frontiers | Frontiers in Forests and Global Change

TYPE Review
PUBLISHED 14 February 2024
DOI 10.3389/ffgc.2023.1305779

OPEN ACCESS

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RECEIVED 02 October 2023
ACCEPTED 29 November 2023
PUBLISHED 14 February 2024

CITATION
Singhal V, Jinger D, Rathore AC, Pal R, Samal I, Bhoi TK, Paramesh V, Fahad S, Jaremko L, Abdelsalam NR and Jaremko M (2024) COVID-19, deforestation, and green economy. *Front. For. Glob. Change* 6:1305779. doi: 10.3389/ffgc.2023.1305779

COVID-19, deforestation, and green economy

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Corona has severely impacted many sectors in the past 2. 5 years, and forests are one of the major hits among all sectors affected by the pandemic. This study presents the consolidated data on deforestation patterns across the globe during COVID and also analyzes in depth the region-specific contributing factors. Exacerbated deforestation during COVID alarms biodiversity conservation concerns and pushes back the long-term efforts to combat pollution and climate change mitigation. Deforestation also increases the risk of the emergence of new zoonotic diseases in future, as deforestation and COVID are intricately related to each other. Therefore, there is a need to check deforestation and inculcation of conservation measures in building back better policies adopted post-COVID. This review is novel in specifically providing insight into the implications of COVID-19 on forests in tropical as well as temperate global regions, causal factors, green policies given by different nations, and recommendations that will help in designing nature-based recovery strategies for combating deforestation and augmenting afforestation, thus providing better livelihood, biodiversity conservation, climate change mitigation, and better environmental quality.

KEYWORDS

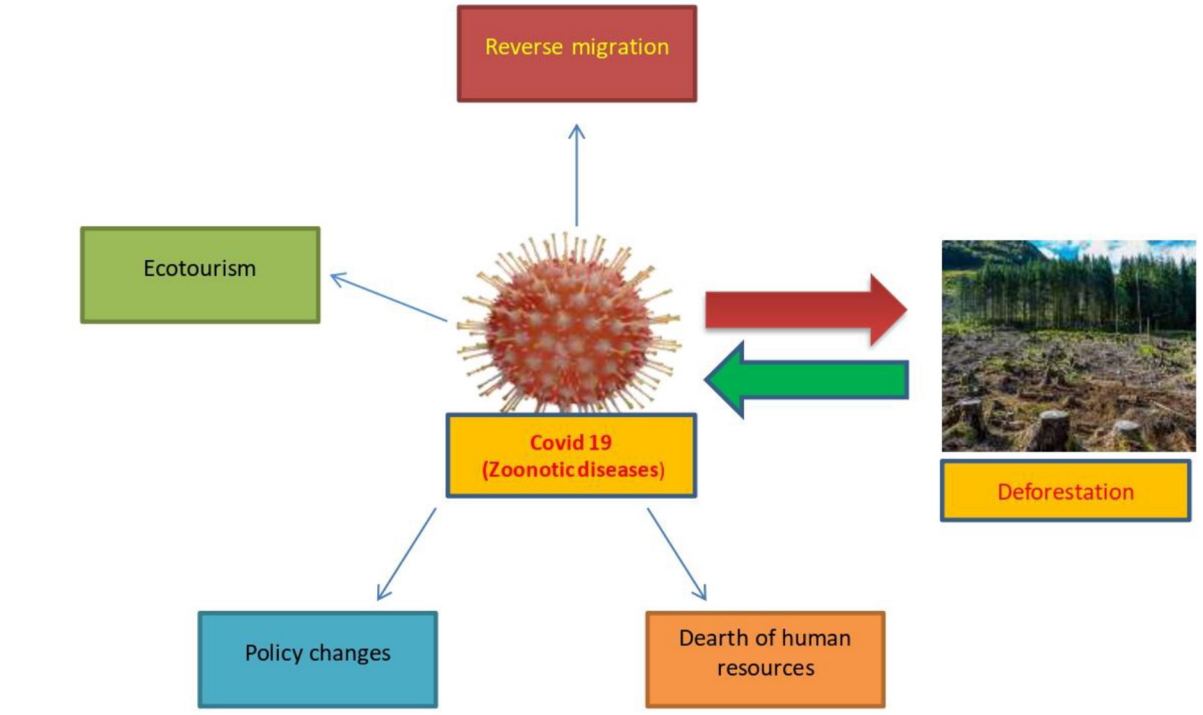
COVID 19, deforestation, green economy, reverse migration, ecotourism

Highlights

- Deforestation precipitated in many parts of the world during the pandemic.
- Illegal felling, reverse migration, ecotourism, reduced monitoring due to reduced funds and dearth of staff, and policy changes are the major factors contributing to the increased rate of deforestation.
- There is an urgent need to check deforestation and promote afforestation to prevent pandemics in future, build resilient ecosystems, and reduce the vulnerability of rural and indigenous communities.
- COVID-induced crisis should be utilized as an opportunity to build back better in a green way.

Introduction

The global economy has been shattered due to the turmoil created by the COVID-19 pandemic. Countries across the world have already faced three waves of COVID-19, with millions of people affected and massive loss of life to date. Repeated lockdowns and other restrictions imposed to contain the spread of the virus have adversely affected various



GRAPHICAL ABSTRACT

segments of the modern economy, such as industries, airlines, farming, fisheries, sports, social events, education, and tourism, among others (Blake and Wadhwa, 2020; Galanakis et al., 2022). Although these restrictions proved to be helpful in checking virus spread, they led to an economic depression, also termed as pandemic depression. Even the economy of many powerful countries gets set back due to a sharp rise in the rate of inflation and escalating unemployment due to disrupted chain supplies, lack of productivity, and excessive expenditure on the health sector (OECD, 2020). Extreme poverty is shooting up again due to the pandemic defeating the progress made over a long period. The World Bank predicted that the poverty rate would rise in the near future, pushing 88 to 115 million more people toward extreme poverty, lifting the global poverty rate as high as 9.4% (Miller, 2020). ILO predicted a maximum possible loss of 230 million full-time jobs of 40 h globally, and OECD estimates a fall of around 1.5% in real GDP growth (OECD, 2020). The COVID-19 pandemic caused severe socio-economic, political, and environmental crises in the world. Exacerbated deforestation from different parts of the world in response to pandemic restrictions owing to a number of factors can further raise severe short- and long-term socio-economic and environmental concerns, affecting the lives of a large chunk of the population who directly or indirectly depend on forests for survival (Troëng et al., 2019; FAO, 2020a). Forest sustains the livelihood of ~20% of the global population, specifically the vulnerable section that depends on forests for food, income, and nutrition (FAO, 2020a; Rahman et al., 2021). In addition, a large segment of people (~2.4 billion) in rural and urban areas use biomass energy for cooking and heating purposes (Sen, 2020; United Nations, 2020a). Forests are also a source of employment for 86 million people in green jobs. Deforestation can also have adverse effects on ambitious targets of reduced emissions for curbing climate change. Reports from International agencies (UNEP, 2020) showed that we are already lagging behind in accomplishing the targets to combat climate change, thus global warming. Furthermore, the COVID-19-induced economic crisis will increase deforestation rates, which can pose a very serious setback to these international efforts. Apart from these, deforestation can increase the risk of zoonotic diseases as the emergence of a majority of new infectious diseases occurs due to human and wildlife interaction as a result of land use changes such as deforestation and expansion of agriculture (Allen et al., 2017; Rohr et al., 2019). Thus, forest loss disrupts the ecosystem's stability and functioning, consequently a humanitarian crisis as forests provide vital ecosystem services that are crucial to human wellbeing and critical for achieving sustainable development goals. Various research studies showed the impact of COVID-19 on the environment in terms of air, water, and soil, but none have thoroughly discussed the effect of the pandemic on forests, though they form a major life-supporting global ecosystem. Although there are few research studies linking the COVID-19 pandemic and deforestation, these are regional and do not provide a holistic view of deforestation patterns across the globe during the pandemic. This is the first comprehensive review that provides a global deforestation scenario during the pandemic, analyzes the region-specific factors contributing to accelerated deforestation, fiscal packages for a green economy, and the policy recommendation for halting and reversing deforestation that occurred as a consequence of COVID-19. Detailed information and a deep understanding of factors leading to deforestation during the pandemic will help

TABLE 1 Detail of Publications referred for review.

Authors	Title	Journal
Attah (2021, 2022)	Initial assessment of the impact of COVID-19 on sustainable forest management African states	Background paper prepared for the United Nations forum on forests secretariat
Bista et al. (2022)	Impacts of COVID-19 pandemic on the livelihoods of rural households in the community forestry landscape in the Middle Hills of Nepal	Trees, forests, and people
Basnyat et al. (2020)	COVID-19 outbreak, timber production, and livelihoods in Nepal	Tribhuvan University Journal
Bhandari et al. (2021)	Global forestry perspective: COVID-19 impact and assessment.	Natl. Acad. Sci. Lett
Brancalion et al. (2020)	Emerging threats linking tropical deforestation and the COVID-19 pandemic	Perspectives in ecology and conservation
FAO (2020b)	The impacts of COVID-19 on the forest sector: How to respond?	Policy brief
Gregory (2021)	COVID, forests and forest peoples: The implications of the pandemic for forest campaign	Discussion paper
Hardcastle and Zabel (2020)	Initial assessment of the impact of COVID-19 on sustainable forest management western European and other states	Background Paper prepared for the United Nations forum on forests secretariat
Ibn-Mohammed et al. (2021)	DESA brief: Investment in forests critical for successful COVID-19 recovery	Policy brief
ILO (2020)	Impact of COVID-19 on the forest sector	ILO sectoral brief
Laudari et al. (2021)	COVID-19 lockdown and the forestry sector: Insight from Gandaki province of Nepal	Forest Policy and Economics
Maraseni et al. (2022)	Impact of COVID-19 in the forestry sector: a case of lowland region of Nepal	Land use policy
Mohan et al. (2021)	Afforestation, reforestation and new challenges from COVID-19: 33 recommendations to support civil society organizations (CSOs)	Journal of environmental management
Rahman et al. (2021)	The COVID-19 pandemic: a threat to forest and wildlife conservation in Bangladesh	Trees, Forests and People
Wunder et al. (2021)	Coronavirus, macroeconomy, and forests: What likely impacts?	Forest policy and economics

the administrators and policymakers in designing the action plan and recovery packages to restore the ecosystem and economy side-by-side from the aftermath of the COVID-19 pandemic. Therefore, a holistic view of COVID-19-led deforestation and policy recommendations for green recovery is the call of the hour and has its own scientific value.

Methodology

The present study was carried out by collecting the published literature since the beginning of the COVID-19 era, such as research articles, case studies, review articles, policy papers, opinions, and blogs from various government and non-government websites related to the impact of COVID on forestry. Primary pieces of literature were recorded through scientific engines, namely Scopus, Science Direct, and Google Scholar, using key words COVID-19, forestry, illegal felling, ecotourism, reverse migration, deforestation, and green economy. The direct studies linking COVID-19 and forests have been summarized in Table 1. After thoroughly reviewing and analyzing the published pieces of literature on the topic, the present article has been compiled, outlining the status of deforestation during the pandemic period, causal factors, and remedial measures adopted by governments in different parts of the world.

