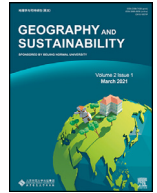




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Perspective

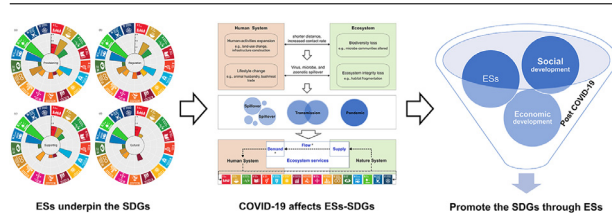
## Integrate ecosystem services into socio-economic development to enhance achievement of sustainable development goals in the post-pandemic era

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### HIGHLIGHTS

- Ecosystem services (ESs) underpin the achievement of sustainable development goals (SDGs).
- Man-made ecosystem degradation may trigger pandemics.
- COVID-19 interferes the flow and demand of ESs.
- Promote the SDGs through ESs in the post-pandemic era.

### GRAPHICAL ABSTRACT



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### ABSTRACT

The COVID-19 pandemic has stalled and rolled back progress on Sustainable Development Goals (SDGs). Ecosystem services (ESs), defined as the contributions of ecosystems to human well-being, underpin the achievement of SDGs. To promote SDG achievement in post-pandemic era, we teased out the links between ESs and SDGs while examining the impact of COVID-19. We found that ESs benefited all SDGs, yet man-made pressures led to degradation of ecosystems and their services. There is broad consensus that the virus lurks in degraded ecosystems and generates spillover due to human interference. The pandemic and global lockdown/restriction disrupted the flow of ESs and altered human ESs demand, threatening the efforts for the SDGs. We suggested: 1) to study the association and traceability of ESs-SDGs under the pandemic; 2) to prioritize pressing issues such as health care, livelihood, and resource security and in the long run, we should promote human-nature harmony to achieve the SDGs; and 3) to enhance ESs and to promote the SDGs through local community efforts, ESs accounting, and ecosystem restoration. This paper provides insights into the importance of ESs to the SDGs and the ways to integrate ESs into socio-economic development to promote the SDG achievement after the pandemic.

### 1. Introduction

The year 2021 marked the last decade remain to deliver the 2030 Agenda for sustainable development while the world struggled to combat COVID-19 pandemic. Until March 2021, more than 110 million people were infected by the SARS-CoV-2 virus, the cause of COVID-19, resulting in 2 million deaths (WHO, 2021). Not only the pandemic doubled the number of starving people to 270 million (Nature, 2021), but it also pushed 100 million people into poverty, triggering the worst global recession since World War II (Blake and Wadhwa, 2020), and exposing

more pandemic risks related to ecosystem degradation (IPBES, 2020). As SARS-CoV-2 batters the world, it is challenging to simultaneously end poverty, spur economic growth, tackle climate change, preserve ecosystems by 2030 (UN, 2020a).

The pandemic situation contrasts with the ambitions back in 2015. The 2030 Agenda, adopted by all UN Member States in 2015, provides a shared blueprint for sustainability. At its heart, 17 Sustainable Development Goals (SDGs) with 169 nested targets, point out the pathways to achieve social, economic, and environmental dimensions of prosperity and sustainability (UN, 2015). Embedded in the SDGs are targets

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to protect, restore, and promote the sustainable use of ecosystems and their services (UN, 2015; Wood et al., 2018). Progress in the SDGs was already off track even before the pandemic. With SARS-CoV-2 outbreak, 116 of the 169 targets were impeded (Naidoo and Fisher, 2020), particularly in the categories of poverty, economics, industry and equality. If implemented unsustainably, 10% of the targets such as target 9.1 that supports economy by expanding infrastructure, target 14.7 that develops marine resources to increase economic benefits, and target 17.11 that increases exports of developing countries could even trigger a future pandemic by exacerbating socio-ecological tensions and worsening the impact of zoonotic diseases (Naidoo and Fisher, 2020). Because goals linked to socioeconomic development (e.g., urbanization, agriculture, industry and infrastructure construction) are likely to be achieved at the expense of ecosystems and biodiversity, they can degrade ecosystem services (ESs) and cause 31% of new infectious diseases (Everard et al., 2020).

