

Biodiversity and health: Investing in biodiversity protection towards health gains

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Abstract

Biodiversity is declining faster than at any time in human history and the direct drivers of change in nature with the largest global impact are related to human activities: land and sea use changes; direct exploitation of organisms; climate change; pollution; and invasion of alien species. The One Health approach, and other holistic approaches, integrates human, animal, and plant health, as well as the health of their shared environment, informing and supporting a multidisciplinary and holistic approach that integrates monitoring, planning, and evaluation to optimize co-benefits and outcomes for public health. This chapter intends to provide a systematic overview on how conserving nature and biodiversity can contribute to improve the implementation of the One Health and other holistic approaches, to prevent new pandemics and to promote well-being. A detailed analysis regarding how the targets in the updated zero draft of the Post-2020 Global Biodiversity Framework can contribute to improve the implementation of the One Health or other holistic approaches was performed, aiming to support the ambition and commitment needed. Additionally, a list of indicators is proposed to guarantee a suitable monitoring framework and to adequately incorporate the value of biodiversity for health, well-being, and more specifically contributing to the reduction of the risk of new pandemics. This work highlights the importance of preventing biodiversity loss for human health and well-being. The linkages between biodiversity and human health reinforce the need of holistic approaches such as One Health to understand the intricate linkages between the health of plants, animals, humans, and our shared environment.

Keywords: One Health approach; Biodiversity; Research and Innovation; Public health; Global biodiversity framework

1. Background

Nature is essential for human existence and good quality of life. Most of nature's contributions to people are not fully replaceable, and some are irreplaceable. Nature plays a critical role in providing food and feed, energy, medicines and genetic resources, clean air, fresh water, climate regulation, pest and disease regulation, disaster risk reduction, as well as spiritual and cultural values, all of them fundamental for people's physical and mental well-being and for maintaining culture [1].

Biodiversity can be defined as the variability among all living organisms including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems [2]. Biodiversity is declining faster than at any time in human history [1]. The direct drivers of change in nature with the largest global impact are related to human activities: land and sea use changes; direct exploitation of organisms; climate change; pollution; and invasion of alien species. The impact of human activities is driving a global increase in species extinction risk [3] and an overall decline in species population abundance [1]. Up to 1 million species (approximately 25% of the known species) are already threatened with extinction across terrestrial, freshwater, and marine vertebrate, invertebrate and plant groups that have been studied in sufficient detail. Additionally, the mammal biomass on Earth is composed mainly of humans and livestock (96%), 36% corresponding to *Homo sapiens*. Wild mammals, both terrestrial and aquatic, represent only 4% of the total amount of mammal biomass [4].

The diversity of functional groups and traits of species and populations is essential for ecosystem integrity and for the generation of ecosystem services [5,6,7]. Biodiversity also underpins ecosystem functioning providing food, medicines, goods, and services that are critical to human health and well-being. Biodiversity, besides other important roles, is highly relevant for buffering shocks and extreme events, which will become more and more frequent in the face of the current climate change scenarios [8] and increasing environmental pollution. Thus, biodiversity is a key environmental determinant of human health and well-being. Its conservation and sustainable use are crucial to maintain ecosystem services [2].

Biodiversity loss can destabilize ecosystems, promote outbreaks of infectious disease, increase the incidence, mortality and prevalence of non-communicable diseases, and undermine nutrition security and protection from natural disasters. Protecting public health from these risks lies outside the traditional roles of the health sector and depends on working with partners engaged in conservation, and the sustainable use and management of natural resources [2]. However, these benefits are not consistently considered in health and development decision-making processes. With the increasing frequency and impact of disease emergencies linked to environmental and animal sources, expertise from environmental science and management is critically needed to improve prevention and detection of disease threats. These issues have been pointed out as key areas of research in the context of the COVID-19 pandemic [9].

The One Health approach integrates human, animal, and plant health, as well as the health of their shared environment, informing and supporting a multidisciplinary and holistic approach that integrates monitoring, planning, and evaluation to optimize co-benefits and outcomes for public health [10]. Furthermore, the One Health approach supports global health by improving coordination, collaboration and communication between multiple disciplines and sectors at the human-animal-plant-microbiome-environment interface to tackle shared health threats such as antimicrobial resistance, food safety, zoonotic diseases, and many others [11].

In this scope and with the same aims, other holistic approaches besides One Health can be considered. In 2015, the Rockefeller Foundation-Lancet Commission introduced a novel approach called Planetary Health concerning the health of human civilization and the state of the natural systems on which it depends, and proposed a concept, a strategy, and a course of action. The Planetary Health strategy includes the need to act urgently, a need that has been highlighted by the 2018 report of the Intergovernmental Panel on Climate Change (IPCC) [12] and by the 2019 report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [1]. The urgency to act is also embraced in the framework of the United Nations 2030 Agenda for Sustainable Development.

The Sustainable Development Goals (SDG) are an urgent call for action, recognizing that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and boost economic growth, while tackling climate change and working to preserve our oceans and forests [2]. Although these goals have attracted wide interest and commitment from many organizations and stakeholders, current trends in terms of action to achieve them are not encouraging. The first Global Sustainable Development Report [13] presents alarming data, such as rising inequalities, climate change, biodiversity loss, and increasing amounts of waste. However, a systemic approach such as Planetary Health could be taken to redirect the key development activities in our societies towards a more sustainable path [14].

Recently, a conceptual framework was proposed to improve this linkage between health and biodiversity, proving that this is an area of research demanding for attention [15]. This framework considers four domains in the interaction between biodiversity and human health: (i) reducing harm (e.g. provision of medicines, decreasing exposure to environmental pollution); (ii) restoring capacities (e.g. attention restoration, mental health); (iii) building capacities (e.g. facilitating physical and mental activity, spiritual experiences); and (iv) causing harm (e.g. exposure to dangerous wildlife, chronic and infectious diseases or allergens) [16].