Global deforestation pattern

Like many other sectors, COVID-19 has also affected the forest sector for a myriad of reasons, such as illegal felling, reverse migration, halted ecotourism, and accelerated demand for forest-based products. Global tree cover loss in different countries in 2020 has been presented in Figure 1.

According to an estimate by the University of Maryland, ~12 million hectares of forests disappeared in 2020 alone in tropical regions (WRI, 2021). WWF observed forest loss to be 1.5 times higher in March 2020 than for the same month in the previous year for 18 countries (WWF, 2020; Wunder et al., 2021). A sum of 9583 km^2 of deforestation alerts was announced throughout the tropical world by GLAD (Global Land Analysis & Discovery) in the initial month of the COVID lockdown period in 2020, declared by regional governments to contain the COVID-19 spread, which was almost twice that observed in the previous year (4732 km^2). There was a notable spike in the deforestation rate (Figure 2) in certain parts of the globe (South America, Africa, and Asia-Pacific) in the first semester of 2020 (Brancalion et al., 2020).

According to an estimate by the same agency (GLAD), a hike of 77% percent has been found in deforestation alerts since the beginning of the coronial period against the average of the past 3 years (2017–2019) (Stanley et al., 2020). However, some workers did not agree with GLAD alert-based studies linking COVID-19 and deforestation (Saavedra, 2020; Wunder et al., 2021). The

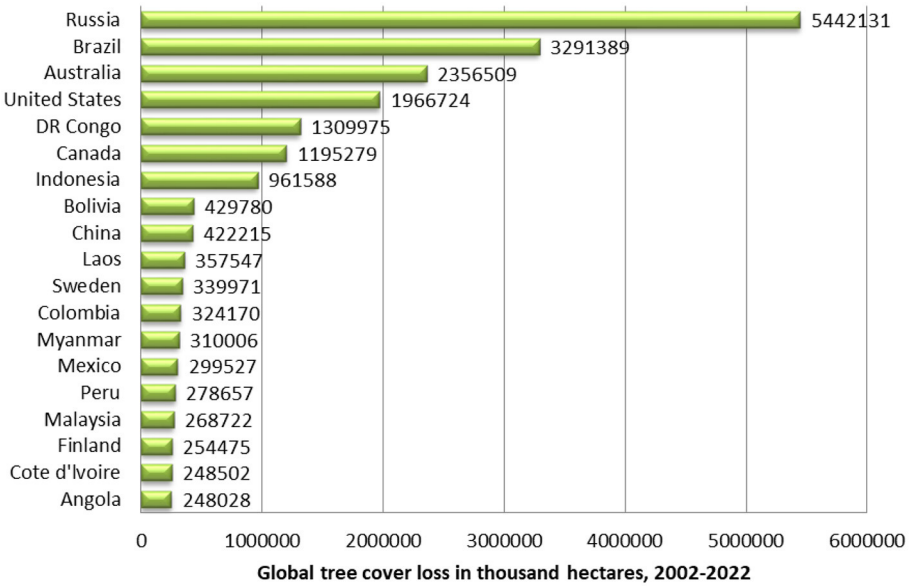


FIGURE 1
Global tree cover loss in 2020 (Source: WRI, 2021).

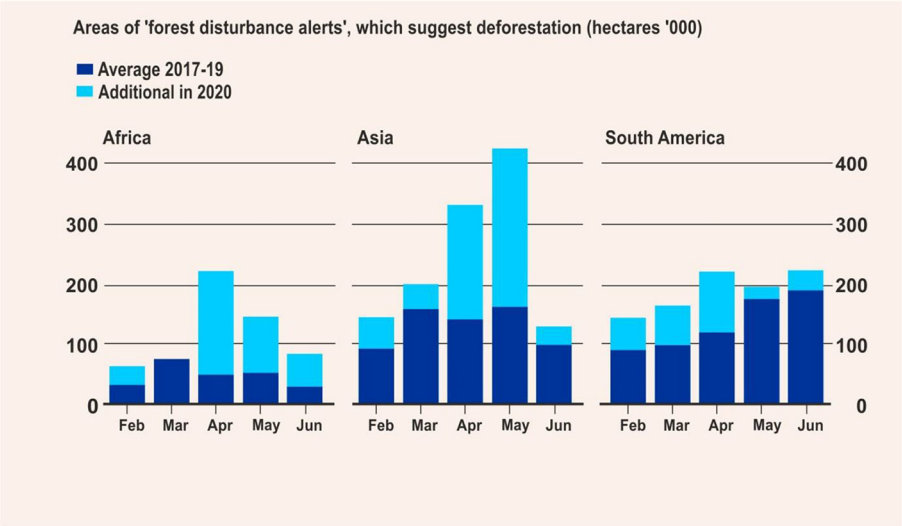


FIGURE 2
Area of forest disturbance alerts (deforestation) in major continents (Source: Brancalion et al., 2020).

Amazon rainforest has lost more than 9000 km^2 (3500 square miles) during the year up to March 2020, constituting an increase of 47% and 9.5% compared to 2018 and 2019, respectively. This is the highest annual recorded loss since 2008 (Qin et al., 2019). Approximately 6.45 lakh ha of rainforest was lost globally in March 2020 only, led by Indonesia, almost thrice of that for the same month in 2019 (Wunder et al., 2021). The other two countries that occupied second and third places were the Democratic Republic of Congo and Brazil, respectively. Indonesia observed the greatest forest loss (1.3 lakh ha) than any other country across the globe during March 2020, which amounted to 130% over the mean of the previous 3 years (2017–2019) for the same calendar month (Wunder et al., 2021). According to an analysis by Greenpeace, the deforestation rate was 50% higher in the first trimester of 2020 in Indonesia than in the previous year in 2019 for the same duration, which also coincided with the fire season (Sloan et al., 2022). The deforestation rate has continued to rise in the Amazon region even during the COVID-19 pandemic period. For instance, as COVID-19 spread across Brazil, which accounts for 60% of Amazon, the rate of forest loss also increased to 55% in the first trimester of 2020 to that of the same period in 2019, which was the highest in the past 12 years (Butler, 2020). Other countries of the Amazon

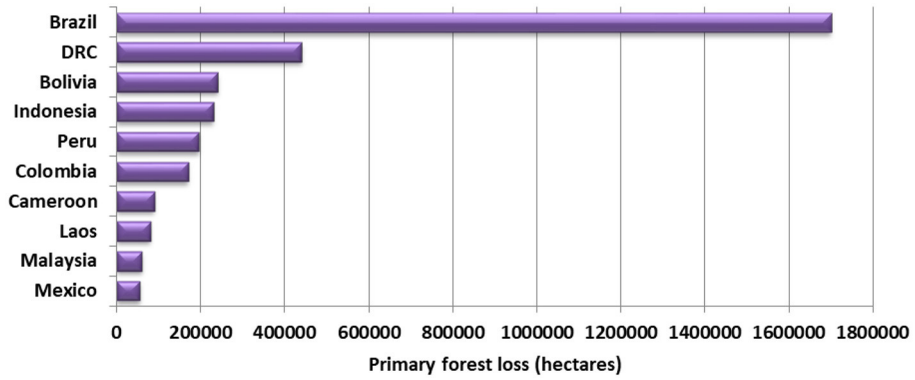


FIGURE 3
Top 10 countries for 2020 primary forest loss (Weisse and Goldman, 2021).

region vis-à-vis Colombia, Cambodia, and Peru also experienced an increased deforestation rate in 2020, particularly in March and April, than the previous year for the same duration as a result of lockdown and quarantine (West et al., 2023). It is a matter of grave concern that 1.2 billion hectares of tropical forests lost in 2020 also included 4.2 million hectares of primary tropical forests. The same pattern of deforestation was observed in 2021, when the tropical regions lost 11.1 million hectares of forests, including the loss of 3.75 million tropical primary rainforests, which are important as the center of biodiversity and carbon sink (Lambin and Furumo, 2023). Brazil lost 1.7 million hectares of primary forest cover in 2020, 25% higher than 2019 and more than thrice than DRC, the second highest country. Bolivia was positioned at number three in terms of primary forest loss in 2020, whereas the South Asian countries, palm-producing Indonesia and Malaysia, occupied fourth and ninth positions, respectively (Figure 3) (Weisse and Goldman, 2021; Céspedes et al., 2023).

The rate of primary forest loss in Brazil has been persistently high for the past several years. Non-fire losses, which in Brazil are most often associated with agricultural expansion, increased 9% from 2020 to 2021. This finding is consistent with Brazil's official monitoring system, PRODES (Silva-Junior et al., 2023), which found that 2021 had the highest rate of clear-cut deforestation in the Amazon since 2006, when measures were put in place to drastically reduce deforestation. DRC lost nearly half a million hectares of primary forest in 2021 due to the expansion of small-scale agriculture and harvesting trees to meet energy demands. Primary forest loss in Bolivia reached its highest level on record in 2021 at 291 thousand hectares, surpassing Indonesia once again to have the third-most primary forest loss among tropical countries. There are reports of increased deforestation in India, where nearly 38.5 thousand hectares (Kha) of tropical forest were lost between 2019 and 2020. The northeastern states of India possessing the largest forest areas (Assam, Mizoram, Nagaland, Manipur, Arunachal Pradesh) observed 29% more forest cover loss in 2020, breaking the declining trend of tree cover loss during the past 2 years (Roy, 2021; Vancutsem et al., 2021). The GLAD deforestation alert services showed that the total deforestation alerts rose by 77% within 10 months in 2020 as compared to the previous year in Bangladesh. Deforestation alerts were more pronounced during the months of lockdown as compared to the period before lockdown. The GLAD service reported that ~222 ha of additional forest area (8%) in Bangladesh was deforested in the first 10 months of 2020 compared to the preceding year (Rahman et al., 2021). Other countries across the world also registered higher rates of deforestation; similar to Latin America, Mesoamerica surpassed the previous levels of primary tropical forest loss by 27% in 2020 during the COVID pandemic, whereas Nicaragua accounted for a 15% loss of primary tree cover in last 3 years. Belize also stood high with respect to forest loss in 2020, nearly twice the previous year. The primary forest loss rose to 36% in West Africa in 2020. Madagascar also showed an upward trend in deforestation during the pandemic (Eklund et al., 2022). Expansion of agriculture and fuelwood demand due to reverse migration, land grabbing, and relaxation in law enforcement, forest fires and lack of management practices due to a dearth of human resources and budget deficit during the ongoing pandemic may be cited as factors for the spike in deforestation rates in several regions of the world.

