented rate since 2008. In 2019, Brazil's National Space Research Institute (INPE) [47] reported 10,129 sq. km forests were cleared across eight Brazilian states known as "legal amazon" between August 2018 and July 2019.

Similarly, Brazilian deforestation data (PRODES) showed that Brazilian amazon mulled by continuous deforestation in 2020 (between August 2019 and July 2020) was approximately 11,088sq.kms in Legal amazon states [48]. Above 20,810km^2 area has undergone deforestation and degradation altogether in Legal Amazon [48]. Similarly, the Cerrado region is constantly under pressure from it, which has undergone deforestation at the rate of 7340.12 km^2 in 2020 [48].

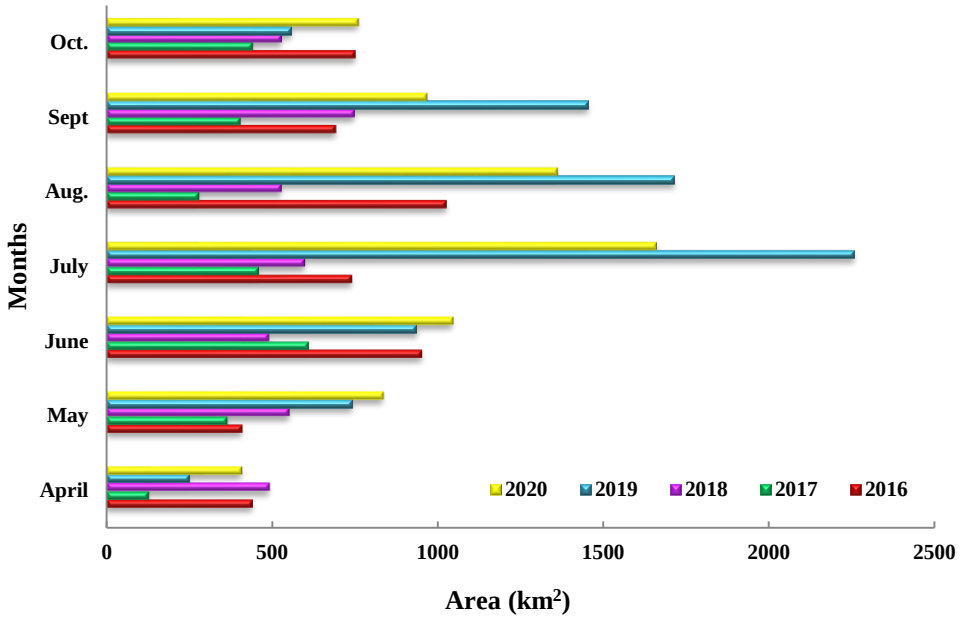


FIG.4. Monthly variation of Legal Amazon 2020 (DETER Project Area)

The FIG.4. depicts the rate of deforestation in the Legal Amazon before, and during pandemic. Although movements of people were drastically reduced, illegal logging, land clearing, and mining operated unhindered in the interest of land grabbers, farmers, ranchers, and developers under the cover of pandemic and governments acquiesce. Deforestation alerts went 33% up compared to that of last year between August 2019 and July 2020 [49]. Similar is the case with contiguous rainforest in the Rio Platano Biosphere reserve in eastern Honduras, the Mosquitia region bordering Honduras and Nicaragua. Likewise, Belizean forest and rain forest in Guatemala was disproportionately affected by human greed in 2020.

Uncontrolled fires spread in some important ecosystems such as Pantanal wetlands, Chiquitano Forest, and Beni Savanna and Amazon Rain Forest in Bolivia burning down 1.3 million acres [50]. World witnessed record number of forest fires in Atlantic forest, North American Boreal forest, Siberian Boreal forest (Taiga forest) in Russia, and Northwest Pacific, and Temperate Coniferous forest in United States. Greenpeace International [51] reported approximately 47 million acres of land including over 25 million acres of Siberian Boreal forest (esp. in far Eastern Russia, and Eastern Russia) were burnt in 2020. In the United States, wildfires have burnt an estimated 6.9 million acres combined in 11 States in 2020 [52]. Mongabay [53,54] reported forest clearance activities have spiked in many Asian countries such as Indonesia, Cambodia, Nepal, and Myanmar and South American countries such as

Brazil, Colombia, and Peru during pandemic period. The effect of climate change on the forests were perceived in later years as numbers of wildfires/bush fires, drought, disease, and insect outbreaks are increasing. Even the sincere efforts to combat illegal logging, and land clearing by some governments have gone futile during pandemic as lockdown imposed prorogation of forest patrolling and government authorities needed army and police to be deployed to enforce lockdowns and/or to deal with imminent health crisis situation.

Massive numbers of local or regional episodes of deforestation, forest fires jeopardize its ecosystem services, threatened the livelihood or the safety-net for millions of poor people. By doing so, we jeopardize our food security, and our health and survival. The monetary values of ecosystem services (Non cash benefits) of forest are significantly higher than cash generated from logs, timber, pulp and paper [55]. In the wake of coronavirus pandemic, it may serve as natural pharmacies and help regulate infectious diseases [56]. Studies show that nature imparts inspiring energy such as joy, vitality, harmony, and freedom. Time spent in forest is a quality time since it helps to boost immune system, relieves stress, relaxes mind, and lowers blood pressure. Above all, protection of forest can be deemed as a precautionary measure to help prevent the transmission of noble infectious diseases from animals without distressing them.

Positive Impact of COVID-19 on Forest: Pandemic has mixed impact on the forest. Despite the illegal logging and deforestation in some parts of the world, there were some glimpses of affirmative actions' being taken such as afforestation and forest restoration being proposed by Indian government amid pandemic. Indian government proposed the funding for Compensatory Afforestation Fund Management and Planning Authority aimed at hitting against increased forest product sales and growing unemployment among tribal population with one fell swoop [57]. Eastern Indian State, Jharkhand designed an afforestation program for returned rural migrant workers whose income is lost due to COVID related lockdowns and businesses closures in urban areas [58]. Similarly, Pakistan extended "10 Billion Tree Tsunami Program" to include day laborers, minorities, women and vulnerable communities whose income is severely affected by SARS-CoV-2 locked down [59]. It is an ambitious 5 year plan with a goal to plant 10 billion saplings by 2023 to combat with the threats of climate change. Green initiatives projects and programs are ongoing or are underway in Ethiopia, Niger, Mali, Gabon, Canada, UK, and Myanmar, in order to tackle the global deforestation [60]. Similarly, Iceland included land quality recovery and land reclamation projects as well as creating birch plantation forest in the second COVID-19 economic stimulus package [61]. All these affirmative action's though not enough to counter the deforestation in some other regions of the world, is commendable in the wake of increasing zoonoses and climate change effects. Biomass is still the predominant source of energy for rural population to meet their energy needs [62]. The dependence on natural resources will grow after pandemic as more and more people fall below poverty line due to job losses and looming recessions in countries. Therefore, the countries need to be devising ways to stop deforestation such as providing self-sustaining (income generating) trainings, creating new employment opportunities, and encourage renewable energy use through tax breaks and incentives.

COVID-19 and Disinfectant Uses

Contact transmission either by touching, hugging, and shaking hands or through touching contaminated surface or object (fomite transmission) is equally responsible for the transmission of virus as air borne transmission. In order to intervene the viral transmission, social distancing and proper mask use along with proper hand wash or hand sanitization and surface disinfection are recommended [63]. DHS Science and Technology directorate [64] evaluated disinfectant efficacy against SARS-CoV-2 virus and determined 70% isopropyl alcohol and 0.26% sodium hypochlorite significantly reduce the viral load. Demand for hand sanitizers and surface disinfectants outstripped the sources of supplies in earlier months of COVID-19 breakout. To keep up the supplies in this global health crisis, FDA temporarily allowed industries, and research institutions to strategically produce the hand sanitizers with the aid of certified compounders [65]. In UK, Health and Safety Executive (HSE) using article 55(1) of the biocidal products regulation allowed short term derogations of requirements in order to ensure the supply of hand sanitizers [66]. The primary ingredient in most hand sanitizers contains ethyl alcohol (ethanol), isopropyl alcohol (propan-2-ol), and benzalkonium chloride. Few manufacturers sold subpotent alcohol, methanol contaminated, and microbial contaminated hand sanitizers in the market with a motive of making money at the expense of people's health and hygiene.

EPA approved a list of following disinfectants for use against SARS-CoV-2 on surfaces. The various types of disinfectants varying in active ingredients are listed in the TABLE 1.