The increasing importance of this linkage means it is urgent for it to be considered in the worldwide institutional agendas. All governments and decision makers need to address health impacts of major environmental threats on a regular basis, to prompt timely and corrective actions. A shift from fragmented to systematic actions will promote Human and Planetary Health, conserving nature and biodiversity, and slowing down climate change. Improving cooperation between various sectors including health, environment, energy, agriculture, trade, and transport, as well as chemical and other industries, is crucial. To achieve this, we need a multidisciplinary approach in the European Union (EU) with full commitment of the relevant sectors. There is substantial evidence that initiating a European Strategy for Planetary Health in support of the Green Deal [17] could help to achieve the United Nations' SDG. Now is the moment to unite, from individual, to planetary scale, in shared actions [14]. Now is the moment to do more and better towards health gains!

1.1. Biodiversity, health, and human well-being

There is a close interrelationship between global environmental issues, such as the crisis associated with biodiversity loss and climate change, and health issues [2, 10, 15, 18]. The health sector depends on biodiversity and ecosystem functions and services and, on the other hand, the health sector has potential impacts on biodiversity that may threaten the provision of ecosystem services. Additionally, health has an important role in the 2030 Agenda, with SDG 3 calling on all stakeholders to “ensure healthy lives and

promote wellbeing for all at all ages”. In addition to socio-economic determinants of human health, the impact of environmental, climate, ecosystem change and degradation on health is increasingly recognized. Human health and livelihood ultimately depends upon ecosystem products and services [15]. The World Health Organization (WHO) periodically produces data on the global burden of disease attributable to the environment, with the most recent available data, published in 2018, indicating 630 000 deaths in the EU in 2012 [19]. Thus, tackling the upstream drivers of environmental degradation and biodiversity loss is of utmost importance.

The incidence of infectious diseases is influenced by biodiversity at the level of pathogens, vectors, and reservoir hosts, including livestock; by the diversity of habitats; and by human movements, wildlife-livestock-human contact interface and behaviour. Ecosystem disturbances can affect the risk of acquiring infectious diseases by promoting the direct contact between human and microbes, or they can do so indirectly through their impact on infectious agents, reservoirs, and vectors [2,10,18]. Biodiversity conservation reduces the risk of zoonotic diseases by providing or maintaining habitats for wild species, thus minimising the potential contact between wildlife, livestock, and humans. The interlinkages between biodiversity and human health and well-being have been extensively reported [2, 20]. Some of them can be summarised as follows:

- Biodiversity, be it in the form of pollinators (Figure 1), soil biota or natural pest controllers, for example, plays a critical role in supporting food production. A broad diversity of species, varieties and breeds underpins good nutrition and varied diets.

Figure 1 – Butterflies play an important role in pollination. A Silver-studded Blue (*Plebejus argus*) in Alvão Natural Park.



Source: Photo provided by João Pargana

- Terrestrial and freshwater ecosystems underpin the water cycle and the provision of clean water supplies, regulating nutrient cycling, soil erosion and water purification.
- Marine biodiversity is essential for a healthy planet. It plays a vital role in maintaining the functionality and productivity of ecosystems. Oceans represent a significant source of water, food, biomass, oxygen, and other important aspects to human health, as well as having an important role in carbon sequestration.
- Many medicines, such as some antibiotics, are derived from naturally occurring substances. A large proportion of antibacterial drugs can be traced back to chemicals of natural origin. Plant, microbial and marine species hold vast potential for new medicinal products.
- The human body depends on its microbiota to support the function of the gastrointestinal tract, the regulation of the immune system and the prevention of infections. Reduced contact with healthy ecosystems can reduce diversity in this human microbiota and lead to immune dysfunction and diseases, such as allergies and intestinal disorders.
- Spending time in natural environments is also associated with improved mental health and increased levels of physical activity with consequent health benefits. The benefits of access to biodiverse green or blue spaces are particularly significant for urban residents of low socio-economic status. Interaction with nature can contribute to treatment for depression, anxiety, and behaviour problems, including in children (Figure 2).

Figure 2 – Landscape in Peneda-Gerês National Park and one of the natural environments available for health benefits.



Source: Photo provided by João Pargana

- Biodiversity contributes to ecosystem resilience and is essential for enabling the adaptation of our agricultural production systems to climate change. For example, new species may be drawn into agricultural production as the climate shifts. Vegetation reduces erosion and plays a role in flood mitigation, reducing the impact of natural disasters on health and well-being.
- Living organisms act as bio-indicators of human health stressors. For example, lichen act as indicators of air pollution, while crustaceans are an indicator group of species for water quality.

1.2. Biodiversity and pandemics

Pandemics have their origin in diverse microbes carried by animal hosts, but their emergence is entirely driven by human activities. The fundamental causes of pandemics are the same global environmental changes that cause biodiversity loss and climate change [10]. These include deforestation, land- and sea-use change, agricultural expansion and intensification, and wildlife trade and consumption. These activities bring wildlife, livestock, and people into closer contact, allowing animal microbes to spillover into people and causing infections, sometimes outbreaks, and more rarely epidemics and pandemics [10]. The recent increase in global consumption and trade, caused by demand in developed countries and emerging economies, as well as by demographic pressure, has led to a series of emerging diseases that originate mainly in developing countries [10].

New diseases in humans can emerge either as a result of a modification in the nature or behaviour of commensal microorganisms that lead to a disease, or through infection by novel organisms, usually through contact with animals and the environment [18, 21]. About 60% of human infections are estimated to have an animal origin, and 75% of emerging human infectious diseases “jump species” from (non-human) animals to people [21, 22]. In fact, the majority (70%) of emerging infectious diseases such as Ebola, Zika, Nipah encephalitis originate from microbes found in nature. Almost all known pandemics, namely influenza, HIV/AIDS and COVID-19 are zoonoses since their natural hosts are animals. Around 80% of pathogens infecting animals are “multi-host,” since they survive among different animal hosts [21, 23], rarely including humans (Figure 3). Domestic animals and peri-domestic wildlife also have a role in creating bridges for the emergence of human diseases, since this can happen in an evolutionary sense, or the animal could serve as a physical transmitter. Additionally, an estimated 1.7 million still unknown viruses are thought to exist in mammal and avian hosts and up to half of these could have the ability to infect humans. The most important reservoirs of pathogens with pandemic potential are mammals (in particular bats, rodents and primates) and some birds (in particular water birds), as well as livestock (e.g. pigs, camels, mink, poultry) [10,21].