Formed by ecosystem structures, functions or processes, ESs underpin all aspects of human wellbeing—from basic livelihood to moderate prosperity and sustainable development (MA, 2005), directly or indirectly contributing to the achievement of SDGs. For instance, wood fuels provide primary energy for more than 2 billion people, and different species provide medicines for about 4 billion people. Different ESs also provide fresh water, maintain soil quality, maintain pollination service, and regulate the climate. Globally, more than 75% of the food and cash crops depend on pollinator diversity and 5.6 gigatons of carbon a year—about 60% of the anthropogenic emissions are sequestered by ecosystems (IPBES, 2019).

COVID-19 is a stress test on the SDG progress, generating stagnation and even backslide. In addition, multiple pressures indicate that degraded nature and its services could threaten the survival of humanity and the achievement of SDGs. Climate change will intensify natural disasters such as droughts, floods, storms, and wildfires. Urban and agricultural areas will encroach on pristine land on which all life relies. Population growth will increase the pressure on limited natural resources. More zoonotic pandemics will lurk in the deteriorate ecosystems (IPBES, 2020). To prevent future pandemics and promote sustainable development, a key path lies in further embedding ESs into socioeconomic development and building sustainable human-nature relationships. This perspective paper teases out the links between ESs and SDGs under COVID-19 and proposes strategies to strengthen the link between ESs and socio-economic development for achieving the SDGs after the pandemic.

## 2. How do ESs associate with the SDGs?

### 2.1. ESs underpin the achievement of SDGs

Achieving SDGs requires a secure supply and sustainable use of ESs. Most of our primary needs (e.g., food, water, bioenergy, medicines, and materials) as well as our cultural and spiritual needs are supplied by diverse ESs, ESs are also key to regulate climate and maintain biodiversity. ESs contribute to at least 12 SDGs and more than 40 targets by functioning in provision, regulation, support, and culture (Wu, 2013) (Fig. 1). Among all the relevant SDGs, goals that most rely on ESs are SDG15 (Life on Land), SDG14 (Life Below Water), SDG2 (Zero Hunger), SDG6 (Clean Water & Sanitation), followed by SDG1 (No poverty), SDG11 (Sustainable Cities & Communities), and SDG3 (Good health & Well-being) (Wood et al., 2018; Yang et al., 2020). Among ESs, critical services, including providing food and water (e.g., crops, fisheries, livestock, freshwater, and aquaculture), conserving biodiversity and natural heritage, and regulating climate, are critical to achieve multiple SDGs and targets (Wood et al., 2018). These key ESs also appear most frequently—top 25% among all mentioned ESs—in the 2030 agenda document (Geijzendorffer et al., 2017).

Although only 12 goals are strongly supported by ESs (IRP, 2019), sustainable use of ESs can benefit all SDGs directly or indirectly by re-

ducing the costs of restoring degraded ecosystems and facilitating the flow of services to human well-being. For instance, for every \$1 invested in ecosystems, \$3 to \$75 in economic benefits can be obtained from ESs. Besides, restoring 350 million hectares of degraded ecosystems could sequester 13–26 gigatons of greenhouse gases over the next 10 years (UN, 2020b). Ecosystem restoration, ES sustainable use, and wildlife-habitat expansion will directly benefit life underwater and on land (SDG14, 15). In addition, stable ecosystems and biodiversity ensure high primary productivity. ESs also play an important role in alleviating poverty and hunger (SDG1, 2). ESs, coupled with sustainable human interventions, support healthy and livable living environment (SDG3, 11), provide work opportunities and income (SDG1, 5, 8, 10, 16), ensure the supply of clean water (SDG6) and organic agriculture (SDG2, 12), mitigate climate change (SDG13), and optimize the use and management of ESs by cross-sectoral collaboration, education and innovation (SDG4, 7, 9, 17) (Blicharska et al., 2019).