TABLE 1: EPA approved disinfectants for use against SARS-CoV-2

Active Ingredient(s)	**Contact Time (in mins)**	**Formulation Type**	**Surface type (Use Site)**
Quaternary ammonium (Quats)	10	Dilutable	HN, FCR (H, I, R)
Hydrogen Peroxide	1-10	Dilutable	HN (H, I, R)
Peroxyacetic acid (Peracetic acid)	1-10	Dilutable	HN (H, I, R)
Tetraacetyl ethylenediamine	1	Dilutable	HN (H)
Phenolic	10	Dilutable	HN (H, I, R)
Isopropanol (Isopropyl alcohol)	3-10	Ready to use	HN, FCR (I)
Sodium carbonate peroxyhydrate		Dilutable	HN, FCR, P (H, I, R)
Ethanol (Ethyl alcohol)	10	Ready to use	HN, FCR (H, I, R)
Sodium hypochlorite	1-5	Dilutable	HN, FCR (H, I, R)
Sodium chlorite	5	Dilutable	HN (H, I)
Octanoic acid	2-10	Dilutable	HN (H, I)
Sodium dichloroisocyanurate	5	Dilutable	HN, FCR (H, I, R)
Dodecylbenzenesulfonic acid, L-lactic acid	0.25	Electrostatic spray, Ready to use	HN, FCNR (H, I, R)

Citric acid	5-10	Ready to use	HN, FCR (H, I, R)
Iodine	10	Dilutable	HN, FCR (I)
Glycolic acid	10	Ready to use	HN (R)
1,2-Hexanediol	10	Ready to use	HN (H, I)
Chlorine dioxide	10	Dilutable	HN (H, I, R)
Potassium Peroxymonosulfate, Nacl	10	Dilutable	HN, FCR (H, I)
Thymol	10	Ready to use	HN, FCR (H, I, R)

Abbreviations: Quats – Quarternary ammonium, Surface Type: HN – Hard non-porous, FCR – Food Contact post rinse Required, FCNR- Food contact no rinse, P – Porous, Use Sites: H - Healthcare, I - Institutional, R – Residential

Disinfectant Use and Human Health: Although hand hygiene is vital to remain safe from COVID-19, some researchers have reported effects of sanitizers resulting from its misuse or excessive use. Topical ethanol applications permeate through lacerated skin rendering percutaneous toxicity especially in children. American Association of Poison Control Center (AAPCC) [67] reported 24,802 (67%) exposure cases of hand sanitizer in children 12 years and under of the total 37,032 cases in the year 2020, an increase of 72% case counts compared to 2019. Similarly, alcohol-based hand sanitizer might cause contact dermatitis in people (especially in Asian population) with aldehyde dehydrogenase deficiency (ALDH) [68]. ALDH2 detoxifies acetaldehyde which is an ethanol metabolite. Dermal contact of ethanol develops irritation and allergic condition of skin and eyes whereas chronic exposure results in skin becoming dry, cracking along with itchy, peeling and redness of skin while chronic high exposure may damage liver and nervous system [69]. Another important ingredient of hand sanitizers and disinfectants is isopropanol. These are assigned "1" for health hazard ratings due to their capacity to defat and worsen existing dermatitis. It may cause headache, dizziness, and confusion, loss of co-ordination, unconsciousness, and even death with repeated high exposure [70]. Apart from these health impacts, FDA indicated that acetaldehyde was found in excessive levels in some fuel ethanol products. Acetaldehyde is notorious for genotoxic carcinogen when comes in contact with tissues directly. Even some ethanol contained gasoline and benzene impurities from fermentation and distillation processes that can cause cancer [65]. Although the manufacturers are continuously under the radar of monitoring agencies, chances of unintended contamination cannot be overlooked at times when active ingredient is in high demand.

Bleach serves best for the disinfection of contaminated surface against H5N1, influenza viruses, and SARS- COV viruses [71]. Mass sterilization with low concentration of bleach which has sodium hypochlorite (NaOCl) as active ingredient were drifted in the streets, playgrounds, theatre, and public places in some countries which led to bleach exposure to general public and native plants and animals. China, Korea, France, Spain, Indonesia, Vietnam, Brazil and few others doused large amount of disinfectant chemicals in public places [72]. This malpractice was later denunciated by WHO reiterating it as ineffective and undermines the people's health with underlying health conditions. WHO recommends the use of 0.5% (equivalent to 5000 ppm) sodium hypochlorite for disinfection as it is effective against influenza viruses.

The lack of proper knowledge of cleaning for the application of disinfectants and not complying with the recommended directions of use may inhibit intended action against bacteria, viruses, protozoa, and fungi. Mixing of bleach with other chemical compounds or cleaning products might have unintended consequences, sometimes lethal [73]. Its mixture with the surfactants or soaps could form carbon tetrachloride, chloroform and halogenated volatile organic compounds [73]. As for example, bleach with acid based cleaners (acetic acid, citric acid) produces hypochlorous acid (chlorine gas) which if inhaled cause pulmonary issues such as breathing problems, sore throat, coughing, and even cause acute lung injury [74]. Similarly, chloroform resulting from mixing of bleach and alcohol is toxic during inhalation and through skin contact. Likewise, chloramine is released when bleach combines with ammonium salts in soaps or dishwashing liquids. All these disinfectants could possibly contribute to the asthma, chronic bronchitis [75], and chronic obstructive respiratory disorder [76] related to occupational health exposure.

The [TABLE 1] lists the different types of disinfectants approved by EPA. Almost half of the disinfectants approved contain quats as active ingredients. Most common quats are alkyl dimethyl benzyl ammonium chloride (ADBAC) aka benzalkonium chloride (BAC), and dodecyl dimethyl ammonium chloride (DDAC). Although quats for residential use has low toxicity, few accidental ingestion and overdoses have been reported as the cause for human deaths [77]. EPA didn't recognized them to be carcinogenic, mutagenic, or genotoxic, and is not even a dermal sensitizer [78-80]. However studies contradict it by showing ADBAC and DDAC exposures are tied to allergic skin reaction and Asthma [80], most specifically sensitizer induced occupational asthma by inhalation of quats [81]. Quats are assigned category II for acute toxicity by the oral and inhalation routes and category III by dermal route [79]. Repeated oral exposure to DDAC and C12-C16 ADBAC may result in irritation, reduced food consumption, reduced weight gain, and weight loss [80]. Similarly, inhalation of aerosols of Quats is linked to bronchoconstriction and lung damage in humans as observed in a mice study [82]. Few studies even indicated quats specifically ADBAC & DDAC exposure lead to developmental and reproductive toxicity [83, 84].

Misinformation/disinformation on COVID-19 by media and anti-science public figures has negative impact on health and wellness of general public. Misinformation is harmful in such a way that it leads to the deaths [85]. Misleading information, rumors such as highly concentrated alcohol consumption disinfects body in the same way as it sanitizes hands is deemed as the leading cause of deaths [86] of over 800 people, 5876 with critical hospitalizations and 60 lost their vision in Bolivia all due to methanol poisoning [87,88]. An internet panel survey of 502 U.S adults conducted by Porter Novelli Public Services showed that 39% of respondents were employing high risk practices such as applying disinfectant and cleaning products on bare skin, inhaling or ingesting these products, and washing foods with bleach in an anticipation of remaining safe from SARS-CoV-2 virus [89]. This study showed that ≤ 10% of respondents either drank or gargled a household cleaner or soapy water, or bleach solution. This indicates people's anxiety, fear, and confoundment elevated by infodemics.

Disinfectants Effects on Organisms: The earlier dumping of chlorine disinfectants on the public places especially around community centers, city centers and suburbs to combat COVID-19 by several countries has repercussions not just on human health as discussed above but also on urban ecosystems, urban wildlife, and aquatic organisms. As an illustration, overuse of chlorine disinfectants led to the deaths of numerous animals of at least 17 species in

Chongqing, a city in southern China (You, 2020 as cited in [90]). These includes: wild boars (*Sus scrofa*), Siberian weasels *(Mustela sibirica)*, common black birds, (*Turdus merula*), and many other predatory and non-predatory birds. If keystone species became accidentally poisoned by our unscrupulous practices of chemical use and disposal, some ecosystems couldn't withstand the environmental changes and will put an end to the ecosystem or become drastically altered.

Quats Effect on the Environment: Quats, an active ingredient in hand sanitizer and disinfectants has been tremendously used in domestic, commercial, hospital & healthcare facilities, and industrial settings particularly during COVID-19 pandemic, which are either washed down the drain or washed off the surfaces and enter the storm water system or surface water directly. Concentrations of quats in surface water and waste water effluent vary between ≤ 1μg/l to 60μg/l approximately while 10 times higher in influent waste water at normal times [91]. Most of the quats are biodegraded or sorbed to suspended particulates and sludge. Lower number of methyl alkyl groups and methyl substituted by benzyl group adversely affect biodegradation [92]. At unusual times such as in COVID period however, wastewater influent laden with quats is much larger in volume and much of which end up in sediments. Water discharged from waste water treatment plants (WWTPs) may arouse water quality issue attributable to the disruption of its operation, inhibition of microbial processes due to overburden of chemicals, and the ineffectiveness of the treatment plant due to mixing of chemicals producing toxic products by synergistic effect of some chemicals. Quats are even toxic to some bio-indicators of aquatic environment such as algae, rotifers, fish, daphnids, invertebrates, microorganisms [93] and benthic dwellers [91] at varying acute and chronic toxicity ranges [94]. Some studies even predicted changes in microbial communities and their developing of antibiotic resistance over time with increasing concentration of quats in aquatic environment [91, 93, 95].

Abundant amount of qarts are tied to the suspended particles, sediments and sludge due to their high affinity to these organic and inorganic factions. However, they do not undergo biodegradation in anaerobic conditions in anaerobic digesters [93]. Therefore, quats laden sewage sludge bio-solids application on land becomes another route of environmental contamination of soil. They pose risk to soil floras and faunas. As for example, the disruption of intracellular localization of dehydrogenase in soil microbes [96] which transfer hydrogen from organic matter to inorganic acceptors. This significant microbial activity will be inhibited at 50 mg/kg to 100 mg/kg of Hexadecyl and octadecyl trimethyl ammonium bromides in soil and potentially nitrification is inhibited as well at 50 mg/kg in soil. Likewise, earthworm tissue has been reported to bioaccumulate quats (Sarkar et al., 2013 as cited in [93]). In the wake of the pandemic, unprecedented increase in the usage of disinfectants will elevate the quats in the environment (aquatic and terrestrial) which might adversely affect environment, plants, animals and humans. Therefore, thorough studies need to be conducted and periodic overhauling of registered disinfectants needs to be carried out by EPA. We need to conservatively and prudently use them following the directions on labels and recommendations until cure for SARS-COV-2 is within our grasp.

Biodiversity and COVID-19

Maintaining forest dynamics is critical to conserving biodiversity of plants and animals [97]. Deforestation upends this complex intricately balanced forest ecosystem. Deforestation led habitat destruction and human induced climate.