Figure 3 – Horseshoe bats are believed to be the primary hosts of *SARS-CoV-2*. A colony of the horseshoe bat *Rhinolophus ferrumequinum* found in a cave roost in Vila Pouca de Aguiar.



Source: Photo provided by João Pargana

Unsustainable exploitation of the environment due to land- and sea-use change, intensive animal breeding, deforestation, agricultural expansion and intensification, wildlife trade and consumption, and other activities, disrupts natural interactions among wildlife and their microbes, increasing the contact among people, livestock, wildlife, and their pathogens [10, 18]. This proximity with humans (unnatural hosts) increases the spillover risk and has led to almost all known pandemics [10, 18, 24, 25].

In 2020, the COVID-19 pandemic raised global attention to the consequences of the emergence of zoonotic diseases. The response to the current acute pandemic has mainly focused on containment measures that have shown a dramatic social and economic impact [10]. Healthy and resilient societies depend on giving nature the space it needs. This ongoing pandemic makes the need to protect and restore nature even more urgent. The pandemic is raising awareness to the links between our own health and the health of ecosystems, and it is demonstrating the need for sustainable supply chains and consumption patterns that do not exceed the planetary limits [10]. This reflects the fact that the risk of emergence and spread of infectious diseases increases as nature is destroyed [10, 18, 24, 25]. Protecting and restoring biodiversity and well-functioning ecosystems is therefore key to boost our resilience and prevent the emergence and spread of future diseases [1, 2, 10, 21]. Unfortunately, according to several published reports, at the global level, none of the 20 Aichi targets included in the Strategic Plan for Biodiversity 2011-2020 (adopted by decision X/2 at the tenth meeting of the Conference of the Parties of the Convention on Biological Diversity) have been fully achieved, though six targets have been partially achieved [26].

Strengthening health systems and increasing epidemiological surveillance of wild and domesticated animals focused on “highly probable pathogen reservoirs”, as well as of humans, using modern science-based technologies, may help to predict and detect at early stages incidents and potential spillovers. However, we must also be aware that the identification of these potential intermediary hosts or wild reservoirs may take a long time or not happen at all, so the best option is to act in a preventive way, eliminating or minimizing the risks [2, 18, 21]. The One Health approach, which recognizes the interconnection between health in people, animals, plants, and their shared environment, is, together with other integrated approaches, a fundamental pillar of prevention and early detection. With this approach in mind, ten science-based policy recommendations were proposed [21]:

- Raise awareness and increase zoonotic literacy and emerging disease risks and prevention at all society levels to build extensive support for risk-reduction strategies;
- Increase investments in holistic approaches, including the One Health perspective, strengthening the integration of environmental considerations in the World Health Organization (WHO) and in other health organizations;
- Boost scientific enquiry into all the dimensions of emerging diseases (health, social and economic), including zoonoses, to assess risks and develop interventions at the interface of the environment, animal health and human health;
- Improve cost-benefit analyses of emerging diseases prevention interventions to include full cost of all the emerging diseases dimensions and guarantee ongoing and well-resourced preparedness and response mechanisms;
- Develop effective means of monitoring and regulating practices associated with zoonotic disease, including food systems from farm to fork and improving sanitary measures;
- Include health considerations in incentives for (sustainable) food systems, including wildlife source foods;
- Identify key drivers of emerging diseases in intensive animal production and smallholder production;
- Support integrated management of landscapes and seascapes that enhance sustainable co-existence of agriculture and wildlife, including investing in sustainable methods of food production that diminish pollution while reducing risk of zoonotic disease transmission;
- Reinforce the existing and build new capacities among health stakeholders to improve outcomes and to increase literacy in the human, animal and environment health dimensions of zoonotic and other diseases;
- Mainstream and implement the One Health approach, or other holistic approaches, in land-use and sustainable development planning, implementation and monitoring.
- In spite of these already identified science-based policy recommendations, regardless the enormous real and potential socio-economic impacts of emerging zoonotic diseases, and although the consensus that prevention is better than cure, investments and political will to control them at their source have been unsatisfactory until now [21].). Therefore, the current pandemic should be considered the “cost of inaction” in biodiversity protection and a higher ambition and stronger commitments should be the focus when discussing the Post-2020 Global Biodiversity Framework respective targets [27].

1.3. Post 2020 Global Biodiversity Framework

To date, the most remarkable global commitment to safeguard species has been Aichi Target 12 of the Strategic Plan for Biodiversity 2011–2020 (the “Strategic Plan”) under the Convention on Biological Diversity (CBD) [28]. This global commitment states the following: “By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.” Unfortunately, the ongoing situation (decline in species populations, and many species facing extinction) shows a clear failure of this global commitment [26, 29].

The Post-2020 Global Biodiversity Framework (Post-2020 GBF) is a stepping-stone towards achieving the CBD’s 2050 Vision of ‘Living in harmony with nature’, where “by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people”. This framework will replace the Strategic Plan for Biodiversity 2011-2020 and will set the basis for shaping policies and guiding efforts and resources to halt and reverse biodiversity loss worldwide.

Like the Paris Agreement, with its clear statement on limiting carbon emissions, the Post-2020 GBF will establish a set of goals and targets intending to preserve and restore the diversity of life on Earth, with strong commitments of all governments, and is due to be adopted by the Conference of the Parties of the CBD, at its fifteenth meeting.

The updated Zero Draft of this framework proposed four outcome goals—three of those relating to different levels of ecological organization (ecosystems, species, and genetic diversity), and the other the means of implementation are available to achieve all goals and targets in the framework. To accomplish these four goals, the framework proposes 20 action targets and related indicators—an appropriate, potentially powerful and ambitious framework that needs a strong commitment at political level [30].

This chapter intends to provide a systematic overview on how conserving nature and biodiversity can contribute to improve the implementation of the One Health and other holistic approaches, to prevent new pandemics and to promote well-being.