### 2.2. Degraded ESs threaten the achievement of SDGs

Since the last century, ESs have been exploited intensively, with the risk of approaching or surpassing planetary boundaries (Steffen et al., 2015). A large part of ESs (78%) decreased their contribution to human well-being in recent decades (IPBES, 2019). Despite the intensive ESs exploitation, the benefits harvested cannot compensate for the losses or even meet the minimum needs of all the people. Due to ecosystem degradation (e.g., reduced soil fertility and loss of pollinator diversity), global land productivity has fallen by 23% and annual crop yield has been reduced by more than \$200 billion since 1970 (IPBES, 2019; UNEP, 2021). Although a series of restoration initiatives—from nature reserves to “Grain for Green”—are progressing well, they have not stopped the decline in the abundance of native species in major terrestrial communities that so far have reached 20% (IPBES, 2019). Biodiversity loss and ecosystem fragmentation have become one of the earth’s environmental emergencies, threatening the achievement of 80% of the SDG targets (UNEP, 2021). Land degradation has negatively affected 40% of the world’s population, impeding the SDG progress towards poverty reduction, food security, human health and water security (SDG1–3, 6). The availability of natural resources and ESs may exacerbate inequalities between genders and countries (SDG5, 10). Progress on sustainable energy, production, and economic growth (SDG7, 8, 12) can be hampered by the natural capital loss. More than 2500 conflicts related to natural resources were caused worldwide (WEF, 2020), endangering the development of peaceful and inclusive societies (SDG16, 17) (IPBES, 2019; UNEP, 2021).

## 3. How does COVID-19 affect the ESs-SDGs association?

### 3.1. Man-made ecosystem degradation can trigger pandemics

Disease regulation, as one of the key ESs, supports the SDGs by safeguarding human health (Everard et al., 2020). Pandemics and other zoonotic diseases threaten human survival and increase economic loss by \$1 trillion a year, undermining hard-won progress towards the SDGs (IPBES, 2020). Tracing source of the pandemic indicates that virus spills are likely to be driven by ecosystems degradation (IPBES, 2020).

There is broad consensus that intensified interactions between humans and ecosystems (e.g., shorter distance and increased contact rate) facilitate emerging zoonotic diseases (Bloomfield et al., 2020), which account for 70% of all new diseases (IPBES, 2020). Human-activities expansion and lifestyle changes (e.g., land-use change, infrastructure construction, bushmeat trade, and wet markets) tend to approach ecosystem barriers, bringing wildlife, livestock, and people into close contact and increasing the probability of virus spillover (Wilkinson et al., 2018). Livestock are usually immunosuppressed and have low genetic diversity, making them susceptible to infectious diseases (Espinosa et al., 2020). As people encroach into previously undisturbed ecosystems, virus can



**Fig. 1.** Number of SDG targets that are strongly supported by ESs. Values 0–6 represent the number of targets (169 targets in total). ESs are divided into four categories: (a) provisioning, (b) regulation, (c) supporting, and (d) cultural. The data were extracted from the results of expert questionnaire survey by Wood et al. (2018) (See Supplementary information).

find suitable host in human-dominated landscapes (Gibb et al., 2020) (Fig. 2). Any of the five diseases that emerge each year could evolve into a pandemic (Gibb et al., 2020). Therefore, in order to prevent the recurrence of similar ecology-related emergency, optimizing the relationship between ecosystem security and human development is the key to a sustainable post-pandemic era.