Outside the tropics

Temperate regions also bore the brunt of the COVID-19 pandemic. Russia, which is at the top position with respect to overall forest cover, showed a surge of 48% in 2020 during the pandemic over the previous year for forest loss. Russia lost ~5.44 million ha of forest cover in 2020 owing to forest fires in Siberia and the Russian Far East. In a similar vein, Australia's forest loss also hiked by 42% due to forest fires that took a heavy toll on the forest cover across the eastern parts of the country from the middle of 2019 to the beginning of 2020. Canada and the US, however, unlike other countries, observed a decline in forest loss in 2020. Canada lost 1.2 million ha of tree cover, which was the lowest in the past two decades. Central Europe also registered massive forest cover loss in 2020, the greatest being in Germany and the Czech Republic, which was three times higher than in 2018 (Butler, 2021). The spike was due to a lack of forest management practices due to a dearth of human resources and a curtailed budget during the COVID pandemic, of which fire and bark beetles could not be controlled (Bercak et al., 2023). Outside the tropics, boreal forests

experienced the highest rates of tree cover loss in 2021 (Rotbarth et al., 2023). While tree cover loss in boreal forests rarely results in permanent deforestation, the rate of loss reached unprecedented levels in 2021, increasing 29% over 2020. Russia experienced the worst fire season since record-keeping began in 2001, with more than 6.5 million hectares of tree cover loss in 2022 (Johansen, 2023).

Spike in deforestation

Excessive harvesting of timber and non-timber forest products (NTFPs) has been on the increase in response to global mayhem during this pandemic due to restrictions on movement, lockdown, social distancing, staff shortage, weak enforcement, relaxation of government policies, and budget deficit. In addition, reliance on forests has also increased during the colonial period to meet the rising demand for forest-based essential hygiene and sanitary products such as tissue paper, toilet paper, paper towels, and alcohol-based hand rub (FAO, 2020a). The demand for toilet paper, in particular, skyrocketed at the beginning of the outbreak, and some companies reported an increase of up to 700% in their sales (Garbe et al., 2020; Jones, 2020). As per directions of the WHO, crowded places should be avoided to prevent and slow down the transmission of COVID-19. In this scenario, people are dependent on e-commerce for the purchase of goods instead of visiting the markets. The growth of e-commerce is likely to contribute to increased demand for packaging boxes made up of paper and cardboard for home delivery services. Even the manufacturing of paper gowns, surgical masks, and caps used in personal protective equipment (PPE) kits for medical workers also utilizes wood pulp and fiber (United Nations, 2020b). Three of the four largest pulp-exporting countries, Brazil, the US, and Chile, increased their shipments between 12 and 26% in March (month-over-month). The five top importing countries all purchased more pulp in March than in February, with China and South Korea increasing their volumes the most (40 and 29%, respectively). Enterprises have taken innovative measures to expand their production, particularly of products for which demand has been stable or has increased during the crisis, such as surgical masks. In Italy, the decision to classify paper as an essential product due to its importance for food packaging and sanitary and pharmaceutical products ensured the continued operation of paper mills during the state of emergency. In Canada, a paper mill that turned to manufacture medical-grade pulp suitable for masks and gowns doubled its production. Researchers suggested that Ashwangandha (*Withania somnifera*), along with other Ayurvedic rasayanas, such as *Tinospora cordifolia* (Guduchi), *Asparagus racemosus* (Shatavari), and *Phylanthus emblica* (Amalaki), are helpful against COVID-19 due to their immunomodulatory properties and potential as an immunity booster (Patwardhan et al., 2020). The exploitation of wild medicinal plants for their proven scientific use and additional pressure on forests for food, fuelwood, and fiber may precipitate deforestation to a greater extent. Many countries, such as Brazil, Colombia, Cambodia, Indonesia, Nepal, India, Bangladesh, and Madagascar, reported a higher incidence of illegal extraction of forest resources since the initiation of the pandemic (Muche et al., 2022). In Nepal, a compilation of studies of 11 protected areas revealed 227% higher cases of timber theft during the first month of lockdown than last month. Higher numbers of crime cases related to natural resources were recorded during that period compared to collective numbers of the preceding 11 months (Department of National Parks and Wildlife Conservation and WWF Nepal). The movement of restrictions during the lockdown made it difficult to enforce law and order, monitoring, and conservation practices, which potentially exaggerated the large-scale illegal logging activities within the forest sector (Brancalion et al., 2020; Maraseni et al., 2022). Environmental organizations across the globe, viz Brazil, Colombia, Philippines, Kenya, Cambodia, Venezuela, and Madagascar, reported a rise in cases of timber theft, poaching, and illegal mining and warned that it is very difficult to halt or reverse the precipitation of deforestation occurring during the pandemic (Fair, 2020). A similar situation has been reported in Malaysia and Indonesia, which have the highest rates of forest loss in Southeast Asia; illegal timber mining from rainforests of Sulawesi (Indonesian island) rose by 70% in 2020 (Chandra, 2021). In Ecuador, an increase in illegal mining by indigenous people has been witnessed in the Choco and Amazon rainforests (Brown, 2020). Africa is no exception, where illegal logging and poaching in the forest areas hiked during the pandemic. Due to the diverted attention of the government on the medical sector, criminal syndicates became active and increased their illegal activities of felling and poaching in the forests in Africa, which already cost the continent US$17 billion annually (African Union, 2020). There are reports of illegal logging in forest regions across Eastern, Western, Central, and Southern Africa. To quote, in Tanzania, illegal felling activities observed a 20% hike during the pandemic compared to the usual number of such events in the past. Such an incidence of illegal extraction of valuable timber was also reported to be happening in Uganda and Kenya during the pandemic. Survey reports from Central Africa also revealed the role of the pandemic in speeding up the illegal felling instances in the Congo Basin (Mbzibain, 2020). As the governments are financially overburdened while dealing with the pandemic, national forest institutions are facing a fund crisis to deploy the staff to carry out forest protection and conservation activities (African Union, 2020). Illegal activities (timber mining and poaching) have also affected mangrove forests in the coastal belt of the EAC region, where pole-cutting and charcoal production accelerated during COVID-19 (Parris-Piper et al., 2023). Therefore, the pandemic is likely to increase deforestation, leading to biodiversity loss and environmental pollution if the forestry sector is left unattended during the course of the pandemic. Illegal activities in the forests will also distort the supply chain of valuable timber species, adversely impacting marketing and trade. This will cause revenue losses to the government and thus significantly impact the livelihood of people engaged in this sector.

Dearth of human resources

Disruption of human resources during the pandemic is one of the major factors adversely affecting forest protection, conservation, and management activities (Corlett et al., 2020). Absenteeism in the workforce due to a number of factors during the pandemic is also on the rise. For example, many forest reserves in Africa, Latin America, and Asia have recorded a low presence

of workers since the outbreak of the pandemic. Poor attendance or absenteeism stressed the entire system, leading to higher incidences of illegal logging and hunting during the lockdown period in 2020 (United Nations, 2020a; Pérez Caldentey et al., 2023). More than 50% of countries in Africa reported that the pandemic hampered regular field monitoring and patrolling in forest reserves during the pandemic in the year 2020 (Waithaka, 2020; Waithaka et al., 2021). As the security forces were engaged in implementing COVID lockdowns and enforcing containment guidelines, there was a dearth of manpower to protect forests and wildlife (Werikhe, 2022). The illness and deaths of forest officials of different levels during the pandemic affected the overall performance of forest departments in guarding the protected areas. Wildfires particularly were also difficult to control during the course of the pandemic. In the past few years, incidences of wildfires have been recorded frequently, and the situation has become very intense during the simultaneous occurrence of multiple fires. Deficit staff due to viral infection, quarantine measures, and social distancing affected the ability of workers to deal with multiple fires in active season. Other forest management operations were also delayed by many countries during the pandemic by COVID-19 taking into consideration the wellbeing of workers and forest communities. In Canada, an aerial spray program for checking jack pine budworm was abandoned by the Ontario Ministry of Natural Resources and Forestry. Some provinces canceled prescribed burning while others worked at low capacity. In the US, management operations such as prescribed burning were held back at the majority of places while other activities, such as trimming trees near electrical lines, were slowed down due to pandemic restrictions (Heller, 2020; Stanturf and Mansuy, 2021). Repeated lockdowns and movement restrictions had a negative impact on sustainable forest management and protection measures in all the sub-regions of Africa. The attack of defoliating insects (*Limantrya dispar*) on cork, a valuable non-timber forest product in the countries of the western Mediterranean, could not be controlled during the pandemic, resulting in the hampering of harvesting operations (Araújo, 2020). A dearth of human resources adversely affected many activities linked to forest protection, conservation, and management, and the pitfalls can be observed in terms of illegal logging activities, poaching, rampant wildfires, pest disasters, forest clearance for agriculture, invasive plant growth, and overgrazing/husbandry needs (Simental and Bynum, 2023).

Policy changes

In response to the pandemic, there will be a major shift in budget reallocations as the health sector and COVID containment will be on the priority list at the expense of other important agendas, such as natural resource management and climate change. As developing countries are less prepared to face such disasters, there are more chances of budget curtailing and reallocation in these countries (Werikhe, 2022). Governments across the globe are changing their policies (relaxation of environmental regulations, diversion of funds, and holding back important forestry events) to deal with the pandemic crisis, which is adversely impacting forest protection, conservation, and management activities to a significant extent (Wang B. et al., 2022; Wang J. et al., 2022). The economic recession during the pandemic is expected to reduce funds for forests. The forests in some parts of Asia, Africa, and Latin America are already facing the wrath of this pandemic in terms of curtailed budgets due to the diversion of public funds to the health sector to save human lives from COVID-19. For instance, Mexico and Ecuador in Latin America have already declared budget cuts in the natural resource management sector, challenging law enforcement for forest protection and management of some serious issues, such as climate change (Bertola et al., 2023). The socio-economic crisis has forced governments across the world to review their policy decisions and reorient these toward developmental activities to meet the ends. Governments are promoting agriculture and the industrial sector by providing subsidies and relaxing legislation, which will have detrimental effects on nature and subsequently human health. Deforestation in Brazil precipitated during the pandemic period due to the weakening of environmentally favorable policies through 57 amendments in the legislation in 2021. Various relief policies by different countries in South Asia are also adversely affecting the forests significantly. As in Indonesia, efforts for employment generation and economic revival under Omnibus Law can put forests at risk by compromising environmental regulations. Indonesian Government also changed its previous policy to restore 165,000 ha of abandoned peat land in the wake of the pandemic by bringing it under agriculture to fulfill the food shortage during the pandemic. These peatlands were earlier planned to be restored to reduce emissions and meet national targets (Worrall et al., 2003). To improve economic growth, Indonesia has abandoned the practice of checking the legal states of timber export, which will definitely acerbate illegal timber extraction and deforestation in Indonesia (Maxton-Lee, 2020). Hence, the present relief policies of Indonesia are jeopardizing environmental security by relaxing environmental regulations and converting carbon-rich peatlands into food estates. Similarly, the Manitoba province government in Canada has already cut environmental funding (Robinson et al., 2023) as part of its plan to cope with the fiscal deficit resulting from the COVID-19 pandemic. Unfortunately, this will be counterproductive in the long run since the health of the planet is intricately linked to public health. The budget cut will surely hamper the ongoing and planned nature conservation and protection activities in different forest areas worldwide. After a thorough examination of recovery packages announced by governments across the different parts of the globe, Friedlingstein et al. (2022) reported the withdrawal of the budget for environmental protection in 64 cases from 22 countries. Governmental policies played a major role in the conservation of protected areas by law enforcement. Several countries have set targets to increase their forest cover and reduce emissions to fight climate change. However, many governments have changed their policies and prioritized other sectors over forestry in response to the present crisis. The ongoing pandemic has diverted the attention of governments and public funds toward the general wellbeing of the people and health sector, putting the forests at very high risk. COVID-19 has put the world on hold for quite some time, resulting in the postponement of many important national and international conferences. These postponements gave a setback to the international efforts to address serious

environmental issues such as biodiversity loss, greenhouse gas emissions, and climate change (Korngold, 2023). The after-effects of this pandemic will definitely be long-lasting on national and international environmental goals and emission targets.