2. The role of the Post-2020 Global Biodiversity Framework in promoting human health and well-being

A detailed analysis regarding how the targets in the updated zero draft of the Post-2020 Global Biodiversity Framework can contribute to improve the implementation of the One Health or other holistic approaches, to prevent new pandemics and to promote well-being, was performed, aiming to support the ambition and commitment needed. Table 1 presents the results of this analysis and intends to describe with some detail how each target can influence human's health and well-being and which actions should be taken to promote health in the scope of each target.

Additionally, a list of specific indicators is proposed to guarantee that the proposed Post-2020 Global Biodiversity Framework monitoring framework adequately incorporate the value of biodiversity for health, well-being, and more specifically contributing to the reduction of the risk of new pandemics.

Table 1 - Targets to support the ambition on Biodiversity and Health. Elements between square brackets are still under discussion, and indicators that are part of GBF monitoring framework are in italics.

Targets	Influence on health	Actions to take	Possible indicators
(a) Reducing threats to biodiversity			
<p>Target 1. By 2030, [50%] of land and sea areas globally are under spatial planning addressing land/sea use change, retaining most of the existing intact and wilderness areas, and allow to restore [%] of degraded freshwater, marine and terrestrial natural ecosystems, and connectivity among them.</p>	<ul style="list-style-type: none"> - Degradation of ecosystems can lead to increased emerging disease risk [10]. - Pathogens of aquatic ecosystems can directly threaten biodiversity [10]. - Conservation is the key to sustainability and Protected Areas (PA) remains the core of global conservation strategies [31]. 	<ul style="list-style-type: none"> - Ensure ecosystem connectivity, which is critical for maintaining important ecological and evolutionary processes [32]. - Implement adequate land and sea spatial management planning, considering “One health” approach and the information provided by health surveillance reports for zoonosis [32]. - Promote the active restoration and remediation of degraded ecosystems [32]. - Conserve and protect the mainly intact ecosystems [33]. 	<ul style="list-style-type: none"> - Number of zoonoses outbreaks per year provided by health surveillance reports - Area (ha) of restored and remediated ecosystems - Degree of coverage and effectiveness of spatial planning measures to protect biodiversity (%)
<p>Target 2. By 2030, protect and conserve through well connected and effective system of protected areas and other effective area-based conservation measures at least 30 per cent of the planet with the focus on areas particularly important for biodiversity.</p>	<ul style="list-style-type: none"> - PA represent a fundamental tool in nature conservation policies. Some species rely on efficient PA management for their survival [10]. - PA are important to increment the global area free of harmful anthropogenic activities, reducing the wildlife-livestock-human contact interface and hence the risk of spillovers [10]. 	<ul style="list-style-type: none"> - Ensure a network of, well planned and well managed, ecologically representative PA. - Assure by the Governments area-based conservation [32]. - Conserve protected areas to reduce the wildlife-livestock-human contact interface [10]. 	<ul style="list-style-type: none"> - Extent of protected areas and OECMs (ha) and their connectivity (%) - Results on management and effectiveness of PA - <i>Degree (%) of particularly important areas for biodiversity covered by PA.</i>

Targets	Influence on health	Actions to take	Possible indicators
	<ul style="list-style-type: none"> - Ensuring connectivity is essential for managing healthy ecosystems, conserving biodiversity, and adapting to climate change across all biomes and spatial scales. - Well-connected ecosystems support a diversity of ecological functions such as migration, hydrology, nutrient cycling, pollination, seed dispersal, food security, climate resilience and disease resistance [34]. 		
<p>Target 3. By 2030, ensure active management actions to enable wild species of fauna and flora recovery and conservation, and reduce human-wildlife conflict by [X%].</p>	<ul style="list-style-type: none"> - Environmental changes causing biodiversity loss on a global scale are increasing the risk of spillover [10]. - Rapidly growing human populations are often on the frontline of disease emergence [10]. - Underlying drivers of almost all recent Emergent Infectious Diseases (EIDs) are anthropogenic environmental changes [10]. 	<ul style="list-style-type: none"> - Avoid wildlife contact/conflict [10]. 	<ul style="list-style-type: none"> - Number of zoonoses outbreaks per year provided by health surveillance reports - <i>Number of endangered species with effective management plans and recovery progress.</i> - Number of PA management plans effectively addressing and reporting human-wildlife conflict.
<p>Target 4. By 2030, ensure that the harvesting, trade and use of wild species of fauna and flora is legal, at sustainable levels and safe.</p>	<ul style="list-style-type: none"> - Farming, trade and unsustainable consumption of wildlife and wildlife derived products led to biodiversity loss and emerging diseases including COVID-19 [10]. 	<ul style="list-style-type: none"> - Implement rigorous enforcement of existing laws, regulations, and international treaties. - Limit or prohibit the trade of endangered species and highly probable pathogen host 	<ul style="list-style-type: none"> - Number of zoonoses outbreaks per year provided by health surveillance reports - <i>Proportion of traded wildlife</i>

Targets	Influence on health	Actions to take	Possible indicators
	<ul style="list-style-type: none"> - Trade in mammals and birds poses a high risk for disease emergence [10]. - Many plant species are threatened by unsustainable harvest for horticulture, food, or medicine. 	<ul style="list-style-type: none"> species. - Strengthen the sanitary and phytosanitary measures of the World Trade Organization [35]. - Develop One Health preparedness and effective response strategies. - Ensure that harvesting, trade and use of wild species of fauna and flora is legal, at sustainable levels, safeguarding indigenous peoples and local communities. - Modify previous calls for taxes, or levies on meat consumption or livestock production [10]. 	<p><i>that is legal and safe (not poached, illicitly trafficked or unsustainable)</i></p> <ul style="list-style-type: none"> - Proportion of harvested wildlife (both terrestrial and marine) which populations are within biologically sustainable levels
<p>Target 5. By 2030, manage, and where possible control, pathways for the introduction of invasive alien species, achieving [50%] reduction in the rate of new introductions, and control or eradicate invasive alien species to eliminate or reduce their impacts, including in at least [50%] of priority sites.</p>	<ul style="list-style-type: none"> - Invasive alien species (IAS) have been recognized as one of the main causes for biodiversity loss globally [36]. - IAS may promote pathogen pollution, leading to the emergence of diseases and potentially affecting the economy. - Animal IAS should be the focus of intense study by epidemiologists due the risk for zoonotic pathogen emergence [36]. 	<ul style="list-style-type: none"> - Increase awareness of people working in the fields of animal and public health [36]. - Improve the understanding of the key epidemiological events and factors driving the emergence of infectious diseases [36]. - Apply preventive and precautionary principles in addressing issues related to IAS [37]. - Implement flexible tools able to prioritize IAS [36]. 	<ul style="list-style-type: none"> - Rate of new introductions of alien species - <i>Rate of invasive alien species spread</i> - Risk level of introduction of invasive alien species. - Number of actions to control and/or eradicate IAS