### 3.2. The COVID-19 pandemic interfered with ESs flow and demand

We need ESs to sustain survival and promote SDGs, a process that covers a constant supply of ESs, flow/delivery, and beneficiaries' demand for ESs (Zhao et al., 2018). However, COVID-19 and global lockdown/restriction have disrupted ESs flow and altered human ESs demand, with adverse effects on socio-economic functioning and SDG progress (Fig. 2). The global resource-supply chains are in jeopardy during the pandemic. Demand for minerals, metals, food, and agricultural raw materials has fallen as global trade and production stagnate (CCSA, 2020). Strawberries were fed to cows due to traffic and market disruptions in India. With schools and restaurants closed, farmers poured unsold milk and white cocoa away in North American countries (Torero, 2020). These issues have hindered progress in SDGs such as poverty reduction, zero hunger and responsible consumption & production. In contrast, the demand for cultural ESs increased, and 69%

of people increased their visits to natural spaces during the COVID-19 lockdown (Grima et al., 2020). These facts suggest that cultural ESs are key to reduce the stress, satisfy spiritual needs, and promote overall well-being.

As global recession looms, the pandemic has generated negative impacts on ecosystems (e.g., deforestation, poaching, overfishing, and loosening of restoration initiatives) (Diffenbaugh et al., 2020) and thus hindered SDG progress. The impacts are especially serious in rural and underdeveloped areas, where people's livelihoods depend directly on ecosystems and their services. Therefore, they are more vulnerable to the pandemic. For example, in a country like Namibia, rare wildlife ecotourism contributes to 10% of the GDP. But due to COVID-19 lockdown in 2020, 60%–80% declines in international tourist arrivals affected many ecotourism-dependent economies such as Namibia (CCSA, 2020). As a result, illegal poaching reemerged—two endangered black rhinos were killed for the first time after years of conservation (Naidoo and Fisher, 2020).

Despite the negative consequences of COVID-19, the global lockdown has also given nature a short-term chance to recover. But once the pandemic ends, there is an urgent need to boost economic growth. The rush to economic recovery may affect the ongoing efforts to optimize the relationship between human well-being and ecosystems, in which ESs act as a bridge and SDGs as a roadmap. Therefore, the efforts to 2030