Reverse migration

COVID-19 caused massive unemployment due to the contraction in the global economy, disruptions in supply chains, and closure of production units, leading to the mass movement of migrants from urban to rural areas for survival (FAO, 2021). There are 164 million migrant workers worldwide, constituting 4.7% of the global labor pool (ILO, 2020). Enforcement of lockdown regulations to contain the spread sent shockwaves to the welfare and economic security of those migrant workers and their families in villages who were involved in seasonal employment. Loss of source of income, fear of being infected, and uncertainty of the situation triggered the mass backward movement of migrants both at the national and international levels to their home state and countries, mostly to rural areas of origin for survival (Khan et al., 2020; Mustaquim and Islam, 2020). In addition to the mass movement of workers from overseas, many nations such as the United States, Mexico, Venezuela, Peru, China, Bangladesh, Nepal, Indonesia, Vietnam, Cambodia, and South and Eastern Africa encountered internal reverse migration from cities to villages and rural areas was reported (Chirisa et al., 2021; Chirisa and Campbell, 2023). In India, the loss of jobs due to the lockdown led to massive reverse migration; ∼6.3 million laborers traveled back from cities to rural native places in May–June 2020 only (Suresh et al., 2020; Bhattacharyya et al., 2023). Reports of a study by the UN say that the crisis will jeopardize poor rural communities, particularly the indigenous population dependent on the forests for their livelihood. The pandemic-induced survival crisis will increase the dependence of vulnerable rural and indigenous communities on forests and other natural resources (Amburgey et al., 2023). Forests act as a safety net for rural and indigenous populations in times of crisis (pandemic or any other disaster) by fulfilling their subsistence needs, thus helping their welfare and prosperity (Sengupta and Jha, 2020). A large chunk of the population, ∼1.0 billion people, globally depend on forests to some extent for foods such as wild meat, edible insects, edible plant products, mushrooms, and fish as part of their balanced diet. Some 2.4 billion people, i.e., one-third of the global pool both in urban and rural areas, depend on bioenergy for cooking food, heating water, and warming their homes. Wood fuel (including fuelwood and charcoal) remains one of the cheap and easily available sources of energy for people in times of natural disasters and humanitarian crises (Rafa et al., 2022). Because the region will observe massive reverse migration, rural areas and natural resources that support that population will be under extreme pressure. Reports from different parts of the world revealed that rural and indigenous communities living at the fringes of forests responded to pandemic-induced survival crisis by increasing dependency on the forests, giving rise to exacerbated incidences of illegal felling and poaching, charcoal production, tenure conflicts, land clearing for agriculture expansion, land encroachment, forest crimes, and other many such activities for immediate economic relief which led to deforestation and biodiversity degradation (Tripathi et al., 2021). Global economy contraction, along with backward massive urban-to-rural migration as a consequence of the pandemic, will have significant short- and long-term repercussions on forests and forest-dependent rural and indigenous communities (Saxena et al., 2021).

Ecotourism

The travel and tourism industry contributes the lion's share of 10.3% to the GDP of the world, even greater than agriculture. It has a major role to play in employment generation as one in every four new employments is created by this sector in the year 2019 only. According to Nature4Climate, "wildlife tourism" is a US$ 343.6bn a year global industry −21.8 million or 6.8% of all tourism jobs around the world are linked to wildlife; tourism in "protected areas" is even bigger, generating US$ 600bn in revenues annually, compared with the $10bn cost of maintaining protected sites. Interestingly, coral reefs generate US$ 36bn for the global tourist trade (Reynolds et al., 2021). The job created by wildlife tourism in Africa is as high as 36.3% nature for climate. The ecotourism sector of the tourism industry is growing at an impressive speed, specifically in Africa, where it has acquired the status of the second-largest industry responsible for earning a major part of the foreign exchange. Ecotourism was conceptualized very recently in 1980 with the purpose of generating revenue from nature for the protection, conservation, and development of natural resources (Stronza et al., 2019). According to an estimate by Folinas and Metaxas (2020), almost all the countries across the globe with tourism destinations saw a sharp decline in tourism (20–30%) in 2020 owing to travel restrictions imposed during COVID-19, as it was clear from the reduced number of travelers (290–440 million). The measures to check the dissemination of corona across the countries, such as border closures, travel restrictions, and time and again lockdowns, collapsed the ecotourism industry completely and gave set back to many ambitious conservation programs across Asia, Africa, and South America aimed at protection and conservation of some of the rare wildlife and the natural habitats. In the opinion of experts, this situation will certainly increase the incidences of illegal activities such as tree mining and wildlife hunting as many of the conservation agencies will be forced to rest their activities due to the dearth of funds available from ecotourism besides threatening employment in this sector (Fernández-Bedoya et al., 2021). Most of the protected sites under ecotourism have been shut down due to the imposition of coronavirus-related restrictions to check the spread of the virus. The tourism industries where these are based on nature to a greater extent—as in the countries of Costa Rica and India—have been under long-term crisis since the outbreak of this pandemic, and this can disturb the associated ecosystems due to hampering conservation efforts, difficulties in law enforcement, and increased dependency of local communities on the nature for their survival (Shah et al., 2023). There are such reports of the forest-based tourism industry being affected severely during the COVID-19 pandemic across the globe. Ecotourism in all protected areas of Bangladesh, including the Sundarbans mangrove forest and the hill forest in Sylhet, was prohibited by the Forest Department in response to the pandemic

situation, causing financial losses besides rendering thousands of people involved in this sector jobless. According to an estimate by the Bangladesh Tourism Board (BTB), the tourism industry in Bangladesh lost USD 177 million in the first quarter of the pandemic and is also anticipated to bear losses of more than USD 700 million by the end of 2020 (Rahman et al., 2021). Reports from Nepal are also similar in line, where ecotourism and the hospitality industry have been the worst affected sectors due to the pandemic. Findings revealed that tourism contributing 8% of the GDP of Nepal, accounting for a million job opportunities, has brutally collapsed (Laudari et al., 2021). The Dhorpatan Hunting Reserve in Nepal, which is famous for hunting Himalayan tahr and blue sheep, lost an income of 10,000 USD in 2020 due to a lack of tourists during the pandemic (Uprety et al., 2021). As a consequence of pandemic-related guidelines and restrictions, 1.2 million USD was missed from the tourism sector on a daily basis (excluding homestay) in the province (ESCAP and Network, 2021). Even the homestay business suffered the mayhem of the pandemic, losing an income of 1.26 million USD during the lockdown period. Tourism is estimated to have directly contributed 2.7% to GDP and 6.7% to the employment of the country in 2019–20. In India, tourism-based employment fell from 12.7 to 8.0% in 2019–2020 (Singh and Neog, 2020). Malaysia also encountered the same scenario where the pandemic crashed the tourism industry severely. Following the restrictions to contain the pandemic, the number of tourists to Sabah fell by 98% in the initial 2 months of lockdown (April and May 2020), causing 90% revenue loss to tourism agencies. Ecotourism in other parts of the world, such as East and Southern Africa, came to a halt as a consequence of restrictions imposed during COVID, leading to a sharp decline in the number of visitors at forest-based sites. This has resulted in revenue losses from ecotourism for funding conservation programs and related expenditures. The local economic crisis has also affected the rural communities living on the fringes of the forest, which are potential ecotourism (Lindsey et al., 2020; Enns et al., 2023). The Zimbabwe Parks and Wildlife Management Authority estimated a US$3.8 million (50%) deficit from April to June 2020 due to a decline in revenue generated by tourism (Lindsey et al., 2020). The community ecotourism sector under the CAMPFIRE in Zimbabwe is one of the most affected industries by the COVID-19 pandemic (Mudzengi et al., 2022). Similarly, the Uganda Wildlife Authority (UWA), which earns 88% of its income from tourist entrance fees, projected a loss of US$1.4 million for conservation activities in the third quarter of 2020 (Lindsey et al., 2020). Out of ∼1.5 million visitors per year in Kenya, on average, 70–80% come to visit national parks and generate a hefty sum of $1.6 billion as annual revenues. According to the African Wildlife Foundation, the pandemic has left ∼3 million people in Kenya jobless who were previously involved in conservation activities at the end of May 2020. Results of preliminary online studies to observe the effect of the COVID-19 pandemic on ecotourism showed that the pandemic caused a significant adverse impact on the number of visitors at forest-based destinations, the livelihood of local communities, and conservation activities in 38 African countries (Waithaka, 2020; Cumming et al., 2021). The revenue generation by federal land management agencies in the United States has decreased manifold due to the pandemic. Generally, these agencies collect revenues by extractingresources and permitting various activities in the forest land under the guidance of forest personnel, which involves fee collection. As per the Matikiti-Manyevere and Rambe (2022), a sharp decline of almost 70%, amounting to US$1.1 billion, has been lost by the US due to the delayed opening of parks, strict health guidelines, and travel restrictions imposed across the globe as well as within the country. This reduction in the revenue generation is likely to affect the 25000 permanent and contractual employers employed at various capacities under the National Park Service, having ∼500 concessionaires in 100 park units. The decline of international tourism will lose trillions of dollars and millions of jobs. The pandemic-led impact on ecotourism will further reduce the funds for the protection and conservation of natural resources, which are already deficit as economic fallout and humanitarian crisis have diverted the attention and funds to the health sector and for securing livelihood (Cherkaoui et al., 2020).