Targets	Influence on health	Actions to take	Possible indicators
<p>Target 6. By 2030, reduce pollution from all sources, including reducing excess nutrients [by x%], biocides [by x%], plastic waste [by x%] to levels that are not harmful to biodiversity and ecosystem functions and human health.</p>	<ul style="list-style-type: none"> - Pollution is one of the drivers of biodiversity loss and disease emergence [10]. - Pollution prevention leads to Environmental Sustainability [38]. - More than 90% of biodiversity loss come from resource extraction and processing of materials, fuels, and food. <p>Exposure to harmful chemicals is a threat to human health and to biodiversity. Examples include negative effects on pollinators, insects, aquatic ecosystems, and bird populations [39].</p>	<ul style="list-style-type: none"> - Promote public awareness and education on IAS. - Involve citizens in IAS control and eradication programs [36]. - Establish a monitoring framework capable of early detection of invasion and rapid intervention. - Promote education to avoid pollution (EcoSchools) [40]. - Promote companies' certification on ecosystems (Blue Flag) [41] and industries (ISO14001.2015) [42]. - Implement measures of prevention at source [35]. - Implement measures to comply with Circular Economy Action Plan. - Enhance circular economy to achieve a positive impact on the ecological systems, avoiding their depletion or overload. - Minimize the environmental footprint of chemicals on climate change, resource use, ecosystems and biodiversity from a lifecycle 	<ul style="list-style-type: none"> - Evolution reports concerning waste and wastewater management - Evolution reports concerning water (covering biocides) and air quality - Evolution reports concerning marine litter, including plastic debris and micro plastics - Evolution reports on pesticides load - Number of establishments certified by EcoSchools, Blue Flag and ISO14001.2015

Targets	Influence on health	Actions to take	Possible indicators
<p>Target 7. By 2030, increase contributions to climate change mitigation, adaption and disaster risk reduction from nature-based solutions and ecosystem-based approaches, ensuring resilience, and minimizing any negative impacts on biodiversity.</p>	<ul style="list-style-type: none"> - Land-use change creates synergistic effects with climate change and biodiversity loss, leading to important emerging diseases [10]. - Biodiversity provides numerous ecosystem services necessary to human well-being. - Climate change can lead to the dominance of some parasitic species in crops that will threat food safety, as well as the ecosystems sustainability. - Climate change can promote invasion by alien species or changes in wild species dominance, as well as in their pathogens [39]. 	<p>perspective [39].</p> <ul style="list-style-type: none"> - Promote Climate action in the scope of European Green Deal [43]. - Promote synergies in the protection and restoration of ecosystems that contribute to reversing biodiversity loss and simultaneously mitigate climate change, either through biomass and soil carbon storage or in blue carbon. 	<ul style="list-style-type: none"> -Actions on implemented NBS and EBA that contribute to adaptation and mitigation of CC. - Actions on implementation on NBS and EBA towards disaster risk reduction outcomes with co-benefits for biodiversity and human health and well-being. - % of public transport increase - % of decrease in fossil fuels use - % of increase in the level of buildings energetic certification - % of increase of sustainable farming and livestock activities – ISO 14001 – 2015 certification)
(b) Meeting people’s needs through sustainable use and benefit-sharing			
<p>Target 8. By 2030, ensure benefits, including</p>	<ul style="list-style-type: none"> - Human activities have substantially impacted ecosystems [44]. 	<ul style="list-style-type: none"> - Implement healthy diets by 2050 through substantial dietary shifts [45]. 	<ul style="list-style-type: none"> - Percentage of the population in sustainable traditional

Targets	Influence on health	Actions to take	Possible indicators
<p>nutrition, food security, livelihoods, health, and well-being for people, especially for the most vulnerable through sustainable management of wild species of fauna and flora.</p>	<ul style="list-style-type: none"> - Unsustainable trade and consumption of wildlife, agricultural intensification, globalized trade, and travel are driving the increasing spillover and spread of novel infectious diseases. - Biodiversity is necessary for food security, dietary health and to sustainable livelihood. - A proper diet is necessary to maintain micro-nutrient balance in the body [45]. - The unsustainable exploitation of marine ecosystems for food and energy resources could lead to disease emergence [10]. 	<ul style="list-style-type: none"> - Improve information and food marketing, investing in public health information and education, aiming the shift to a healthier and more sustainable diet [45]. - Increase the overlap between protected areas, endangered ecosystems and endangered species, aiming towards an effective protection of natural populations and habitats. - Reinforce local governance and land rights, focusing on helping the most vulnerable, including indigenous peoples and marginalized populations. 	<p>occupations, using wild resources for energy, food, or culture (including firewood collection, hunting, and fishing, gathering, medicinal use, craft making, etc)</p> <ul style="list-style-type: none"> - Number of schools that implemented sustainable diet in the scope of the Eco-schools - Number of companies that implemented new food-based dietary guidelines
<p>Target 9. By 2030, support the productivity, sustainability, and resilience of biodiversity in agricultural and other managed ecosystems through conservation and sustainable use of such ecosystems, reducing productivity gaps by at least [50%].</p>	<ul style="list-style-type: none"> - Landscape mosaics and ecological corridors are essential features for the promotion of biodiversity. - The requirement by many species for multiple habitats suggests that their conservation will be most effective in a mosaic environment [46]. - Management regimes that result in homogenization of habitats should be avoided [46]. 	<ul style="list-style-type: none"> - Reinforce efforts to drive sustainable agricultural and fisheries practices. - Improve the provisioning of ecosystem services. - Develop efforts to protect the soil and its biodiversity. - Create an agricultural revolution based and driven by sustainability and system innovation [45]. 	<ul style="list-style-type: none"> - <i>Proportion of agricultural area under productive and sustainable agriculture</i> - % of increase of more sustainable farming and livestock activities – ISO 14001 – 2015 certification - Reports on conservation and sustainable use of marine productivity