Forest Fires and Wildlife during COVID-19 Pandemic: The massive rate of deforestation and slash and burn fires in the Amazonia, wildfires/bushfires in North America and Australia killed or displaced wildlife's from their natural habitat [98]. IPCC considered forest fires as a cue for land conversion to agricultural and pastoral land. Land use change and wildlife exploitation brings humans and wildlife in close proximity; imposing potential risk of new infectious diseases [99]. Bushfire have impacted almost 3 billion native vertebrates in 12.6 million hectares severely limiting species range of 119 animal species (5 invertebrate, 17 bird, 20 mammal, 23 reptile, 16 frog, 22 spiny crayfish, and 16 freshwater fish) in Australia between years 2019 and 2020 [98]. Pugh's frog, blue mountain water skink, the Kangaroo Island dunnarts previously listed endangered and critically endangered are now pushed towards the brink of extinction due to these infernos. Others such as smoky mouse, koala, giant burrowing frog, Vesk's plant louse, western ground parrot, and Kangaroo island regent honeyeater needed immediate management intervention to support their recovery [100]. Wildlifes in Kangaroo Island are worst affected as fire ravaged over one-third of its area making its endemic species' recovery difficult. Endemic plants and animals and specialist species will be the ones in the verge of extinction and thus needs special conservation efforts to tackle their extinction. Similarly, in the United States wildfires in the sagebrush flats in Washington State perished 30% to 70% of the birds and critically endangering future recovery of pygmy rabbits, sage grouse, and sharp tailed grouse largely due to their critical breeding grounds being destroyed [101]. Likewise, white headed woodpeckers, and Grace's warbler which depend on the pine forests in the Pacific Northwest and pine-oak forest in the Southwestern United States respectively has lost their habitats on fire this year [102]. Fire flared through the Western pine forest in Oregon may make the survival and existence of endangered and threatened species such as pine marten, spotted owl challenging [101]. Likewise, Colorado's largest fire in the state's history burned over half a million acres burning continuously for 112 days. All these infernos imperil plant and animal species, and also impact their regeneration, reproductive success, recovery and growth. It interferes with the geographic range limits of animals as well as biodiversity conservation. Not only that, fire is also detrimental to human health as the wildfire smoke not only irritate lungs, cause inflammation, but also compromise human immune system making it prone to lung infections such as SARS-CoV-2 [103].

FIG.5. Peak Fire in Colorado (top Left), Abert's squirrel (*Sciurus aberti*) (bottom left), the Shiras moose (*A. alces shirasi*) (top right), and Bighorn Sheep Ewe (*Ovis candensis*) (bottom right) spotted in Colorado during pandemic

Human Animal Interface: Potential Causes of New Infectious Diseases: WHO defined zoonosis as "any infections transmitted from vertebrate animals to humans". About 60% of all emerging infectious diseases have their roots in animals, and three-fourth of which comes from wildlife's [104]. WHO [5] assessed the zoonotic introduction of SARS-CoV-2, and considered it as likely pathway to humans. The SARS-CoV-2 has similar genetic makeup as seen in bat SARS-CoV. SARSr-CoVs were identified on bats and Pangolins [5].

TABLE 2: Emerging viruses and zoonotic diseases

Disease	Distribution	Hosts/Reservoirs	Exposure	Drivers of emergence
SARS	South-east Asia	Bats, Civets	Direct	Human consumption, capturing and marketing, wet markets as mixing bowl ex. Civets and bats,
Novel Coronavirus (SARS-CoV-2)	Worldwide	Likely Bats, Minks infected from humans act as virus reservoir and spill it back to humans	Direct	Harvesting, handling, and marketing of live bats
Ebola	Africa	Non-human primates, bats	Direct	Logging, hunting and butchering Alteration of natural fauna, Agriculture,

				outbreaks along forest fringes
Nipah	South Asia	Bats, Pigs	Direct/ Indirect	Agro-forestry at forest boarders/ fragmented forest
HIV	Worldwide	African Apes Primate	Direct	Bushmeat hunting, exposure to body fluids or bloods while butchering and/or eating some forms of bushmeat
Zika	Africa, the Americas, Central and Northern Europe Asia, and the Pacific	Rhesus monkeys	Vector	Deforestation, Human expansion in fragmented forest, habitat alteration beneficial for mosquito (Aedes, Anopheles, and Mansonia)
H5N1& H7N9 Avian Influenza A	Eastern Europe, Southeast Asia	Waterfowl & Migratory birds	Direct/ Indirect contact	Destruction of forest or wild bird habitat, Poultry-wild bird interaction at trade market, Encroachment of wetlands or lake areas for human settlement, climate change
Monkey Pox Virus	Mid-western US	Monkeys, Rodents mix with other species inc. Prairie dogs	Direct	Petting Prairie dogs
Crimean-Congo Haemorrhagic Fever	Africa Middle East and Asia	Ticks (Ixodid)	Vector	Ticks maintain virus in nature transstadially and transovarially. Slaughtering infected animals, or veterinary procedures
Lassa Fever	West Africa (Benin, Ghana, Guinea, Liberia, Mali, Togo, Nigeria)	Rodents Multimammate rat (*Mastomys natalensis*)	Direct/Indirect	Food or household items contaminated with faeces and urine of infected rats.

* HIV – Human Immunodeficiency Virus, SARS: Severe Acute Respiratory Syndrome

The [TABLE 2] lists some of the emerging infectious diseases or re-emerging diseases. Some of these diseases have been recently appeared while others are increasing its geographical range and/or range of incidence recently or in near future. Novel Coronavirus has caused havoc in human population infecting approximately 140.3 million people and decimating over 3 million lives.

Mammals belonging to Families Mustelids (minks) and felids (cats, lions and tigers) were documented to have SARS-CoV-2 infections; it then underwent intra-species transmissions as well as cross-transmissions [5]. As such was suspected in minks when SARS-CoV-2 cluster 5 variant detected in farmed minks population was found infecting humans [105]. In response, millions of minks have been culled across Europe. 17 million minks culled

Illegal Hunting and illicit trade: Amazon forest harbors 3 million species of plants and animals. Huge diversity in the tropical forests therefore contains large range of pathogens, parasites and the vectors [42]. World wildlife fund (WWF) reported Sumatran tigers, two-horned rhinos, and Orangutans are in the verge of extinction from poaching, forest degradation, deforestation and human-wildlife conflict in Indonesian Leuser ecosystem on the Sumatra Island unless habitats are conserved and stringent regulations were enforced against poachers. Pandemic provided perfect time for the poachers, wildlife traders, and illegal loggers to intensify their operation due to the absence of park rangers, forest guards, and tourists off of the forest area particularly in South America, Africa, and Asia [106]. Illegal hunting and wildlife trade took a heavy toll on migratory birds, endangered species and elegant animals such as tigers, leopards, antelopes, rhinos in south Asian countries India, Nepal, and Pakistan [106] and wild cats such as jaguars, pumas in Colombia, black rhinos in Botswana, Southern Africa [107], while capturing of exotic birds and amphibians for pet trade is on rise in several parts of the world. Wild mammals captured from wilderness likely carry zoonotic infections onto the person exposed to it [5]. Bush meat hunting has skyrocketed in some parts of Africa. The declining income and food insecurity could have resulted in this increasing wildlife trafficking and bush meat hunting during pandemic [107]. SARS-CoV-2 transmittance by exotic meat consumption is not proven yet; however, bodily fluids/secretions (saliva, urine, mucus, blood, faeces) of infected animals still possess risk of transmission through contact [5].

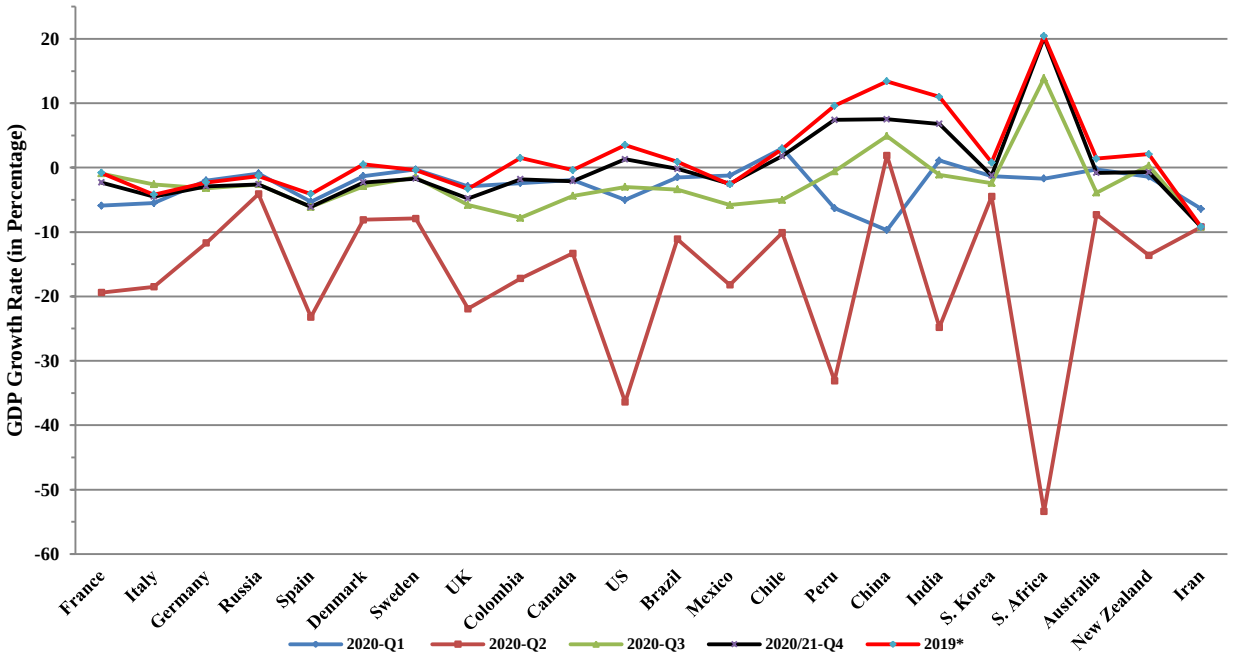
Another animal speculated as the reservoir of SARS-CoV-2 is Pangolin. It is one of the most trafficked mammals in Asia (esp. Vietnam, China, S. Korea), and Africa (Cameroon) for its scales and meat [108]. Pangolins role in the SARS-CoV-2 as the reservoir or the intermediate host [109] or not [110, 111, 5] is still the subject of research. Whatsoever the stress caused in captivity due to food and water shortage, asphyxiation due to stacked animals in small confinements, caged adjacent to other wildlife, being transported to new environment beyond natural range, all make them frail and vulnerable to the pathogen spewed by the weak and diseased, and dying ones. The wildlife trade is possibly culpable for the emergence of new infectious diseases [112-114]. This was the most plausible explanation behind SARS-CoV-2 cross-transmission. According to Lo [115], South China morning post, the biggest customs seizures this year are American ginseng, totoaba fish maws or tatoaba bladders, red sandalwood, and dried shark fins while Pangolin scales, rhino horns, and ivory products smuggling dropped surprisingly so did the wildlife smuggling cases in Hong Kong due to travel restrictions. However, Hong Kong customs recorded a 12 % surge in the smuggling of endangered species in cargo shipments in 2020 than the previous year. WHO's recent joint report on origins of SARS-CoV-2 didn't dismiss the trade in animals and their products to the introduction and transmission of SARS-CoV-2. Therefore, the ecosystem degradation and forest fragmentation are not the only factors that promote zoonosis but legal and illicit trade of wildlife in wet markets provides ample opportunity for pathogens spillover by facilitating human-wildlife interface and/or human-livestock-wildlife interface [113, 116].