Green economy

The world has witnessed three waves of pandemic till date with fourth in continuation, resulting in severe public health crisis. Measures to check the transmission of COVID-19 has sent shock waves to global economy, exacerbating poverty and job crisis. The COVID-19 pandemic has caused an economic crisis and poverty alleviation (Figure 4) specifically due to exorbitant spending on health (Figure 5), resulting in the accelerated vulnerability of society, especially rural and indigenous communities, and increased pressure on natural resources. The pandemic and environment are interlinked as the zoonotic diseases originate due to close human—wildlife interaction as a consequence of biodiversity loss and land use changes while pandemic causes biodiversity loss by precipitating deforestation in lieu of increased dependency of people on forest as social safety nets during crisis (Terraube and Fernández-Llamazares, 2020; Akinsorotan et al., 2021; Lawler et al., 2021). Therefore, conservation of biodiversity is important to check the next pandemic. The pandemic-induced socio-economic crisis calls for sustainable recovery which demands investment in nature to prevent the future emergence of zoonotonic diseases while rebuilding global economy (Platto et al., 2021). There are multiple green solutions which can be explored, identified, and integrated in pandemic recovery packages with urgency. The nature-based synergies will help in achieving the immediate goal of economic recovery while taking care of long-term targets of biodiversity conservation and healthy ecosystem to prevent human wildlife interaction in close proximity. Conservation of nature is job intensive and can be harnessed to generate employment in various sectors such as afforestation and reforestation, ecosystem restoration, watershed development, management and protection of forests & wildlife, sustainable food production, and resource conservation and recycling (Morand and Lajaunie, 2021). Investing in nature helps in preventing future pandemics, mitigating climate change, and providing ecosystem goods and services to the people. Nature-based solutions employ cost-effective strategies to make human societies more resilient by helping in achieving many of Sustainable Development Goals. The United Nations called for the immediate need of sustainable recovering strategies guided by 2030

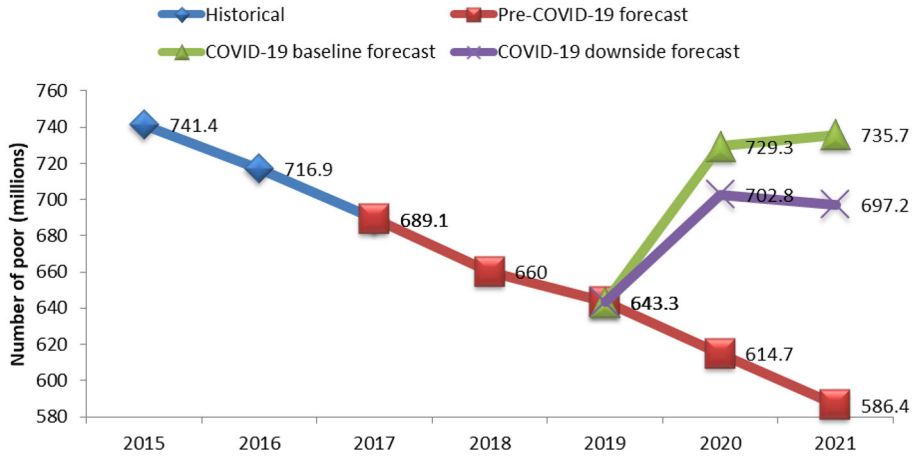


FIGURE 4
Impact of COVID on poverty worldwide (Source: Lakner et al., 2020).

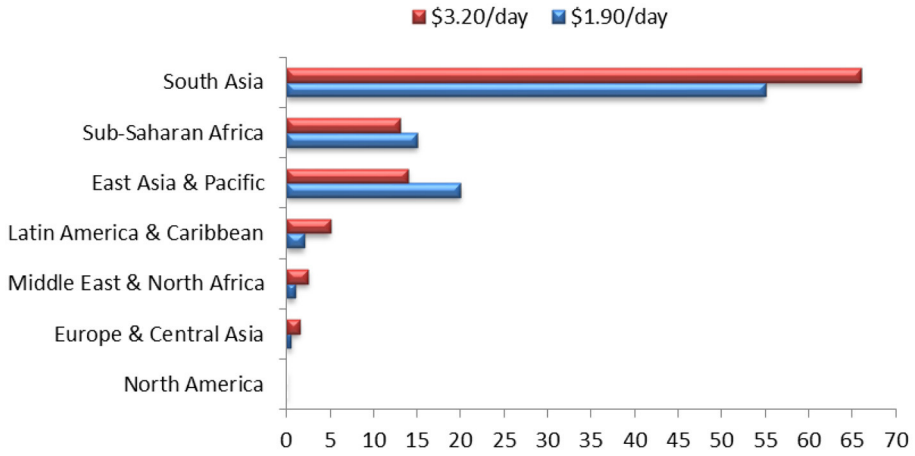


FIGURE 5
Impact of COVID on poverty due to health spending (Source: Blake and Wadhwa, 2020).

agenda to deal with the socio-economic crisis due to COVID-19 at the national level. While issuing guidelines at the country level, the UN announced the Partnership for Action on Green Economy (PAGE) program, which will employ green means for economic reforms based on integrated approaches. PAGE, mobilized by the UN as a joint venture, is an attempt to support nature-based solutions aimed to tackle economic and environmental issues concurrently. Green stimulus packages adopt cost-effective and environment-friendly sustainable integrated measures that work toward economic growth and resilience by creating a healthy ecosystem and mitigating climate change. The COVID-19 situation presents an opportunity for a transition to a green economy, which can help in achieving the sustainable development goals set under the 2030 agenda. The recovery measures guided by SDG and NDC targets will not only reform economic growth but also deal with the issues of climate change, abiding by the fact that the poor and vulnerable are more prone to climate change and ecological instability. Many governments across the globe have announced a range of fiscal stimulus packages for socio-economic reform following the pandemic crisis. Although various countries have announced financial recovery packages of a considerable amount, they allocated a minor share to green recovery (Koasidis et al., 2022). As per Vivid Economics' Green Stimulus Index, a hefty sum of USD 3.5 trillion has been allocated to different sectors (agriculture, energy, industry, transport, and waste) by 17 economies (OECD and G20 countries), which are intimately related to nature (Figure 6).

However, in most of the countries except France, Germany, and the United Kingdom, funds apportioned to sectors having a negative impact on nature outweigh the finances to the nature-friendly sectors (Rechsteiner, 2021). Across the globe, financial recovery packages of ~10 trillion USD have been announced to date to deal with the pandemic crisis. Canada is one of the major leading countries that have shown their political determination to transition to a green economy. In December 2020, Canada established World Bank Clean Energy

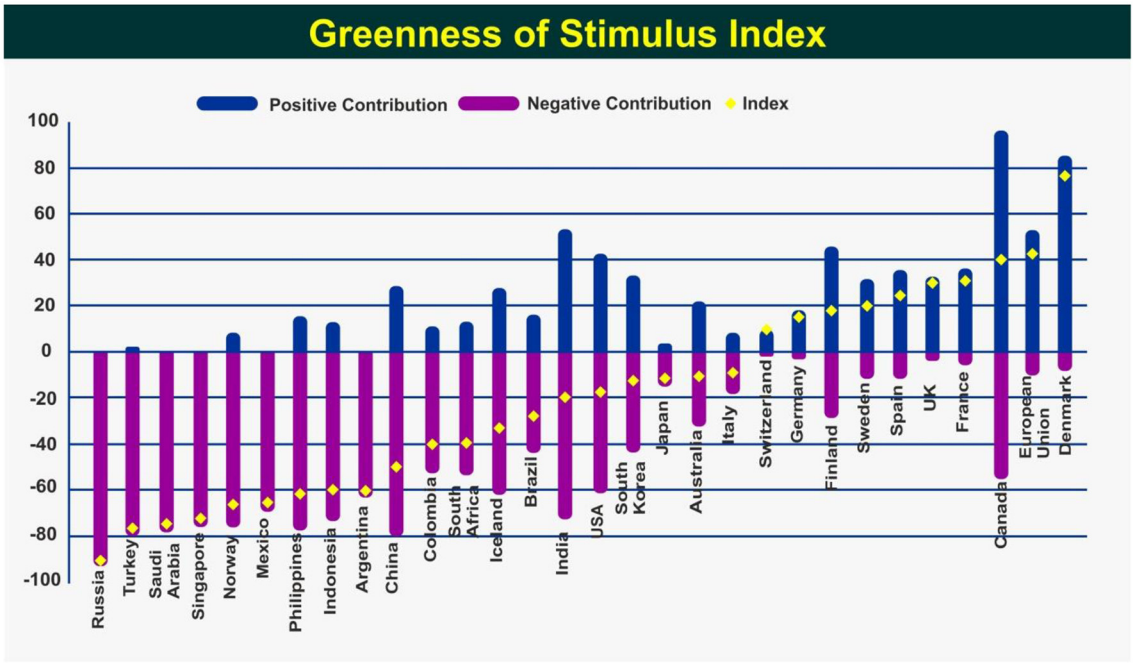


FIGURE 6
Percent allocation of the stimulus package announced by different countries toward nature (Source: Vivid Economics, 2021).

and Forests Climate Facility to support transformational climate actions of World Bank projects, targeted at mitigating climate change by halting deforestation and forest degradation through protection, conservation, and management of forest resources (Rechsteiner, 2021). In the US, there is momentum to steer recovery strategies toward more sustainable environmental and economic development. The USA Government constitutes a Civilian Climate Corps, which will help in employment generation in green areas (Boone et al., 2023). European countries such as Germany decided to invest in the conservation of nature to deal with the pandemic crisis in an environmentally sustainable and socially responsible manner. Netherlands suggested that EU fiscal packages should be guided by a regional "green finance taxonomy" that aims to support investment in green technologies by giving incentives. UK Research and Innovation (UKRI) is sponsoring the projects aimed at exploring the socio-economic and environmental impact of the pandemic outbreak (Ruiu et al., 2022), and France's National Research Agency has called for short-term proposals (RA-COVID-19) for carrying out research on different aspects of COVID-19 related to life and environment (Morand, 2022). Other countries across the globe, such as New Zealand, Australia, India, and Pakistan, are also focusing on nature-based solutions to fight pandemic-generated socio-economic and environmental problems.

Conclusion

COVID-19 has affected many dimensions of human society, forests being one of the major hits. Deforestation took place at an increased rate during COVID period due to exacerbated demand for forest products, a dearth of human resources, diversion of funds, a sharp decline in ecotourism, and reverse migration. Deforestation and zoonotic diseases are interlinked to each other intricately. Deforestation causes increased chances of human and wildlife interaction, thus communication of zoonotic diseases to mankind. Zoonotic diseases precipitate deforestation due to greater dependency on forests during a crisis, deficit manpower, and curtailed budgets due to the priority of the health sector over natural resource management. Therefore, efforts should be aimed at building back better through a green economy. Investing in nature is a sustainable way of recovering from the pandemic, economically by employment generation and environmentally through maintaining and restoring ecosystem health and climate change mitigation. Governments across the globe are announcing huge fiscal packages to deal with COVID-19 induced socio-economic crises. This situation provides an opportunity to steer COVID-19 stimulus packages toward nature-based solutions for transition to a green economy, which will not only help in socio-economic recovery but also in building community resilience to cope with livelihood crisis, particularly for rural communities that depend on nature and land use for their survival. Nonetheless, the recovery spending could provide a unique opportunity to change this: If recovery packages would focus on accelerating the transition toward low-carbon energy and improving energy efficiency, it could be a significant boost toward reaching the Paris Agreement targets and national climate policy goals (Ortiz et al., 2021). The present disruption due to the pandemic, in this way, may facilitate the shift toward sustainability, which is an ambitious goal to achieve as per the 2030 agenda. Policymakers should use this opportunity to propose inclusive policies for using the recovery funds for a green and sustainable future. Recent studies by economists suggested "investment in ecosystem health

and resilience" to be one of the major recommendations to achieve economic recovery and climate mitigation goals. The concept of green recovery pushes for building a sustainable and resilient future (Moglia et al., 2021). The efforts to recover from the pandemic-created crisis should be centered on employment generation, mostly in green sectors, judicious use and sustainable management of natural resources, ecosystem resilience, and acknowledging the rights of indigenous communities. COVID-19 has caused a major setback to climate change programs and other efforts to achieve sustainable development goals, the recuperation of which is possible only through green recovery. The COVID-19 crisis divulged the strength of forestry as an effective measure to address social, economic, and environmental issues. Recognizing the importance of forestry in poverty alleviation, employment generation, enhancing ecosystem resilience, and reducing the vulnerability of rural and indigenous communities, it is a wakeup call to introduce forestry-based solutions into pandemic recovery strategies to strengthen the economy and societies to face the global challenges in future.