Targets	Influence on health	Actions to take	Possible indicators
<p>Target 10. By 2030, ensure that nature-based solutions and ecosystem approach contribute to regulation of air quality, hazards and extreme events and quality and quantity of water for at least [XXX million] people.</p>	<ul style="list-style-type: none"> - Besides causing biodiversity loss, environmental changes are also driving the increasing spillover of viral diseases or other public health threat arising from zoonotic diseases [10]. - The same human activities that are destabilizing the Earth's climate also contribute directly to poor health [47]. - Nature based solutions (NbS) are essential to protect, sustainably manage, and restore natural and modified ecosystems (landscapes, seascapes, and cities) providing environmental, social, and economic benefits and help build resilience. - NbS support the delivery of a range of ecosystem services providing human health and well-being. 	<ul style="list-style-type: none"> - Effectively implement the European Directives on the protection of groundwater and on Drinking Water. - Effectively implement the Thematic Strategy on Air Pollution, to improve air quality in Europe. - Effectively implement the Clean Air Programme for Europe. - Adopt nature-based solutions for energy supply, transport, and food systems, as far as possible. - Switch to low-carbon energy sources. 	<ul style="list-style-type: none"> - Number of sustainably managed fisheries - Analysis of costs and effectiveness of NbS implemented and/or in place - Population affected by respiratory and cardiovascular diseases (burden of disease) - Data evolution of air pollution - Data evolution on waste and wastewater production and management - Data evolution on water supply, quality and underground water availability - Reports on clean energy sources (wind, waves, ...) - Number of companies certified by ISO 14001:2015
<p>Target 11. By 2030, increase benefits from biodiversity and green/blue spaces for human health and well-being, including the</p>	<ul style="list-style-type: none"> - Green/blue spaces benefit nature and provide services regarding people health: mitigate urban heat island effect, absorb CO₂ and NO₂, increase air quality, absorb noise, help prevent the effects of drought, 	<ul style="list-style-type: none"> - Implement more green/blue spaces in urban areas to avoid contact with wildlife in non-urban environment [10]. - Promote Green and Blue areas through Blue 	<ul style="list-style-type: none"> - Proportion of total urban area corresponding to green/blue spaces for public use or benefit. - Area (m²) of green spaces per

Targets	Influence on health	Actions to take	Possible indicators
<p>proportion of people with access to such spaces by at least [100%], especially for urban dwellers.</p>	<p>secure soil, increase water retention, reduce flood risk, improve water quality, and may be used to food production [48].</p> <ul style="list-style-type: none"> - Proximity to green and blue spaces is good for our physical and mental health as it reduces our stress levels and provides space for outdoor activity [49]. - Exposure to lakes, rivers and the sea was found to have a positive impact on mental health and to promote physical activity [50]. 	<p>Flag certification [41], Green Flag for parks and green spaces [51] and ISO 14001:2015 for companies [42].</p> <ul style="list-style-type: none"> - Promote and support investments in green and blue infrastructure and cooperation across borders through the European Territorial Cooperation. 	<p>citizen (for cities with more than X thousand people)</p> <ul style="list-style-type: none"> - Maximum distance between green spaces - % of increase in green/ blue spaces (referenced to a baseline) - Companies/spaces certified by Blue Flag, Green Flag, ISO 14001: 2015 - Evolution reports on Europe Green capital Award
<p>Target 12. By 2030, increase by [X] benefits shared for the conservation and sustainable use of biodiversity through ensuring access to and the fair and equitable sharing of benefits arising from utilization of genetic resources and associated traditional knowledge.</p>	<ul style="list-style-type: none"> - Most of the world's genetic resources are located in low and middle-income countries. - Indigenous peoples and other communities in low and middle-income countries have an advanced knowledge on how to use local genetic resources for agricultural or medicinal purposes. - Access to genetic resources should only be allowed after the consent of their providers, who should also obtain a share of the benefits. 	<ul style="list-style-type: none"> - Allow the access to traditional knowledge associated with genetic resources. - Share benefits from the use of those genetic resources and knowledge. - Implement measures for providers of genetic resources and knowledge: PIC (Prior Informed Consent) and MAT (Mutually Agreed Terms). - Strengthen the work between the European networks for genetic resources and biodiversity networks [20]. 	<ul style="list-style-type: none"> - <i>Number of users that have shared benefits from the utilization of genetic resources and/or traditional knowledge associated with genetic resources with the providers of the resources and/or knowledge.</i>

Targets	Influence on health	Actions to take	Possible indicators
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- Traditional knowledge systems highlight the importance of equitable “access and benefit sharing” (ABS) [10].

(c) Tools and solutions for implementation and mainstreaming

Target 13. By 2030, integrate biodiversity values into **policies, regulations, planning, development processes, poverty reduction strategies and accounts** at all levels, ensuring that **biodiversity values are mainstreamed across all sectors** and **integrated into assessments of environmental impacts.**

- Human activities are increasingly disturbing both the structure and functions of ecosystems and altering native biodiversity.
- Ecosystem disturbances can affect the risk of acquiring infectious diseases directly or they can do so indirectly through their impact on the biodiversity of infectious agents, hosts, reservoirs, and vectors.
- Exposure to harmful chemicals is a threat to human health and to biodiversity.
- About 40% of cancer occurrences in the EU are preventable. Prevention is also the most cost-efficient long-term cancer control strategy. **Exposure to pollution, carcinogenic substances,** and radiation, as well as infectious agents, are risk factors for cancer [52].
- Some of the environmental triggers