Positive impulses during COVID-19: Although it is hard to overlook these disheartening incidents occurred during COVID-19 pandemic, there are some signs of positive developments in terms of wildlife conservation and wildlife trade. Some of the West African countries such as Sierra Leone, Senegal, which has been fulfilling Chinese rosewood demand illegally before coronavirus outbreak completely ceased their operation in pre- and during pandemic [117] due to lack of demand and the travel restrictions globally. Similarly, National People's Congress – China banned marketing and consumption of wild animals on February 24, and on June 5th, 2020 pangolin (native to china only) was awarded highest level of wildlife protection closing loopholes for its consumption and use in pharmacopoeia [108]. This is a big leap in terms of wildlife trade and wildlife conservation by the Chinese government, a counter measure against wet market. Similarly, Republic of Korea acknowledged the public sentiments by banning imports of invasive alien species [118]. Decreased human activity led to the diminished fear of humans in animals which in turn increased their presence even occupying sometimes unusual places at unusual time [119]. Some examples are Free roaming flocks of goats in Llandudno, Wales, wild boar in Barcelona, Spain in daytime, Turkey, a raccoon walks in central park in New York, pumas in downtown Santiago, Chile, and Dolphins in Italy's Gulf of Trieste [120]. Similarly, sightings of birds flocking around airports, Shorebirds such as Kentish plover (*Charadrius alexandrines)* laying eggs more evenly than before in the shores, reproductive successes of swallows and swifts (*Apus apus*) and relative ease of wildlife sightings [119] are the result of multiple factors such as reduction of landscape of fear, low air pollution during COVID-19 pandemic. Despite conservation efforts being seriously affected during pandemic, increase in species richness of faunas in less disturbed areas and drastically reduced road mortality of amphibians and reptiles were reported [119, 121].

Wildlife harbors large numbers of pathogens currently undiscovered that has the potential to infect humans in future. Pandemic gave a sense of urgency to identify, diagnose, and address the causes of zoonotic diseases. Expansion of virus surveillance in other animals beyond bats & pangolins will go a long way to improve the wellbeing of both humans and animals. People called for Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to expand its dimension to include not just economically valuable species but keystone species, and those vulnerable to trade. A backlash and public outcries about the legal wildlife trade is growing for the lack of properly regulated and scrutinized system which in disguise supporting illegal wildlife trade.

COVID-19 Effect on Health and Economy

Economists believe that speeding up vaccines rollout could potentially reverse the current state of global poverty, recession, and economic downturn, an aftershock of COVID-19 pandemic. It is estimated that ≤ 34.3 million people will be plunged into extreme poverty in 2020 while the number might increase over 160 million due to its spillover effect by 2030 [41]. International Monetary Fund [122] reported that approximately 95 million may have been forced into extremely poverty level in 2020. Also, the pandemic has flushed the decade's long progress made on poverty alleviation down the drain. It is expected that the cumulative per capita income losses between 2020-2022 is ≤ 20% of 2019 per capita GDP in emerging markets and developing economies whereas 11% losses in advanced economies [123].



Note: '*' represent annual growth rate in the given year

FIG. 6.Comparisons of Quarterly GDP Growth Rates 2020 with GDP Annual Growth Rate 2019

Gross Domestic Product (GDP) measures the market value of goods and services a country produces within specific period of time usually in a year. It therefore, measures the economic growth of a country. The United States of America was ranked first among countries with highest GDP in 2019 with 21.4 trillion U.S. dollars followed by China, Japan, Germany, India, and UK [124]. Figure 6 depicts the effect of COVID-19 containment policy on the economy of the countries severely affected by it. The containment strategies were either not necessary or not enforced until the end of fourth quarter 2019 for most countries besides China. Due to early insurgency of virus in some parts of the country, Chinese government response towards this contagion was aggressive at the beginning of first quarter of 2020. Many other countries which encountered surge in cases initially were unprepared and have feeble non-medical interventions in place for controlling the contagion. The level of government stringency to contain the virus has different level of impact on the economy. The government stringency ranged from social distancing to stay at home order, lockdown, quarantine and isolation, was strictly enforced in countries which saw uptick in cases. Figure 6 indicates the economic performance of Nordic countries in response to government stringency policies relating to COVID-19. Higher level of stringency such as lockdowns, social distancing negatively affected the economy and case numbers [125]. The economic gain of fourth quarter 2019/2020 was mostly remained positive, however lockdowns, businesses closure or restrictions, stalled manufacturing, travel ban, contraction in investment, plummeted exports, plunge in discretionary spending, and skeptical of government support during pandemic led to the contraction of quarterly GDP compared to preceding quarters.

In US, during the second quarter of 2020, the real GDP decreased at 31.4% per annum while it decreased at 5% per annum in the first quarter [126]. The decrease in GDP during first quarter and second quarter of 2020 [FIG.2.] is attributed to the stay at home order, change in consumer spending habits in response to pandemic, school/colleges/business/non-essential health services closure, and new restrictions and closures in some areas, pandemic assistance/coronavirus stimulus from government, limited consumer spending or personal consumption expenditure, and imports [127]. After 2nd quarter, the economic recovery was on the roll with vaccine optimism, laxed restrictions and discussions over economic support in US. Cutler and Summers [128] put a price tag on COVID-19 pandemic over $16 trillion on the basis of lost output and diminished familial health in the United States. The indirect losses from COVID-19 outweigh the related direct costs such as treatment cost and mortality.

Downturn in travel and tourism income for example in Nepal, Fiji and few others where tourism and remittance contributes heavily to the GDP will have to encounter higher economic risk because of global recession [129]. Tradeoff between economic risk and health risk made some countries to choose difficult path. Sweden's laissez-faire approach that led to the more deaths compared to the Nordic neighbors as is evident from [FIG.7. (b)] was harshly criticized by many scientists and countries. Sweden COVID-19 deaths reached 787 per million in Dec. 20, 2020 which is about 3.2 to 10.5 times higher than its neighbors [130]. Unlike Sweden, which has favorable demographics (more youths and adults than senior citizens) and larger share of single person households, the fatality rate would have increased in many other countries if they had adopted the Swedish model.

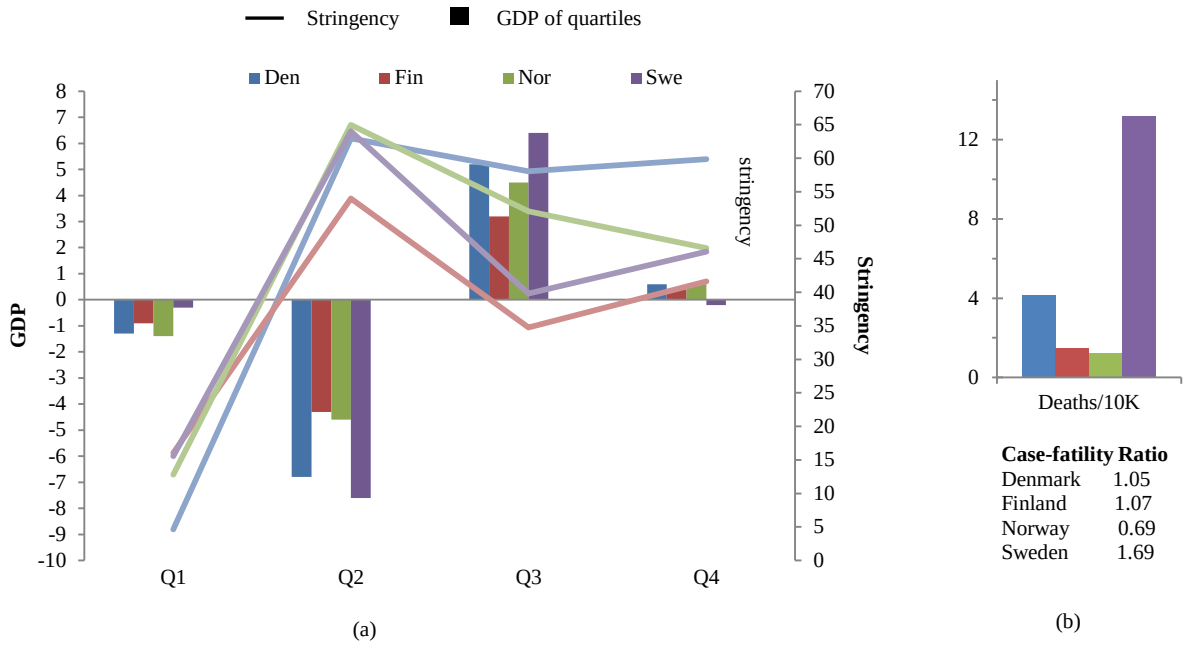


FIG.7. (a) Government response stringency index indicating severity and timing of measures undertaken versus quarterly GDP. (b) Total deaths attributable to COVID-19 in Nordic countries between First quarters of 2020 till the first quarter of 2021.