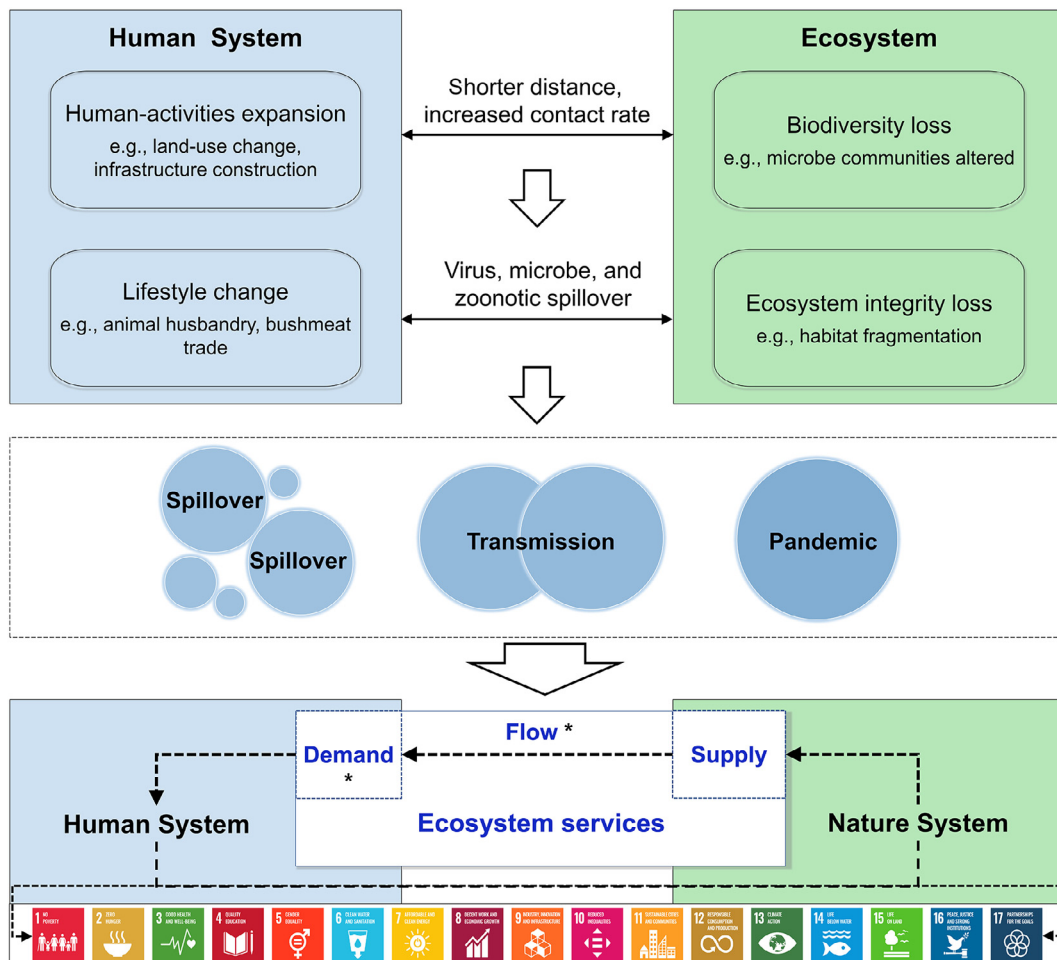


Fig. 2. The origin and evolution of the pandemic and its impact on ESs-SDGs. \*Human demand for ESs and the flow of ESs are affected by COVID-19 pandemic.

agenda should integrate ecosystem and its services into socio-economic development to increase the resilience of SDG strategies.

#### 4. How to promote the SDGs through ESs in the post-pandemic era?

##### 4.1. Combat COVID-19 systematically, lay the prerequisite for SDG acceleration

###### 4.1.1. Recognize the phenomena, dig into the causes

COVID-19 created a unique test to understand the interactions of ESs-SDGs in changing scenarios, leaving many phenomena worth exploring. For instance, for different ESs types and 17 SDGs, which links of ESs-SDGs are affected by the pandemic? Which ESs are affected in their supply, flow, and demand? What are the driving mechanisms? As for the underlying causes of the pandemic, much evidence links the COVID-19 outbreak to degraded ecosystems and zoonoses. Studies also demonstrate that meteorological and environmental conditions could influence the spread of virus (Briz-Redon and Serrano-Aroca, 2020). However, the conclusions on COVID-19's root cause are not yet unified and are still controversial. This unprecedented pandemic warns that humanity's relationship with nature is complex and out of control. The UN Environment Programme also issued a report warning that climate change, biodiversity loss and pollution have become three global human-nature emergencies (UNEP, 2021). Researchers should strengthen the traceability research of pandemics and identify the factors affecting transmission. Just like treating a disease, it is critical to find out the cause according to the symptoms so that targeted treatment can be made.

###### 4.1.2. Short-term key breakthrough, long-term overall promotion

In the short term, a key breakthrough for all countries is to contain the pandemic and its adverse impacts. It can be done by rolling out global vaccination, allowing 70%–80% coverage in one country as soon as possible, followed by a second country and a third. And vulnerable groups (e.g., health care workers, the elderly) should first achieve herd immunity (<https://www.bjnews.com.cn/detail/161629138915866.html>). Improving health care systems are also critical, followed by ensuring resource security, and restoring livelihoods and production. In the long term, smoothing the supply, flow, and demand of ESs and optimizing the human-nature relationship are essential for the SDG implementation. The environment has partly recuperated and improved during the lockdown. To maintain this good momentum, it is vital to reduce emissions, promote ecosystem restoration, and control environmental pollution once the economy recovers. Facing financial and energy constraints after COVID-19, governments should seek solutions (e.g., Nature-Based Solutions) that minimize trade-offs, promote synergies, and address multidimensional development issues, so as to systematically promote the SDGs.