- Implement cross-sectoral knowledge development and knowledge co-production.
- Increase awareness of biodiversity values for people working in the fields of animal and public health [36].
- Promote the implementation of One Health Approach
- Implement strategies complying with the concept of “Biodiversity in all politics”, ensuring gains in all sectors.
- Promote education and awareness-raising about the conservation of biodiversity.
- Monitor and evaluate the biodiversity mainstreaming in nutrition and health sectors [53].
- Drive change through knowledge and research to better understand **cancer risk**

- Number of references to biodiversity in the national health plans
- Financial impact of environment-related diseases
- Evolution reports on waste and wastewater production and management
- % of harmful chemicals banned from consumer products (ECHA and SAICM reports available and regularly published)
- Report the positive impact on health and well-being by maintaining healthy ecosystems.
- Report the negative impact on health due to ecosystems

Targets	Influence on health	Actions to take	Possible indicators
	<p>(pollution) for cancer are also drivers for biodiversity loss. The reduction or elimination of these triggers will simultaneously contribute for the prevention of cancer and to reduce biodiversity loss.</p>	<p>factors, as well as improving diagnoses, therapies, treatments, and prevention policies [52].</p> <ul style="list-style-type: none"> - Create new eco-friendly jobs, support educational opportunities, and train people in new skills. - Identifying synergies and trade-offs of biodiversity with other environmental issues such as climate mitigation and adaptation policies, air pollution, freshwater, and marine environment. - Assess the benefits to health and well-being that can be delivered by healthy ecosystems, and conversely identifying emerging risks and health impacts linked to ecosystems degradation (cost of inaction). 	<p>degradation.</p>
<p>Target 14. By 2030, achieve reduction of at least [50%] in negative impacts on biodiversity by ensuring production practices and supply chains are sustainable.</p>	<ul style="list-style-type: none"> - The food supply industry is tightly linked to raw materials consumption derived from living systems. - Considerable quantities of these resources marketed every day, are linked with Habitat fragmentation; Land use change; Water scarcity; Climate change; Overexploitation of fishery resources; Deforestation; Pollution and waste production [54]. 	<ul style="list-style-type: none"> - Support businesses solutions to biodiversity challenges related to their activities [54]. - Integrate the Biodiversity issue into sustainable business strategies. - Increase sustainable business strategies, through Companies' certification on ISO14001:2015 [42] with increased Biodiversity protection goals. 	<ul style="list-style-type: none"> - Agriculture sector reports regarding sustainable production practices - % of increase of more sustainable farming and livestock activities – ISO 14001 – 2015 certification - Trends in food losses and waste reduction-reports on diet

Targets	Influence on health	Actions to take	Possible indicators
<p>Target 15. By 2030, eliminate unsustainable consumption patterns, ensuring that people everywhere understand and appreciate the value of biodiversity, and thus make responsible choices commensurate with 2050 biodiversity vision, considering individual and national cultural and socioeconomic conditions.</p>	<ul style="list-style-type: none"> - These factors impact negatively on Biodiversity and should be top priority issues for Biodiversity protection. - Europe consumes more resources than most other regions; More consumption implies more water scarcity. - Current consumption leads to unsustainable waste levels. - Intensive animal production (e.g. mink, poultry, pigs, camels) can also trigger the closer contact with humans and potentiate spillover [55]. - Antimicrobial resistance (AMR) threatens the effective prevention and treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses, and fungi [56]. 	<ul style="list-style-type: none"> - Implement programmes to support national and regional initiatives to accelerate the shift towards sustainable consumption and production [57]. - Increase public awareness of zoonotic diseases and of pandemic prevention and control strategies [55]. - Implement better monitoring and better knowledge on which viruses are circulating [33]. - Accelerate our transition to a sustainable food system [58]. - Review of the EU school scheme legal framework with a view to refocus the scheme on healthy and sustainable food. 	<ul style="list-style-type: none"> at schools in the scope of the Eco-schools - Health surveillance reports regarding zoonoses and microbial resistance profile; - Eco-schools reports on diet and food loss -Reports on shifting to healthier and more sustainable diets through National Food Consumption surveys. - Reports on ISO14001:2015 implementation regarding the goals in the scope of sustainability and biodiversity protection
<p>Target 16. By 2030, establish and implement measures to prevent, manage or control potential adverse impacts of biotechnology on biodiversity and human health reducing these</p>	<ul style="list-style-type: none"> - Application of biotechnology to improve crop plants, medicinal plants, livestock, and microbes and to get new products from various biological systems is a fast-growing sector [59]. -There are adverse impacts of 	<ul style="list-style-type: none"> - Implement sustainable strategy to provide food security for a growing population promoting biodiversity conservation and avoid further habitat loss in natural ecosystems. - Apply agricultural biotechnology tools, 	<ul style="list-style-type: none"> - Extent to which necessary legal, administrative, technical, and other biosafety measures are in place to prevent, manage and control potential adverse impacts of biotechnology on biodiversity

Targets	Influence on health	Actions to take	Possible indicators
<p>impacts by [X].</p>	<p>Biotechnology on Biodiversity, such as the introduction of genetically modified organisms (GMO) into natural ecosystems [60]. Adverse impacts on biodiversity through the introduction of GMOS may also result from disturbance of the dynamic population equilibrium of ecosystems [59].</p> <ul style="list-style-type: none"> - Another direct impact of biotechnology could be episodic genetic erosion, which could threaten the genetic diversity on which this technology depends [59]. - Awareness of the rapid expansion of modern biotechnology and the growing public concern over its potential adverse effects on biological diversity, taking also into account risks to human health. - Recognizing that modern biotechnology has great potential for human well-being if developed and used with adequate safety measures for the environment and human health. - Other potentially significant risks were identified, such as [62]: <ul style="list-style-type: none"> ▪ transfer of genetic material to wild populations, leading to a loss of 	<p>implementing bioprospecting activities by establishing partnerships with public and private sector institutions in industrial and developing countries [60].</p> <ul style="list-style-type: none"> - Ensure the implementation of regulation that promotes the adequate management of risks associated with Living Modified Organisms (LMOs) resulting from biotechnology which are likely to have impacts on biodiversity and human health [61]. 	