Source data: Our World in Data and Coronavirus Resource Center, John Hopkins

FIG.7. (a) depicts the government response stringency index of Nordic Countries in response to coronavirus and FIG.7. (b) Portrays its corresponding effects on GDP and Mortality. Stringency index versus economic performance of the country provides better perspective on the COVID mitigation measures taken by the government and its effect on their economy. Besides Sweden, most of these Nordic countries are performing better in terms of curtailing the number of COVID-19 related deaths and mitigating the impact on the economy. Sweden refrained from active lockdowns, schools and businesses closure and continued with the voluntary social distancing giving more weight to the people's own responsibility to curtail the spread while Norway and Denmark's early and timely instituted total and partial lockdowns, strict restrictions, cautiously loosening or tightening of restrictions as per cases surge or decline, and economic support altogether helped to reduce human causality and helped to protect against severe economic downturn as is observed in FIG.7.(a) & (b). Early implementation of more stringent policies helped save thousands of lives in European countries compared to those either not implemented or implemented later [131].
After a long wait, the grim prospect of the economy is finally looking pleasing with vaccines' approval and roll out. The latest projection on global economic growth for 2021 and 2022 is between 5.5% - 5.6% and 4.0% - 4.2% respectively [123,132]. The economic recovery will be disproportional, stronger and much faster in high income countries due to their capacity to procure highly effective vaccines and rapid vaccine deployment to their population, better healthcare, and supporting policies such as stimulus and relief package to support their people, and to spur economic activities. In sharp contrast, the developing economies except India and china will be more vulnerable.

Current Challenges and New Avenues

Wearing masks, social distancing, hand hygiene, limiting mass gatherings & indoor events, restrict mobility and clean & disinfect touched surfaces are the precautionary measures still in effect as global pandemic surpassed 140.3 million coronavirus cases and over 3 million deaths globally. With just 4.25% of the total world population, United States tops the list with over 23.2% of global cases and heavy death tolls (approximately 19.4% of the total global deaths) from COVID-19. In US, FDA issued an emergency use authorization for the Pfizer-BioNTech COVID-19 vaccine on December 11, 2020, the Moderna COVID-19 vaccine a week later, and J&J/Janssen vaccine on February 27, 2021. In addition to these vaccines, UK and EU authorized Astrazeneca vaccines produced by Astrazeneca of Cambridge, UK, and the University of Oxford, UK to protect against COVID-19. Scaling up the production and vaccine distribution is the major challenge at present. Vaccine companies are backlogged of orders to be fulfilled especially from wealthier nations. The major constraint at this time is the adequate vaccine manufacturing capacity and some vaccine raw material in short supply.

There is a growing concern about mutations that are giving rise to new coronavirus variants. Two most transmissible COVID variants or "variants of concern (VOC)' that have been first identified in the UK and the South Africa are B.1.1.7 (201/501Y.V1 or VOC202012/01) and B.1.351 (20H/501Y.V2) respectively. Another VOC, variant that is not much in circulation and was first identified in Japan is P.1. This variant has additional 17 mutations that make it hard for antibodies to recognize the virus. The 501Y.V1 has already been detected in forty plus countries [133], and

501.V2 in 10 European Union/ European economic area and few other countries [134]. The new addition to the list of "variant of concern or VOC" is the Indian variant known as B.1.617 on May 9, 2021by WHO. Although the reproduction rate for previously circulated coronavirus is declining in many regions of the world due to multiple interventions in interplay such as increasing the pace of vaccination, lockdowns, and other non-pharmaceutical interventions as of February 1st, 2021, it is still well above "1", signaling no retreat in the number of new cases soon. The B.1.1.7 (VOC202012/1 or 20I/501Y.V1) variant is dominant at present as it is highly transmissible with reproduction number 43-90% higher than previously circulating one. It is more infectious [135] and has high risk of mortality by infection [136]. The new VOC B.1.617 which took a heavy death toll in India has already spread over 40 nations is highly transmissible and renders less potency of the current vaccines in neutralizing antibody response to the B.1.617 variant [137].

Extensive coronavirus testing and contact tracing service at people's convenience, isolation and quarantine for laboratory confirmed patients as well as travelers across the borders, and partial lockdowns seem to be working strategy in many countries. Highly affected countries could control the spread of virus by revamping their services and restructuring frail public health systems. Genome sequencing is critical to decipher the mutations to the virus. Mutating virus is more transmissible as is evident from B.1.1.7, B.1.351, and B.1.617. Therefore, genomic sequencing could be another avenue to stop the circulation of new variants. CDC and Public Health England (PHE) also emphasized on doubling down on sequencing effort to fight against COVID-19 and the emerging variants. The hard work of scientists in making COVID-19 vaccine a reality in record time might become all for naught if other variants take-off jeopardizing vaccine efficacy or compromised efficiency. The ongoing mutations of SARS-CoV-2 bolstered the need to continuously monitor and surveillance of structural changes in the spike glycoproteins of virus and test the vaccine efficacy thereof targeting those spikes. Efficacy study of the messenger-RNA based vaccine BNT162b2 (commonly known as Pfizer BioNTech COVID 19 vaccine) to pseudoviruses bearing B.1.1.7 spike protein by scientists from Pfizer & BioNTech show that the vaccine could neutralize SARS-CoV-2 and its B.1.1.7 variant [138]. Similarly pseudovirus of B.1.1.7, B.1.351 and few other variants were assessed for the neutralization of their mutated spike protein using sera from human and non-human primates who received mRNA-1273 vaccine. Scientists from Moderna and their collaborators found that the Moderna vaccine is capable to neutralize these new strains. However, 6.4 fold reduced neutralization titer against B.1351 compared to B.1.1.7 and SARS-CoV-2 though still protective, may still be supplemented with booster shot to boost titers against B.1351 [139]. Likewise, Novavax vaccine is showing promising result against the SARS-CoV-2 and its B.1.1.7 variant while its effectiveness is below 60 % against B.1.350 variant. Most of high efficacy vaccine makers against SARS-CoV-2 are working to make booster shots to increase its efficacy against B.1.351. A vaccine efficacy trial is underway and near completion for handful of other pharmaceutical companies which could be anticipated to reach the arms of the people in near future. Meanwhile, International communities, WHO, UN's HIV/AIDS agency, USAIDS are urging wealthier nations on temporary waiver of Intellectual Property Right (IPR) for vaccines. The intent behind waiver is to allow more countries produce their own vaccines by the help of knowledge shared by vaccine developers for the greater good. We are running out of time in a war against the COVID-19 pandemic. The wealthier nations have the power to bring an end to the pandemic by fully co-operating with COVAX project, and/or temporarily waiving IPR on COVID

vaccines. If wealthier nations don't become the part of the solutions, the pandemic will reign claiming millions more lives and changing the world forever. It will be too late when current vaccines efficacy lack lusters in case of emergence of new highly virulent variants through multiple mutations.

Vaccine Distribution Inequalities

A widening rift between rich and poor became more discernible during this global pandemic where vaccine procurement disparities and unfair allocation dominated for the most part of 2020/21. Poorer countries are struggling to secure funding before they could secure vaccine. Until the first week of February, 2021, 125 million COVID-19 vaccines administered across 73 high and middle income countries while it's close to null to the lowest income countries, depicts today's realms of inequality in the world. India, China, and Russia could mitigate this wide gap and disparities to vaccine accessibility by production and distribution of vaccines to developing nations. The only drawback to these vaccines produced is the rushed approval by their respective country for emergency use without complete clinical trials, and thus unanimity over vaccine efficacy. WHO partnered with few others in an effort to procure and deliver COVID-19 vaccine doses to middle lower and lower income countries around the globe in equitable manner, forming COVAX project. However, WHO has been sidelined by increased bilateral contracts between suppliers and high income countries in regards to their increasing nationalist agendas. Wealthier countries have monopoly over the vaccines leaving poor nations afflicted with grievances [140]. About 6.5 billion people live in low and lower middle income countries [141]. As of April 9, only 0.2% of doses have been administered in low income countries through the global solidarity initiative, COVAX facility although over 700 million vaccines were administered worldwide. About 87% of these jabs went to the higher income countries alone [142]. Besides availability issue, skepticism towards vaccines exist in the people of poor countries given the fact that they either will receive sub-potent, low efficacy vaccine that never went through all phases of clinical trials or clinical scrutiny as happened in the past [143,144]. Some sixty-four high income countries have made commitment to support COVAX project which is aimed at ensuring access to the safe and effective vaccine to lower- middle and low income economies of the world. If they keep their promises and fulfill their obligations towards international community, we will win the war against the virus in near future.

Moving forward, highly efficacy vaccine is important to end pandemic and prevent global economic loss of US $ 375 billion per month [145]. In this globalized world, no one will remain safe unless large swaths of people all around the world are vaccinated as slow vaccine deployment allow more time and chances for virus mutations among unvaccinated populations and unhindered circulations beyond boarders begetting emergence of new variants possibly resistant to the existing vaccines [99]. Infections from new strains (variants) is still surging although the cases from previous version SARS-CoV-2 is levelling off or is even falling in some region of the world with several factor in interplay. Finger-crossed, vaccine will eventually become available globally sooner than later. Until then it is imperative for us to utterly follow CDC's, WHO's, and specific country's health and safety measure, guidelines and recommendations.