Government and non-government national and international bodies should take swift initiatives at the policy level to reap the benefits of sustainable forest management by allocating funds to the forestry sector in response to COVID-19. Although the UN Strategic Plan for Forests 2030 already envisaged forestry as a vital component for economic development, social wellbeing, and environmental resilience, integrated efforts at the political level and accelerated decisive actions are urgently needed to achieve a green future. The green recovery from the pandemic is possible only through sustainable and healthy forest ecosystems and resilient communities residing on the fringes of the forest.

Policy recommendations

The following recommendations in the context of forests for COVID-19 green recovery could be acknowledged:

1. Strengthening of forest governance by using modern technologies such as real-time satellite imagery, which rely less on manpower.
2. Ensuring legal and sustainable global timber trading.
3. Employment generation in the green sector.
4. Recognizing the role of indigenous communities in forest protection and conservation and ensuring legal protection of their land tenure rights.
5. Incentives for halting deforestation and reducing emissions.
6. Ruling out the relaxation of environmental laws during the pandemic and effective enforcement of environmental regulations to check illegal felling, wildlife trade, and land-use changes.
7. Design and formulate policies and strategies for a post-COVID-19 green recovery.
8. Exploiting the potential of carbon sequestration in the forest products sector for building back better post-COVID-19.
9. Conceptualization of green cities through expansion of natural ecosystems in urban areas is an effective way of conserving nature while being socio-economically beneficial.
10. Integration of agroforestry in the nature-based solutions for COVID-19 recovery as an immediate means of alleviating poverty and hunger by improving productivity and diversifying the livelihood of particularly small landholders.
11. Industries such as ecotourism, which rely on natural ecosystems, should be supported by COVID-19 fiscal recovery packages.
12. Intensify international cooperation and finance to conserve and restore the ecological integrity of natural ecosystems and address the drivers of ecosystem degradation, fragmentation, and conversion.
13. Environmental responsibility should be fixed for the sectors that are associated with a heavy biodiversity footprint, such as agriculture, energy, and industry.

Author contributions

VS: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. DJ: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. AR: Data curation, Formal analysis, Writing – original draft. RP: Conceptualization, Data curation, Formal analysis, Writing – original draft. IS: Formal analysis, Writing – review & editing. TB: Conceptualization, Data curation, Formal analysis, Writing – original draft. VP: Data curation, Formal analysis, Writing – review & editing. SF: Data curation, Formal analysis, Writing – review & editing. LJ: Funding acquisition. NA: Funding acquisition. MJ: Funding acquisition.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

The authors thank the Indian Council of Agricultural Research, New Delhi, and ICAR-Indian Institute of Soil and Water Conservation, Dehradun, for providing the necessary facility.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

African Union (2020). *African Forests and the COVID-19 Pandemic*. Addis Ababa; African Union.

Akinsorotan, O. A., Olaniyi, O. E., Adeyemi, A. A., and Olasunkanmi, A. H. (2021). Corona virus pandemic: implication on biodiversity conservation. *Front. Water* 3, 635529. doi: 10.3389/frwa.2021.635529

Allen, T., Murray, K. A., Zambrana-Torrelio, C., Morse, S. S., Rondinini, C., Di Marco, P., et al. (2017). Global hotspots and correlates of emerging zoonotic diseases. *Nat. Commun.* 8, 1124. doi: 10.1038/s41467-017-00923-8

Amburgey, E., Gurung, T. W., Gurung, Y. T., and Craig, S. R. (2023). The co-production of disasters: how the nexus of climate change, tourism, and COVID-19 increases socioeconomic vulnerability in Mustang, Nepal. *Critic. Asian Stu.* 18, 1–24. doi: 10.1080/14672715.2023.2174891

Araújo, J. F. (2020). *Roads as a Driver of Changes in the Bird Community and Disruptors of Ecosystem Services Provision (Doctoral dissertation, Universidade de Lisboa (Portugal))*. Lisboa: Universidade de Lisboa.

Attah, A. N. (2021). *Initial Assessment of the Impact of COVID-19 on Sustainable Forest Management African States*. New York, NY: United Nations Forum on Forests Secretariat.

Attah, A. N. (2022). *Second Assessment of the Impact of COVID-19 on Forests and Forest Sector in the African Region Prepared for the 17th session of the United Nations Forum on Forests*. Available online at: https://www.un.org/esa/forests/wp-content/uploads/2022/05/2nd-assessment-Covid19-Africa-final.pdf (accessed May 2, 2022).

Basnyat, B., Baral, S., Tiwari, K. R., Shrestha, G. K., Adhikari, B., Dahal, Y. N., et al. (2020). COVID-19 outbreak, timber production, and livelihoods in Nepal. *Tribhuvan Univ. J.* 36, 15–32. doi: 10.3126/tuj.v34i0.31536

Bercak, R., Holuša, J., Kaczmarowski, J., Tyburski, L., Szczygieł, R., Held, A., et al. (2023). Fire protection principles and recommendations in disturbed forest areas in central europe: a review. *Fire* 6, 310. doi: 10.3390/fire6080310

Bertola, L., Lara, C., and Martínez, C. (2023). *25 Natural Resource Wealth and Fiscal Institutions in Latin America since Independence. Taxation and Inequality in Latin America: New Perspectives on Political Economy and Tax Regimes*. London: Routledge, 2.

Bhandari, M. S., Pandey, S., Dabral, A., Meena, R. K., and Kant, R. (2021). Global forestry perspective: COVID-19 impact and assessment. *Natl. Acad. Sci. Lett.* 44, 571–574. doi: 10.1007/s40009-021-01062-x

Bhattacharyya, R., Sarma, P. K., and Das, T. K. (2023). Mass exodus of India's internal migrant labourers during the first phase of COVID-19: a critical analysis. *SN Soc. Sci.* 3, 108. doi: 10.1007/s43545-023-00691-x

Bista, R., Parajuli, R., Giri, K., Karki, R., and Song, C. (2022). Impacts of COVID-19 pandemic on the livelihoods of rural households in the community forestry landscape in the Middle Hills of Nepal. *Trees Forests People* 9:100312. doi: 10.1016/j.tfp.2022.100312

Blake, P., and Wadhwa, D. (2020). *Year in Review: The Impact of COVID-19 in 12 Charts*. Available online at: https://blogs.worldbank.org/voices/2020-year-review-impact-covid-19-12-charts (accessed January 2022).

Boone, C. G., Bromaghim, E., and Kapuscinski, A. R. (2023). Sustainability careers. *Ann. Rev. Environ. Res.* 48, 5353. doi: 10.1146/annurev-environ-120920-105353

Brancalion, P. H. S., Broadbent, E. N., de-Miguel, S., Cardil, A., Rosa, M. R., and Almeida, C. T. (2020). Emerging threats linking tropical deforestation and the COVID-19 pandemic. *Perspect. Ecol. Conserv.* 18, 243–246. doi: 10.1016/j.pecon.2020.09.006

Brown, K. (2020). *The Hidden Toll of Lockdown on Rainforests*. Available online at: https://www.bbc.com/future/article/20200518-why-lockdown-is-harming-the-amazon-rainforest (accessed March 2022).

Butler, R. A. (2020). *Despite COVID, Amazon Deforestation Races Higher. MONGABAY*. Available online at: https://news.mongabay.com/2020/04/despite-covid-amazon-deforestation-raceshigher/ (accessed January 20, 2020).

Butler, R. A. (2021). *Global Forest Loss Increased in 2020. Mongabay Series: Global Forests, Planetary Boundaries*. Available online at: https://news.mongabay.com/2021/03/global-forest-loss-increases-in-2020-but-pandemics-impact-unclear/ (accessed June 2023).

Céspedes, J., Sylvester, J. M., Pérez-Marulanda, L., Paz-Garcia, P., Reymondin, L., Khodadadi, M., et al. (2023). Has global deforestation accelerated due to the COVID-19 pandemic?. *J. Forestr. Res.* 34, 1153–1165. doi: 10.1007/s11676-022-01561-7

Chandra, W. (2021). *Translated by Hans Nicholas Jong Illegal loggers use pandemic as cover to ramp up activity in Sulawesi Mongabay Series*. Available online at: https://news.mongabay.com/2021/05/illegal-loggers-use-pandemic-as-cover-to-ramp-up-activity-in-sulawesi/ (accessed November 2022).

Cherkaoui, S., Boukherouk, M., Lakhal, T., Aghzar, A., and El Youssfi, L. (2020). Conservation amid COVID-19 pandemic: ecotourism collapse threatens communities and wildlife in Morocco. *E3S Web of Conf.* 183, 01003. doi: 10.1051/e3sconf/202018301003

Chirisa, H., and Campbell, M. (2023). "Spatial demography as the shaper of urban and regional planning under the impact of rapid urbanization: reconnoitering the future," in *The Palgrave Encyclopedia of Urban and Regional Futures*. Cham: Springer International Publishing, 1618–1626.

Chirisa, I., Mavhima, B., Nyevera, T., Chigudu, A., Makochekanwa, A., Matai, J., et al. (2021). The impact and implications of COVID-19: reflections on the Zimbabwean society. *Soc. Sci. Hum. Open* 4, 100183. doi: 10.1016/j.ssaho.2021.100183

Corlett, R. T., Primack, R. B., Devictor, V., Maas, B., Goswami, V. R., Bates, A. E., et al. (2020). Impacts of the coronavirus pandemic on biodiversity conservation. *Biol. Conserv.* 246, 108571. doi: 10.1016/j.biocon.2020.108571

Cumming, T., Seidl, A., Emerton, L., Spenceley, A., Kroner, R. G., Uwineza, Y., et al. (2021). Building sustainable finance for resilient protected and conserved areas: lessons from COVID-19. *Parks* 27, 149–160. doi: 10.2305/IUCN.CH.2021.PARKS-27-SITC.en

Eklund, J., Jones, J. P., Räsänen, M., Geldmann, J., Jokinen, A. P., Pellegrini, A., et al. (2022). Elevated fires during COVID-19 lockdown and the vulnerability of protected areas. *Nat. Sust.* 5, 603–609. doi: 10.1038/s41893-022-00884-x

Enns, C., van Vliet, N., Mbane, J., Muhindo, J., Nyumu, J., Bersaglio, B., et al. (2023). Vulnerability and coping strategies within wild meat trade networks during the COVID-19 pandemic. *World Dev.* 170, 106310. doi: 10.1016/j.worlddev.2023.106310

ESCAP, U., and Network, I. B. A. (2021). *Towards a Roadmap for Inclusive Business in Wellness Tourism in Indonesia*. Bangkok: ESCAP.