Targets	Influence on health	Actions to take	Possible indicators
	<p>biodiversity;</p> <ul style="list-style-type: none"> ▪ diffusion of toxic effects on other organisms; ▪ invasive effects on native species; ▪ introduction of new diseases by replacing the population of the original disease vector with another [2]; ▪ negative economic effects on small-scale farmers, challenged by the production of synthetic alternatives to their natural products; ▪ privatisation of nature and restricted access for public benefit; ▪ changes in people's perception of nature and biodiversity (e.g. focus on commercial value and profit potential); ▪ policymakers, scientists, and industry being distracted from addressing the deeper underlying causes of biodiversity loss, including potentially less commitment to protecting endangered species (if extinct species can be restored synthetically). 		
Target 17. By 2030,	- Price control and subsidies in agriculture,	- Implement positive incentives: monetary or	- Biodiversity-relevant taxes,

Targets	Influence on health	Actions to take	Possible indicators
<p>redirect, repurpose, reform, or eliminate incentives harmful for biodiversity, including [X] reduction in the most harmful subsidies, ensuring that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity.</p>	<p>urban development, water provision, transport, energy and forestry can distort the costs of the use of biological resources [63].</p> <p>- Another source of biodiversity loss can be unawareness of the ecosystems function and structure, and lack of hard data to demonstrate their importance [63].</p>	<p>non-monetary inducements which encourage or motivate governments, organisations, and individuals to safeguard biological diversity.</p> <p>- Implement disincentives: mechanisms that internalise the costs of use of and/or damage to biological resources to discourage activities that deplete it.</p> <p>- Implement indirect incentives: trading mechanisms and other institutional arrangements that create or improve upon markets and price signals for biological resources, encouraging the conservation and sustainable use of biological diversity.</p> <p>- Eliminate perverse incentives: incentives which induce behaviour that reduce biodiversity.</p>	<p>charges, and fees on payments for ecosystem services and on biodiversity relevant tradable implemented</p> <p>- Reports on ISO14001:2015 implementation regarding the goals in the scope of sustainability and biodiversity protection</p>
<p>Target 18. By 2030, increase by [X%] financial resources from all international and domestic sources, through new, additional, and effective financial resources commensurate with the ambition of the goals and targets of the framework and implement the strategy for capacity-building and</p>	<p>- Environmental changes that drive biodiversity loss also drive disease emergence [19].</p> <p>- Changes in the incidence of infectious diseases are known to accompany changes in biodiversity and ecosystem disturbances, such as deforestation, dam and irrigation systems, and agricultural development.</p>	<p>- Implement incentive measures that can be directed at three main target groups [63]:</p> <ol style="list-style-type: none"> 1) people whose behaviour enhances biodiversity related goods and services; 2) people who benefit from biodiversity-related goods and services and who attach value to biodiversity; 3) those whose behaviour diminishes or harms biodiversity-related goods and 	<p>- Health surveillance reports regarding zoonoses</p> <p>- Reports on ISO14001:2015 implementation regarding the goals in the scope of sustainability and biodiversity protection</p>

Targets	Influence on health	Actions to take	Possible indicators
<p>technology transfer and scientific cooperation to meet the needs for implementing the post-2020 global biodiversity framework.</p>		<p>services affecting both groups 1) and 2).</p>	
<p>Target 19: By 2030, ensure that quality information, including traditional knowledge, is available to decision makers and public for the effective management of biodiversity through promoting awareness, education, and research.</p>	<p>- Poor information on the importance of biodiversity often leads to bad choices in biodiversity protection and, consequently in the rising of pandemic risk.</p>	<ul style="list-style-type: none"> - Establish education and awareness campaigns - Inform about the economic benefits of maintaining biodiversity and the costs of biodiversity loss. - Establish international monitoring programs on ecosystem disturbance and the resultant effects on human health. 	<ul style="list-style-type: none"> - Reports on ISO14001:2015 implementation regarding the goals in the scope of sustainability and biodiversity protection - Eco-Schools and Blue Flag certification
<p>Target 20. By 2030, ensure equitable participation in decision-making related to biodiversity and ensure rights over relevant resources of indigenous peoples and local communities, women, and girls as well as youth, in accordance with national circumstances.</p>	<ul style="list-style-type: none"> - Traditional knowledge associated with genetic resources that comes from indigenous peoples and local communities (IPLCs) provides valuable information regarding the particular properties and value of these resources and their potential use for the development of new medicines [64]. - Benefits derived from the use of genetic resources may include the sharing of the results of research and development carried out on genetic resources, the 	<ul style="list-style-type: none"> - Promote research exchanges: a researcher from a provider country collaborates with research staff from the user country [64]. - Promote provision of equipment, improvement of infrastructure and sharing of technologies: the user of genetic resources sets up laboratories or a drug manufacturing facility in the provider country [64]. - Implement payment of royalties: royalties generated from the commercialization of a product based on genetic resources are shared between the provider and the user of genetic 	<ul style="list-style-type: none"> - The percentage of surface lands legally controlled by the inhabitants through formal and native title.

Targets	Influence on health	Actions to take	Possible indicators
<p>transfer of technologies which make use of those resources, and participation in biotechnological research activities [64].</p> <p>-Benefits may also be monetary when products based on genetic resources are commercialized [64].</p>	<p>resources and associated traditional knowledge [64].</p> <p>- Establish preferential access for the provider country to any medicine derived from genetic resources and associated traditional knowledge: preferential rates to purchase medicine [64].</p>		

3. Conclusions and way forward

This work highlights the importance of preventing biodiversity loss for human health and well-being. The linkages between biodiversity and human health reinforce the need of holistic approaches such as One Health to understand the intricate linkages between the health of plants, animals, humans, and our shared environment. The One Health approach and others, such as Planetary Health, can address the common drivers of biodiversity loss, disease risk and negative health outcomes by reducing the loss and degradation of biodiversity, enhancing human health and well-being, and preventing future pandemics. The identification and implementation of policies that will bring benefits to both health and sustainability should be a driver for the next years. We need to act now and promote the mainstream of biodiversity and health linkages into national policies, strategies, programmes, and accounts. This will imply ambition, commitment, and dedication.

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Conflict of Interest

None.

I have full control of all primary data and permission is given to the journal to review the data if requested.

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