Sustainability: Green Growth

The nature's capacity to generate resources, absorb, renew and recycle wastes is strained due to ever increasing human pressure on the earth's capital. According to global footprint network [146], the earth's annual bio-capacity produced resources and services for the mankind lasted until August 22 for 2020 which was prolonged about 3 weeks relative to 2017, 2018, and 2019. The overshoot date for 2020 has moved 3 weeks later due to reduced carbon footprint and forest product footprint by 14.5%, and 8.4% respectively as a consequence of coronavirus pandemic. The trend of overshoot data was published by global footprint network which shows that we are running into resource deficit every year earlier than before and borrowing resources to fulfill our demands from future generations. In other words, human activities are becoming more unsustainable. The resuming of businesses, industries, and transport is propelling the economic engine while it is exacerbating to pollution, deforestation, resource depletion and environmental degradation rapidly. China economy took a leap of 11.6% in second quarter of 2020 since then it is making positive gains as shown in FIG.6. Similar is the case with the United States which achieved economic gains between July-September and October-December of 33.4% and 4.3%. This fast recovery from the recession comes at environmental costs as rebounding production industries spewing out massive pollutants, and extracting and consuming substantial amount of raw materials (minerals, oil and gas, forest product) more than pre-pandemic level. Decoupling economic growth or GDP from environmental impacts is imperative for sustainability however it is far from being achievable at present [147]. GDP growth is associated with increase in material & energy use and generation of pollutants and wastes. During pandemic, some of the countries even weakened or dismantled the environmental agencies. Environmental regulatory rollbacks or deregulations were aimed at providing regulatory relief in the support of "as usual development or brown economic recovery". Transitioning into green economy will be difficult for developing countries in the wake of pandemic due to piling of tremendous amount of debt, and other fiscal constraints. The economic recovery shouldn't be pursued at the expense of the environment. The new investment should be shifted to low carbon and resource efficient technologies and infrastructures, which in turn, will protect forest and biodiversity. Investing in new green technologies and infrastructure will shape our resilient future by reducing our overall footprints and balancing economic growth in accordance with the biocapacity of the earth. Some governments have utilized post-pandemic to spur green growth through directing relief packages, recovery, and rebuilding plan to include green investments.

Vaccines are of foremost importance to save the human capital and gear up the economic engine; however, international co-operation, incentivized financial support, and debt relief by international community will give an impetus to support for green growth in low income and developing economies. Similarly, public-private partnership and supportive fiscal policies domestically also becomes subsidiary to spur green economy.

Conclusions

Pandemic due to COVID-19 has several effects on social, economic, health and environmental fronts. An endeavor was made to comprehensively dissect how COVID changed all these aspects. Some mixed responses of COVID-19 effect on the environment, health, economy were presented. Zoonotic spillover followed by human to human

transmission is to be blamed for the current pandemic and health crisis; however, it boils down to the long standing environmental deterioration by anthropogenic activities to be the underlying cause of this predicament. This pandemic is not the first one, and won't be the last one unless we scramble to find the balance between human system and natural system. Lockdowns, quarantine, stay at home orders, travel restriction, and other forms of social isolation was viewed by many naturalists, bio-prospectors, and environmentalist group as a boon for nature that allowed nature to finally respite, relent & recover from long-standing environmental degradations and destructions. Temporary reductions in particulate matter (especially $PM_{2.5}$), carbon dioxide, and NO_X levels were witnessed in many densely populated cities of the world. The global economy was trampled down in 2020 due to the global pandemic, hitting hard on developing economies making their recovery to pre-pandemic level almost uncertain. The IMF prediction indicates that higher income countries such as US, Japan, UK, and Eurozone which were briefly in recession is slowly coming out of recession. In the meantime economy and employment is not impressive globally. Some governments are using COVID-19 recovery excuses in rolling back environmental regulations and taxes to support fossil fuel based economy or "as usual business". The myriad environmental problems and even the health crisis we encounter today are partly due to our adherence to fossil fuel based economy and unsustainable development practices. Therefore, the new development/recovery model should include green recovery and green jobs creation such as Increasing green spaces, urban green infrastructure, transitioning into low carbon emission systems, promote clean and renewable energy technologies, protection of wildlife and their habitat, investment in ecological restoration projects such as wetlands restoration, biodiversity restoration, forest restoration, development of conservancy, bioengineering etc. and environmental health. It is imperative to simultaneously address environmental objectives and green recovery to beget sustainable outcomes in future. Some countries made sincere efforts to include green recovery such as providing loans and tax reliefs to renewable R&D projects, clean energy development, green transport, circular economy, in the COVID-19 relief package. Some included reforestation and restoration project to provide jobs for migrant workers, and members of household who lost jobs and income source during pandemic.

Virus rollout has increased the hope of getting back to pre-pandemic output levels for these higher income countries sooner than expected earlier. There were some short-lived positive gains on environment due to COVID-19 imposed quarantines, lock downs, and shut downs; however these temporary gains couldn't be glorified in the wake of negative consequences of COVID-19 on environmental, social, economy, and health. Larger portion of these populations may have achieved immunity through infections and yet to achieve the goal of herd immunity, vaccination is the best way possible forging ahead. Thus, until herd immunity is achieved, stricter non-pharma intervention should remain in place. Conspiracies, misinformation related to vaccines, unhealthy competition among states and countries for procurement of equipments and unfair vaccines acquisition and hoarding has to end to win the war against the pandemic. Above all, global solidarity, the strong coordination among governments and multilateralism could have evaded excess deaths which is the lesson learned from this coronavirus pandemic.

Acknowledgments

The author would like to express his gratitude to all the reviewers and the entire editorial board. The author is thankful to Prof. Emeritus Robert Engelken for his continuous guidance and support.

REFERENCES

1. World Health Organization. (2004). Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003.
2. World Health Organization. (2013). Middle East Respiratory Syndrome Coronavirus (MERSCoV). Retrieved February 5, 2020.
3. Center for Disease Control and Prevention. 2020, Feb. 15. COVID-19. Retrieved March, 15, 2020.
4. National Institutes of Health. (2020). Coronavirus diseases and conditions: COVID-19, MERS & SARS.Retrieved July 13, 2020.
5. World Health Organization. (2021). WHO-convened global study of origins of SARS-CoV-2: China Part. Joint WHO-China Study 14 January-10 February 2021
6. World Health Organization. (2020, July 09). Transmission of SARS-CoV-2 - Implications for infection prevention precautions (Scientific brief).
7. World Health Organization. (2021, April 18). WHO Coronavirus (COVID-19) Dashboard. Retrieved April 24, 2021.
8. World Health Organization. (2021, April 15). Statement- Surging pandemic surpasses 1 million deaths in the WHO European region.
9. WHO. 2018. Ambient (outdoor) air pollution. Retrieved Oct. 1, 2020.
10. Zhu, Y., Xie, J & Cao, L. (2020). Association between short term exposure to air pollution and COVID-19 infection: Evidence from China. Sci. Total Environ., 727. 138704.
11. Xing, Y-F, Xu, Y-H, et.al. (2016). The impact of PM2.5 on the human respiratory system. J. Thorac Dis., 8(1), E69-E74.
12. California Air Resources Board. (2020). Inhalable particulate matter and health ($PM_{2.5}$ and PM_{10}). State of California. Retrieved September 10, 2020,
13. Karagulian, F., Belis, C.A., Dora, et.al. 2015. Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level. Atoms. Environ., 120, 475-483.
14. Helfand, W.H., Lazarus, J., & Theerman, P.D. (2001). Pennsylvania: An environmental disaster of the 20th century. Am. J. Public Health, 91(4), 553.
15. EPA. 2018. 2014 National Air Toxics Assessment (NATA): Assessment results. United States Environmental Protection Agency. Retrieved December 20, 2020,
16. Petroni, M., Hill, D. and Collins, M.B. (2020). Hazardous air pollutant exposure as a contributing factor to COVID-19 Mortality in the United States. Environ. Res. Lett., 15, 0940a9.
17. Totlandsdal, A.I., Cassee. 2010. Diesel exhaust particles induce CYP1A1 and pro-inflammatory responses via differential pathways in human bronchial epithelial cells. Part. Fibre Toxicol., 7, 41.

18. Mirowsky, J.E., Peltier, R.E. 2015. Repeated measures of inflammation, blood pressure, and heart rate variability associated with traffic exposures in healthy adults. Environ. Health, 14, 66.
19. Stieb, D.M., Evans, G.J., To, T.M., Brook, J.R., and Burnett, R.T. 2020. An ecological analysis of long-term exposure to PM2.5 and incidence of COVID-19 in Canadian health regions. Environ. Res., 191, 110052.
20. Coker, E.S., Cavalli, L., Fabrizi, E., et.al. 2020. The effects of air pollution on COVID-19 related mortality in Northern Italy. Environ. Resour. Econ. (Dordr), 1-24.
21. Comunian, S., Dongo, D., Milani C., et.al. 2020. Air pollution and Covid-19: The role of particulate matter in the spread and increase of Covid-19's morbidity and mortality. Int. J Environ Res Public Health, 17 (12), 4487.
22. Ali, N., & Islam, F. 2020. The effects of air pollution on COVID-19 infection and mortality - A review on recent evidence. Front. Public health, 8, 580057.
23. Yongjian, Z., Jingu, X., Fengming, H., 2020. Association between short term exposure to air pollution and COVID-19 infection: evidence from China. Sci. Total Environ., 138704.
24. Chen, N., Zhou, M., Dong, X., et al. 2020. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet, 395, 507-513.
25. Kumar, P., Hama, S.et. al. 2020. Temporary reduction in fine particulate matter due to 'anthropogenic emissions switch-off' during COVID-19 lockdown in Indian cities. Sustain. Cities Soc., 62, 102382.
26. Chauhan, A., & Singh, R.P. 2020. Decline in $PM_{2.5}$ concentrations over major cities around the world associated with COVID-19. Environ Res.187, 109634.
27. Venter, Z.S., Aunan, K., Chowdhury, S., & Lelieveld, J. 2020. COVID-19 lockdowns cause global air pollution declines. Proc. Natl. Acad. Sci. U.S.A, 117(32), 18384-18990.
28. NASA Earth Observatory (2020a). Nitrogen dioxide levels rebound in China 2020.
29. Pansini, R., & Fornacca, D. 2020. Early evidence of a higher incidence of COVID-19 in the air polluted regions of eight severely affected countries. MedRxiv, 20086496.
30. International Energy Agency. 2021. Global energy review: CO_2 emissions in 2020: Understanding the impacts of Covid-19 on global CO_2 emissions. IEA, Paris.
31. Tollefson, J. (15 January, 2021). COVID curbed carbon emissions in 2020 – by not by much. Nature 589, 343-343.
32. Liu, Z., Ciais, P., Deng, Z. et al. 2020. Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic. Nat. Commun., 11, 5172.
33. Tollefson, J. May 20, 2020. How the coronavirus pandemic slashed carbon emissions – in five graphs. Nature 582, 158-159.
34. Collivignarelli, M.C., Abbà, A., 2020. Lockdown for COVID-2019 in Milan: What are the effects on air quality? Sci. Total Environ., 732, 139280.
35. Mostafa, M.K., Gamal, G., and Wafiq, A. 2021. The impact of COVID-19 on air pollution levels and other environmental indicators – A case study of Egypt. J Environ. Manage., 277: 111496, 1-15.