Fair, J. (2020). *COVID-19 Lockdown Precipitates Deforestation Across Asia and South America [WWW Document] MONGABAY*. Available online at: https://news.mongabay.com/2020~/07/covid-19-lockdown-precipitates-deforestation-across-asia-and-south-america

FAO (2020a). *The Impacts of COVID-19 on the Forest Sector: How to Respond?* Rome:FAO, 6.

FAO (2020b). *Lessons Learned from COVID-19 Crisis to the Better Management of Forest and Water Resources*. Rome. Available online at: http://www.fao.org/in-action/forest-and-waterprogramme/news/news-detail/en/c/1275837/ (accessed November 14, 2020).

FAO (2021). *Reverse Migration to Rural Areas of Origin in the Context of the COVID-19 Pandemic*. FAO.

Fernández-Bedoya, V. H., Meneses-La-Riva, M. E., and Suyo-Vega, J. A. (2021). ecotourism in times of COVID-19: a systematic review from the five continents on how this activity is being carried out and what proposals they have for the near future. *Culture.* 10, 1–10. doi: 10.36941/ajis-2021-0148

Folinas, S., and Metaxas, T. (2020). Tourism: The Great Patient of Coronavirus COVID-2019. *Int. J. Adv. Res.* 8, 365–375. doi: 10.21474/IJAR01/10788

Friedlingstein, P., Jones, M. W., O'sullivan, M., Andrew, R. M., Bakker, D. C., Hauck, J., et al. (2022). Global carbon budget 2021. *Earth Syst. Sci. Data* 14, 1917–2005. doi: 10.5194/essd-14-1917-2022

Galanakis, C. M., Brunori, G., Chiaramonti, D., Matthews, R., Panoutsou, C., Fritsche, U. R., et al. (2022). Bioeconomy and green recovery in a post-COVID-19 era. *Sci. Total Environ.* 808, 152180. doi: 10.1016/j.scitotenv.2021.152180

Garbe, L., Rau, R., and Toppe, T. (2020). Influence of perceived threat of Covid-19 and HEXACO personality traits on toilet paper stockpiling. *PloS ONE* 15, e0234232. doi: 10.1371/journal.pone.0234232

Gregory, M. (2021). *COVID, Forests and Forest Peoples: The Implications of the Pandemic for Forest Campaigns. Discussion Paper, Fern*. Available online at: https://www.fern.org/fileadmin/uploads/fern/Documents/2021/Covid_and_forests.pdf (accessed February 2023).

Hardcastle, P., and Zabel, A. (2020). *Initial Assessment of the Impact of COVID-19 on Sustainable Forest Management Western European and other States. Background Paper Prepared for the United Nations Forum on Forests Secretariat*. Available online at: https://www.imf.org/en/topics/imf-and-covid19/ (accessed December 2022).

Heller, M. (2020). *Officials Cut Back on Controlled Burns Due to COVID-19*. Available online at: https://www.eenews.net/greenwire/2020/04/03/stories/1062777803 (accessed December 1, 2020).

Ibn-Mohammed, T., Mustapha, K. B., Godsell, J., Adamu, Z., Babatunde, K. A., Akintade, D. D., et al. (2021). A critical analysis of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies. *Res. Conserv. Recycl.* 164, 105169. doi: 10.1016/j.resconrec.2020.105169

ILO (2020). *Protecting Migrant Workers During the COVID-19 Pandemic: Recommendations for Policy-Makers and Constituents*. Geneva. Available online at: https://www.ilo.org/global/topics/labourmigration/publications/WCMS_743268/lang--en/index.h (accessed March 2021).

Johansen, B. E. (2023). "Climate Crisis: Code Red for Humanity and Our Home Planet: A Scorecard for an Apocalypse," in *Global Warming and the Climate Crisis:*

Science, Spirit, and Solutions, ed B. E. Johansen (Cham: Springer International Publishing), 97–197.

Jones, L. (2020). *What's Behind the Great Toilet Roll Grab? BBC News.* Available online at: https://www.bbc.com/news/business-52040532 (accessed September 2022).

Khan, M. A., Tahir, A., Khurshid, N., Husnain, M. I. U., Ahmed, M., Boughanmi, H., et al. (2020). Economic effects of climate change-induced loss of agricultural production by 2050: a case study of Pakistan. *Sustainability* 12, 1216. doi: 10.3390/su12031216

Koasidis, K., Nikas, A., Van de Ven, D. J., Xexakis, G., Forouli, A., Mittal, S., et al. (2022). Towards a green recovery in the EU: aligning further emissions reductions with short-and long-term energy-sector employment gains. *Energ. Policy* 171, 113301. doi: 10.1016/j.enpol.2022.113301

Korngold, A. (ed) (2023). "Climate and environment," in *Corporate Governance for an Inclusive, Sustainable, and Prosperous Future* (Cham: Springer International Publishing), 23–69.

Lakner, C., Mahler, D. G., Negre, M., Prydz, E. B., and Sangraula, P. (2020). How much does reducing inequality matter for global poverty? *Global Poverty Monitor. Tech.* 13, 1–33.

Lambin, E. F., and Furumo, P. R. (2023). Deforestation-free commodity supply chains: myth or reality?. *Ann. Rev. Environ. Resour.* 48, 436. doi: 10.1146/annurev-environ-112321-121436

Laudari, H. K., Pariyar, S., and Maraseni, T. (2021). COVID-19 lockdown and the forestry sector: insight from Gandaki province of Nepal. *Forest Policy Econ.* 131, 102556. doi: 10.1016/j.forpol.2021.102556

Lawler, O. K., Allan, H. L., Baxter, P. W., Castagnino, R., Tor, M. C., Dann, L. E., et al. (2021). The COVID-19 pandemic is intricately linked to biodiversity loss and ecosystem health. *The Lancet Planetar. Health* 5, e840–e850. doi: 10.1016/S2542-5196(21)00258-8

Lindsey, P., Allan, J., Brehony, P., Dickman, A., Robson, A., Begg, C., et al. (2020). Conserving Africa's wildlife and wildlands through the COVID-19 crisis and beyond. *Nat. Ecol. Evol.* 4, 1300–1310. doi: 10.1038/s41559-020-1275-6

Maraseni, T., Poudyal, B. H., Aryal, K., and Laudari, H. K. (2022). Impact of COVID-19 in the forestry sector: A case of lowland region of Nepal. *Land Use Policy* 120, 106280. doi: 10.1016/j.landusepol.2022.106280

Matikiti-Manyevere, R., and Rambe, P. (2022). The impact of COVID 19 on the tourism industry: the role of fourth industrial revolution technologies in mitigating the impacts. *Afr. J. Hosp. Tour. Leisure* 11, 1173–1187. doi: 10.46222/ajhtl.19770720.283

Maxton-Lee, B. (2020). *Forest Conservation and Sustainability in Indonesia: A Political Economy Study of International Governance Failure.* London: Routledge.

Mbzibain, A. (2020). "Rapid appraisal of impacts on IPLCs, women and forest illegality in the Congo Basin," in *Webinar series on COVID-19 and the Forest Sector - Experience from Forest Communities of COVID-19 Impacts*

Miller, D. C. (2020). *As the Pandemic Pushes Millions Toward Poverty, Forests and Trees can Safeguard Livelihoods. Forest News*. Available online at: https://forestsnews.cifor.org/69506/as-the-pandemic-pushes-millions-towards-poverty-forests-and-trees-can-safeguard-livelihoods?fnl=en (accessed December 2021).

Moglia, M., Frantzeskaki, N., Newton, P., Pineda-Pinto, M., Witheridge, J., Cook, S., et al. (2021). Accelerating a green recovery of cities: Lessons from a scoping review and a proposal for mission-oriented recovery towards post-pandemic urban resilience. *Dev. Built Environ.* 7, 100052. doi: 10.1016/j.dibe.2021.100052

Mohan, M., Rue, H. A., Bajaj, S., Galgamuwa, G. P., Adrah, E., Aghai, M. M., et al. (2021). Afforestation, reforestation and new challenges from COVID-19: thirty-three recommendations to support civil society organizations (CSOs). *J. Environ. Manage.* 287, 112277. doi: 10.1016/j.jenvman.2021.112277

Morand, S. (2022). One Health: an ecosystem-based ecology of health. *Field Actions Sci. Rep. J. Field Actions* 24, 58–63.

Morand, S., and Lajaunie, C. (2021). Biodiversity and COVID-19: a report and a long road ahead to avoid another pandemic. *One Earth* 4, 920–923. doi: 10.1016/j.oneear.2021.06.007

Muche, M., Yemata, G., Molla, E., Musaya, A. M., and Tsegay, B. A. (2022). COVID-19 lockdown and natural resources: a global assessment on the challenges, opportunities, and the way forward. *Bull. Natl. Res. Cent.* 46:20. doi: 10.1186/s42269-022-00706-2

Mudzengi, B. K., Gandiwa, E., Muboko, N., and Mutanga, C. N. (2022). Innovative community ecotourism coping and recovery strategies to COVID-19 pandemic shocks: the case of Mahenye. *Dev. Souther. Afr.* 39, 68–83. doi: 10.1080/0376835X.2021.1980375

Mustaquim, M., and Islam, W. (2020). Risk and Vulnerability of Migrant Labours from West Bengal and their Life Satisfaction during Pandemics of COVID-19: A Case Study. *Asian J. Soc. Sci.* 9, 40–45.

OECD (2020). *OECD Economic Outlook.* Paris: OECD Publishing.

Ortiz, A. M. D., de Leon, A. M., Torres, J. N. V., Guiao, C. T. T., and La Viña, A. G. (2021). Implications of COVID-19 on progress in the UN conventions on biodiversity and climate change. *Global Sust.* 4, e11. doi: 10.1017/sus.2021.8

Parris-Piper, N., Dressler, W. H., Satizábal, P., and Fletcher, R. (2023). Automating violence? The anti-politics of 'smart technology'in biodiversity conservation. *Biol. Conserv.* 278, 109859. doi: 10.1016/j.biocon.2022.109859

Patwardhan, B., Chavan-Gautam, P., Gautam, M., Tillu, G., Chopra, A., Gairola, S., et al. (2020). Ayurveda rasayana in prophylaxis of COVID-19. *Curr. Sci.* 118, 1158–60.

Pérez Caldentey, E., Kreiter, Z., and Abeles, M. (2023). *Capital Flow Regulation: Selected Experiences in Developing Countries From Latin America, Africa and Asia-Pacific and Analysis of the Type of Capital Controls Needed to Confront the Disruptive Effects of the COVID-19. Financial Openness, Financial Fragility and Policies for Economic Stability. A Comparative Analysis Across Regions of the Developing World.* Santiago: ECLAC, 39–86.