###### 4.2. Couple ESs and socio-economic development, improve the quality of SDG implementation

The world expects to restore production and boost economy, turning the tables as soon as possible after the lockdown and recession. Some researchers also argued that capital-constrained governments should focus on a few prioritized SDG targets (Shepherd et al., 2015; Naidoo and Fisher, 2020). To avoid post-pandemic development at the expense of

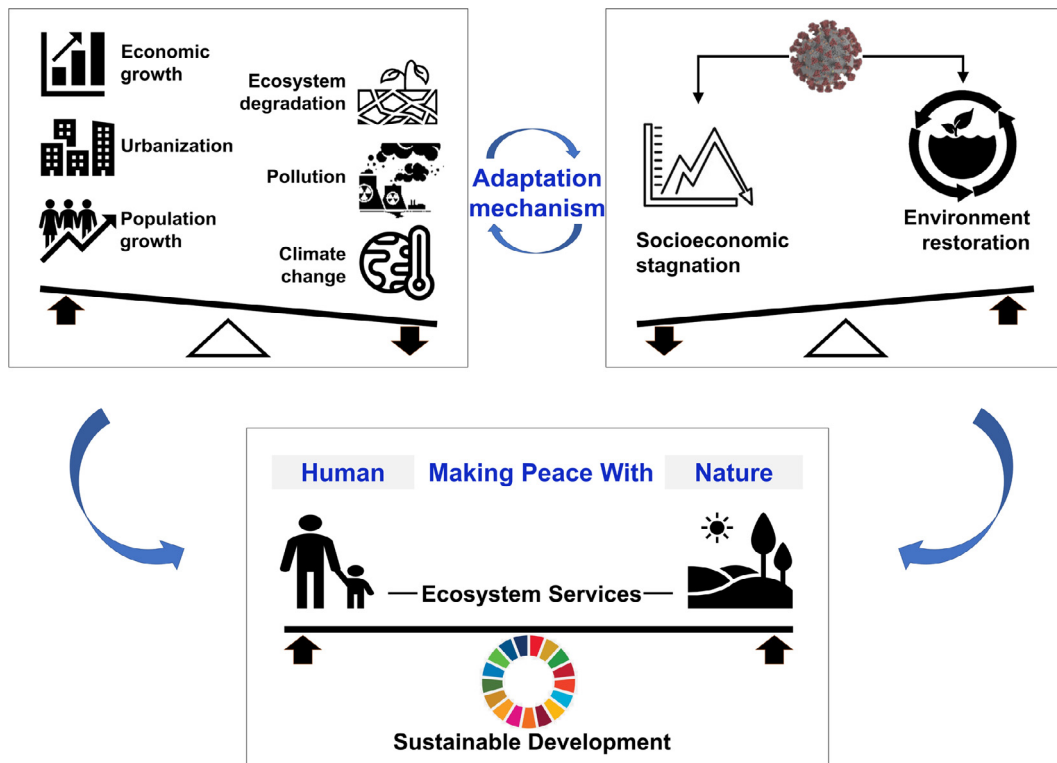


Fig. 3. The adaptation mechanism of human-natural system under different pressures.

biodiversity, ecosystems and their services, coupling ESs with socio-economic development is required based on the following actions.

#### 4.2.1. Reform who owns, uses, and manages ESs

Lack of sound management of ecological resources—both ownership and use right—is the underlying drivers of ESs degradation (Vasseur et al., 2017). For communities whose livelihoods depend primarily on ecosystem goods and services (e.g., timber, mining, agriculture), the lack of rights and interests can lead residents to focus on short-term gains without a sense of responsibility for conservation, leaving very few ecosystems worldwide undisturbed (IPBES, 2019). Therefore, it is important to reform or optimize the ownership and use of natural resources, devolve rights and duties for ecosystem regulation to individuals or communities, and empower them to use ESs and reap the benefits effectively. In addition to improving the environmental policy, governments can also guide communities to diversify local revenue streams by developing and marketing ecological products. This participatory approach will contribute to the SDG achievement by harnessing grassroots efforts to restore ecosystems and leveraging ESs to promote livelihoods for local communities.