36. Shi, X., & Brasseur, G.P. 2020. The response in air quality to the reduction of Chinese economic activities during the COVID-19 outbreak. Geophys. Res. Lett., 47, e2020GL088070.
37. Sicard, P., De Marco, A., Agathokleous., et al. 2020. Amplified ozone pollution in cities during the COVID-19 lockdown. Sci. Total Environ., 735, 139542.
38. Steinbrecht, W., Kubistin, D., Plass-Dülmer, C., et al.2021. COVID-19 crisis reduces free tropospheric ozone across the Northern Hemisphere. Geophys. Res. Lett., 48.
39. United States, & AirNow Program (U.S.). AirNow. Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, 2000. Retrieved October 10, 2020
40. Secretariat of the Convention on Biological Diversity (2020). Global Biodiversity Outlook 5 – Summary for policy makers. Montreal. 1-208.
41. UN/DESA 2020. Forests at the heart of a green recovery from the COVID-19 Pandemic. Policy Brief No. 80. New York: United Nations Department of Economic and Social Affairs.
42. FAO and UNEP. 2020. The state of the world's forests 2020: Forests, biodiversity and people. Rome.
43. Golar, G., Malik, A., Muis, H. 2020. The social-economic impact of COVID-19 pandemic: implications for potential forest degradation. Heliyon, 6(10), 1-10.
44. International Union for Conservation of Nature. (2021, February).
45. Bloomfield, L.S.P., McIntosh, T.L., and Lambin, E.F. 2020. Habitat fragmentation, livelihood behaviors and contact between people and nonhuman primates in Africa. Landscape Ecol., 35, 985-1000.
46. Dobson, A.P., Pimm, S.L., Hannah, L., 2020. Ecology and economics for pandemic preventation. Science, 369(6502), 379-381.
47. IPNE, Instituto Nacional de Pesquisas Espaciais. 2020. Project PRODES: Monitoring deforestation of the Brazilian Amazon Forest by Satellite. Retrieved December, 21, 2020.
48. National Institute for Space Research. 2020.
49. World Wildlife Fund. (2020, August 27). 2020 forest fires globally could be worse than 2019, WWF warns. NASA Earth Observatory. 2020, October. Fierce fires in Bolivia.
50. GREENPEACE International 2020, July 20. Siberia a climate hotspot: wildfires rage covering Russian cities in smoke.
51. United States Department of Agriculture (2020, September 16). USDA assists farmers, ranchers, and communities affected by Western wildfires (Press Release No. 0374.20).
52. Mongabay. 2020, July 3. COVID-19 lockdown precipitates deforestation across Asia and South America.
53. Mongabay. 2020, October 12. In Bolivia, more than 25% of major fires this year burned in protected areas.
54. Campos-Arce, J.J. 2019. Forests, inclusive and sustainable economic growth and employment. Background analytical study prepared for the fourteenth session of the United Nations Forum on Forests. 1-52.
55. Karjalainen, E., Sarjala, T., and Raitio, H. 2009. Promoting human health through forests: overview and major challenges. Environ. Health Prev. Med., 15(1), 1-8.
56. Press Information Bureau India 2020, May 14. Rs 6000 crore employment push using CAMPA funds.
57. Barik, S. (2020, May 04). Jharkhand unveils three schemes to add rural jobs.

58. Reuters. (2020, April 28). As a ‘green stimulus’ Pakistan sets virus-idled to work planting trees.
59. BBC (2019, Sept. 2019). Climate Change: What is being done around the world to plant trees?
60. Musto (2020, May 11). Iceland using coronavirus stimulus money to fight climate change. Nypost..
61. Thapa, S., and Engelken, R. (2020). Optimization of pelleting parameters for producing composite pellets using agricultural and agro-processing wastes by Taguchi-Grey relational analysis. Carbon Resour. Convers., 3(1), 104-111.
62. CDC (2020, October 5). COVID-19 (Coronavirus Disease) Scientific Brief: SARS-CoV-2 and potential airborne transmission. Centers for Disease Control and Prevention, October 5, 2020.
63. Department of Homeland Security. (2020). Evaluation of disinfectant efficacy against SARS-CoV-2: Emerging results. Department of Homeland Security Science and Technology Directorate, USA.
64. FDA (2020, August 7 updated). Temporary policy for manufacture of alcohol for incorporation into alcohol based hand sanitizer products during the public health emergency (COVID-19): Guidance for Industry. Center for Drug Evaluation and Research, Food and Drug Administration.
65. HSE. 2020. Manufacture and supply of biocidal hand sanitizer products during the coronavirus pandemic. Health and Safety Executive, December 1, 2020.
66. American Association of Poison Control Centers. (2020, December). COVID-19 (Hand Sanitizer). National Poison Data System (NPDS) Bulletin. Poison Information and Prevention Education Repository (PIPER).
67. Lachenmeier D.W. (2008). Safety evaluation of topical applications of ethanol on the skin and inside the oral cavity. J. Occup. Med. Toxicol. (London, England), 3 (26), 1-16.
68. New Jersey Department of Health. (2016). Hazardous substance fact sheet (ethyl alcohol). Retrieved Jan. 11, 2021, from https://www.nj.gov/health/eoh/rtkweb/documents/fs/0844.pdf
69. NJDH. 2016. Right to Know: Hazardous substance fact sheet: Isopropyl alcohol.
70. Conly, J., Eremin, S., Seto, W.H., & Pessoa-Silva, C.L. (Eds.). 2014. Infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care.
71. Roth, A. (2020, August 7). Wildlife deaths from coronavirus disinfectant use alarm scientists. National Geographic.
72. Odabasi, M. (2008). Halogenated volatile organic compounds from the use of chlorine-bleach-containing household products. Environ. Sci. Technol., 42 (5), 1445-1451.
73. Bracco, D., Dubois, MJ., & Bouali, R. (2005). Intoxication by bleach ingestion. Can. J. Anaesth., 52(1), 118-119.
74. Medina-Ramón, M., Zock, J-P., Torralba, Y., Kogevinas, M., Sunyer, J., Torralba, Y., Borrell, A., Burgos, F., Antó, J.M. (2005). Asthma, chronic bronchitis, and exposure to irritant agents in occupational domestic cleaning: a nested case-control study. Occup. Environ. Med., 62(9), 598-606.
75. Dumus, O., Varraso, R., Boggs, K.M., Quinot, C., Zock, J.-P., Henneberger, P.K., Speizer, F.E., Le Moual, N., Camargo Jr., C.A. 2019. Association of occupational exposure to disinfectants with incidence of chronic obstructive pulmonary disease among US female nurses. JAMA Network Open 2 (10), e1913563.

76. Ellenhorn, M.J., Schonwald, S., Ordog, G., et al. 1997. Ellenhorn's medical toxicology: diagnosis and treatment of human poisoning (2nd ed.). Baltimore, MD: Williams and Wilkins.
77. EPA. 2006. Reregistration eligibility decision for alkyl dimethyl benzyl ammonium chloride (ADBAC). EPA739-R-06-009. Office of prevention, pesticides and toxic substances. US EPA. Washington, D.C.
78. EPA. 2006. Reregistration eligibility decision for aliphatic alkyl quarternaries (DDAC). EPA739-R-06-008. Office of prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, Washington, D.C.
79. Luz, A., Deleo, P., Pechacek, N., and Freemantle, M. 2020. Human health hazard assessment of quaternary ammonium compounds: Didecyl dimethyl ammonium chloride and alkyl (C12-C16) dimethyl benzyl ammonium chloride. Regul. Toxicol. Pharmacol., 116, 104717.
80. Vandenplas, O., D'Alpaos, V., Evrard, et al. 2013. Asthma related to cleaning agents: a clinical insight. BMJ Open, 3, e003568.
81. Larsen, S.T., Verder, H., & Nielsen, G.D. 2011. Airway effects of inhaled quaternary ammonium compounds in mice. Basic Clin. Pharmacol. Toxicol., 110(6), 537-543.
82. Hrubec, T.C., Melin, V.E., Shea, et al. 2017. Amient and dosed exposure to quaternary ammonium disinfectants causes neural tube defects in rodents. Birth Defects Res. 109, 1166-1178.
83. Melin, V.E., Melin, et.al. 2016. Quaternary ammonium disinfectants cause subfertility in mice by targeting both male and female reproductive processes. Reproductive Toxicology, 50, 163-170.
84. WHO. 2021, 27 April. Fighting misinformation in the time of COVID-19, one click at a time.
85. WHO. 2020, April 14. Alcohol does not protect against COVID-19; access should be restricted during lockdown. Geneva, Switzerland: WHO, Regional office for Europe.
86. Hassanian-Moghaddam, H., Zamani, N., Kolahi, A-A, et.L. 2020. Double trouble: methanol outbreak in the wake of the COVID-19 pandemic in Iran – a cross-sectional assessment. Crit. Care 24, 402.
87. The guardian 2020, July 17. Desperate Bolivians seek out toxic bleach falsely touted as Covid-19 cure.
88. Gharpure, R., Hunter, C.M., Schnall, A.H., et al. 2020. Knowledge and practices regarding safe household cleaning and disinfection for COVID-19 prevention – United States, May 2020. MMWR Morb Mortal Wkly Rep 2020; 69, 705-709.
89. Nabi, G., Wang, Y., Hao. 2020. Massive use of disinfectants against COVID-19 poses potential risks to urban wildlife. Environ.
90. Hora, P.I., Pati, S.G., et.al.2020. Increased use of quaternary ammonium compounds during the SARS-CoV-2 pandemic and beyond: Consideration of environmental implications. Environ. Sci. Technol. Lett., 7(9), 622-631.
91. Kaj, L., Wallberg, P., Brorström-Lundén, E. 2014. Quaternary ammonium compounds: analyses in a Nordic cooperation on screening. Report number: TemaNord2014, Nordic Council of Ministers, Copenhagen, Denmark.
92. Zhang, C., Cui, F., Zeng, 2015. Quaternary ammonium compounds (QACs): A review on occurrence, fate and toxicity in the environment. Sci. Total Environ., 518-519: 352-362.