Platto, S., Zhou, J., Wang, Y., Wang, H., and Carafoli, E. (2021). Biodiversity loss and COVID-19 pandemic: the role of bats in the origin and the spreading of the disease. *Biochem. Biophys. Res. Commun.* 538, 2–13. doi: 10.1016/j.bbrc.2020.10.028

Qin, Y., Xiao, X., Dong, J., Zhang, Y., Wu, X., Shimabukuro, Y., et al. B. (2019). Improved estimates of forest cover and loss in the Brazilian Amazon in 2000–2017. *Nat. Sust.* 2, 764–772. doi: 10.1038/s41893-019-0336-9

Rafa, N., Van To, T. T., Gupta, M., and Uddin, S. M. N. (2022). The pursuit of energy in refugee contexts: discrimination, displacement, and humanitarian energy access for the Rohingya refugees displaced to Bangladesh. *Energ. Res. Soc. Sci.* 83, 102334. doi: 10.1016/j.erss.2021.102334

Rahman, M. S., Alam, M. A., Salekin, S., Belal, M. A. H., and Rahman, M. S. (2021). The COVID-19 pandemic: a threat to forest and wildlife conservation in Bangladesh?. *Trees Forests People* 5, 100119. doi: 10.1016/j.tfp.2021.100119

Rechsteiner, R. (2021). German energy transition (Energiewende) and what politicians can learn for environmental and climate policy. *Clean Technol. Environ. Policy* 23, 305–342. doi: 10.1007/s10098-020-01939-3

Reynolds, A. C., Pabel, A., Ferguson, S. A., and Naweed, A. (2021). Causes and consequences of sleep loss and fatigue: the worker perspective in the coral reef tourism industry. *Annal. Tour. Res.* 88, 103160. doi: 10.1016/j.annals.2021.103160

Robinson, E., McAdams, B., Somogyi, S., and Thomas-Francois, K. (2023). Managerial decision-making during the COVID-19 pandemic and its impact on the sustainability initiatives of Canadian foodservice businesses. *J. Foodserv. Bus. Res.* 26, 352–380. doi: 10.1080/15378020.2022.2121587

Rohr, J. R., Barrett, C. B., Civitello, D. J., Craft, M. E., Delius, B., DeLeo, G. A., et al. (2019). Emerging human infectious diseases and the links to global food production. *Nature Sust.* 2, 445–456. doi: 10.1038/s41893-019-0293-3

Rotbarth, R., Van Nes, E. H., Scheffer, M., Jepsen, J. U., Vindstad, O. P. L., Xu, C., et al. (2023). Northern expansion is not compensating for southern declines in North American boreal forests. *Nat. Commun.* 14, 3373. doi: 10.1038/s41467-023-39092-2

Roy, P. (2021). *North East India Saw Largest Share of the Country's Tree Cover Loss: Study.* Available online at: https://www.downtoearth.org.in/factsheet/north-east-india-saw-largest-share-of-the-country-s-tree-cover-loss-study-79653 (accessed March 2023).

Ruiu, G., Ruiu, M. L., and Ragnedda, M. (2022). How the COVID-19 pandemic impacted the perception of climate change in the UK. *Am. Behav. Sci.* 27, 00027642221085885. doi: 10.1177/00027642221085885

Saavedra, S. (2020). Is global deforestation under lockdown. *SSRN Electr. J.* 1–32. doi: 10.2139/ssrn.3668029

Saxena, A., Dutta, A., Fischer, H. W., Saxena, A. K., and Jantz, P. (2021). Forest livelihoods and a "green recovery" from the COVID-19 pandemic: insights and emerging research priorities from India. *Forest Policy Econ.* 131, 102550. doi: 10.1016/j.forpol.2021.102550

Sen, M. (2020). *Forests At the Heart of a Green Recovery from the COVID-19 pandemic. UN/DESA Policy Brief #80. United Nations.* Available online at: https://www.un.org/development/desa/dpad/publication/un-desa-policy-brief-80-forests-at-the-heart-of-a-greenrecovery-from-the-covid-19-pandemic/ (accessed November 14, 2020).

Sengupta, S., and Jha, M. K. (2020). Social policy, COVID-19 and impoverished migrants: challenges and prospects in locked down India. *The Int. J. Commun. Soc. Dev.* 2, 152–172. doi: 10.1177/2516602620933715

Shah, S. H. A., Rafique, N., Saleem, S., Amjad, R., and Arshad, B. (2023). "Revamping hotel industry in south east asian region: outlook of existing situation after COVID-19," in *Resilient and Sustainable Destinations After Disaster*, eds J. Kumar, G. E. Bayram, and A. Sharma. (New York, NY: Emerald Publishing Limited), 267–275.

Silva-Junior, C. H., Silva, F. B., Arisi, B. M., Mataveli, G., Pessôa, A. C., Carvalho, N. S., et al. (2023). Brazilian Amazon indigenous territories under deforestation pressure. *Sci. Rep.* 13, 5851. doi: 10.1038/s41598-023-32746-7

Simental, A. J., and Bynum, T. (2023). "The role of public health in emergency management: 1: preparedness, pandemics, present and future challenges post-COVID-19," in *The Distributed Functions of Emergency Management and Homeland Security*, ed D. A. McEntire (London: CRC Press), 175–217

Singh, M. K., and Neog, Y. (2020). Contagion effect of COVID-19 outbreak: another recipe for disaster on Indian economy. *J. Pub. Affairs* 20, e2171. doi: 10.1002/pa.2171

Sloan, S., Locatelli, B., Andela, N., Cattau, M. E., Gaveau, D., Tacconi, L., et al. (2022). Declining severe fire activity on managed lands in Equatorial Asia. *Commun. Earth Environ.* 3, 207. doi: 10.1038/s43247-022-00522-6

Stanley, J., March, A., Ogloff, J., and Thompson, J. (2020). *Feeling the Heat: International Perspectives on the Prevention of Wildfire Ignition*. Wilmington, DE: Vernon Press.

Stanturf, J. A., and Mansuy, N. (2021). COVID-19 and forests in Canada and the United States: Initial assessment and beyond. *Front. Forests Global Change* 4, 666960. doi: 10.3389/ffgc.2021.666960

Stronza, A. L., Hunt, C. A., and Fitzgerald, L. A. (2019). Ecotourism for conservation?. *Ann. Rev. Environ. Resour.* 44, 229–253. doi: 10.1146/annurev-environ-101718-033046

Suresh, R., and James, J., and RSj, B. (2020). Migrant workers at crossroads–The COVID-19 pandemic and the migrant experience in India. *Soc. Work Pub. Health* 35, 633–643. doi: 10.1080/19371918.2020.1808552

Terraube, J., and Fernández-Llamazares, Á. (2020). Strengthening protected areas to halt biodiversity loss and mitigate pandemic risks. *Curr. Opin. Environ. Sust.* 46, 35–38. doi: 10.1016/j.cosust.2020.08.014

Tripathi, H. G., Woollen, E. S., Carvalho, M., Parr, C. L., and Ryan, C. M. (2021). Agricultural expansion in African savannas: effects on diversity and composition of trees and mammals. *Biodiv. Conserv.* 30, 3279–3297. doi: 10.1007/s10531-021-02249-w

Troëng, S., Barbier, E., and Rodríguez, C. M. (2019). *The COVID-19 Pandemic is not a Break for Nature-Let's Make Sure There is One After the Crisis. Emissions Gap Report. UN Environment Programme*. Available online at: https://www.unep.org/resources/emissions-gap-report-2019 (accessed April 2021).

UNEP (2020). *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission. A Scientific Assessment with Key Messages for Policy-Makers A Special Volume of UNEP's Frontiers Report Series United Nations Environment Programme*. Washington, DC: UNEP.

United Nations (2020a). *United Nations Department of Economic and Social Affairs Forests: at the Heart of a Green Recovery From the COVID-19 Pandemic, Policy Brief No. 80*, 1–4. Available online at: https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/PB_80.pdf

United Nations (2020b). *Policy Brief: COVID-19 and Transforming Tourism*. Available online at: https://www.un.org/sites/un2.un.org/files/sg_policy_brief_covid-19_tourism_august_2020.pdf (accessed July 31, 2020).

Uprety, Y., Chettri, N., Dhakal, M., Asselin, H., Chand, R., Chaudhary, R. P., et al. (2021). Illegal wildlife trade is threatening conservation in the transboundary landscape of Western Himalaya. *J. Nat. Conserv.* 59, 125952. doi: 10.1016/j.jnc.2020.125952

Vancutsem, C., Achard, F., Pekel, J. F., Vieilledent, G., Carboni, S., Simonetti, D., et al. (2021). Long-term (1990–2019) monitoring of forest cover changes in the humid tropics. *Sci. Adv.* 7, eabe1603. doi: 10.1126/sciadv.abe1603

Vivid Economics (2021). Available online at: https://www.vivideconomics.com/wp-content/uploads/2021/07/Green-Stimulus-Index-6th-Edition_final-report.pdf (accessed October 2022).

Waithaka, J. (2020). *The Impact of COVID-19 Pandemic on Africa's Protected Areas Operations and Programmes*. Gland: IUCN-WCPA Paper.

Waithaka, J., Dudley, N., Álvarez, M., Arguedas Mora, S., and Chapman, S., Figgis, P., et al. (2021). Impacts of COVID-19 on protected and conserved areas: A global overview and regional perspectives. *Int. J. Protec. Area & Conserv.* 27, 41–56. doi: 10.2305/IUCN.CH.2021.PARKS-27-SIJW.en

Wang, B., Zhu, L., Yang, T., Qian, Z., Xu, C., Tian, D., et al. (2022). Poplar agroforestry systems in eastern China enhance the spatiotemporal stability of soil microbial community structure and metabolism. *Land Degr. Dev.* 33, 916–930. doi: 10.1002/ldr.4199

Wang, J., Khan, Y. A., Khodaei, M., Khezr, S., Karimi, M. S., Salem, S., et al. (2022). The Effects of financial development and pandemics prevalence on forests: evidence from Asia-pacific region. *Front. Environ. Sci.* 10, 173. doi: 10.3389/fenvs.2022.850724

Weisse, M., and Goldman, L. (2021). *Primary Rainforest Destruction Increased 12% From 2019 to 2020*. Available online at: https://www.globalforestwatch.org/blog/data-and-research/global-tree-cover-loss-data-2020/ (accessed January 2023).

Werikhe, A. (2022). Towards a green and sustainable recovery from COVID-19. *Curr. Res. Environ. Sust.* 4, 100124. doi: 10.1016/j.crsust.2022.100124

West, T. A., Wunder, S., Sills, E. O., Börner, J., Rifai, S. W., Neidermeier, A. N., et al. (2023). Action needed to make carbon offsets from tropical forest conservation work for climate change mitigation. *Science* 381, 873–877. doi: 10.1126/science.ade3535

Worrall, F., Reed, M., Warburton, J., and Burt, T. (2003). Carbon budget for a British upland peat catchment. *Sci. Total Environ.* 312, 133–146. doi: 10.1016/S0048-9697(03)00226-2

WRI (2021). Available online at: https://research.wri.org/gfr/latest-analysis-deforestation-trends?utm_medium=mediaandutm_source=articleandutm_campaign=globalforestreview (accessed December 2022).

Wunder, S., Kaimowitz, D., Jensen, S., and Feder, S. (2021). Coronavirus, macroeconomy, and forests: What likely impacts?. *Forest Policy Econ.* 131, 102536. doi: 10.1016/j.forpol.2021.102536

WWF (2020). Available online at: https://www.dw.com/en/wwf-rainforest-deforestation-more-than-doubled-under-cover-of-coronavirus/a-53526064~2020 (accessed June 2021).