#### 4.2.2. Integrate ESs accounting into socio-economic development

Although the benefits of a protected ecosystem and restoration far outweigh the costs, ecosystem-restoration projects are often underfunded and face chronic financial constraints (Coad et al., 2019). This means that ESs should not only be protected and restored, but also integrated into socio-economic development to achieve the SDGs more effectively. In this context, “Beyond-GDP for development”—shifted from “GDP for growth” (Steffen et al., 2015; Naidoo and Fisher, 2020)—provides a vision and pathway towards this integration. Harmonious human-ecosystem nexus and the ESs’ integration into economic accounts (Standard National Accounts) (Maeler et al., 2008) play a critical role in the Beyond-GDP initiative. Based on the survey and statistics of the extent, condition and function of ecosystems, national accounts should gradually incorporate ESs accounts, and quantify the actual ESs

flow—supply and use—in physical and monetary terms (UN et al., 2014; Vallecillo et al., 2019). By measuring the ESs’ value and reflecting ESs’ contribution to sustainable development, ESs accounting can warn and correct the socio-economic growth that comes at the cost of fertile soil, clean water, stable climate, and resilient ecosystems.

#### 4.2.3. Improve the quality of ecosystem restoration for long-term socio-economic development

The achievement of ecosystem restoration initiatives in global sustainability policies (e.g., SDGs, Aichi Targets, UN decade for ecosystem restoration) (Geijzendorffer et al., 2017; UN, 2020b) is quantified primarily by the total area restored, such as restoring 350 million hectares of degraded land in the Bonn Challenge (<https://www.bonnchallenge.org/>). After the pandemic, cash-strapped governments cannot roll out large-scale ecological projects without prioritizing them (Strassburg et al., 2020). To avoid focusing solely on increasing the area/quantity of ecosystem restoration, some key considerations need to be taken before implementing ecosystem restoration. For example, which ecosystems play a more critical role in the SDGs or is more vulnerable to disturbance (e.g., Tibetan Plateau—an area that is climate-sensitive and affects the sustainable development of Southeast Asia)? What are the priority areas for restoration? How can ecosystem-restoration effort be best distributed spatially to maximize the SDG benefits?

In addition to spatial priority, biodiversity is also key to improving ecosystem-restoration quality and contributing to the SDG achievement. In recent decades, “earth greening” has been detected around the world, in which the expanding area of ecosystem restoration, especially through afforestation projects, plays a key role (Chen et al., 2019). However, afforestation is mainly carried out through monoculture plantations—usually with low biodiversity, simple niches, less ESs, and high vulnerability—are not sustainable (Lewis et al., 2019; Zhang et al., 2020). Improving biodiversity is essential to increase the ecosystem resilience to perturbations, such as pest invasions and disease spillovers.

Therefore, ecosystem restoration requires not only increased area but also improved ecosystem structure and function, among which the importance of biodiversity cannot be overlooked (Suding et al., 2015).

## 5. Conclusions

ESs act as a bridge connecting human and nature, and the SDGs are a blueprint to promote the coordinated development of human and nature. They reinforce each other and progress together. But humans interfere with the processes and states of the ecosystem, causing spill-over effects. Both ESs and the SDGs are now threatened by potential risks in global change scenarios (e.g., pandemics, population growth, climate change, ecosystem degradation). There seems to be an adaption mechanism in the human-nature system, like the two ends of a scale rising and falling under different pressures. Human health and development are disrupted by the pandemic that could be driven by degraded ecosystems. On the other hand, due to the impeded flow and reduced demand for ESs under COVID-19 lockdown, ecosystems are partially able to recover from human disturbance. For balance and sustainability, we must make peace with nature (Fig. 3). To balance human development with ecosystem health, the SDGs are an appropriate roadmap. Moving along the path towards the SDGs, it is time to conserve ESs, make their supply sustainable, foster responsible demand of ESs, and integrate ESs into socio-economic development.

## Declaration of interests

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

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.geosus.2021.03.002.

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