93. DeLeo, P.C., Huynh, C., Pattanayek, M., 2020. Assessment of ecological hazards and environmental fate of disinfectant quaternary ammonium compounds. Ecotoxicol. Environ. Saf., 206, 111116.
94. Pereira, B.M.P, & Tagkopoulos, I. 2019. Benzalkonium chlorides: Uses, regulatory status, and microbial resistance. Appl. Environ. Microbio. , 85(13), e00377-19.
95. Zhang, N., He, X., Gao, Y., Wang, H., et.al. 2010. Pedogenic carbonate and soil dehydrogenase activity in response to soil organic matter in Aretmisia ordosica community. Pedosphere, 20, 229-235.
96. Forest Resources Association. 2000. Assessing forest integrity and naturalness in relation to biodiversity: Global forest resources assessment 2000.
97. WWF. 2020. Emergency response to the Australian bushfires.
98. OECD. 2020. Biodiversity and the economic response to COVID-19: Ensurnig a green and resilient recovery.
99. DAWA. 2020. Wildlife and threatened species bushfire recovery expert panel: Provisional list of animals requiring urgent management intervention released on 20 March 2020. Australian Department of Agriculture, Water, and the Environment Accessed on 5 December, 2020.
100. Pennisi, E. (2020, September 30). As wildfires continue in Western United States, biologists fear for vulnerable species. Science.
101. National Center for Environmental Health. 2020. Natural disasters and severe weather: Wildfire smoke and COVID-19. NCEH, 25 August, 2020.
102. Andersen, K.G., Rambaut, A., Lipkin, W.I., 2020. The proximal origin of SARS-CoV-2. Nat. Med., 26, 450-452.
103. Kesslen, B. 2020. Here's why Denmark culled 17 million minks and now plans to dig up their buried bodies. The Covid mink crisis, explained. NBC.
104. DW. (2020, July 8). Coronavirus: South Asia sees rise in poaching during lockdowns. DW,
105. Moulds, J. (2020, May 12 updated). 5 Ways the coronavirus is affecting animals around the world. World Economic Forum, 2020.
106. WWF. (2020). What is a pangolin?
107. Zhang, T., Wu, Q., & Zhang, Z. 2020. Probable pangolin origin of SARS-CoV-2 associated with the COVID-19 outbreak. Curr. Biol., 30, 1346-1351.
108. Liu, P., Jiang, J-Z, Wan, et.al. 2020. Are pangolins the intermediate host of the 2019 novel coronavirus (SARS-CoV-2)? PLoS Pathog 16(5):e1008421.
109. Lee, J., Hughes, T., Lee, et.al.2020. No evidence of coronaviruses or other potentially zoonotic viruses in Sunda pandolins (Manis Javanica) entering the wildlife trade via Malaysia (Short Commuication). EcoHealth 17, 406-418.
110. Karesh, W.B., Cook, R.A., Bennett, E., & Newcomb, J. 2005. Wildlife trade and global disease emergence. Emerg Infect Dis., 11(7), 1000-1002.
111. Daszak, P., Epstein, J.H., Kilpatrick, et.al.2007. Collaborative research approaches to the role of wildlife in zoonotic disease emergence. Curr Top Microbiol Immunol. 315, 463-475.

112. Gómez, A., & Aguirre, A.A. 2009. Infectious diseases and the illegal wildlife trade. In Olivier A.E Sparagano, J-C. Maillard, & J.V. Figueroa (Eds.), Animal Biodiversity and Emerging Diseases Prediction and Prevention (1st ed., 16-19). Wiley-Blackwell.
113. Lo, Clifford. 2020, November 28. Covid-19 pandemic forces endangered species smugglers into using cargo shipments, resulting in Hong Kong seizing HK$149 million worth of goods. South China Morning Post, November 28, 2020.
114. Mallapaty, S. 2020. Scientists call for pandemic investigations to focus on wildlife trade. Nature, 583, 344.
115. Inveen, C. 2020, March 31. Cornavirus comes to rescue of Sierra Leone's plundered rosewood. Reuters, March 31, 2020.
116. Borzee, A., McNeely, J., Magellan, K., 2020. COVID-19 highlights the need for more effective wildlife trade legislation. Trends Ecol. Evol. 35 (12), 1052-1054.
117. Manenti, R., Mori, E., Canio, V.D., et.al.2020. The good, the bad and the ugly of COVID-19 lockdown effects on wildlife conservation: Insights from the European locked down country. Biol. Conserv., 249, 108728.
118. The Guardian. (2020, April 22). The urban wild: animals take to the streets amid lockdown – in pictures.
119. Łopucki, R., Kitowski, I., Magdalena, et.al. 2021. How is wildlife affected by the COVID-19 Pandemic?
120. International Monetary Fund. 2020. World Economic Outlook: A long and difficult ascent. Washington, DC.
IMF 2021. World economic outlook, managing divergent recoveries. World Economic Outlook No. 2021/001. International Monetary Fund Research Department.
121. Plecher, H. 2020. Countries with the largest gross domestic product (GDP) 2019. Statista 2020.
122. Ashraf, B. N. 2020. Economic impact of government interventions during the COVID-19 pandemic: International evidence from financial markets. J. Behav. Exp. Finance, 27, 100371.
123. Trading economics.com. 2021. GDP Growth Rate (2019-2021).
124. Bureau of Economic Analysis 2020. Gross domestic product: Gross domestic product, 2nd quarter 2020 (advanced estimate) and annual update.
125. Cutler, D. M. & Summers, L. H. 2020. The COVID-19 pandemic and the $16 trillion virus. JAMA, 324 (15), 1495-1496.
126. Noy, I., Doan, N., Ferrarini, B., & Park, D. 2020. The economic risk of COVID-19 in developing countries: where is it highest? Special Paper 257, LSE Financial Markets Group Paper Series, pp1-13.
127. Roser, M., Ritchie, H., Ortiz-Ospina, E., & Hasell, J. (2020). Coronavirus Pandemic (COVID-19) Deaths. [online], OurWorldInData.org.
128. Fuller, J.A., Hakim, A., Victory, K.R., et al. (2021, January 15). Mitigation policies and COVID 19 associated mortality- 37 European countries, January 23-June30, 2020. MMWR Morb Mortal Wkly Rep 2021, 70, 58-62.
129. OECD 2021. Strengthening the recovery: The need for speed. OECD Economic Outlook, Interim Report March 2021, OECD Publishing, Paris.

130. World Health Organization (January 5, 2021). COVID-19 weekly epidemiological update – 5 January 2021. Emergency Situational Updates.
131. European Centre for Disease Prevention and Control (2021). Risk related to the spread of new SARS-CoV-2 variants of concern in the EU/EEA – first update – 21 January 2021. ECDC: Stockholm; 2021.
132. Davies, N.G., Abbott, S., Barnard, R.C., Jarvis, C.I., Kucharski, A.J., …..Edmunds, W.J. (2021). Estimated transmissibility and impact of SARS-CoV-2 lineage B.1.1.7 in England. Science, 372(6538), eabg3055.
133. Challen, R., Brooks-Pollock, E., Read, J.M., Dyson, L., Tsaneva-Atanasova, K., & Danon, L. (2021). Risk of mortality in patients infected with SARS-CoV-2 variant of concern 202012/1: matched cohort study. BMJ, 372:n579.
134. Vaidyanathan, G. (2021, May 11). Coronavirus variants are spreading in India – what scientists know so far. Nature 593, 321-322.
135. Muik, A., Wallisch, A-K., Sanger, B., Swanson, K.A., Muhl, J., Chen, W., et al. (2021). Neutralization of SARS-CoV-2 lineage B.1.1.7 pseudovirus by BNT162b2 vaccine-elicited human sera. bioRxiv 2021.01.18.426984.
136. Wu, K., Werner, A.P., Moliva, J.I., Koch, M., Choi, A., Stewart-Jones, G.B.E., Bennett, H., ……..& Edwards, D.K. (2021). mRNA-1273 vaccine induces neutralizing antibodies against spike mutants from global SARS-CoV-2 variants. bioRxiv 2021.01.25.427948.
137. Amnesty International. 2021. The State of the World's Human Rights. Amnesty International Report 2020/21. Amnesty International Ltd, London, UK.
138. The World Bank (2021). Data: Low & middle income. The world Bank Group.
139. United Nations. (9 April, 2021). Low- income countries have received just 0.2 percent of all COVID-19 shots
140. Lloyd-Roberts, S. (November 1, 2012). Have India's poor become human guinea pigs? BBC News. November 1, 2012.
141. Frayer, L. (February 2, 2021). India has COVID-19 vaccine doses. But will the country's population take them? NPR News in Palghar, Maharashtra, India, 2 February 2021. NPR.
142. Global Footprint Network. (2021). Earth Overshoot Day, 2020.
143. Ward, J. D., Sutton, P. C., 2016. Is Decoupling GDP growth from environmental impact possible? PLoS ONE 11(10), e0164733.